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FEDERAL TEST METHOD STANDARD

LUBRICANTS, LIQUID FUELS, AND RELATED PRODUCTS; METHODS OF TESTING

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This Federal Test Method Standard is approved by the Commissioner, Federal Supply Services, General Services Administration, for use of all Federal agencies.

Foreword

This Federal Test Method Standard is issued in loose leaf form to permit the insertion or removal of new or revised sections and test methods.

All users of Federal Test Method Standards should keep them up to date by inserting revised or new sections and test methods as issued and removing superseded and canceled pages.

New and revised material and cancellations will be issued under Change Notices which will be numbered consecutively and will bear the date of issuance. Change Notices should be retained and filed in front of the Alphabetical Index of the Standard until such time as they are superseded by a reissue of the entire Standard.

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CONTENTS

Introduction - Indexes and Addresses.

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Introduction

LUBRICANTS, LIQUID FUELS, AND RELATED PRODUCTS; METHODS OF TESTING

1. SCOPE

1.1 This test method standard is composed of standard test methods for sampling, inspecting, and testing lubricants, liquid fuels, and related products. It is issued pursuant to the Federal Property and Administration Services Act of 1949, as amended, and its application to the purchase of commodities referred to herein is mandatory on all Federal agencies.

1.2 The test methods of this standard, when cited in a specification, form an integral part of that specification. Such a citation, although referenced to the basic number of a method, is intended to apply to the latest version of the method as revised (see paragraph 2) and as amended by any subsequent Change Notices to this Standard.

CAUTION

Change Notices are not cumulative.
Therefore all notices must be consulted
to insure that the latest requirements
are observed.

1.3 Some methods are identical to those published by the American Society for Testing and Materials (ASTM). These methods are listed in the indexes, together with their corresponding ASTM method numbers, and the details of such test methods are omitted from this standard.

2. NUMBERING SYSTEM

2.1 Test methods are identified by numerical designations, each consisting of a basic number, and in some instances a revision numbers (decimal).

a. Basic number. The basic number of a method is its official designation, and should be used without revision number whenever the method is referenced. The number always refers to the same method of determination, the same accuracy, and the same end results, regardless of revision status.

b. Revision number. Revision numbers appear as decimal additions to the basic numbers. These are assigned to basic numbers when changes are made in the method to clarify it or to give additional details that will increase the reproducibility of the test results.

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3. NOTES

3.1 Purchase of specifications and standards. Federal and military specifications and standards may be obtained as outlined under General Provisions in the Index of Specifications and Standards. Federal Government activities may obtain the Index from established distribution points within their agencies. All others may purchase the Index, with cumulative monthly supplements as issued, from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

3.2 Purchase of ASTM test methods. Federal agencies may purchase ASTM test methods under Federal Supply Schedule, Class 35, Part 1, Item No. 35-U-565-35, at the prices and discounts established therein. All others may purchase them from the American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103.

3.3 Patent notice. When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have furnished, formulated, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

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TABLE I. Numerical index of test methods.

Method title	Method No.	Referenced ASTM method No.
Saybolt color of petroleum products.	101.7	D 156
ASTM color of petroleum products.	102.7	D 1500
Color of gasoline.	103.6	
Pour point.	201.9	D 97
Cloud intensity at low temperature.	202.1	
Pour stability of lubricating oils.	203.1	
Diluted pour point.	204.1	
Saybolt viscosity.	304.8	D 88
Viscosity of transparent and opaque liquids (kinematic and dynamic viscosities).	305.6	D 445
Apparent viscosity of lubricating greases.	306.4	D 1092
Viscosity and viscosity change after standing at -65° F (-53.9° C) of aircraft turbine lubricants.	307.2	D 2532
Cone penetration of lubricating grease.	311.8	D 217
Cone penetration of petrolatum.	312.4	D 937
Penetration of lubricating greases after prolonged working.	313.3	
Oil separation from lubricating greases (static technique).	321.3	
Oil separation from lubricating grease during storage.	322.3	D 1742
Performance of lubricating grease in antifriction bearings at elevated temperatures.	331.3	D 3336
Performance of lubricating grease in antifriction bearings at elevated temperatures (alternate method).	333.2	D 3336
Low-temperature torque of ball bearing greases.	334.2	D 1478
Gear wear.	335.3	
Performance of diesel engine lubricating oils under severe operating conditions.	339.6	
Performance of engine lubricating oils under high speed, supercharged conditions.	341.4	STP 509A Pt. 1
Performance of engine lubricating oils under high-temperature, medium-speed, supercharged conditions.	346.2	STP 509A Pt. 2
Performance of aviation piston engine oils in CLR engine (low temperature dispersancy and detergency).	347.3	
Evaporation loss of lubricating greases and oils (high temperature).	350.2	
Evaporation loss of lubricating greases and oils.	351.2	D 972
Effect of evaporation on flammability.	352.1	
Evaporation.	353.1	
Performance of arctic lubricating oils in a two-cycle diesel engine under cyclic, turbo-supercharged conditions.	354.1	

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TABLE I. Numerical index of test methods. (Continued)

Method title	Method No.	Referenced ASTM method No.
Performance of lubricating oils in a two-cycle diesel engine under cyclic, turbo–supercharged conditions.	355	
Stroking properties of hydraulic brake fluids.	361.4	
API gravity of crude petroleum and petroleum products (hydrometer method).	401.7	D 287
Density and specific gravity of liquids by lipkin biscapillary pycnometer.	402.2	D 941
Induction system deposit (ISD) tendencies of motor gasoline.	500.1	
Emulsification tendencies of petroleum fuels by multiple contact extractions.	550.1	
Distillation of petroleum products.	1001.13	D 86
Vapor-liquid ratio of gasoline.	1010.1	D 2533
Distillation of natural gasoline.	1015	D 216
Olefinic plus aromatic hydrocarbons in petroleum distillates.	1040.2	D 1019
Bromine number of petroleum distillates and commercial aliphatic olefins by electrometric titration.	1050.1	D 1159
Flash point by tag closed tester.	1101.8	D 56
Flash point by Pensky-Martens closed tester.	1102.11	D 93
Flash and fire points by Cleveland open cup.	1103.7	D 92
Quenching speed.	1110.2	
Explosive vapors in boiler fuel oil.	1151.2	
Autoignition temperature of liquid petroleum products.	1152.2	D 2155
Vapor pressure of petroleum products (Reid method).	1201.6	D 323
Flock point (refrigerant compressor oil).	1303.2	
Drop melting point of petroleum wax, including petrolatum.	1401.4	D 127
Melting point of petroleum wax (cooling curve).	1402.5	D 87
Freezing point of aviation fuels.	1411.5	D 2386
Dropping point of lubricating grease.	1421.2	D 546
Burning quality of kerosene.	2106.5	D 187
Smoke point of aviation turbine fuels.	2107.4	D 1322
Luminometer numbers of aviation turbine fuels.	2108.2	D 1740
Estimation of net heat of combustion of aviation fuels.	2501.1	D 1405
Heat of combustion of liquid hydrocarbon fuels by bomb calorimeter.	2502.6	D 240
Thermal oxidation stability of gear lubricants.	2504	STP 512 Pt. 5
Thermal stability of U.S. Navy special fuel oil.	2506.1	D 1661
Thermal stability of lubricating and hydraulic fluids.	2508.1	
Water and sediment in fuel oils by centrifuge.	3000 .2	D 1796

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TABLE I. Numerical index of test methods. (Continued)

Method title	Method No.	Referenced ASTM method No.
Water in petroleum and other bituminous materials.	3001.9	D 95
Sediment in crude and fuel oils by extraction.	3002.6	D 473
Water and sediment in crude oils.	3003.10	D 96
Trace sediment in lubricating oils.	3004.6	D 2273
Dirt content of grease.	3005.4	
Contamination in engine oil.	3006.3	
Water displacement and water stability.	3007.2	
Particulate contamination in aviation turbine fuels.	3008.7	D 2276
Solid–particle contamination in hydraulic fluids.	3009.3	
Solid particle contamination in aircraft turbine engine lubricants (gravimetric procedure).	3010.1	
Particulate contamination in aerospace hydraulic fluids using the HIAC particle counter.	3011.1	
Determination of particulate matter in aerospace hydraulic fluids.	3012	
Determination particulate contamination in synthetic turbine engine lubricants.	3013	
Precipitation number of lubricating oils.	3101.5	D 91
Fatty oil in cutting oils by infrared spectrophotometry.	3110.1	
Insoluble in used lubricating oils.	3121.5	D 893
Sulfur in cutting fluids (active and total).	3180.2	
Emulsion (petroleum and petroleum-like products).	3201.7	
Emulsion (soluble cutting oils).	3205.3	
Foaming characteristics of lubricating oils.	3211.3	D 892
Foaming characteristics of aircrafts turbine lubricating oils (static foam test).	3213.1	
Foaming characteristics of aircrafts turbine lubricating oils (dynamic foam test).	3214.1	
Water using Karl Fischer reagent.	3250.1	E 203
Water-miscible substances in aircraft, jet and rocket fuels.	3251.8	D 1094
Water washout characteristics of lubricating greases.	3252.3	D 1264
Water in liquid petroleum products by Karl Fischer reagent.	3253.1	D 1744
Water separation characteristics of aviation turbine fuels (modified).	3256.3	D 2550
Total solids in water for aircraft injection systems.	3289.1	
Existent gum in fuels by jet evaporation.	3302.9	D 381
Oxidation stability of gasoline (induction period method).	3352.5	D 525
Oxidation stability of aviation fuels (potential residue method).	3354.7	D 873
Compatibility of turbine lubricating oils.	3403.2	
Oxidation of crankcase lubricating oils (CLR engine).	3405.2	STP 509A Pt. 4

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TABLE I. Numerical index of test methods. (Continued)

Method title	Method No.	Referenced ASTM method No.
Oxidation and thermal stability of aircraft engine lubricating oils (CLR engine).	3407.2	
High temperature deposits and oil degradation of characteristics aviation turbine oils.	3410.1	
Thermal stability and corrosivity of aircraft turbine engine lubricants.	3411.1	
Compatibility characteristics of universal gear lubricants.	3430.2	
Compatibility of elastomers with aircraft turbine lubricants.	3432.1	
Compatibility of synthetic aircraft turbine lubricants with silicone rubber.	3433	
Storage volubility characteristics of universal gear lubricants.	3440.1	
Bearing deposition of aviation turbine engine lubricants.	3450	
Stability of lubricating oils (work factor).	3451.4	
Bearing compatibility of turbine oils.	3452.2	
Oxidation stability of lubricating greases by the oxygen bomb method.	3453.2	D 942
Leakage tendencies of automotive wheel bearing greases.	3454.2	D 1263
Channeling characteristics of lubricants.	3456.2	
Hydrolytic stability.	3457.2	
Low temperature stability test for oil.	3458.1	
Low temperature stability.	3459.1	
Stability of grease in hot water (water immersion).	3463.2	
Thermal stability of aviation turbine fuels.	3464.8	D 1660
Storage stability test of fluids and lubricants.	3465.1	
Storage stability of lubricating grease.	3467.1	
Homogeneity and miscibility of oils.	3470.1	
Sonic shear stability of polymer-containing oils.	3472	
Volatility of blended oils.	3480.1	
Monobasic acid components of synthetic ester lubricants by gas chromatography.	3500.1	
Aniline point and mixed aniline point of petroleum products and hydrocarbon solvents.	3601.7	D 611
Swelling of synthetic rubbers.	3603.5	
Swelling of synthetic rubber by aircraft turbine lubricants.	3604.2	
Calculation of olefins and aromatics in petroleum distillates from bromine number and acid absorption.	3701.3	D 875
Aromatic hydrocarbons in olefin-free gasolines by silica gel adsorption.	3702.2	D 936
Hydrocarbon types in liquid petroleum products by fluorescent indicator adsorption.	3703.6	D 1319

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TABLE I. Numerical index of test methods. (Continued)

Method title	Method No.	Referenced ASTM method No.
Naphthalene hydrocarbons in aviation turbine fuels by ultraviolet spectrophotometry.	3704.1	D 1840
Molybdenum disulfide purity.	3710.1	
Molybdenurn disulfide content of lubricating grease.	3720.2	
Molybdenurn disulfide content of non-soap thickened lubricating greases.	3722.2	
Thermal shock sensitivity of dry solid-film lubricants.	3805.2	D 2511
Wear life of dry, solid-film lubricants.	3807.1	D 2625
Adhesion of dry, solid-film lubricants.	3810.2	D 2510
Load-carrying capacity of dry, solid-film lubricants.	3812.1	D 2625
Corrosion by dry, solid-film lubricants in high humidity.	3814.1	D 2625
Film thickness of dry solid film lubricants.	3816.1	
Corrosion protection by coatings: salt-spray (fog) test.	4001.3	
Rust-preventing characteristics of steam-turbine oil in the presence of water.	4011.4	D 665
Rust preventive properties of lubricating greases.	4012.1	D 1743
Conradson carbon residue of petroleum products.	5001.11	D 189
Ramsbottom carbon residue of petroleum products.	5002.7	D 524
Deposit-forming tendencies of aircraft turbine lubricants.	5003.2	
Carbonizable substances in paraffin wax.	5011.1	D 612
Carbonizable substances in white mineral oil (liquid petrolatum).	5012	D 565
Neutrality (qualitative).	5101.7	
Acid and base number by extraction (color-indicator titration).	5102.1	
Neutralization number by color-indicator titration.	5105.5	D 974
Neutralization number by potentiometric titration.	5106.4	D 664
Sulfur in petroleum products and liquified petroleum (LP) gases (lamp method).	5201.10	D 1266
Sulfur in petroleum products by the bomb method.	5202.12	D 129
Mercaptan sulfur in petroleum distillates (doctor test).	5203.3	D 484 (Sec. 4c)
Mercaptan sulfur in aviation turbine fuels (color-indicator method).	5204.3	D 1219
Mercaptan sulfur in aviation turbine fuels (amperometric and potentiometric methods).	5206	D 1323
Corrosiveness of greases or semi-solid products at 25° C.	5304.5	
Corrosiveness of lubricants at 232° C (450° F).	5305.1	
Corrosiveness of emulsifiable cutting fluids.	5306.5	
Corrosiveness and oxidation stability of aircraft turbine engine lubricants.	5307.2	

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TABLE I. Numerical index of test methods. (Continued)

Method title	Method No.	Referenced ASTM method No.
Corrosiveness and oxidation stability of light oils (metal squares).	5308.7	
Corrosiveness of greases (copper strip, 100° C).	5309.5	
Rust protection by metal preservatives in the humidity cabinet.	5310.2	D 1743
Effect of grease on copper.	5314.1	D 1261
Corrosion of lead by lubricating oils.	5321.2	
Corrosiveness of oil on a bimetallic couple.	5322.2	
Copper corrosion by petroleum products (copper strip test).	5325.4	D 130
Corrosion protection by gear lubricants in the presence of moisture.	5326.1	STP 512 Pt. 3
Fuel system icing inhibitor in hydrocarbon fuels (iodometric method).	5327.4	
Corrosive sulfur in electrical insulating oils.	5328.3	D 1275
Corrosion protection (humidity cabinet).	5329.2	
Fuel system icing inhibitor in hydrocarbon fuel (calorimetric method).	5330.2	
Corrosion protection of steel against sulfurous acid-salt spray by solid film lubricants.	5331.1	
Fuel system icing inhibitor by freezing point depression method.	5333.1	
Fuel system icing inhibitor in hydrocarbon fuels (refractometer method).	5340.2	
Fuel system icing inhibitor in hydrocarbon fuels (redox method).	5341	
Fuel system icing inhibitor in hydrocarbon fuels (hand refractometer method).	5342	
Silting index of hydrocarbon fuels.	5350.1	
Saponification number by color indicator titration.	5401.8	D 94
Analysis of lubricating grease.	5412.6	D 128
Resistance of grease to fuel.	5414.4	
Resistance of grease to water and a 1:1 water-ethanol solution.	5415.1	
Ash from petroleum products.	5421.4	D 482
Sulfated ash from lubricating oils and additives.	5422.3	D 874
oil content of petroleum waxes.	5431.6	D 721
Unsulfonated residue of petroleum plant spray oils.	5441.1	D 483
Vanadium in Navy special fuel oil.	5445.1	D 1548
Lead in gasoline, gravimetric method.	5501.6	D 526
Lead in gasoline, polarographic method.	5502.1	D 1269
Chemical analysis for metals in new and used lubricating oils.	5601.1	D 811

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TABLE I. Numerical index of test methods. (Continued)

Method title	Method No.	Referenced ASTM method No.
Chlorine in new and used petroleum products (bomb method).	5651.4	D 808
Phosphorous in lubricating oils and additives.	5661.5	D 1091
Dielectric breakdown voltage of insulating liquids using disk electrodes.	5702.1	D 877
Inorganic chlorides and sulfates in insulating oils.	5703.1	D 878
Sludge formation in mineral transformer oil by high-pressure oxidation bomb.	5705	D 1313
Knock characteristics of motor fuels of 100 octane number and below by the motor method.	6001.14	D 2700
Knock characteristics of motor fuels of 100 octane number and below by the research method.	6002.10	D 2699
Knock characteristics of motor fuels above 100 octane number by the research method.	6005.6	D 2699
Knock characteristics of motor fuels above 100 octane nuber by the motor method.	6006.4	D 2700
Knock characteristics of aviation fuels by aviation method.	6011.7	D 614
Knock characteristics of aviation fuels by the supercharge method.	6012.7	D 909
Nitrate–type ignition improvers in diesel fuel.	6050.1	
Ignition quality of diesel fuels by the cetane method.	6051.7	D 613
High-temperature -- high-pressure spray ignition.	6052.1	
Manifold ignition test.	6053.1	
Load-carrying capacity (Mean Hertz load).	6503.2	D 2783, D 2596
Load-carrying capacity of universal gear lubricants by the Tinken machine.	6505.1	
Performance of gear lubricants in axles at high speed, low torque followed by low speed, high torque.	6506.1	STP 512 Pt. 3
performance of gear lubricants in axles under high speed and shock loading.	6507.1	STP 512 Pt. 2
Load-carrying capacity of lubricating oils (Ryder gear machine).	6508.2	
Gear-fatigue characteristics of aircraft gas turbine lubricants at 204° C.	6509.2	
Load-carrying capacity of lubricating oils at 204° C.	6511.2	
Load-carrying capacity of steam turbine oils.	6512.3	D 1947
Wear preventive characteristics of lubricating grease (four-ball method).	6514.2	D 2266

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TABLE I. Numerical index of test methods. (Continued)

Method title	Method No.	Referenced ASTM method No.
Oscillation test of grease in helicopter bearings.	6516.2	
High temperature gear load-carrying capacity of lubricating oils.	6517	
Extreme pressure properties of lubricants (fourball tester).	6520.1	
Fluid resistance of dry, solid film lubricants.	7001.1	D 2510
Sampling petroleum and petroleum products.	8001.6	D 4057
Gaging petroleum and petroleum products.	8003.3	D 1035
Measuring the temperature of petroleum and petroleum products.	8004.4	D 1086
ASTM-IP petroleum measurement tables.	9001.4	D 1250
Conversion of kinematic viscosity to Saybolt universal viscosity or to Saybolt furol viscosity.	9101.4	D 2161
Calculating viscosity index.	9111.3	D 2270
Standard viscosity-temperature charts for liquid petroleum products.	9121.1	D 341
ASTM thermometers (specifications for).	9501.10	E 1
Inspection requirements.	9601.1	
Material handling safety precaution.	10000	

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TABLE II. Alphabetical-key word index of test methods.

Method title	Method No.	Referenced ASTM method No.
Adhesion of dry solid film lubricants.	3810.2	D 2510
Analysis of lubricating grease.	5412.6	D 128
Aniline point and mixed aniline point of petroleum products and hydrocarbon solvents.	3601.7	D 611
Ash from petroleum products.	5421.4	D 482
Ash, sulfated, from lubricating oils and additives.	5422.4	D 874
Autoignition temperature of liquid petroleum products.	1152.2	D 2155
Bromine number of petroleum distillates and commercial aliphatic olefins by electrometric titration.	1050.1	D 1159
Burning quality of kerosene.	2106.5	D 187
Carbonizable substances in white mineral oil (liquid petrolatum).	5012	D 565
Carbonizable substances in paraffin wax.	5011.1	D 612
Channeling characteristics of lubricants.	3456.2	
Chemical analysis for metals in new and used lubricating oils.	5601.1	D 811
Chlorine in new and used petroleum products (bomb method).	5651.4	D 808
Cloud intensity at low temperature.	202.1	
Cloud point of petroleum oils.		D 2500
Color, ASTM, of petroleum products (ASTM color scale).	102.7	D 1500
Color of gasoline.	103.6	
Color, Saybolt, of petroleum products (Saybolt chronometer method).	101.7	D 156
Compatibility, bearing, of turbine oils.	3452.2	
Compatibility characteristics of universal gear lubricants.	3430.2	
Compatibility of elastomers with aircraft turbine lubricants.	3432.1	
Compatibility of synthetic aircraft turbine lubricants with silicone rubber.	3433	
Compatibility of turbine lubricating oils.	3403.2	
Contamination in engine oil.	3006.3	
Conradson carbon residue of petroleum products.	5001.11	D 189
Corrosion of copper by petroleum products, detection of, by the copper strip tarnish test.	5325.4	D 130
Corrosion by dry solid film lubricants in high humidity.	3814.1	D 2625
Corrosion of lead by lubricating oils.	5321.2	
Corrosion-protection by coatings: salt-spray (fog) test.	4001.3	

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TABLE II. Alphabetical-key word index of test methods. (Continued)

Method title	Method No.	Referenced ASTM method No.
Corrosion protection by gear lubricants in the presence of moisture.	5326.1	STP 512 Pt. 4
Corrosion protection (humidity cabinet).	5329.2	
Corrosion protection of steel against sulfurous acid salt spray by solid film lubricants.	5331.1	
Corrosive sulfur in electrical insulating oils.	5328.4	D 1275
Corrosiveness and oxidation, stability of aircraft turbine engine lubricants.	5307.2	
Corrosiveness of emulsifiable cutting fluids.	5306.5	
Corrosiveness of greases or semi-solid products at 25° C.	5304.5	
Corrosiveness of greases (copper strip 100° C).	5309.5	
Corrosiveness of lubricants at 232° C (450° F).	5305.1	
Corrosiveness of oil on a bimetallic couple.	5322.2	
Corrosiveness and oxidation stability of aircraft turbine engine lubricants.	5307.1	
Corrosiveness and oxidation stability of light oils (metal squares).	5308.7	
Density and specific gravity of liquids by Lipkin bicapillary pycnometer.	402.2	D 941
Deposition tendencies of motor gasoline, using Induction System Deposit (ISD).	500.1	
Deposition on bearings using aviation turbine engine lubricants.	3450	
Deposit-forming tendencies of aircraft turbine lubricants.	5003.2	
Dielectric breakdown voltage of insulating liquids using disk electrodes.	5702.1	D 877
Dilution of gasoline-engine crankcase oils.		D 322
Dirt content of grease.	3005.4	
Distillation of natural gasoline.	1015	D 216
Distillation of petroleum products.	1001.13	D 96
Drop melting point of petroleum, including petrolatum.	1401.4	D 127
Dropping point of lubricating grease.	1421.2	D 566
Effect of grease on copper.	5314.1	D 1261
Emulsion (petroleum and petroleum-like products).	3201.7	
Emulsion (soluble cutting oils).	3205.3	
Emulsification tendencies of petroleum fuels by multiple contact extractions.	550.1	

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TABLE II. Alphabetical-key word index of test methods. (Continued)

Method title	Method No.	Referenced ASTM method No.
Evaporation.	353.1	
Evaporation, effect of, on flammability.	352.1	
Evaporation loss of lubricating grease and oils.	351.2	D 972
Evaporation loss of lubricating greases and oils (high temperature).	350.2	
Explosive vapors in boiler fuel oil.	1151.2	
Extreme pressure properties of lubricants (fourball tester).	6520.1	
Fatty oil in cutting oils by infrared spectrophotometry.	3110	
Film thickness of dry solid film lubricants.	3816.1	
Flammability of liquids (high-temperature, high--pressure spray ignition).	6052.1	
Flammability of liquids (manifold ignition test).	6053.1	
Flash and fire points by Cleveland Open Cup.	1103.8	D 92
Flash point by Pensky-Martens Closed Tester.	1102.12	D 93
Flash point by Tag Closed Tester.	1101.8	D 56
Flock point (refrigerant compressor oil).	1303.2	
Foaming characteristics of aircrafts turbine lubricating oils (static foam test).	3213.1	
Foaming characteristics of aircrafts turbine lubricating oils (dynamic foam test).	3214.1	
Foaming characteristics of lubricating oils.	3211.4	D 892
Freezing point of aviation fuels.	1411.5	D 2386
Fuel system icing inhibitor in hydrocarbon fuels (colorometric method).	5330.2	
Fuel system icing inhibitor in hydrocarbon fuels (hand refractometer method).	5342	
Fuel system icing inhibitor in hydrocarbon fuels (iodometric method).	5327.4	
Fuel system icing inhibitor in hydrocarbon fuels (redox method).	5341	
Fuel system icing inhibitor in hydrocarbon fuels (refractometer method).	5340.2	
Fuel system icing inhibitor by freezing point depression method.	5333.1	
Gaging petroleum and petroleum products.	8003.3	D 1085
Gear-fatigue characteristics of aircraft gas turbine lubricants at 204° C.	6509.2	
Gravity, API, of crude petroleum and petroleum products (hydrometer method).	401.7	D 287
Gum, existent, in fuels, by jet evaporation.	3302.9	D 381
Heat of combustion of hydrocarbon fuels by bomb calorimeter (high precision method).		D 2382

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TABLE II. Alphabetical-key word index of test methods. (Continued)

Method title	Method No.	Referenced ASTM method No.
Heat of combustion of liquid hydrocarbon fuels by bomb calorimeter.	2502.6	D 240
Heat of combustion, net, of aviation fuels, estimation of.	2501.1	D 1405
Homogeneity and miscibility of oils.	3470.1	
Hydrocarbons, aromatic, in olefin-free gasolines by silica gel adsorption.	3702.2	D 936
Hydrocarbons, olefinic plus aromatic, in petroleum distillates.	1040.2	D 1019
Hydrocarbons, olefinic and aromatic, in petroleum distillates from bromine number and acid absorption.	3701.3	D 875
Hydrocarbon types in liquid petroleum products by fluorescent indicator adsorption.	3703.6	D 1319
Ignition improvers, nitrate-type, in diesel fuel.	6050.1	
Ignition quality of diesel fuels by the cetane method.	6051.7	D 613
Inorganic chlorides and sulfates in insulating oils.	5703.1	D 878
Insoluble in used lubricating oils.	3121.5	D 893
Inspection requirements.	9601.1	
Interracial tension of oil against water by the ring method.		D 971
Knock characteristics of aviation fuels by the aviation method.	6011.7	D 2700
Knock characteristics of aviation fuels by the supercharge method.	6012.7	D 909
Knock characteristics of motor and aviation-type fuels by the motor method.	6001.14 6006.5	D 2700
Knock characteristics of motor fuels by the research method.	6002.10 6005.7	D 2699
Lead in gasoline, gravimetric method.	5501.6	D 526
Lead in gasoline polarographic method.	5502.1	D 1269
Lead, trace amounts, in gasoline.		D 3116
Leakage tendencies of automotive wheel bearing grease.	3454.2	D 1263
Load-carrying capacity of dry solid film lubricants.	3812.1	D 2625
Load-carrying capacity of fluid gear lubricants.	6512.3	D 1947
Load-carrying capacity of lubricating oils at 204° C.	6511.2	
Load-carrying capacity of lubricating oils high-temperature gear.	6517	
Load-carrying capacity of lubricating oils (Ryder gear machine).	6508.2	
Load-carrying capacity (Mean Hertz Load).	6503.2	D 2596 D 2783

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TABLE II. Alphabetical-key word index of test methods. , (Continued)

Method title	Method No.	Referenced ASTM method No.
Load-carrying capacity of universal gear lubricants by the Timken machine.	6505.2	
Luminometer numbers of aviation turbine fuels.	2108.2	D 1740
Melting point of petroleum wax (cooling curve).	1402.5	D 87
Molyhdeum disulfide content of lubricating grease.	3720.2	
Molybdenum disulfide content of non-soap thickened lubricating greases.	3722.2	
Molybdenum disulfide purity.	3710.1	
Monobasic acid components of synthetic ester lubricants by gas chromatography.	3500.1	
Naphthalene hydrocarbons in aviation turbine fuels by ultraviolet spectrophotometry.	3704.1	D 1840
Neutrality (qualitative).	5101.7	
Neutralization number by color-indicator titration.	5105.5	D 974
Neutralization (acid and base) number by extraction (color-indicator titration).	5102.1	
Neutralization number by potentiometric titration.	5106.4	D 664
Nitrogen, total, in organic materials by modified Kjeldahl method.		E 258
Oil content of petroleum waxes.	5431.6	D 721
Oscillation test of grease in helicopter bearings.	6516.2	
Penetration, cone, of lubricating grease.	311.8	D 217
Penetration, cone, of petrolatum.	312.4	D 937
Penetration of lubricating greases after prolonged working.	313.3	
performance of arctic lubricating oils in a two-cycle diesel engine under cyclic, turbo-supercharged conditions.	354.1	
Performance of aviation piston engine oils in CLR engine (low-temperature dispersancy and detergency).	347.3	
Performance of diesel engine lubricating oils under severe operating conditions.	339.6	
Performance of engine lubricating oils under high-temperature , medium speed supercharged conditions.	346.2	STP 509A Pt. 2
Performance of engine lubricating oils under high-speed, supercharged conditions.	341.4	STP 509A Pt. 1
Performance of gear lubricants in axles in high speed, low torque followed by low speed, high torque.	6506.1	STP 512 Pt. 3

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TABLE II. Alphabetical-key word index of test methods. (Continued)

Method title	Method No.	Referenced ASTM method NO.
Performance of lubricants in axles under high speed and shock loading.	6507.1	STP 512 pt. 2
performance of lubricating grease in antifriction bearings at elevated temperatures.	331.3	D 3336
Performance of lubricating grease in antifriction bearings at elevated temperatures (alternate method).	333.2	D 3336
Performance of lubricating oils in a two-cycle diesel engine under cyclic, turbo-supercharge conditions.	355	
Phosphorus in lubricating oils and additives.	5661.5	D 1091
Pour point, diluted.	204.1	
Pour point of petroleum oils.	201.9	D 97
Pour stability of lubricating oils.	203.1	
Precipitation number of lubricating oils.	3101.5	D 91
Quantity measurement of petroleum (Petroleum Measurement Tables).	9001.4	D 1250
Quenching speed.	1110.2	
Ramsbottom carbon residue of petroleum products.	5002.7	D 524
Reagent water (specification for).		D 1193
Residue, unsulfonated, of petroleum plant spray oils.	5441.1	D 483
Resistance, fluid, of dry solid film lubricants.	7001.1	D 2510
Resistance of grease to fuel.	5414.4	
Resistance of grease to water and a 1:1 water ethanol solution.	5415.1	
Rust-preventing characteristics of steam-turbine oil in the presence of water.	4011.4	D 665
Rust-preventive properties of lubricating greases.	4012.1	D 1743
Rust protection by metal preservatives in the humidity cabinet.	5310.2	D 1748
Safety, material handling precaution.	10000	
Sampling petroleum and petroleum products.	8001.6	D 4057
Saponification number of petroleum products.	5401.9	D 94
Sediment in crude and fuel oils by extraction.	3002.6	D 473
Sediment and water in crude oils.	3003.10	D 96
Sediment and water in crude and fuel oils by centrifuge.	3000.2	D 1796
Sediment and water in distillate fuels by centrifuge.		D 2709
Sediment, trace, in lubricating oils.	3004.6	D 2273
Separation, oil, from lubricating grease (static technique).	321.3	

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TABLE II. Alphabetical-key word index of test methods. (Continued)

Method title	Method No.	Referenced ASTM method No.
Separation, oil, from lubricating grease during storage.	322.3	D 1742
Silting index of hydrocarbon fuels.	5350.1	
Sludge formation in mineral transformer oil by high pressure oxidation bomb.	5705	D 1313
Smoke point of aviation turbine fuels.	2107.5	D 1322
Solid particle contamination in aircraft turbine engine lubricants (gravimetric procedure).	3010.1	
Solids, determination of particulate contamination in synthetic turbine engine lubricants.	3013	
Solids, determination of particulate matter in aerospace hydraulic fluids.	3012	
Solids, particulate contamination in aerospace hydraulic fluids using the HIAC particle counter.	3011.1	
Solids, particulate contamination in aviation turbine fuels.	3008.8	D 2276
Solids, particulate contamination in hydraulic fluids.	3009.3	
Solids, total, in water for aircraft injection systems.	3289.1	
Volubility characteristics, storage, of universal gear lubricants.	3440.1	
Stability of grease in hot water (water immersion).	3463.2	
Stability, hydrolytic.	3457.2	
Stability, low temperature.	3459.1	
Stability of lubricating oils (work factor).	3451.4	
Stability, oxidation, of aviation fuels (potential residue method).	3354.7	D 873
Stability (oxidation) of crankcase lubricating oils (CLR engine).	3405.2	STP 509A Pt. 4
Stability, oxidation, of gasoline (induction period method).	3352.5	D 525
Stability, oxidation, of lubricating greases by the oxygen bomb method.	3453.2	D 942
Stability, shear, sonic of polmer-containing oils.	3472	
Stability, storage, of lubricating grease.	3467.1	
Stability test, low temperature, for oil.	3458.1	
Stability test, storage of fluids and lubricants.	3465.1	
Stability, thermal, of aviation turbine fuels.	3464.9	D 1660
Stability, thermal oxidation, of gear lubricants.	2504	STP 512 Pt.5
Stability, thermal, and corrosivity of aircraft turbine engine lubricants.	3411.1	
Stability, thermal and oxidation, of aircraft engine lubricating oils (CLR engine).	3407.2	
Stability, thermal (high temperature deposit and oil degradation characteristics) of aviation turbine oils.	3410.1	

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TABLE II. Alphabetical-key word index of test methods. (Continued)

Method title	Method No.	Referenced ASTM method No.
Stability, thermal, of U.S. Navy Special fuel oil.	2506.1	D 1661
Sulfur in cutting fluids (active and total).	3180.2	
Stroking properties of hydraulic brake fluids.	361.4	
Sulfur, mercaptan, in aviation turbine fuels (amperometric and potentiometric methods).	5206	D 1323
Sulfur, mercaptan, in aviation turbine fuels (color-indicator method).	5204.3	D 1219
Sulfur, mercaptan, in petroleum distillates (doctor test).	5203.4	D 484 (Sec. 4.2.6
Sulfur in petroleum products (high-temperature method).		D 1552
Sulfur in petroleum products (x-ray spectrographic method).		D 2622
Sulfur in petroleum by the bomb method.	5202.12	D 129
Sulfur in petroleum products (lamp method).	5201.10	D 1266
Swelling of synthetic rubber.	3603.5	
Swelling of synthetic rubber by aircraft turbine lubricants.	3604.2	
Temperature measurement of petroleum and petroleum products.	8004.4	D 1086
Thermal Shock sensitivity of dry solid film lubricants.	3805.2	D 2511
Thermometers, ASTM, (specifications for).	9501.11	E 1
Torque, low-temperature, of ball-bearing greases.	334.2	D 1478
Vanadium in Navy speical fuel oil.	5445.1	D 1548
Vapor-liquid ratio of gasoline.	1010.1	D 2533
Vapor pressure of petroleum products (Reid method).	1201.7	D 323
Viscosity, apparent, of gear oils at low temperatures using the Brookfield viscometer.		D 2983
Viscosity, apparent, of lubricating greases.	306.4	D 1092
Viscosity conversions: kinematic to Saybolt Universal or to Saybolt Furol.	9101.4	D 2161
Viscosity-index calculation from kinematic viscosity.	9111.3	D 2270
Viscosity, kinematic of transparent and opaque liquds (and the calculation of dynamic viscosity).	305.7	D 445
Viscosity, Saybolt	304.8	D 88
Viscosity-temperature charts for liquid petroleum products.	9121.1	D 341
Viscosity and viscosity change after standing at low temperature of aircraft turbine lubricants.	307.2	D 2532
Volatility of blended oils.	3480.1	
Water displacement and water stability.	3007.2	

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TABLE II. Alphabetical-key word index of test methods. (Continued)

Method title	Method No.	Referenced ASTM method No.
Water using Karl Fischer reagent.	3250.1	E 203
Water in liquid petroleum products by Karl Fischer reagent.	3252.1	D 1744
Water in petroleum products and bituminous materials by distillation.	3001.9	D 95
Water reaction of aviation fuels.	3251.9	D 1094
Water and sediment in crude oils.	3003.10	D 96
Water and sediment in crude oils and fuel oils by centrifuge.	3000.2	D 1976
Water and sediment in distillate fuels by centrifuge.		D 2709
Water separation characteristics of aviation turbine fuels (modified).	3256.4	D 2550
Water-washout characteristics of lubricating greases.	3252.3	D 1264
Wear, gear.	335.3	
Wear life of dry solid film lubricants.	3807.1	D 2605
Wear preventive characteristics of lubricating grease (four-ball method).	6514.2	D 2266

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TABLE III. Numerical index of canceled and superseded test methods.-[1/]

Title of canceled test method	Number of canceled method	Number of substitute method2/
Color of motor gasoline (military).	104	None
Effect of engine lubricating oils on ring sticking, wear, and the accumulation of deposits.	332	None
Performance characteristics of diesel engine lubricating oils under normal operating conditions.	336	None
Procedure for evaluating the ability of diesel engine lubricating oil to combat high corrosion, wear, and deposit formation in large-scale propulsion engines.	338	None
Performance characteristics of diesel engine lubricating oils under low ambient temperature operating conditions.	334, 343	None
Performance of engine lubricating oils under medium-speed, supercharged conditions with high sulfur content fuel.	340	None
Performance of diesel engine lubricating oils: high corrosive wear and deposit formation.	342	None
Demerit system for rating deposits, wear, and corrosion in internal combustion engines.	344	None
Performance characteristics of diesel engine lubricating oils under normal operating conditions in 4-cycle engines.	345	None
Performance of crankcase lubricating oils in CLR engine (low temperature deposition).	348	None
Low temperature rusting and deposits.	349	None
Distillation of gas oil and similar distillate ditertiary-butyl disulfide in reference diesel fuels.	600	None
Effects of engine lubricating oil on non-metallic automotive materials.	700	None
Distillation of gas oil and similar distillate fuel oils.	1002	1001
Vapor-liquid ratio of gasoline (alternate method) fuel oils.	1011, 1002	1001
Instantaneous ignition temperature test.	1153	None
Flock test (kerosene).	1301	None
Flock test (mineral seal oil).	1302	None
Wick-feed characteristics of oil (wick-feed oiler).	2001	None
Burning quality of long time burning oil for railway use.	2103	None

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TABLE III. Numerical index" of canceled and superseded test methods. 1/
(Continued)

Title of canceled test method	Number of canceled method	Number of substitute method 2/
Burning quality of mineral seal oil.	2104	None
Thermal stability of grease.	2503	None
Copper and iron in oil, sludge and water, after ASTM D 943 procedure.	3020	None
Steam emulsion (noninhibited oils).	3206	None
Foaming tendency of aircraft turbine lubricants.	3212	3211
Water separation characteristics of aviation turbine fuels.	3255	None
Total and dissolved solids in water for aircraft injection systems.	3290	3289
Oxidation stability of aviation fuels (potential gun) (Air Force, Navy bomb).	3355	3354
Oxidation characteristics of crankcase lubricating oils.	3402	3405
Demerit system for rating deposits, wear, and corrosion for a modified Caterpillar 1-G lubricant test.	3420	None
Separation of universal gear lubricants.	3455	None
High and low temperature stability.	3460	None
Thermal stability of boiler fuel oil (NBTL heater).	3461	None
Coking tendency of oil.	3462	None
Thermal stability of high temperature gas turbine fuels.	3466	None
Shear stability of hydraulic oils.	3471	None
Aniline point change (hydrocarbon oils).	3602	None
Corrosion protection (accelerated condensation apparatus).	4002	None
Reaction threshold temperature.	5050	None
Neutralization number.	5103	5105
Neutralization number of used or compounded oils.	5104	5105
Hydrobromic acid neutralization.	5108	None
Sulfur by the lamp method (volumetric finish).	5210	None
Corrosive sulfur compounds and free sulfur.	5302	5325
Corrosion (copper strip, 212° F).	5303	5325
Corrosion-inhibiting properties of non-aquaeous liquids (static water-drop test).	5311	None
Corrosion inhibiting properties of non-aqueous substances (fog cabinet).	5312	None
Free & corrosive sulfur.	5313	5325

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TABLE III. Numerical index of canceled and superseded test methods. 1/ (Continued)

Title of canceled test method	Number of canceled method	Number of substitute method 2/
Corrosion protection by universal gear lubricants in the presence of water.	5315	None
Chemical activity toward copper of universal gear lubricants.	5316	5325
Performance of gear lubricants in axles at low speed and high torque.	5317	None
Moisture corrosion characteristics of universal gear lubricants.	5318	None
Humidity corrosion test of grease.	5319	4012
Corrosion under static conditions.	5320	None
Corrosion protection by aircraft lubricants.	5323	None
Corrosion by high-sulfur oils (copper stain).	5324	None
Saponification number (potentiometric titration).	5403	None
Resistance of lubricating grease to de-icing fluid.	5410	None
Cycling performance of grease.	5413	None
Elemental lead in hydrocarbon fuels (rapid method).	5505	None
Sulfonated residue, lead, iron, and copper in new and used lubricating oils.	5611	None
Sludge formation in mineral transformer oil.	5704	None
Effect of oil vapor on indicating-type desiccant.	5800	None
Load-carrying capacity (SAE)	6501	None
Load-carrying characteristics of universal gear lubricants in axles under conditions of high speed.	6504	None
Sampling (grease).	8002	8001
Volume calculations and corrections.	8005	None
Conversion of kinetic viscosity to Saybolt furol viscosity.	9102	None

1/ The test methods listed in this index have been either cancelled or superseded. Some of the methods, however, are still referenced in specifications and are listed here for the convenience of users of the specifications.

2/ The word “None” indicates that the test method has been cancelled because it is no longer referenced in any Federal or Military specification.

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TABLE IV. Numerical index of ASTM equivalents for Federal standard test methods.

ASTM	Fed. Std. Test Method	ASTM	Fed. Std. Test Method
D 56	1101.8	D 665	4011.4
D 86	1001.13	D 721	5431.6
D 87	1402.5	D 808	5651.4
D 88	304.8	D 811	5601.1
D 91	3101.5	D 873	3354.7
D 92	1103.7	D 874	5422.3
D 93	1102.11	D 875	3701.3
D 94	5401.8	D 877	5702.1
D 95	3001.9	D 878	5703.1
D 96	3003.10	D 892	3211.3
D 97	201.9	D 893	3121.5
D 127	1401.4	D 909	6012.7
D 128	5412.6	D 936	3702.2
D 129	5202.12	D 937	312.4
D 130	5325.4	D 941	402.2
D 156	101.7	D 942	3453.2
D 187	2106.5	D 972	351.2
D 189	5001.11	D 974	5105.5
D 216	1015	D 1019	1040.2
D 217	311.8	D 1085	8003.3
D 240	2502.6	D 1086	8004.4
D 4057	8001.6	D 1091	5661.5
D 287	401.7	D 1092	306.4
D 323	1201.6	D 1094	3251.8
D 341	9121.1	D 1159	1050.1
D 381	3302.9	D 1219	5204.3
D 445	305.6	D 1250	9001.4
D 473	3002.6	D 1261	5314.1
D 482	5421.4	D 1263	3454.2
D 483	5441.1	D 1264	3252.3
D 484	5203.3	D 1266	5201.10
D 524	5002.7	D 1269	5502.1
D 525	3352.5	D 1275	5328.3
D 526	5501.6	D 1313	5705
D 565	5012	D 1319	3703.6
D 566	1421.2	D 1322	2107.4
D 611	3601.7	D 1323	5206
D 612	5011.1	D 1405	2501.1
D 613	6051.7	D 1478	334.2
D 614	6011.7	D 1500	102.7
D 664	5106.4	D 1548	5445.1

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TABLE IV. Numerical index of ASTM equivalents for Federal standard test methods. (Continued)

ASTM	Fed. Std. Test Method	ASTM	Fed. Std. Test Method
D 1660	3464.8	D 2533	1010.1
D 1661	2506.1	D 2550	3256.3
D 1740	2108.2	D 2596	6503.2
D 1742	322.3	D 2605	3807.1
D 1743	4012.1	D 2625	3812.1
D 1744	3253.1	D 2625	3814.1
D 1748	5310.2	D 2699	6002.10
D 1796	3000.2	D 2699	6005.6
D 1840	3704.1	D 2700	6001.14
D 1947	6512.3	D 2700	6006.4
D 2700	6006.4	D 2783	6503.2
D 2155	1152.2	D 3336	331.2
D 2161	9101.3	D 3336	333.1
D 2266	6514.2	E 1	9501.10
D 2270	9111.3	E 203	3250.1
D 2273	3004.6	STP 509A Pt. 1	341.4
D 2276	3008.7	STP 509A Pt. 2	346.2
D 2386	1411.5	STP 509A Pt. 4	3405.2
D 2510	3810.2	STP 512 Pt. 4	5326.1
D 2510	7001.1	STP 512 Pt. 3	6506.1
D 2511	3805.2	STP 512 Pr. 2	6507.1
D 2532	307.2	STP 512 Pt. 5	2504

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TABLE V. ASTM references cited in Federal or Military Specifications

D 56
D 86
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D 3341
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E 659
F 313
STP 315
STP 509

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TABLE VI. Identifying symbols and addresses of activities responsible for preparation and maintenance of test methods.

Symbol	Service	Activity
NAPC	Navy	Department of the Navy Naval Air Propulsion Center P.O. BOX 7176 Trenton, New Jersey 08628
SFTL	Air Force	Department of the Air Force HDQR San Antonio Air Logistics Center Kelly Air Force Base, Texas 78241-5000
AR	Army	Department of the Army US Army Armament Research and Development Center Dover, New Jersey 07801-5001
SH	Navy	Department of the Navy Naval Sea Systems Command Washington, D.C. 20362
AFWAL/POSF	"Air Force	Department of the Air Force Air Force Wright Aeronautical Laboratories POSF Wright-Patterson Air Force Base, Ohio 45433
AFWAL/POSL	Air Force	USAF/Aero Propulsion Laboratory AFWAL/POSL Wright-Patterson AFB, OH 45433-6563
ME	Army	Department of Army Belvoir Research, Development and Engineering Center Fuels and Lubricants Division Ft. Belvoir, VA 22060-5606

Custodians:
Army-ME
Navy - SH
Air Force - 11

Preparing activity:
Army - ME

Project 91GP-0083

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METHOD 103.6
September 30, 1986

COLOR OF GASOLINE

1. SCOPE

1.1 This method is used for determining the acceptability of color of dyed gasolines (aviation or motor).

2. SUMMARY

2.1 The method consists of comparing the hue and color intensity of the gasoline with those of permanent-color (glass) standards.

3. SAMPLE SIZE

3.1 Approximately 480 mL of gasoline to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Color comparator (Hellige Inc., Garden City, N.Y., Aqua-Testers No. 611A, or equal), split-field, for viewing simultaneously (by transmitted light) the sample and the combination of the reference liquid and the permanent-color standard.

4.2 Fluid tubes (2), glass, 20.0-cm viewing depth, with a fused-on plane bottom plate (Hellige Nessler tube No. 611-T, or equal).

4.3 Plungers, fluid-tube (2), polished optical glass (Hellige Nessler plunger No. 611-PL, or equal).

4.4 Gasoline color standards, permanent - color glass disc (as required):

a. Aviation gasoline standard (Hellige 611-95 and 611-96, or equal).
b. Motor gasoline standard (Hellige 611-97 or equal).

5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Reference liquid; either a sample of the gasoline under test (prior to addition of dye or tetraethyl lead), or distilled [1,3,0].

6. PROCEDURE

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6.1 Clean the optical surfaces of the color comparator.

6.2 Insert empty tubes in the color comparator, and adjust the position of the light source until the intensities of the light from both halves of the comparator split-field are equal.

6.3 Rinse and fill one of the tubes with reference liquid, and insert the plunger.

6.4 Wipe all excess reference liquid from the outside of the tube and from the top of the plunger, and insert the tube in the one side of the comparator.

6.5 Rinse and fill the remaining tube with the sample and insert the plunger.

6.6 Wipe all excess sample from the outside of the tube and from the top of the plunger, and insert the tube in the other side of the comparator.

6.7 Insert the color standard(s) into the comparator, and rotate the standard until the color selection can be viewed by transmitted light.

6.8 Turn on the light source, and visually compare the two fields for hue and intensity. (When testing aviation gasoline, compare its hue and intensity with the minimum and maximum color sections of the glass color standards.)

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Report the color as acceptable if the hue is approximately the same as the standard and if the intensity of the color is as follows:

a. Aviation gasoline intensity: between minimum and maximum standards.
b. Motor gasoline intensity: equal to or greater than standards.

9. PRECISION

9.1 Precision data have not been developed for this method.

Method Prepared By:
Army - ME - 1986

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CLOUD INTENSITY AT LOW TEMPERATURE

1. SCOPE.

1.1 This method is used for determining the stability (at low temperature) of hydraulic fluids or highly refined light lubricating oils.

2. SUMMARY.

2.1 The method consists of storing a sample at -54 “C (-65° F) or lower for a period required by the petroleum product specification, agitating it, and comparing its turbidity with a standard. The sample is poured in a sealed, cleaned, dried sample bottle and stored for a specified number of hours at a maximum of -54° C (-65° F). Within 5 minutes of the comparison time, the turbidity standard is shaken vigorously for 10 seconds and poured into a sample bottle. At the end of the storage time, the sample is removed from cold storage and shaken vigorously for 10 seconds. The frost is eliminated from the sample bottle and it is compared with the turbidity standard. The turbidity of the sample relative to the standard is reported as less than, more than, or equal to the standard.

3. SAMPLE SIZE.

3.1 Approximately 120 mL of test oil (or fluid).

4. REFERENCES, STANDARDS, AND APPARATUS.

4.1 Cooling apparatus, -54° C (-65° F) or lower (ASTM cloud and pour point apparatus, or equal).

4.2 Sample bottles (2), clear-glass 120-mL, with cork stoppers.

5. MATERIALS.

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Methanol-glycerol (technical grade), 1 to 1 solution (by volume) [1,3,0].

5.3 Turbidity standard, prepared within 30 minutes of use, as follows:

a. Pour 25 mL of 0.00322-molar barium chloride into a 250-mL volumetric flask [0,0,2].

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b. Add 125 mL of 0.0050N sulfuric acid, and shake well to insure complete precipitation [3,0,2].
c. Add approximately 25 mL of lN sodium hydroxide to make solution alkaline [3,0,1].
d. Add distilled water to bring total volume to 250 mL.
e. Pour solution into a sample bottle, and seal it tightly with stopper.

Note. For red hydraulic liquids, in place of plain distilled water, use distilled water containing 200 ppm red dye (National Erie Bordeaux B, manufactured by National Aniline Division of Allied Chemical and Dye Corp., or equivalent).

6. PROCEDURE.

6.1 Clean sample bottles, and dry at approximately 100° C for a minimum of 24 hours.

6.2 Pour sample into bottle, and seal bottle tightly with stopper.

6.3 Store sample for the specified number of hours at a temperature no warmer than -54° C (-65° F).

6.4 Before end of storage period, cool the methanol-glycerol solution to -54° C (-65° F).

6.5 Within 5 minutes of making comparison, shake the turbidity standard vigorously for 10 seconds, and pour into the other sample bottle.

6.6 At the end of the storage period, remove sample from cold storage, and shake vigorously for approximately 10 seconds.

6.7 Dip sample into methanol-glycerol solution to eliminate frosting (if necessary), and within one minute of removal from cold storage, compare sample visually with the turbidity standard.

6.8 Note the turbidity of the sample.

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING.

8.1 Report turbidity of sample relative to standard as less than, more than, or equal to the standard.

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9 . PRECISION.

9.1 Precision data have not been developed for this method.

Method Prepared by:

Army - ME - 1986

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METHOD 203.1
September 30, 1986

POUR STABILITY OF LUBRICATING OILS

1. SCOPE

1.1 The test for pour stability is primarily intended for use with engine lubrication oils. However, by establishing proper final cooling temperatures, this method can be used for other lubricating oils such as power transmission fluids and hydraulic oils.

1.2 Good correlation with field test results has been obtained. However, since only two temperature/time cycles are reproduced, this method cannot duplicate all field ambient cycle conditions.

2. SUMMARY

2.1 After preliminary warming, the sample is subjected to a controlled temperature/time cycle over five and one-half to seven days. Two cycles have been established to reproduce pour instability or reversion which has occurred during storage of oils in moderately cold cyclic ambient conditions. Oils exhibiting pour reversion are essentially "solid", resulting from wax gel formation, at temperatures significantly above their ASTM D 97 pour points.

3. SAMPLE SIZE

3.1 Approximately 100 mL of test lubricant.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Test Jar - Identical to ASTM D 97 and D 2500 pour point/cloud point test jar.

4.2 Thermometer - ASTM E-1 6C with temperature range of +20° C to -80° C.

4.3 Cork - to fit test jar.

4.4 Heating bath - hot water to precondition test samples (80° C).

4.5 Cooling bath - low temperature with controller to follow temperature/ time cycles from +15° C to –45° C. Spacing between test jars is to be about 1.5 cm with jars suspended so that cooling medium circulates around bottom and sides of jars.

5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists

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all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Engine crankcase oil.

6. PROCEDURES

6.1 DEFINITIONS

6.1.1 Pour Stability Temperature - That specified temperature at which an oil remains fluid on completion of an established temperature/time cycle. See 6.2.8.

6.1.2 Stable Pour Point - The lowest temperature at which an oil remains fluid when subjected to an established temperature/time cycle. See 6.2.9.

6.2 Test procedures.

6.2.1 Adjust cooling bath temperature to +15° C with one temperature sensing bulb in the cooling medium.

6.2.2 Prepare two temperature measurement samples as follows:

6.2.2.1 Select a sample oil which is known to be fluid below the lowest temperature SAE Grade to be tested.

6.2.2.2 Fill each of two test jars with approximately 40 mL of selected oil sample. Identify these bottles as “Temperature Measurement Sample”.

6.2.2.3 Prepare cork stopper to accommodate the standardized calibrated ASTM thermometer.

6.2.2.4 Insert stopper and thermometer into one jar so that thermometer immersion *line is* visible but not more than 0.3 cm above top of stopper. Place jar in center of cooling bath.

6.2.2.5 Prepare cork stopper to accommodate recorded temperature sensing bulb.

6.2.2.6 Insert stopper and one temperature sensing bulb in the second jar and position the bulb approximately 0.5 cm into the control oil sample. Place jar in center of cooling bath next to jar with thermometer.

6.2.2.7 Place the other temperature sensing bulb in cooling bath medium adjacent to the two control sample bottles.

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6.2.3 Determine cloud point of test oil(s) by ASTM D 2500 procedure.

6.2.4 Prepare duplicate samples of test oil(s) using test jars filled with approximately 40 mL of test oil(s). Identify these with their SAE grade.

Note: Clean, dust-free jars and stoppers are required to eliminate possible contamination which may contribute to erroneous results.

6.2.5 Pretreat the duplicate test oil samples.

6.2.5.1 Place test sample jars in a hot water bath at +80° C for 2 hours. Shake each test jar with sample several times.

6.2.5.2 Loosen stopper and allow sample to cool to room temperature. Then reinsert stopper.

6.2.5.3 Place test sample jars in cooling bath adjacent to control sample jars. All samples must be at same level if liquid bath is used.

6.2.6 Prepare bath for cyclic temperature test.

6.2.6.1 Temperature of bath should be at +15° C. Check thermometer and recorded temperature of temperature sensing bulbs.

6.2.6.2 If liquid bath is used, adjust level in bath to slightly above sample level in test jars.

6.2.6.3 Select temperature cycle A or cycle C (figure 1 or figure 2): use cycle A followed by cycle C for oil with cloud point of -5 to +45° C and cycle C for oils with cloud point below -5° C. Figure 2 includes temperature/time tables for use with programmable controllers.

6.2.6.4 Initiate the temperature cycle selected in 6.2.6.3.

6.2.7 During the final cool down, check proper temperature control each day as follows:

6.2.7.1 Read the “Temperature Measurement Sample” thermometer. Return this sample to the center of the bath.

6.2.7.2 Compare this temperature with the recorded temperature.

6.2.7.3 Determine whether a correction is required in the reading of recorded temperature. Estimate the correct time to make the first pour stability determination at the correct thermometer temperature (±1° C).

6.2.8 Pour stability determinations are made at the temperatures specified for the SAE grades of the test samples. The determination whether a test

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sample is “fluid” or “solid” at the specified temperature is conducted as follows:

6.2.8.1 Select the SAE grade test sample to be checked.

6.2.8.2 Carefully remove the test jar vertically from the bath and slowly tilt 90 degrees to horizontal position. For 5 seconds observe the surface of the sample for movement.

Note: Handle jars at stopper end only to prevent heating the sample. If frosting occurs, wipe jars with cloth or glove; do not use unprotected finger.

6.2.8.3 If the surface moves, the sample is “fluid”. If no movement is detected, the sample is “solid”.

6.2.8.4 Select the duplicate test sample and repeat pour stability determination (see 6.2.8.2 and 6.2.8.3).

6.2.8.5 If additional SAE grades are included in the test bath, repeat all steps in 6.2.8 for the remaining duplicate test samples at specified temperatures .

6.2.9 Alternate method for determination of stable pour point. In this determination, the viscosity grade of the oil is not relevant. The stable pour point is determined during the final cool down in the temperature/time cycle as follows:

6.2.9.1 At the sample temperature of -5° C, carefully remove the test jar vertically from the bath and carefully tilt only enough to ascertain whether the oil surface moves and is “fluid”. If movement is detected while tilting, return the bottle to vertical and carefully replace in bath. Total time for this operation shall be less than 3 seconds.

Note: Handle jar at stopper end only to prevent heating the sample. If frosting occurs, wipe jar with a cloth or glove; do not use unprotected finger.

6.2.9.2 If no movement of the oil is detected when the jar is tilted to 90 degrees (horizontal) for 5 seconds the sample is "solid”.

6.2.9.3 For oils which remain fluid, repeat step 6.2.9.1 at successively lower temperatures, in 3° C increments, until no movement of the oil is detected and the oil is “solid” by 6.2.9.2. Record the reading of the temperature measurement sample thermometer.

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

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8. REPORTING

8.1 Report pour stability as follows: If both (duplicate) samples show movement, report as “fluid at -XX° C". If one sample is fluid and the duplicate is solid or if both samples are solid, report as “solid at -XX° C".

8.2 Report stable pour point as 3° C higher than the temperature recorded in 6.2.9.3.

9. PRECISION

9.1 Precision data have not been developed for this method.

Method Prepared By:

Army - ME - 1986

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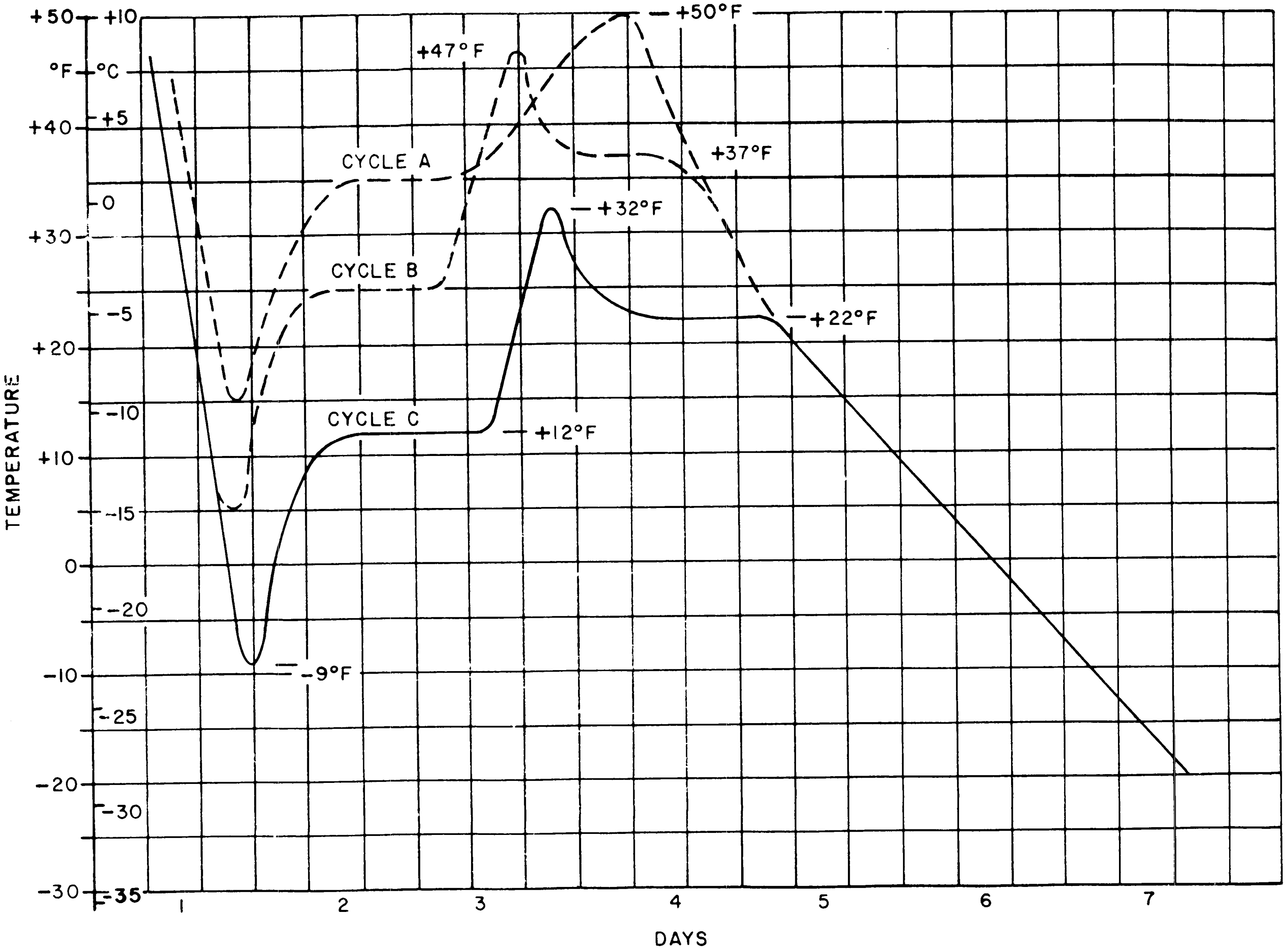

FIGURE I. Temperature/time profile.

X-4320

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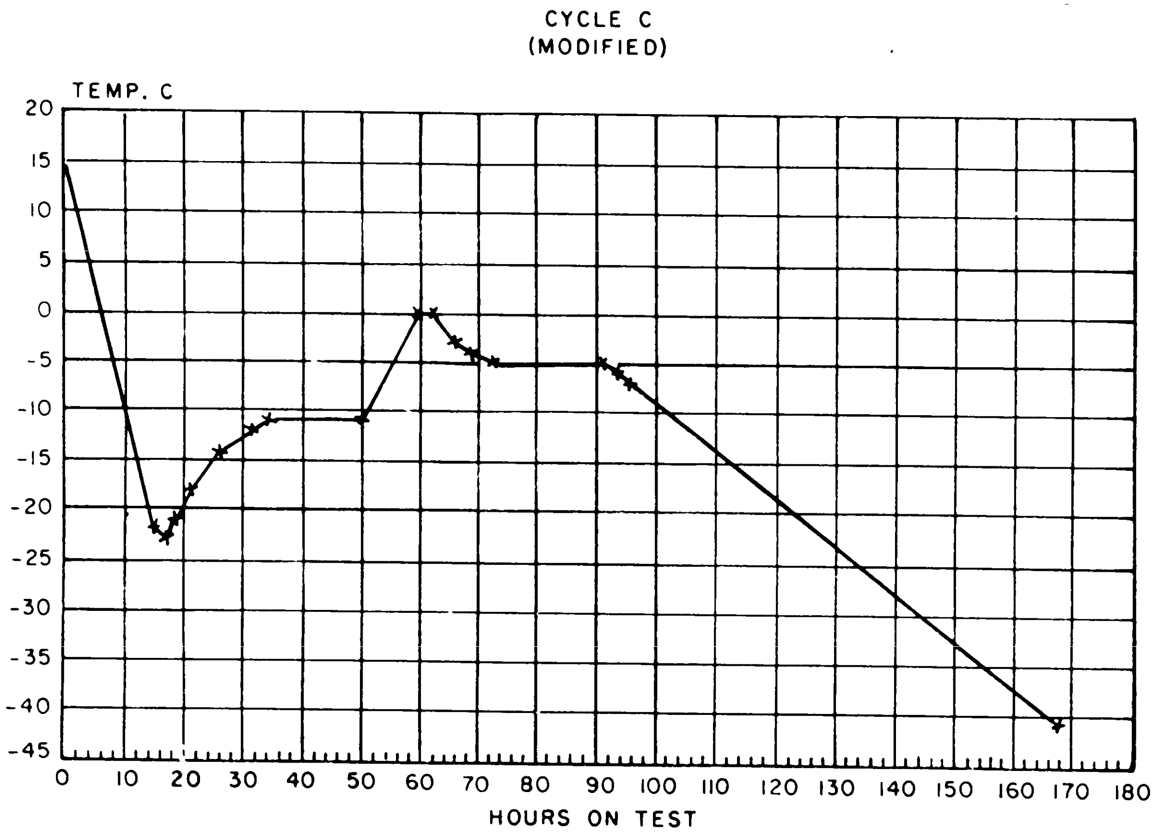

PROGRAM FOR CYCLE C (MODIFIED), SOFT METRICATION

PROGRAM SETTINGS

Total Time Hours	Time Hours	Direction & Temp., C
0	0	Set at 15
15	15	Down to -22
17	2	Down to -23
19	2	up to -21
21	2	Up to -18
26	5	up to -14
31	5	up to -12
34	3	up to -11
50	16	At -11
60	10	up to o
62	2	At 0
63	1	Down to -1
66	3	Down to -3
69	3	Down to -4
73	4	Down to -5
91	18	At -5
94	3	Down to 06
96	2	Down to -7
168	72	Down to -41

TEST CHECK TIMES

Approx. Hours	Temp. ° C
91	- 5
98	- 8
104	-11
111	-14
117	-17
124	-20
130	-23
136	-26
143	-29
149	-32
156	-35
162	-38
168	-41

FIGURE 2. Temperature profile for cycle c.

X-4321

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DILUTED POUR POINT

1. SCOPE

1.1 This method is used for indicating the flow characteristics of engine oils that have been diluted with aviation gasoline.

2. SUMMARY

2.1 The test consists of diluting the oil with a mixture of naphtha and xylene, and (without preheating) determining the pour point of the diluted oil.

3. SAMPLE SIZE

3.1 Approximately 90 mL (3 fluid ounces) of the oil *to* be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Test setup, pour point, as specified in ASTM D 97, Pour Point of Petroleum Oils.

5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Diluent, consisting (by volume) of naphtha (80 percent) and xylene (20 percent) conforming to the following specifications:

a. Naphtha (TT-N-95, type I), capable of being cooled to -60° C (-76° F) without forming a cloud or precipitate. [1,4,0].
b. Xylene (TT-X-916, grade A), having a distillation range no greater than 10° C (18° F) which includes 140° C (284° F). [2,3,0].

6. PROCEDURE

6.1 Prepare approximately 90 mL (4 fluid ounces) of a mixture consisting (by volume) of 70 percent of test sample and 30 percent diluent.

6.2 Determine the pour point of the mixture in accordance with ASTM D 97, omitting the preliminary step of heating to 48° C (118° F).

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7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Report the pour point temperature in accordance with ASTM D 97.

9. PRECISION

9.1 Repeatability. As specified in ASTM D 97.

9.2 Reproducibility. As specified in ASTM D 97.

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Navy - NAPC - 1986

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PENETRATION OF LUBRICATING GREASES AFTER PROLONGED WORKING

1. SCOPE

1.1 This method is used for determining the consistency of lubricating greases that have been subjected to severe mechanical working.

2. SUMMARY

2.1 The method consists of working the grease mechanically under specified conditions for 100,000 double strokes (approximately 28 hours), then checking the worked penetration in accordance with ASTM D 217.

3. SAMPLE SIZE

3.1 Sufficient grease to be tested to pack grease worker.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Grease worker, as specified in the “Cone Penetration of Lubricating Grease” ASTM D 217, with the following differences:

a. Machine grease-working, 60 double strokes per minute.
b. Plunger plate, 270 holes 0.16 mm (1/16 inch) diameter, arranged as in Figure 1.

5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which list’s all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Grease to be tested.

6. PROCEDURE

6.1 Pack sample in grease worker, and assemble and vent grease worker as described in “Procedure for Worked Penetration” of ASTM D 217.

6.2 Mount grease worker in machine and work grease for 100,000 double strokes while maintaining the’ ambient temperature at 25 + 1° C (77 + 2° F).

6.3 Remove the worker from the machine, making certain that plunger is pushed all the way down.

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6.4 Open the vent cock and insert the thermometer as in “Procedure for Worked penetration” of ASTM D 217.

6.5 Place grease worker in the waterbath, bring temperature of sample to 25 . +1° c (77 +2° F) and determine worked penetration in accordance with ASTM D 217.

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Report penetration after mechanical working as determined in paragraph 6.5.

9. PRECISION

9.1 Precision data have not been developed for this method.

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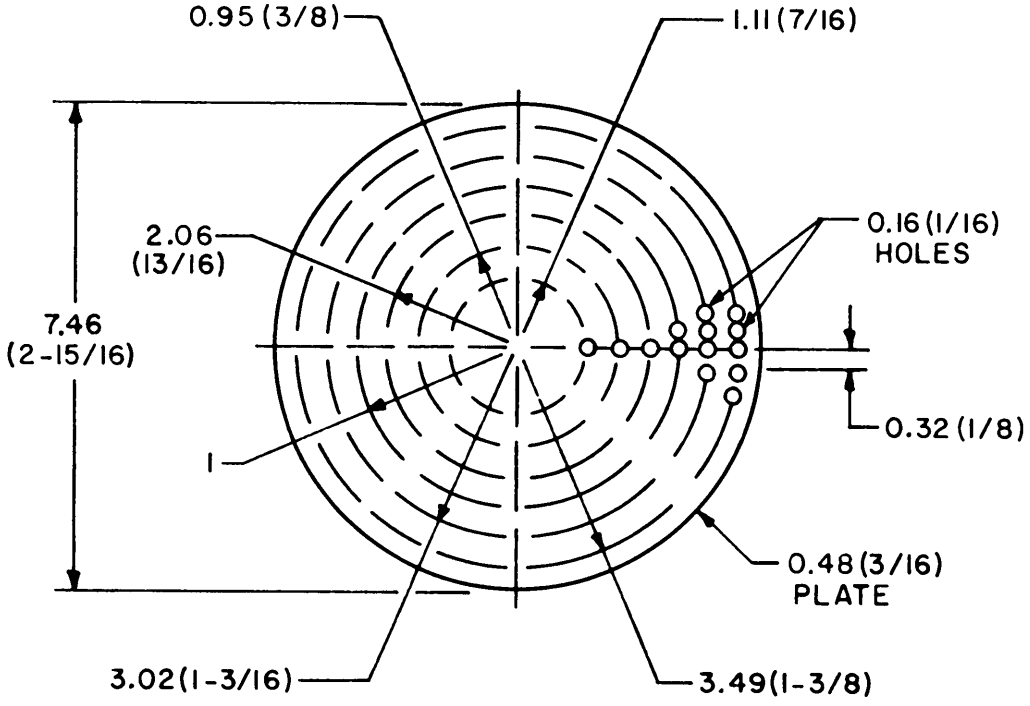

DRILL MAXIMUM NUMBER OF HOLES ON EACH CIRCLE

DIMENSIONS IN CENTIMETERS (INCHES)

FIGURE 1. Plunger plate.

X-4322

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METHOD 321.3
September 30, 1986

OIL SEPARATION FROM LUBRICATING GREASE
(Static Technique)

1. SCOPE

1.1 This method is used for determining the tendency of the oil in lubricating grease to separate at an elevated temperature.

2. SUMMARY

2.1 The test consists of heating the sample in a wire-gauze cone under static conditions for the time and at the temperature required by the specification, then determining the percentage (by weight) of the oil drained through the cone. Unless otherwise specified, the test shall be conducted for 30 hours at 100° ±0.5° C (212° F ±1° F)

3. SAMPLE SIZE

3.1 Approximately 10 g of grease to be tested (weighed to within 0.1 g).

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Test setup (Figure 1), consisting of:

a. Cone, nickel gauze, 60-mesh (holes 558 per square cm, wire 0.019 cm, openings 0.028 cm [holes, 3600 per square inch, wire 0.0075 inch, openings 0.011 inch]), with a wire handle.
b. Beaker, tall-form, without spout, 200-mL.
c. Cover, close-fitting, with hook approximately centered on underside.

4.2 Oven, capable of maintaining the specified temperature within 0.5° C (1° F).

5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

6. PROCEDURE

6.1 Preheat oven to test temperature.

6.2 Weigh clean beaker (without cone or cover) to within 0.01 g.

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6.3 Place sample in cone, so that top of specimen is smooth and convex (to prevent trapping of free oil).

6.4 Assemble test setup as shown in figure 1.

6.5 Heat test setup in oven for the specified time at the specified temperature.

6.6 Remove setup from oven, and allow it to cool to room temperature.

6.7 Remove cone from beaker, tapping it gently against the inside of the beaker to remove any oil adhering to its tip.

6.8 Determine the weight of oil collected in the beaker to within 0.01 g.

7. CALCULATIONS

7.1 Calculate the percentage (by weight) of separated oil in the original sample.

$$\text{percentage separated} = \frac{W_b - W_a}{W_b} \times 100$$

W_b = the weight of the grease before heating.
W_a = the weight of the grease after heating.

8. REPORTING

8.1 Report the percentage of separated grease.

9. PRECISION

9.1 Precision data have not been developed for this method.

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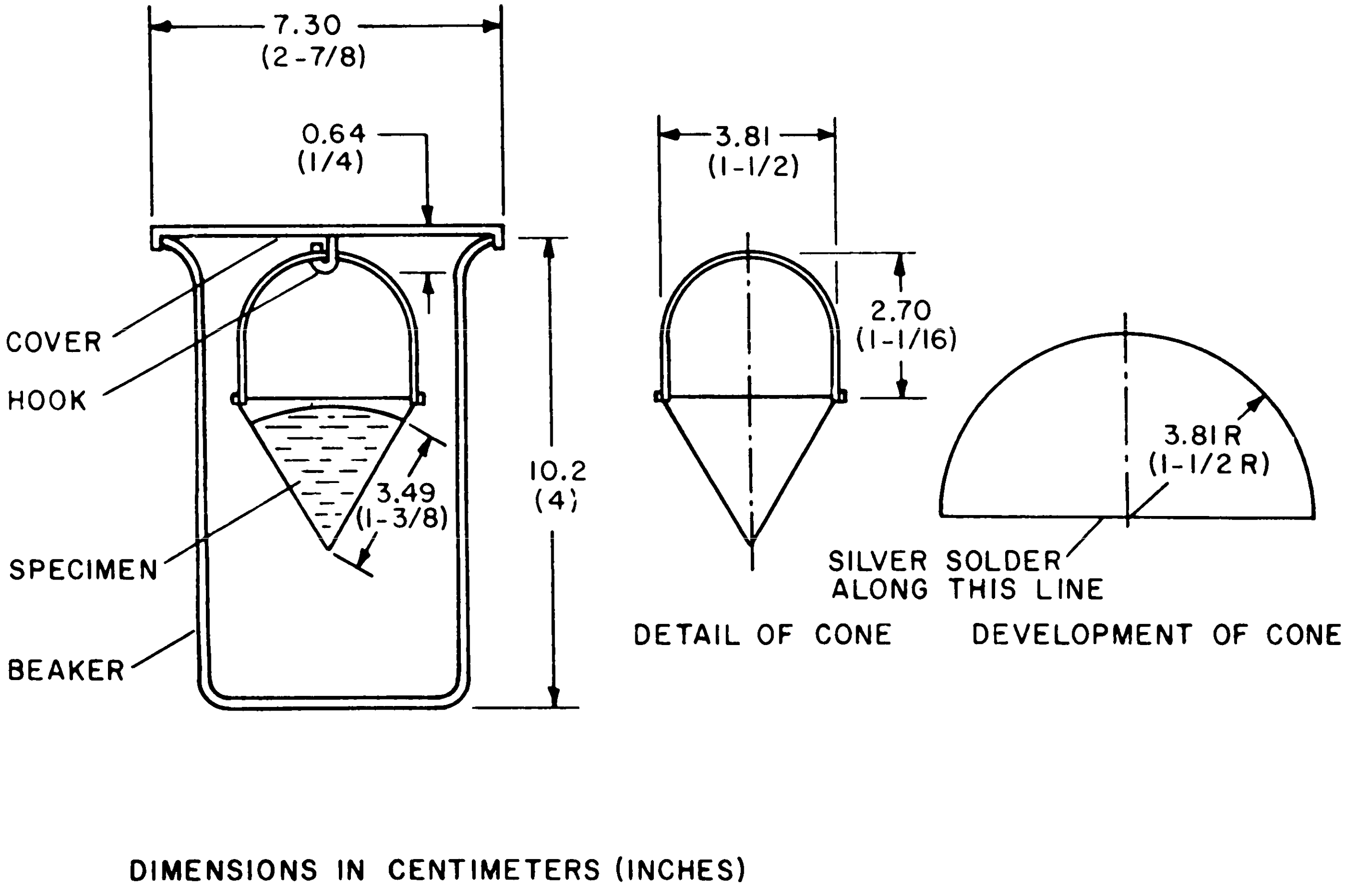

FIGURE I. Test setup.

X-4323

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GEAR WEAR

1. SCOPE

1.1 This method is used for determining the relative lubricity of greases.

2. SUMMARY

2.1 This method consists of lubricating test gears (2 sets) of known wearing quality with the grease to be tested, running the gears under specified loads, and reporting the wear as the average loss in weight of the gears.

3. SAMPLE SIZE

3.1 Approximately 1 g of grease to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Gear wear tester (Figure 1), consisting essentially of:

a. Drive shaft, including 2.54 cm (1 inch) OD drive pulley and provision for mounting a brass test gear (see Figure 2).
b. Driven shaft, inluding 2.54 cm (1 inch) OD loading weight pulley and provision for mounting a steel gear (see Figure 2).

4.2 Drive mechanism, reciprocating (sinusoidal linear motion), 7.98 cm (3.14 inch) amplitude, 60 CPM, with a cycle counter (6000 cycles minimum).

4.3 Weight, 2.27 kg (5 lb.) (see Figure 1).

4.4 Weight, 4.54 kg (10 lb.) (see Figure 1).

4.5 Brush, stiff-bristle (toothbrush or equal).

4.6 Oven, 71° C (160° F).

4.7 Balance, sensitivity 0.1 mg.

4.8 Container (for holding Di-2-ethylhexyl sebacate in contact with steel gear).

5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

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5.2 Dry Cleaning Solvent (ASTM D 484), Type I. [0,2,0].

5.3 Petroleum Ether (O-E-751). [1,4,0].

5.4 Di-2-ethylhexyl Sebacate, commercial grade. [0,0,0].

5.5 Test gear sets (2), composed of one brass and one steel gear (see Table 1).

TABLE I. Gear specifications.

	Brass gear	Steel gear
Pitch diameter	1.107 cm (0.4359 inch)	1.211 cm (0.9769 inch)
Helix angle	55° LH	35° LH
Number teeth	16	25
Rootdiatmeter	0.000 (0.000 inch) +1.02 cm (0.400 inch) -0.025 cm (-0.010 inch)	0.000 (0.0000 inch) +1.12 cm (0.441 inch) -0.025 cm (-0.010 inch)
Composition	QQ-613 Comp. 24	MIL-S-7720 Comp. 302
Brinell hardness	100-140	210-250
Tooth form	Involute 14 1/2° pressure angle	
Normal pitch	64	
Shaft Angle	90°	

6. PROCEDURE

6.1 Mount the brass gear on the drive shaft and the steel gear on the driven shaft. Scribe alignment marks on the gears to insure that tile gears are placed in the same position relative to each other on each assembly at the test setup.

6.1.1 Preparation and cleaning of gears.

6.1.1.1 . Clean, dry, and weigh test gears as follows:

a. Scrub test gears, using stiff-bristle brush and dry cleaning solvent (see note 1).
b. Rinse gears in petroleum ether, and dry in oven at 71° C (160° F) (see note 1).

Note 1. CAUTION. Dry-cleaning solvent and petroleum ether are both toxic and flammable. Use only in a well ventilated area. Do not breathe their fumes or allow them to come in contact with the skin. Keep all flames from the solvent, especially the petroleum ether.

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c. Remove gears from oven, cool, and record the weight (to the nearest 0.1 mg) at the brass gear.

6.2 Assemble the test setup as follows:

a. Mount brass gear on drive shaft and steel gear on driven shaft of the gear wear tester (see Figure 1). Insure proper positioning of the test gears by lining up the scribe marks (see 6.1).
b. Using flexible cord wound around the pulleys, couple the drive shaft to the reciprocating drive mechanisms and apply a 2.27 kg (5-lb) weight to the driven shaft.

6.3 Perform gear break-in run as follows:

a. Place container (see 4.8) under the gears, and fill it with Di-2 etylhexyl sebacate until the lower teeth of the steel gear are immersed.
b. Start the reciprocating drive mechanism, and allow it to operate for 1500 complete cycles.
c. After the test period, remove, clean, and dry the gears, and reweigh the brass gear (see paragraph 6.1.1.1).
d. Retain the gear set for use in testing if loss in weight of brass gear does not exceed 2.0 mg; discard (as defective) both gears of the set if loss exceeds 2.0 mg.

<u>Note 2</u>. A drop feed lubricator has beep found effective to insure removal of wear debris during break-in run for the tests.

6.4 Assemble the test setup (paragraph 6.2) and throughly coat the gear teeth with the grease to be tested. Then start the reciprocating drive mechanism, and allow it to operate for 6000 cycles.

6.5 At the end of the test run, remove the gears, clean and dry them, and reweigh the brass gear as described in paragraph 6.1.1.1.

6.6 Repeat the procedures described in paragraph 6.2, substituting a 4.54 kg (l0-lb) weight and 3000 cycle operation.

6.7 At the end of the 3000 cycle run, remove and clean gears, and reweigh the brass gear as described in paragraph 6.1.1.1.

6.8 Conduct two complete tests, using new gear sets each time, and calculate the average weight loss (per 1000 cycles) of the brass gears for the 6000 cycle and 3000 cycle runs.

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7. CALCULATIONS

7.1 Calculation for average weight ± loss, to the nearest mg.

$WL = A - B$
WL = Weight loss in brass area.
A = Orginal weight of brass gear, in mg.
B = Final weight of brass gear in mg.

8. REPORTING

8.1 Report the average weight loss (per 1000 cycles) of the brass gears for the 6000 cycle and 3000 cycle runs.

9. PRECISION

9.1 Precision data have not been developed for this method.

Method Prepared by:

Navy - NADC - 1986

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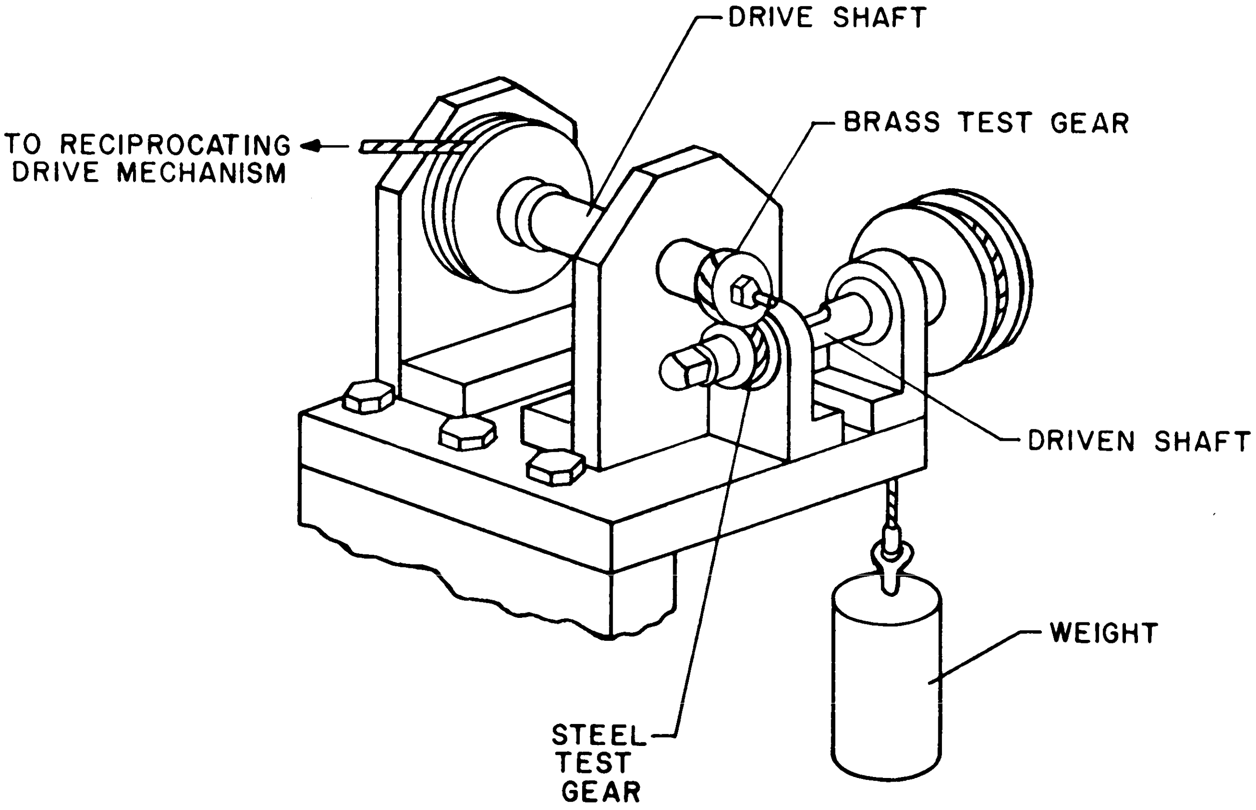

FIGURE 1. Gear wear tester.

X-4331

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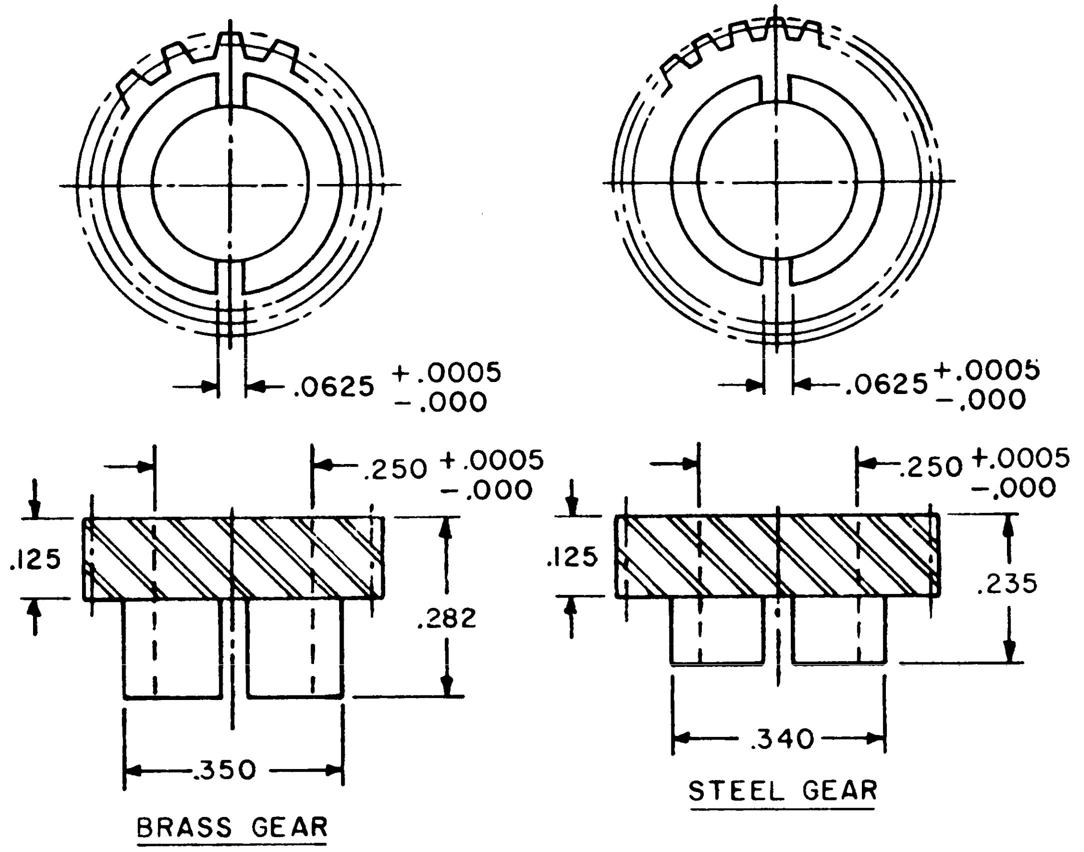

SPECIFICATIONS		
	BRASS GEAR	STEEL GEAR
MATERIAL	QQ-B-613, COMP 22	MIL-S-7720, COMP 302
BRINELL HARDNESS	100-140	210-250
OUTSIDE DIAMETER	.467 +.000, -.002	.508 +.000, -.002
PITCH DIAMETER	.4359	.4769
TOOTH FORM	INVOLUTE 14-1/2° PRESSURE ANGLE	
HELIX PITCH	55° L.H.	35° L.H.
NORMAL PITCH	64	
ROOT DIAMETER	.400 MAX.	.441 MAX.
SHAFT ANGLE	90°	
NO. OF TEETH	16	25
TOOTH THICKNESS TOLERANCE	-.001 -.003	

NOTES:
1. DIMENSIONS ARE IN INCHES.
2. TOLERANCES: UNLESS OTHERWISE SPECIFIED, DECIMALS 3 PLACES ± .001.

FIGURE 2, Test gears for gear wear test apparatus,

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METHOD 339.6
September 30, 1986

PERFORMANCE OF DIESEL ENGINE LUBRICATING OILS UNDER SEVERE OPERATING CONDITIONS

1. SCOPE

1.1 This method describes a test procedure for evaluating the performance characteristics of diesel engine lubricating oils when used under severe operating conditions with high sulfur fuel and sea water contamination.

2. SUMMARY

2.1 A three-cylinder two-cycle diesel engine is operated with a test oil, contaminated with sea water, for a period of 300 hours under propulsion operating conditions. Performance of the test oil is indicated by the condition of the engine parts (piston ring sticking, deposits, valve and port condition, bearing corrosion, engine wear, and deterioration of the oil).

3. SAMPLE SIZE

3.1 Test oil. A minimum of 95 L (25 gallon) of the test oil are required.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 References.

4.1.1 CRC Diesel Engine Rating Manual No. 5, Coordinating Research Council, Inc., 30 Rockefeller Plaza, New York, N.y. 10020.

4.1.2 CRC Rust Rating Manual No. 7, Coordinating Research Council, Inc., 30 Rockefeller Plaza, New York, N.Y. 10020.”

4.2 Engine. The engine used in the test shall be a three-cylinder General Motors Series 71 diesel engine, conforming to the dimensions and mechanical specifications hereunder specified, together with appropriate loading and accessory equipment.

4.2.1 Dimensional specifications. The engine shall conform to the following specifications:

Number of cylinders	3
Bore, inches	4.25
Stroke, inches	5
*Oil system capacity (wet) (Includes oil pan, cooler, oil lines, and strainer)	13.7 L (14.5 quarts)

*Adjust oil piping size and length to bring oil level to "full" mark on dipstick, 13 cm (5 inches) below shoulder on dipstick.

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4.2.2 Engine Modifications. The engine shall be as specified by the manufacturer except for the following modifications:

1. Radiator, fan, and generator shall not be used. Oil and water cooling shall be by heat exchangers supplied with cooling water from an external source.
2. The engine shall be fitted with the following specific parts.

   a. Breather pipe, made from 5/8 inch (0.048 inch wall thickness) copper tubing running from existing hole in back of head to inlet of blower, installed as shown in Figure 1.
   b. Shallow crankcase pan, GM Part No. 5190901.
   c. Water cooled exhaust manifold, GM Part No. 5166485.
   d. Main Bearings, upper, GM Part No. 5179631.
   e. Main bearings, lower, GM Part No. 5179630.

4.2.3 Lubricating oil filters shall not be used for these tests. Full flow 0.003-inch (or finer) metal edge strainers shall be used.

4.2.4 Fuel injectors of 7.0 cm capacity shall be used, GM Part No. 5228305 (HV7).

4.3 Instrumentation. Temperature measurements shall be made in the following positions:

a. "out" jacket coolant temperature at the jumper from the head to the water cooled exhaust manifold, cylinder No.1 1/
b. "In" jacket coolant temperature at the water pump inlet elbow 1/.
c. "out" lubricating oil temperature in line (within 15 cm [6 in] of engine) leading to lubricating oil cooler 1.
d. "In" lubricating oil temperature in line (within 15 cm [6 in] of engine) leading from oil cooler to engine 1/.
e. Oil sump at bottom front of oil pan, beneath oil pump. Center thermowell 2.5 cm (1 in) above pan and 3.8 cm (1.5 in) from front of sump as shown in Figure 2 1/ .
f. Fuel oil temperature at the discharge from the fuel filter 1/.
g. Air box temperature in the air box opposite blower 1/.
h. Air intake temperature in the air intake fitting of the blower 1/.
i. Cylinder exhaust temperature in manifold at threaded holes provided by the manufacturer.

4.3.1 Pressures shall be obtained at the following locations:

a. Oil gallery
b. Fuel inlet gallery.

1/ To be recorded on a strip chart recorder at intervals not greater than 5 minutes.

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c. Air box opposite blower.
d. Exhaust stack 2.5 cm (1 in) below the outlet flange (engine side).

4.3.2 Conventional instrumentation as required for test work shall be used on the dynamometer.

4.3.3 A fuel flow meter either volumetric or gravimetric shall be used to measure fuel consumption. Fuel flow, when measured volumetrically, shall be corrected to 15.5° C (60° F) before calculating heat input, as required by 6.4.3.2.

5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Fuel.

5.2.1 Only fuels approved by Naval Sea Systems Command, Code 05M4, Washington, DC 20362 may be used for final acceptance of an oil. To be approved the fuel must meet the requirements set forth below. Approvals will apply to all batches of fuel made by a refiner from the same base stocks providing they remain within the tolerances established for the chemical and physical characteristics.

5.2.2 The fuel used for the test shall be conventionally refined commercial fuel having the following properties:

Property			ASTM Method No.
Flash Point,	°C(°F) (min)	60 (140)	D 93
Pour Point,	°C(°F) (max)	-6.5 (20)	D 97
Appearance		Clear and Bright 1/	
Distillation Range, °C(°F)			D 86
50% Evaporated, min		260 (500)	
90% Evaporated		330-350(625-660)	
End Point, max		385 (725)	
Viscosity, Kinematic, Centistokes at 40° C (100°F)		1.8-4.5	D 445
Carbon Residue on 10% Distillation Residue, % (max)		0.20	D 524
Corrosion		Pass	D 130
Alkali and Mineral Acids		None	D 664

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Ash Content, Percent (max)	0.01	D 482
Sulfur, Percent	0.95 - 1.05 2/	D 129
Cetane Number (min)	45	D 613

1/ If there is any doubt that the appearance is clear and bright, the oil shall be tested by ASTN Method D 1796 using a centrifuge tube with division markings which enable readings down to 0.005 percent; a maximum of 0.05 percent by volume water and sediment is allowed.

2/ Sulfur must be natural sulfur.

A minimum of 7100 L (1875 gal) of fuel is required per test.

5.2.3 Physical, chemical and base stock data on the fuel must be submitted along with a 19 L (five gallon) sample to the approving agency (see 5.1.1).

5.2.4 An engine test as required by this method shall be conducted using the reference engine oil specified by the approving agency (see 5.1.1). Results will be submitted to the approving agency in a manner similar to that used to present a candidate engine oil.

5.3 Engine parts. The new parts shown in Table I shall be installed for each test.

5.4 Data forms. Samples of convenient data forms can be obtained from the approving agency (see 5.2.1).

5.5 Tyme solution (Delchem Division of Pennwalt Chemical Corporation or equivalent), [u,u,u].

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TABLE I. New engine parts required for each test.

Nomenclature	Description	GM Part No.	Quantity Required
Piston	Cast iron, tin plated	5189054	Three
Compression and oil ring set	Compression, chrome plated oil ring, cast iron	5193477	Three Assemblies
Exhaust valves		5193197	Six
Connecting-rod bearings	Clevite 35 upper 1/	5150106, F12	Two (Cylinder Nos.1 & 3)
Connecting-rod bearings	Clevite 35 lower 1/	5151528, F12	Two (Cylinder Nos. 1 & 3
Connecting-rod bearings	Silver coated upper 1/	5179632, F21	One (Cylinder No. 2)
Connecting-rod bearings	Silver coated lower 1/	5179633, F21	One (Cylinder No. 2)
Cylinder liner	Single row port	5188868	Three
Exhaust rocker arm assembly left		5150304	Three
Exhaust rocker arm assembly right		5150305	Three
Injector rocker arm assembly		5179954	Three
Rocker arm shaft		5150322	Three
Push rod		5128640	Nine
Cam follower assembly		5115087	Nine

1/ May be obtained from Cleveland Graphite Bronze Co., Cleveland, Ohio.

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6. PROCEDURE

6.1 Engine reconditioning and assembly. The engine shall be cleaned and reconditioned thoroughly prior to each test; all parts shall be inspected and defective or worn parts replaced. The engine shall be assembled in accordance with the manufacturer's procedures and tolerances.

6.1.1 Fuel injectors. The fuel injectors shall be checked at the beginning of each test for fuel leaks, spray pattern, plugged orifices, and opening or pop pressure which must be within limits of manufacturer's specifications. The injector shall be checked during the test if engine operation indicates a faulty injector; the injector shall be replaced, if necessary.

6.2 Flush run. The engine shall be filled with new test oil and run as follows:

Speed (rpm)	Time (hrs)	Engine (hp)
700	1	7.5
800	1	15.0

The engine shall then be stopped and the oil drained immediately from the engine. Care shall be taken to drain the cooler and oil strainer completely. The use of a suction device or a supplementary vent plug on the strainer housing is recommended. The crankcase shall be drained for a period of one hour.

6.3 Break-in run. The engine shall be filled with new test oil and run as follows:

Speed (rpm)	Time (hrs)	Engine (hp)
1,400	1/2	20
1,600	1/2	40
1,800	1	60
1,800	1	75

The engine shall then be stopped and the oil drained immediately from engine, strainer and cooler, as described in 6.2. Check valve lash, injector timing and control rack setting. Adjust if necessary. Thereafter, no further setting of an injector control rack for purpose of adjusting individual cylinder exhaust temperature, shall be made.

6.4 Test run. The test shall consist of 300 hours of engine operation at test speed and fuel rate in 15 cycles, each cycle being as follows: 15 minutes warm up, 20 hours at test speed and fuel rate, 10 minutes shutting down and

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three hours and 35 minutes not operating. Before the start of each period of operation, 150 mL of synthetic sea water, (see 6.4.1), shall be added to the crankcase. Lubricating oil additions shall be made at the end of each period of operation as prescribed in 6.4.8. During the course of the test, the engine shall be shut down for three separate periods of approximately 48 hours each which correspond to normal week-end periods. Unscheduled shut down times of 8 hours or more may be deducted from such shut down periods.

6.4.1 Sea-water addition. The sea water for crankcase addition shall be made in accordance with Procedure B of ASTM Standard Test Method D 665.

6.4.2 Warm up. At the start of the 300 hour test, add 13.7 L (14.5 quarts) of new oil and 150 mL of synthetic sea water to crankcase. Start engine at 1000 r.p.m., set controls for oil and water temperature and operate on the following schedule.

Run 5 minutes at 20 hp. and 1000 r.p.m.
Run 5 minutes at 40 hp. and 1500 r.p.m.
Run 5 minutes at 60 hp. and 1800 r.p.m.

Put engine on rated fuel input at 1800 r.p.m., for 20 hour test run.

6.4.3 Standard operating conditions. The engine shall be operated under the following conditions.

6.4.3.1 Type of operation. Cyclic: 15 minutes warm-up (see 6.4.2), 20 hours at test speed and load (see 6.4.3.2), 10 minutes shutting down (see 6.4.7) and three hours and 35 minutes stopped (for purpose of cooling).

6.4.3.2 Test speed and load conditions:

Speed, r.p.m.	1800 +10
Fuel rate heat input minimum	720,000 B.T.U./hr 1/
Fuel rate heat input maximum	750,000 B.T.U./hr 1/
Jacket coolant (out) temperature °C(°F)	93 +3 (200 +5)
Oil temperature, sump °C(°F) minimum	121– 1 (250 - 2)
Fuel oil temperature, °C(°F)	50 ±ll (120 ±20)
Fuel oil pressure, p.s.i.g. minimum	20
Lubricating oil pressure, p.s.i.g.	30-45
Exhaust back pressure, inches Hg. (gage)	2 +0.5
Intake air temperature, °C(°F)	15.5 - 50 (60 - 120)
Lubricating oil consumption, average for 2nd and 3rd 100-hr periods maximum	0.25 2/

1/ Based on higher (gross) heating value.

2/ Note 6.4.8.1

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6.4.4 While minimum oil sump and jacket water outlet temperatures are established for the test, circumstances may cause a test which is under good control to occasionally deviate slightly from the minimum values prescribed. To eliminate the need for completely rerunning such a test, the following provisions shall apply to cover such unforeseen minor deviations.

6.4.4.1 Sump oil temperature deviations over 1°C (°”F) [i.e. below 120° C (248°F)]:

a. Any periods of test operation during which the temperature is below 120° C for 5 minutes or less (as determined from the temperature recording chart) shall be counted toward test operating time. A period of ten minutes will be allowed at the beginning of each load cycle for oil sump temperature to reach 120° C. This time period begins from the time full load and speed are put on the engine following the prescribed 15 minute warm-up. If the oil sump temperature reaches 120° C within this allowed time period no correction is made for the time the temperature was rising to 120° C. If the time to reach 120° C is greater than the allowed 10 minutes, correction to “make-up” time will be made as specified in (b).

b. Any periods of test operation in which the temperature is below 120° C for longer than 5 minutes (except for the 10 minute allowance at the start of each cycle) shall not be counted toward test time. The total of all such periods shall be added for the whole test. If this cumulative total (hereafter termed "make-up time”) is 5 hours or less the last test cycle will not be extended beyond the normal 20 hours of operation by the amount of this "make-up time”. If the “make-up time” is between 5 and 20 hours inclusive an additional 20 hour cycle will be run. A shutdown period such as prescribed in 6.4 and 6.47 shall precede the extra test cycle (Note - Oil make-up and salt-water addition for the extra cycle will follow procedure prescribed for standard test cycle). If "make-up time” exceeds 20 hours, the test shall be rerun.

6.4.4.2 Jacket coolant (out) temperature deviations over 30° C (5° F) [i.e., below 90° C (195° F)]:

a. The same method as outlined in 6.4.4.1 (a) and (b) will be applied where jacket coolant temperature is below 90° C (195° F).

6.4.4.3 Correction for oil and water temperature deviations determined under 6.4.4.1 and 6.4.4.2 shall be applied simultaneously rather than sequentially, i.e., if the “make-up time” for low oil temperature deviations totals one hour and twenty minutes and the “make-up time” for low jacket water temperatures totals forty-five minutes, the test is extended by the longer of these which is one hour and twenty minutes and not by two hours and five minutes. The procedures of 6.4.4.1 and 6.4.4.2 will be applied for any deviations during the extension of a run due to "make-up time".

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6.4.5 The following data shall be entered into the log at hourly. intervals and maintained within the prescribed limits specified in 6.4.3.2:

1. Speed, r.p.m. 1/
2. Fuel flow rate 1/
3. Water jacket (out) temperature, °c(°F) 1/, 3/
4. Fuel temperature °C(°F) 1/, 3/
5. Fuel pressure, p.s.i.g. _
6. Lubricating oil pressure, p.s.i.g. 1/
7. Exhaust back pressure, inches Hg, (gage)
8. Intake air temperature, °C(°F) 1/, 3/ 17,
9. Lubricating oil sump temperature, °C(°F) 1/, 3/
10. Brake Horsepower 1/, 2/
11. Water jacket (in) temperature °c (°F) 2/, 3/
12. Air box temperature, °C(°F) l/, 2/ , 3/
13. Oil from engine to cooler, °C(°F) 2/, 3/
14. Oil from cooler to engine, °C(°F) 2/, 3/
15. Cylinder exhaust temperatures, °C(°F) 1/ 2/
16. Air box pressure, inches Hg (gage) 1/, 2/

6.4.6 Oil sampling. One 30 mL (four ounce) sample for dilution test shall be taken, after at least four hours engine operation, during each 20 hour test cycle. The sample shall be replaced by 30 mL (four ounces) of new test oil. 475 mL (one pint) samples shall be taken at 100, 200 and 300 hours of operation. In taking samples, 475 mL (one pint) shall be withdrawn and returned to the crankcase before taking the required samples. The 475 mL samples shall be taken just prior to shut down while engine is operating. The sample shall be taken from the tapped opening in the oil system located toward the front of the cylinder block on the side opposite the blower. The sample shall be replaced by adding 475 mL (one pint) of new test oil to the crankcase.

6.4.7 Shutting down engine. Drop the speed to 1500 r.p.m., the load to 50 hp., the jacket water temperature to approximately 80° C (175° F) and the oil temperature to approximately 107° C (225° F) for 5 minutes. Then drop the speed to 1000 r.p.m., the load to 20 hp., jacket water temperature to approximately 66° C (150° F) and the oil temperature to approximately 93° C (200° F) for 5 minutes. Then secure engine. Blank or valve off exhaust line for test engine if it is connected to a common exhaust duct used by other operating engines.

1/ These conditions shall be reported as minimum, maximum and average.

2/ If any of these conditions change unduly during the test, the engine should be shut down and the cause of the deviation determined. Also see 6.1.1.

3/ To be recorded on a strip chart recorder at intervals not greater than 5 minutes.

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6 .4.8 Oil additions. After the engine is shut down at the completion of each 20 hours test cycle, drain 1.6 kg (3.5 pounds) of used oil from the engine into a clean container and retain. Add 1.6 (3.5 pounds) of new oil to the engine. Check oil level. If low, add the retained used oil in sufficient quantity, but not to exceed 1.6 kg (3.5 pounds), to being the oil level either to the full mark or as close to it as can be attained. To provide accurate oil consumption data, this oil addition limit of 1.6 kg (3.5 pounds) may be exceeded only at the completion of cycle Nos. 5, 10 and 15.

6.4.8.1 Actual Oil Consumption. The actual engine-oil consumption shall be determined by weighing all oil added to and drained from the engine. The actual oil consumption average for each 100-hour test period in kg per hr (pounds per hour) shall be computed by subtracting the weight of all oil drained from the weight of all oil added during that period and dividing the remainder by 100.

6.5 Completion of test. At the end of the last full load cycle (plus any added time to comply with 5.4.4), the engine shall be shut down in accordance with 6.4.7. Cooling water and lubricating oil shall be shut down in accordance with 6.4.7. Cooling water and lubricating oil shall be drained from engine. The engine should be disassembled promptly and the deposit ratings completed within 36 hours after completion of test.

6.6 Inspection and analysis. The various parts of the engine shall be inspected and rated as follows.

6.6.1 Ring sticking. Rate all rings as stuck or free as defined in paragraph IIIA2(l), (p 6) of the CRC Rating Manual. 1/

6.6.2 Sluggish and pinched rings. Use CRC Rating Manual paragraph IIIA2 (a)(l), (p 6) for definition of ring condition. Rate each sluggish ring as 0.5 demerit. Rate each pinched ring as 1.0 demerit for each 20 percent of fraction thereof of the circumference pinched. The ring pinching demerit of a single piston is the numerical sum of the pinching and sluggish demerits.

Example: Piston with No. 1 ring free, No. 2 ring 25 percent pinched, No. 3 ring 10 percent pinched, and No. 4 ring sluggish.

Ring pinching demerit	
No. 1	0.0
No. 2	2.0
No. 3	1.0
No. 4	0.5
Total	3.5 demerits

1/ The CRC Rating Manual referred to in this method unless otherwise noted is the "CRC Diesel Engine Rating Manual" (CRC Manual No. 5) (see 4.1.1).

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6.6.3 Deposits on top land. Rate top land in accordance with CRC Manual paragraphs IIC2(a), (p 4) and IIIA2(c), (p 8). Rate for lacquer using the CRC Color Scale and Nomograph (pp 36 & 37). Rate for deposits (carbon and ash combined) using Figure 3. Select the applicable texture factor in accordance with CRC Manual paragraph IIC2(d) (1) to (3), (p 5). Report lacquer and deposit (carbon ash combined) demerits separately. The engine demerit rating shall be the average of those demerits of the three pistons.

6.6.4 Deposits on intermediate lands. Rate the intermediate lands in the same manner specified for the top land in 6.6.3. Report lacquer and deposit (carbon) demerits separately. The intermediate land rating for a single piston shall be the average of the three intermediate land demerits. The intermediate land demerit rating for the engine shall be the average of the intermediate land demerits of the three pistons.

6.6.5 Compression ring groove deposits. Rate the ring grooves for lacquer and carbon filling in accordance with CRC Manual paragraph IIIA(2), (p 8). Use CRC Color Scale and Nomograph (pp 36 & 37) to rate ring grooves for lacquer. Rate ring groove carbon filling using Figure 3. Select the applicable texture factor in accordance with paragraph IIC2(d)(l) to (3), (p 5) of the CRC Manual. Report lacquer and carbon filling demerits separately. The compression ring groove demerit for the engine shall be the average of those ring groove demerits for the three pistons.

6.6.6 Oil ring grooves. Rate and report the oil ring grooves in the same manner specified for the compression ring grooves in 6.6.5.

6.6.7 Oil ring slots and piston drain hole restriction. Use CRC Manual paragraph IIC2(C), (p 5), IIIA2(a)(3), (7), and Figure 4 to determine the demerit ratings. Report oil ring slot and piston drain hole demerits separately. These ratings shall be averaged for each piston and the engine demerits shall be the average of those ratings of the three pistons.

6.6.8 Piston skirt deposits. Use CRC Manual paragraph IIC1, (p 4) and IIIA2(b), (p 7); CRC Color Scale and Nomograph (pp 36 & 37). The engine piston skirt deposit demerit shall be the average of those demerits for the three pistons.

6.6.9 Cylinder head deposits. Rate cylinder head with valves in place for deposits using Figure 5. Obtain demerit rating for each specified thickness from the percent area covered and the selected ordinate indicating the appropriate texture factor. The texture factor is defined in the CRC Manual paragraph IIC2(d)(l) to (3), (p 5). The engine cylinder head demerit rating shall be the numerical sum of the individual thickness ratings rounded to the nearest tenth demerit.

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Example: Cylinder head with 70 percent medium deposit 0.020 cm (1/128 inch) thick or less, 20 percent hard deposit 0.040 cm (1/64 inch) thick, and 10 percent soft deposit 0.080 cm (1/32 inch) thick.

Cylinder head demerit

70% medium 0.020 (1/128) or less	0.56
20% hard 0.40 (1/64)	0.50
10% soft 0.030 (1/32)	0.15
Total	1.21 or 1.20 demerits

6.6.10 Cylinder liner deposits. Rate cylinder liner deposits only in the area of compression ring travel using CRC Manual paragraph IIC1, (p 4) and IIIB1, (p 9); and CRC Color Scale and Nomograph (pp 36 & 37). The engine cylinder liner deposit rating shall be the average of that rating for the three liners. Corrosion, if present, shall be described in detail.

6.6.11 Inlet port restriction. Use CRC Manual paragraph IIC2(C), (p 5); paragraph IIIB4, (p 10); and Figure 4 to rate port restriction. The port restriction rating for the engine shall be the average of that of the three liners.

6.6.12 Valve sticking. Rate all valves as stuck, sluggish, or free. Report the number of stuck valves and sluggish valves separately for each of the three cylinders.

6.6.13 Valve Face and Seat Condition. Demerits shall be assigned to both the valve face and head seat as follows:

Condition	Demerit (depending upon severity)
Clean	0
Fitting	1-3
Leakage or channeling	4-6
Channeling and borderline burning	7-9
Burning.	10

Pitting is characterized by small pits or indentations which have not yet resulted in leakage. Leakage, channeling, channeling and borderline burning, and burning are described in CRC Manual Paragraph IIIC3(a) (pp 11 & 13). Reporting is to be by demerits, not by the more detailed method of specifying degrees for each condition as described in the CRC Manual. In assessing the demerits for a given condition, however, the extent or total degrees of the valve or seat condition noted is considered in determining severity. The demerit rating shall be the sum of the individual demerits for all conditions noted. The seat and the valve face condition demerits are reported separately. Each is an average of demerits on all three cylinders of the engine.

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6.6.14 Valve deposits. Rate the valve upper stem and tulip deposits in accordance with CRC Manual paragraph IIIC3(f) and Figure 13 (p 21). The engine valve deposit rating is the average of the individual ratings of the six exhaust valves. Any unusual deposits on other parts of the valves shall be reported.

6.6.15 Oil system sludge deposits. A demerit rating of O shall be assigned to each part listed below when the parts are clean. Tne individual demerit ratings of these four parts shall be obtained using Figure 6 and the percent area covered with sludge of the specified thickness.

Engine part
Rocker arm chamber
Rocker arm cover
Oil Screen
Crankcase oil pan

These parts shall be allowed to stand and drain for 8 hours. Those deposits which do not drain off, but which can be removed by wiping are rated as sludge. The engine oil system sludge rating shall be the average of the individual ratings of the parts listed above.

6.6.16 Air box deposits. The air box shall be rated as indicated in 6.6.15. Only that portion of the air box visible from the cover side (approximately 50 percent of the total surface) shall be rated.

6.6.17 Bearing deposits. A demerit rating of 10 shall be assigned to a bearing when 100 percent of the area is covered by a dull black deposit; a demerit of 5 when 100 percent is covered by black shiny lacquer; a demerit rating of O when no deposit is visible. A demerit rating of 1.0 shall be assigned when the bearing half shell is completely discolored; a demerit rating of O when no discoloration is evident. Intermediate demerits for the bearing half shell shall be assigned in accordance with the percentage of the area affected by each of the three preceding factors. The total demerit for a bearing shall be the average of the two half shells, The final demerit rating for all test bearings of like material shall be the average of the total demerit ratings for all such bearings.

6.6.18 Cylinder liner wear. Rate each liner using the increase in liner diameter (average of measurements at 45, 90, and 135 to the crankshaft centerline before and after test) at the upper end of travel of the top compression ring and Figure 7. The engine cylinder liner wear rating shall be the average of that rating of the three liners.

6.6.19 Top compression ring wear. Use the decrease in top ring weight and Figure 8 to determine the top ring wear demerit. The top ring wear rating for the engine shall be the average of the individual top ring ratings.

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6.6.20 Valve stem and guide condition. A demerit rating of 10 shall be assigned when the diametral wear as indicated by valve stem to guide clearance shows a 0.005 cm (0.002 inch) increase at any point. The final engine rating shall be the average of the individual valve stem and guide condition ratings. Scoring or scratching, if present, shall be described as to extent.

6.6.21 Top land metal scuffing. Use the percent area scuffed, depth of scuffing, and Figure 9 to determine the top land scuffing demerit. The top land scuffing rating for the engine shall be the average of the individual top land demerits.

6.6.22 Bearing wear and corrosion. Use the weight loss of each connecting rod bearing half shell and Figure 10 to determine the individual wear demerit rating. Only the single half shell having the higher demerit rating shall be reported for each cylinder. For no loss of weight, the demerit rating shall be 0. The weight loss includes that due to corrosion as well as that loss due to mechanical wear. Bearings which show obvious mechanical failures shall not be used in computing this rating.

After inspection for deposits, these deposits on the bearings must be removed before weighing. A material found satisfactory for removing bearing deposits is Tyme solution, manufactured by the Delchem Division of Pennwalt Chemical Corporation. The bearings are placed in this solution for 20 minutes at room temperature and then cleaned with a non-metallic brush.

6.6.23 Valve Actuator System Rust. Use CRC color intensity factor (see 4.1.2) area of coverage, and Figure 11 to obtain the rust demerit for the rocker arm shafts and cam followers. Each push rod and rocker arm shall be given a demerit rating of 1 if the area of rust coverage is 5 percent or greater and a demerit rating of 0 if the area of rust coverage is less tnan 5 percent. The valve actuator system rust demerit shall be the average of the individual ratings of the above four parts for the three cylinders of the engine.

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 The test report shall contain the following:

8.1.1 Demerit ratings for categories of Section 6 in both individual and summary form.

8.1.2 Photographs. At the completion of the test, photographs (8 x 10 prints) shall be taken of the following engine parts:

a. All pistons – both thrust and anti-thrust sides (without piston rings after rating rings for sticking and pinching).

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b. Air box with all liners in place (from cover side).
c. Air box covers.
d. Inlet ports before removal of liners from the block using 90° apex polished metal cone slightly less than cylinder diameter.
e. Rocker-arm (assembly).
f. Rocker-arm cover.
g. Exhaust valves to show stem and tulip area before rating.
h. All valve actuator parts (in color).
i. Oil screen.
j. Crankcase pan.
k. All connecting rod bearings.
l. Cylinder liners (in color).

Photographs should be augmented by description of broken rings, burned valves, corroded bearings, scuffed pistons or any unusual wear patterns or corrosion on any engine part.

8.1.3 Analysis of lubricating oil. Oil samples shall be analyzed as indicated in Table II and reported.

8.1.4 Data plot. The following test operating data shall be plotted and included in the test report:

Fuel rate, btu/min
Brake horsepower
Sump oil temperature, °C(°F)
Jacket water temperature, °C(°F)
Air box temperature, °C(°F)
Air in temperature, °C(°F)
Air box pressure, inches Hg (gage)

The plotted data shall show the operating conditions at five-hour intervals. In addition to the five-hour points, any hourly reading which falls outside the test limits shall be plotted. Also, the air box pressure shall be plotted in such a manner to show short periods of increased or decreased pressure indicative of inlet port plugging or unplugging.

8.2 Engine parts. The pistons, piston rings, valves, valve actuator parts and connecting rod bearings shall be forwarded to the qualifying agency. The valve actuator parts shall be packaged in such a manner to prevent further corrosion during storage and shipment.

9. PRECISION

9.1 The complexity of the method does not lend itself to a quantitative statement of precision.

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TABLE II. Lubricant analysis schedule.

	Sample			
Tests	New	Every 20 hrs. test cycle (120 mL)	100,200 and 300 hrs. operation (0.5 L)	ASTM Method No.
Gravity, API	X			D 287
Viscosity:				
Centistokes at 40° C (100° F)	X	X	X	D 88
Centistokes at 99° C (210° F)	X	-	-	D 88
Dilution, percent	-	X	X	1/
Neutrality (qualitative)	X	-	X	5101 2/
Acid and base number	X	-	X	D 664
Carbon residue, percent	X	-	X	D 524
Sulfated residue, percent	X	-	X	D 874
Pentane and toluene insolubles			X	D 893

1/ Determined from the change in viscosity at 40° C (100° F) using Viscosity-Temperature Chart A in ASTM D 341. Compare the viscosity of the daily oil sample with the viscosity of the used oil obtained from the previous 20 hours of operation. Do not use the viscosity of the new oil as the standard for comparison except on the first 20-hour sample.

2/ Method number in Fed. Test Method Std. No. 791.

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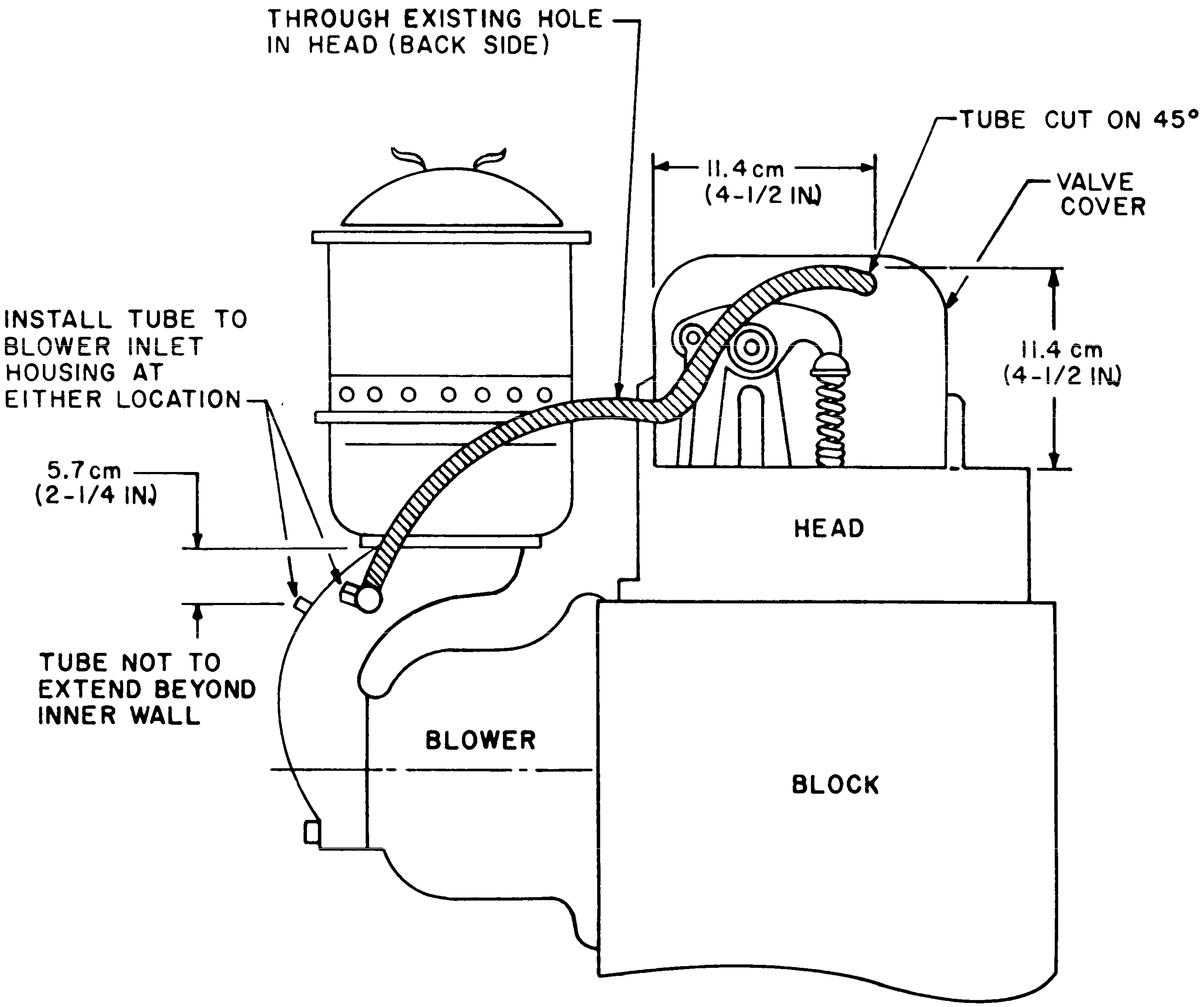

FIGURE I. **Breather pipe installation.**

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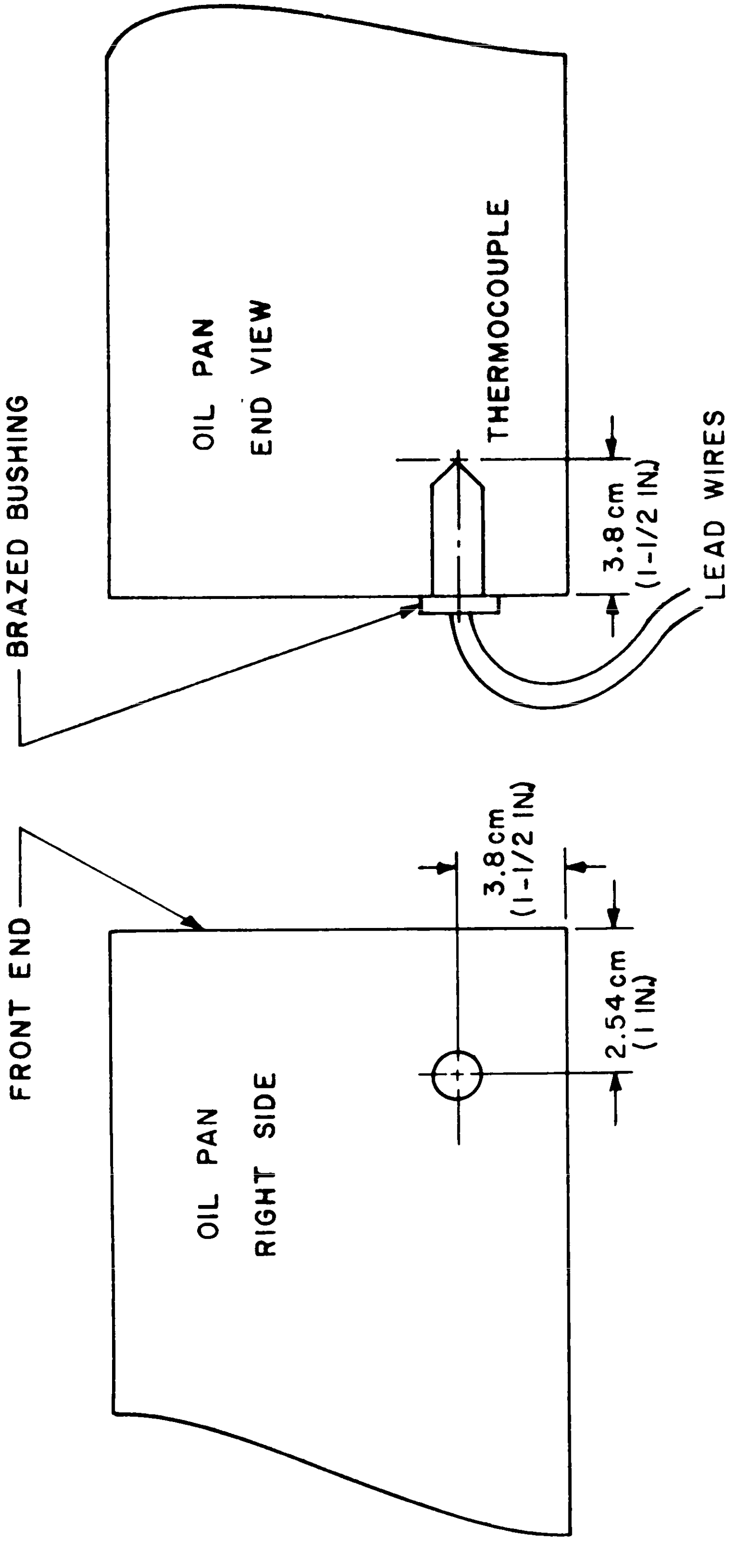

FIGURE 2. Sump thermocouple location.

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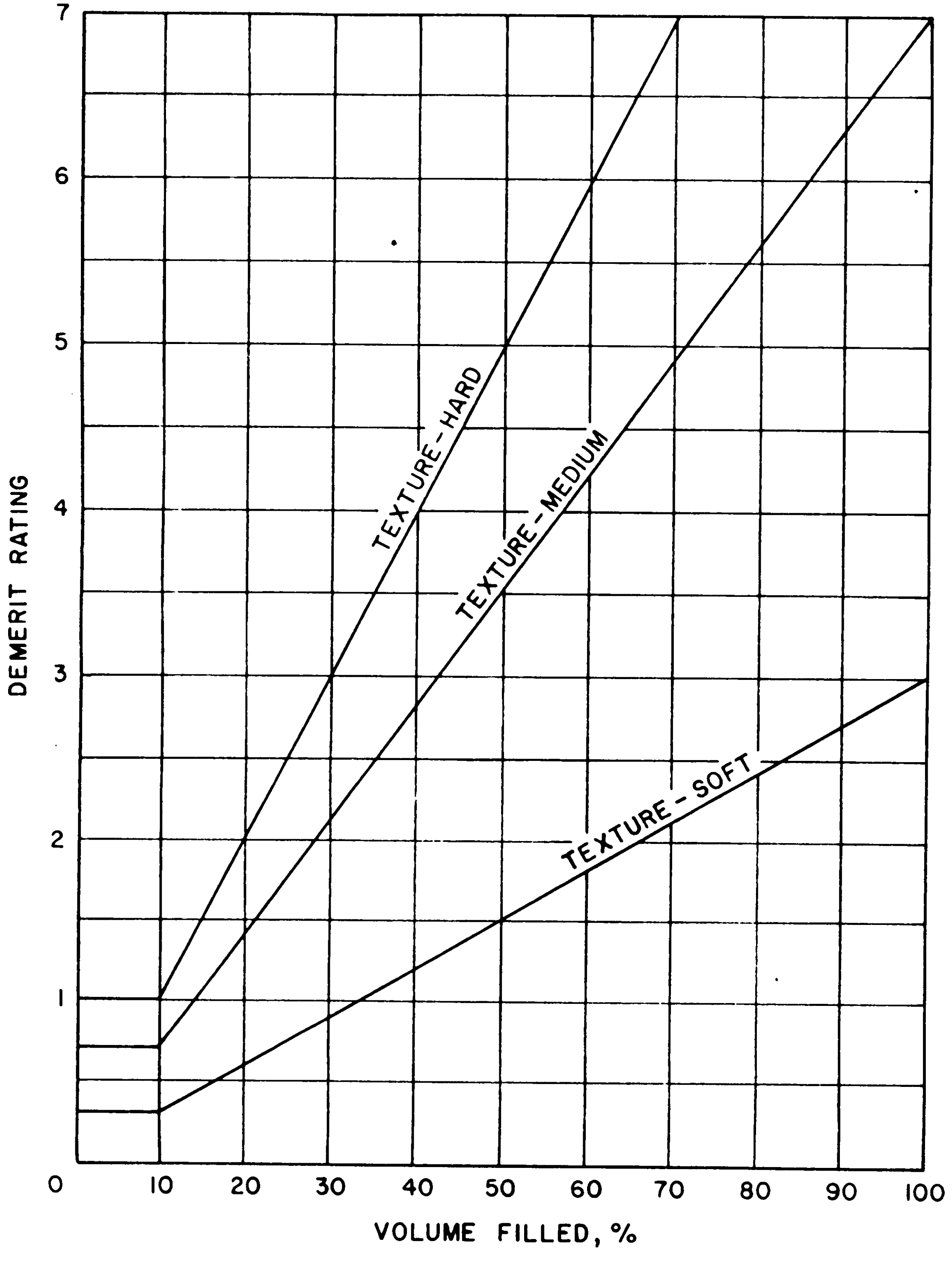

FIGURE 3. Deposits on top land, intermediate lands, and ring groove.

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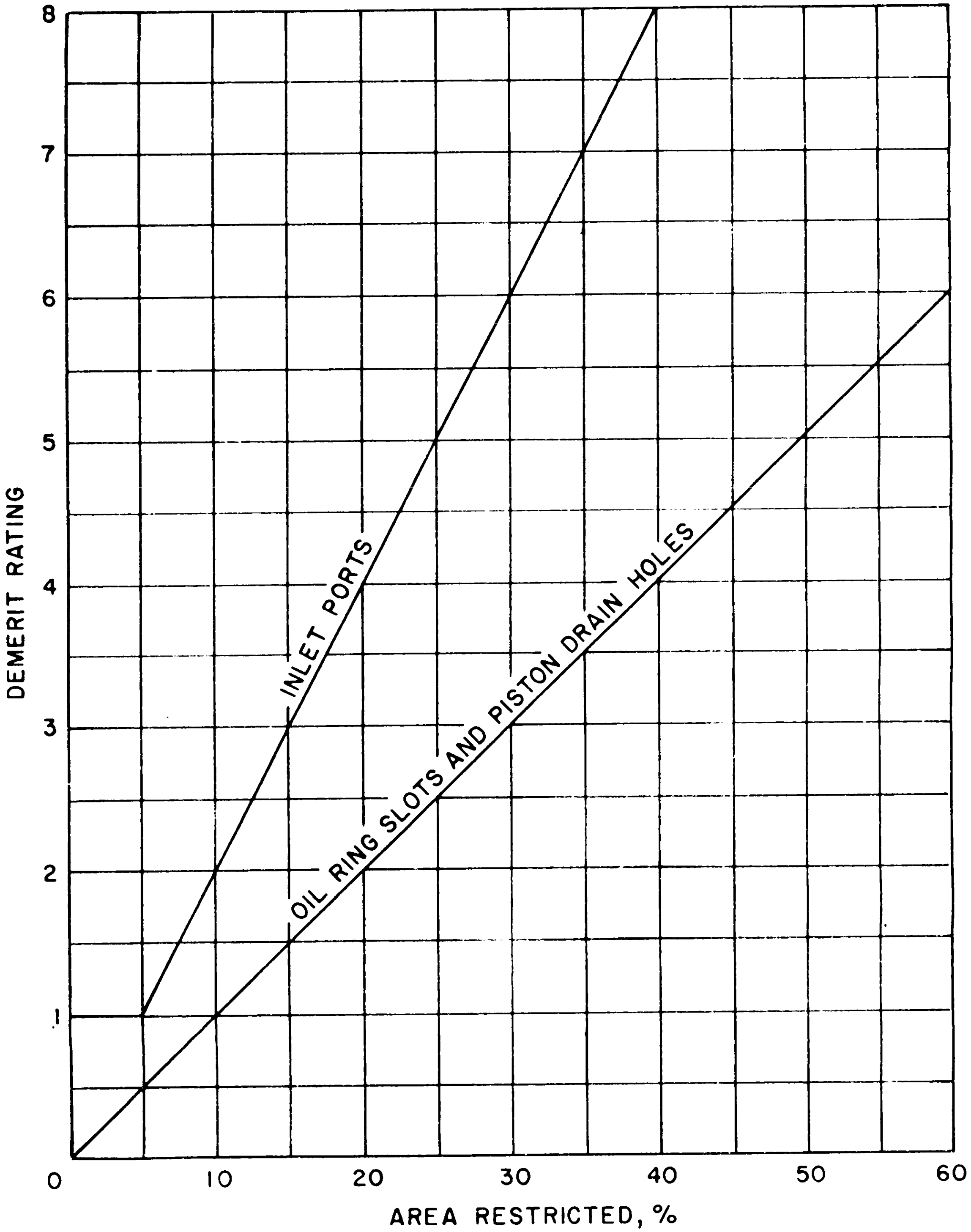

FIGURE 4. Restrictions in inlet ports, oil-ring slots, and piston drain holes.

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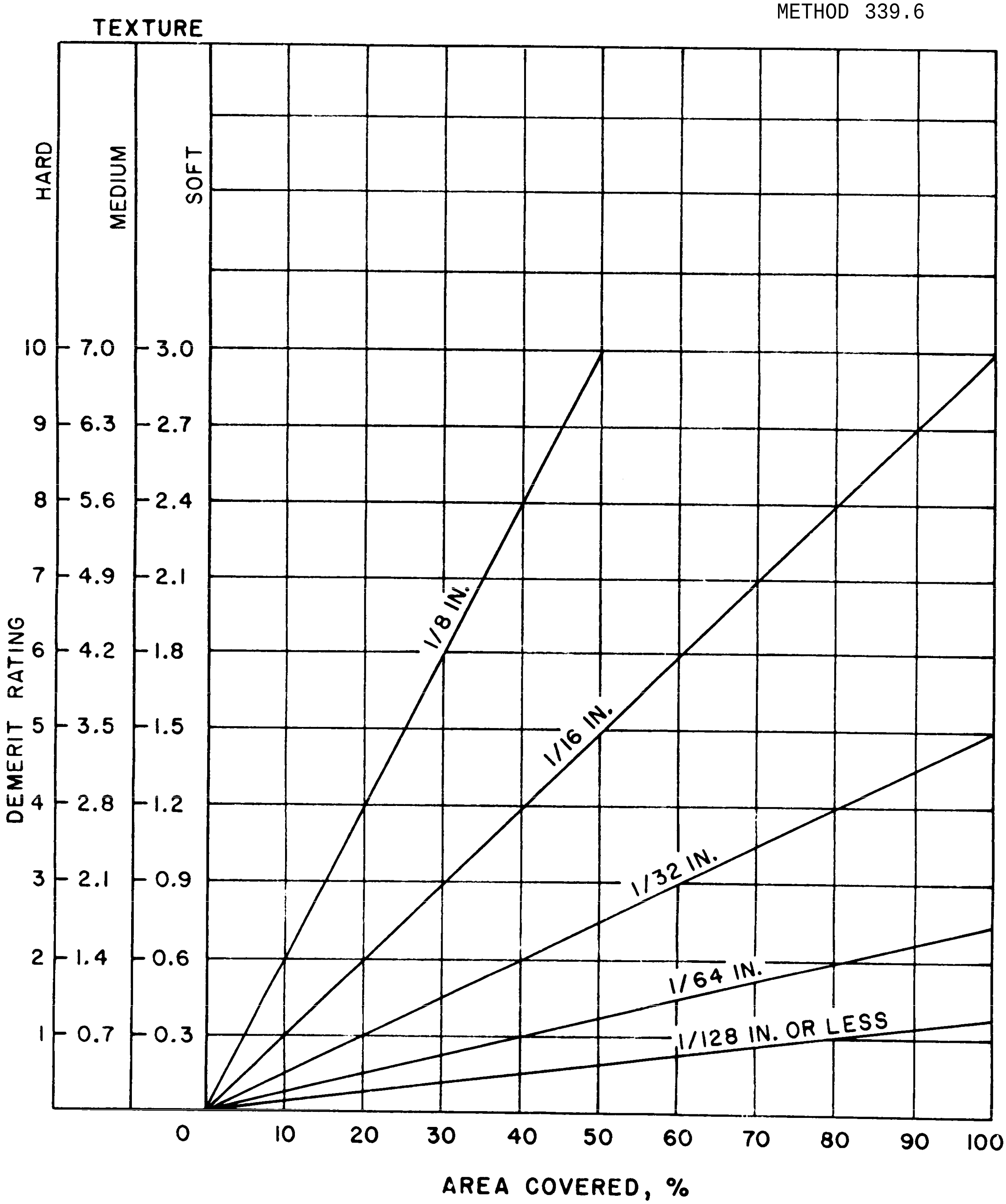

FIGURE 5. Cylinder head deposits.

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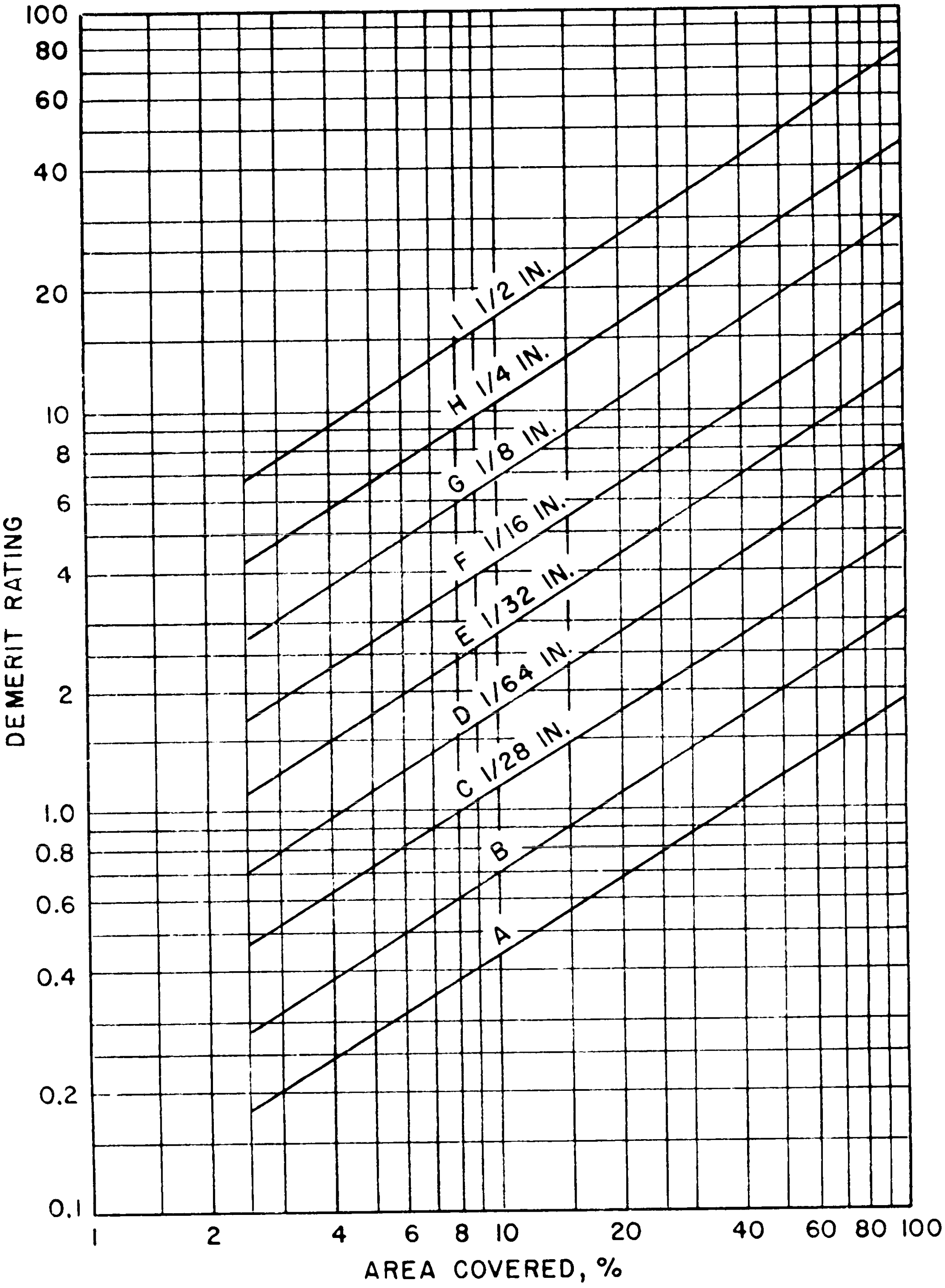

FIGURE 6. Oil system sludge.

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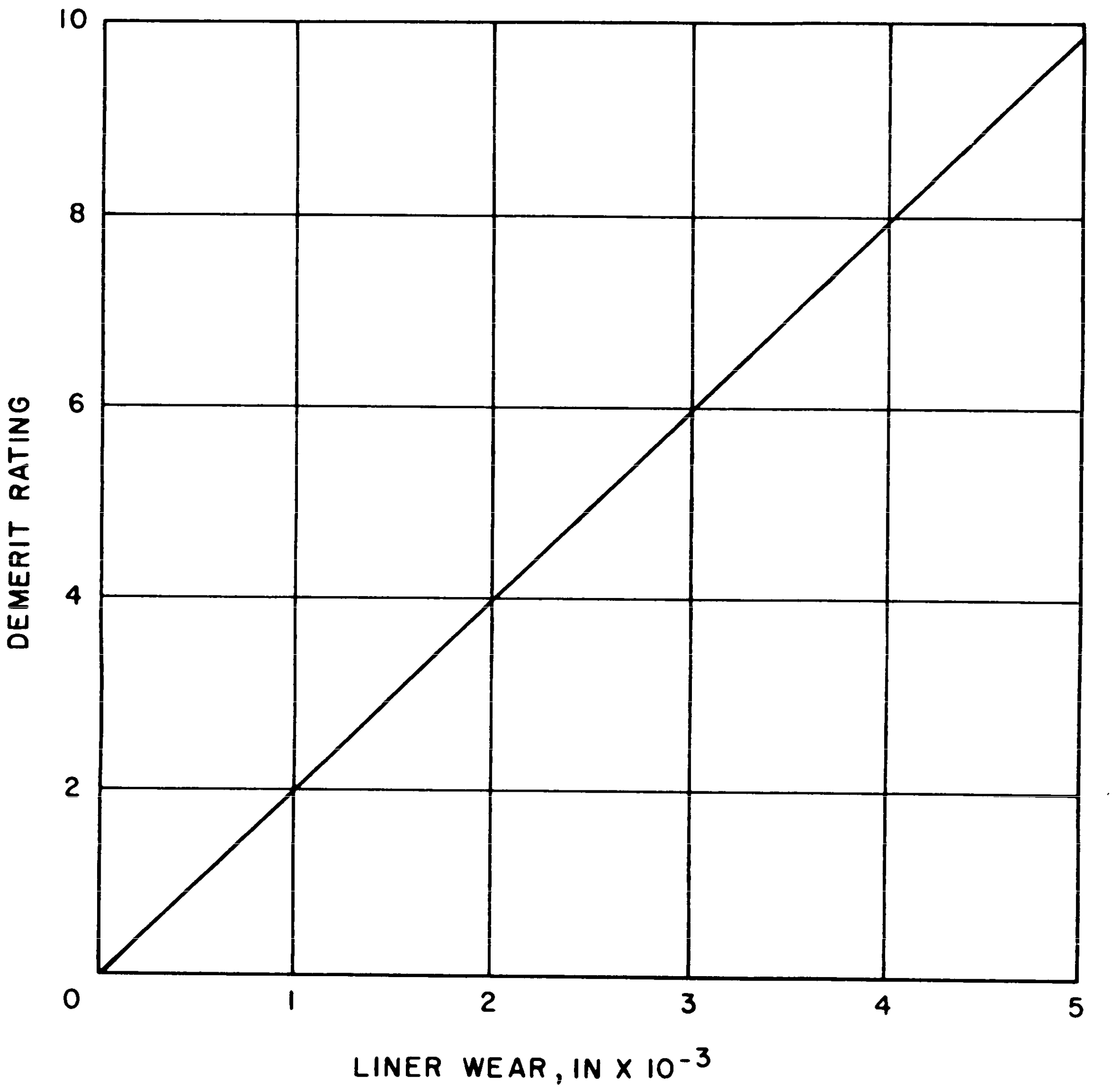

FIGURE 7. Cylinder liner wear.

X-4340

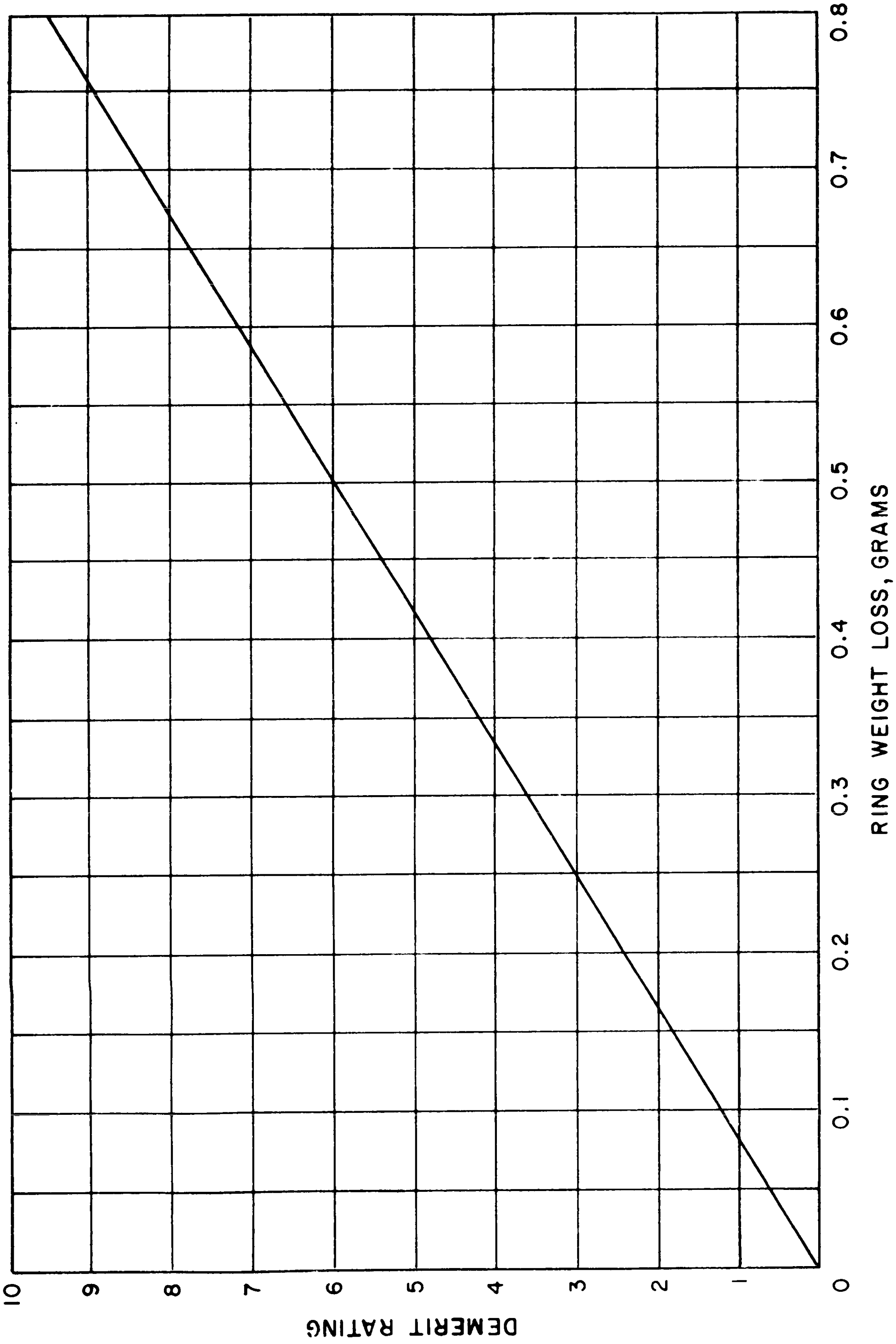

FIGURE 8. Top ring wear.

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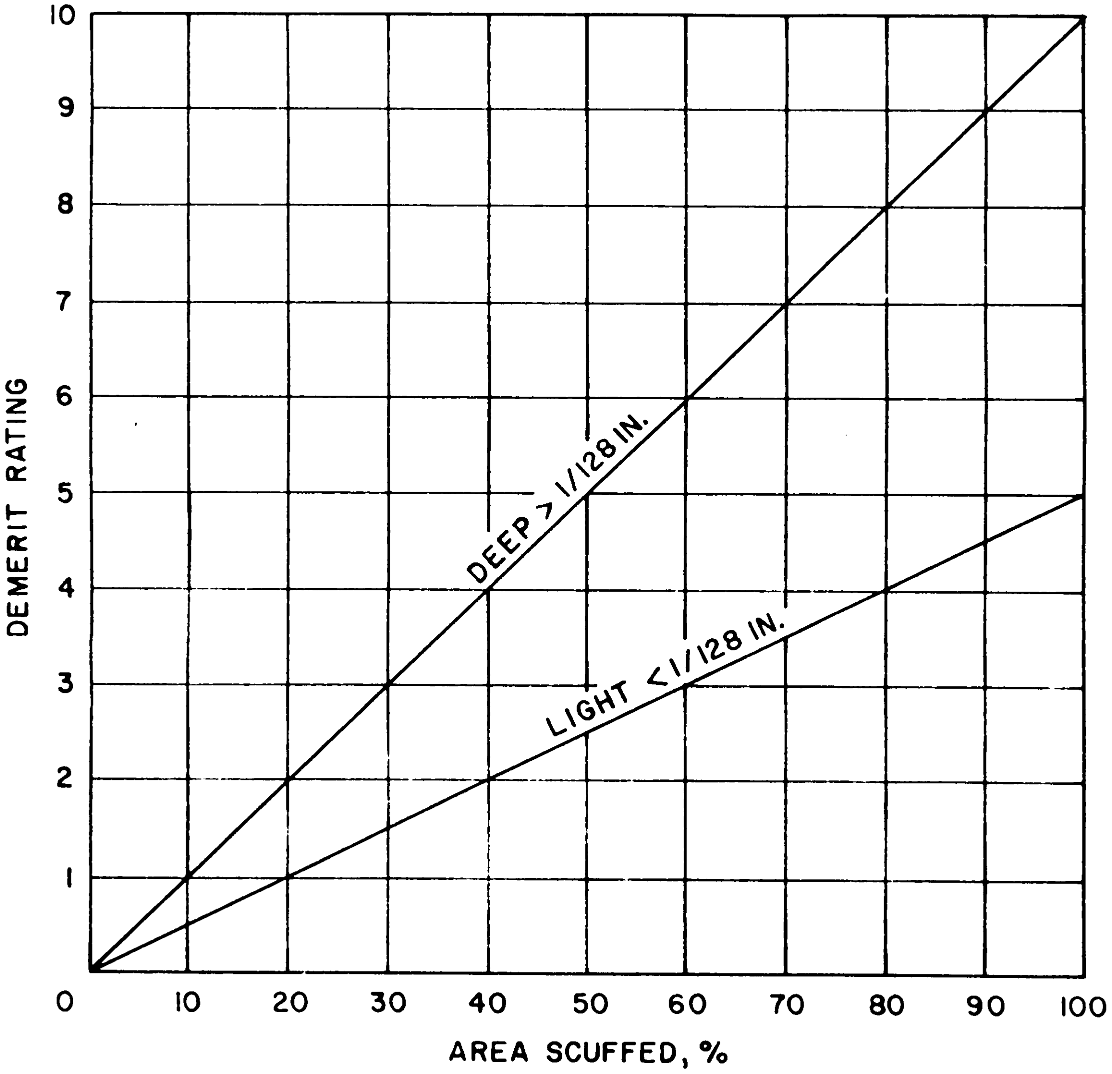

FIGURE 9. Metal scuffing on top land.

X-4342

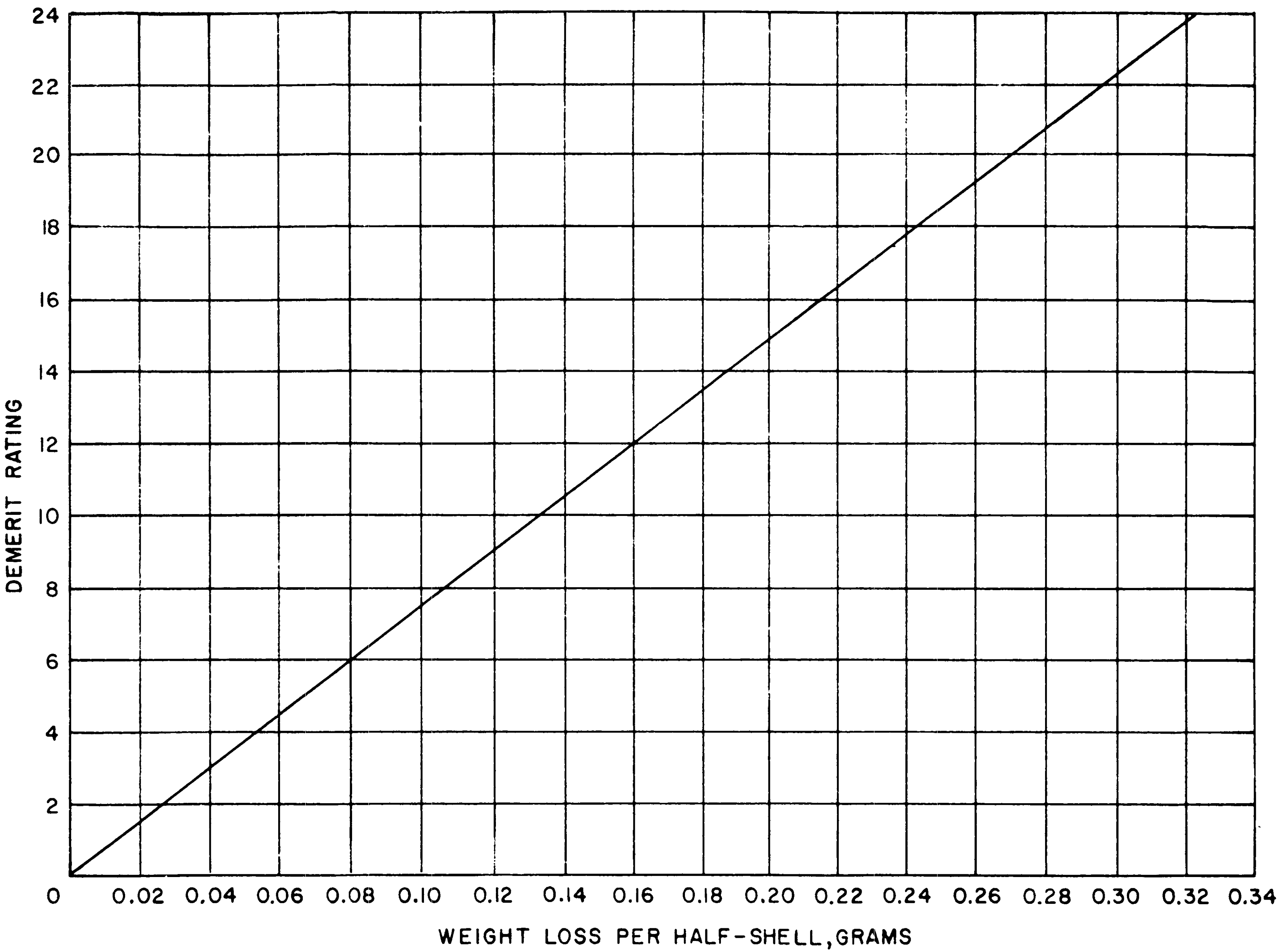

FIGURE 10. Wear of connecting rod bearings.

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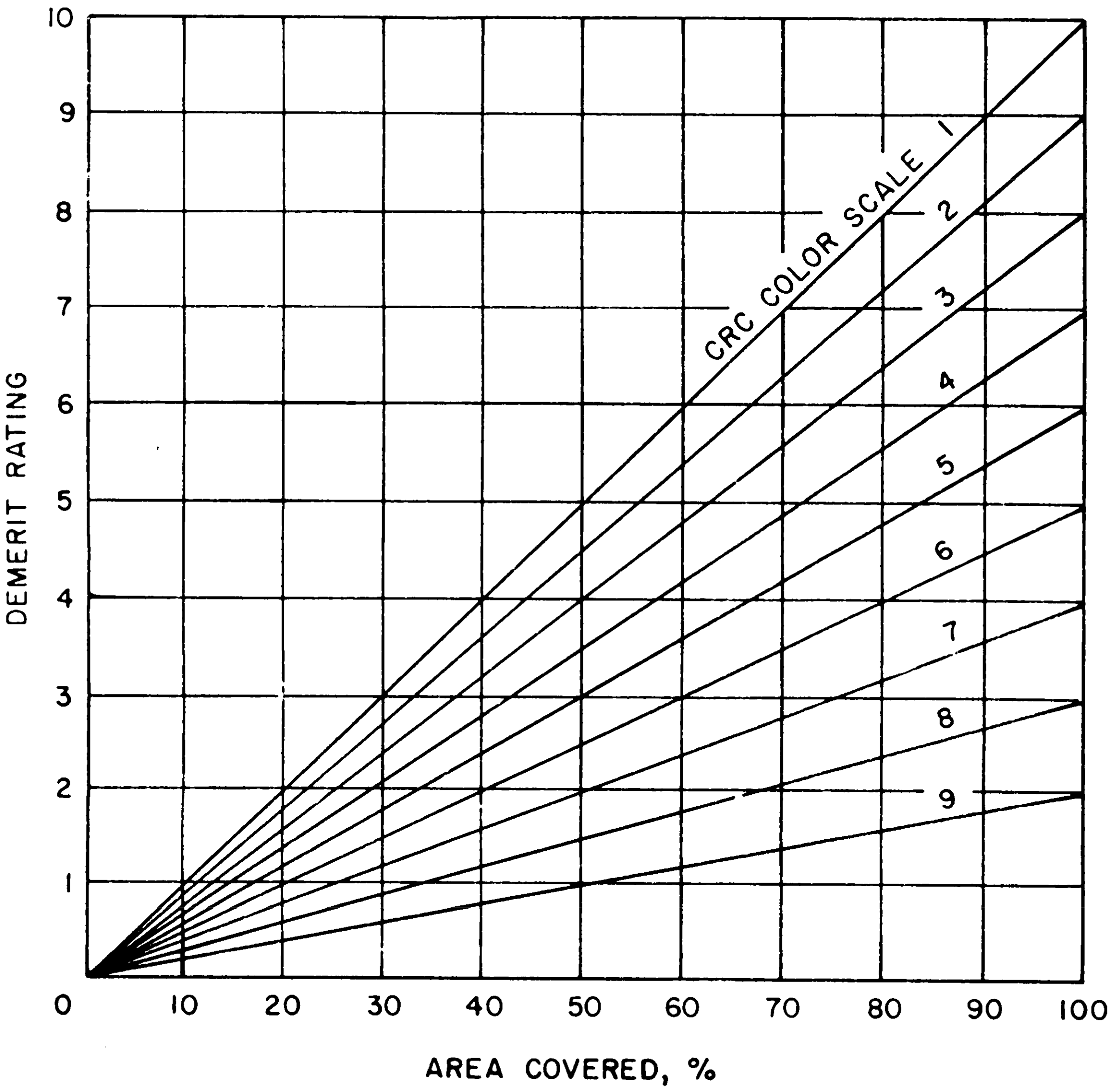

FIGURE II. Rust in valve operating system.

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PERFORMANCE OF AVIATION PISTON ENGINE OILS IN CLR ENGINE (LOW TEMPERATURE DISPERSANCY AND DETERGENCY)

1. SCOPE

1.1 This method is used for determining the low-temperature detergency and dispersancy characteristics of crankcase lubricating oils for aviation piston engines.

2. SUMMARY

2.1 This method involves the operation of the CLR Oil Test Engine with constant speed, air-fuel ratio and fuel flow conditions for 100 hours under conditions conducive to the formation of engine deposits. Prior to each test the engine is thoroughly cleaned and a 15-minute warm-up with test oil is conducted. Performance of the test oil is judged by a visual examination of deposits at 20, 40, 60, 80 and 100 hours.

3. SAMPLE SIZE

3.1 Approximately 12 L of test oil.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Test engine, single-cylinder; 3.8-inch bore, 3.75-inch stroke, 42.5 cubic-inch displacement, spark ignition (Laboratory Equipment Corporation [Labeco], Mooresville, Ind., CLR Oil Test Engine) and incorporating the following parts:

a. Connecting-rod bearing, copper-lead (Labeco Part No. 8276).
b. Main bearings, babbitt (Labeco Part No. 8252).

NOTE 1: Undersize babbitt main bearings (Labeco Part No. 8252-U) should be used if necessary to maintain the prescribed bearing clearance.

c. Crankshaft thrust washers, babbitt (Labeco Part No. 8292).
d. Camshaft thrust washer, aluminum (Labeco Part No. 8405).
e. Valve stem oils seals (Labeco Part No. 3299 or equivalent).
f. Carburetor, modified Stromberg type BXV-2 (Labeco Part No. 9651).
g. Distributor (Labeco Part No. 9667).
h. Spark plug (Champion H-10 or equivalent).
i. Oil filter. No oil filter is to be used during either warm-up or test operation.
j. Crankcase ventilating system; suitable for maintaining specified crankcase pressure and for permitting measurement of crankcase offgas. (The valve rocker box cover should not be vented to atmosphere.)

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k. Cooling system positive-circulating, with means for temperature control. The boss on the timing gear side of the cylinder barrel is used for the coolant inlet. The boss above the spark plug at the flywheel end of the cylinder head is used for the coolant outlet. The . coolant outlet is connected to the false bottom of the oil pan on the spark plug side of the engine with No. 8 Aeroquip or equivalent hose. Coolant is returned to the temperature control apparatus through the boss in the opposite side of the oil pan.

NOTE 2: A closed cooling system is suggested, particularly in areas where the water supply contains solids which tend to precipitate.

l. Exhaust system, wet or dry.
m. Manifold heater assembly (Figure 1), Labeco Part No. 8456.
n. Piston rings, top ring, and second ring (Labeco Parts No. 4937 and No. 4938, respectively). File ends of rings to obtain the specified gap. Remove any burrs.
o. Oil ring (Labeco Part No. 3304).
p. Valve lifters (Labeco Part No. 8202).
q. Blowby regulator, Labeco Part No. 2498 (order must specify thread size required), installed in existing one-half or three-eighth inch NPT opening located on the flywheel side of the cylinder barrel.
r. Humidity control unit (Labeco Part No. 20,000 or equivalent) with minimum capacity of approximately 45.4 kg of air per hour (100 pounds of air per hour) conditioned with 11.4 g of moisture per kg of dry air (80 grains of moisture per pound of dry air).

4.2 Measuring and recording equipment, consisting of:

a. Power absorbing equipment, capable of maintaining the prescribed engine speed and load.
b. Water manometers, for measuring crankcase vacuum connected to the hole in the oil gallery plate and for measuring exhaust back pressure connected to a boss on the exhaust pipe within 10 cm (4 inches) of the cylinder head exhaust flange.
c. Mercury manometer for measuring intake manifold vacuum, inserted in a tap to be located as shown in Figure 1.
d. Oil pressure gage, to be installed in side cover plate above the external oil inlet plug.
e. Dry-gas meter for measuring crankcase off-gas; measurements are to be taken on the outlet side of the crankcase breather assembly.

NOTE 3: A 0.95 L (l-quart) minimum capacity dropout pot may be installed between crankcase breather and gas meter for collection of contaminants .

f. Thermocouples, closed tip, for determining jacket-coolant inlet and outlet temperatures, to be located within 10 cm (4 inches) of the inlet and outlet bosses on the engine.

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g. Thermocouple for measuring sump-oil temperature at tip of dipstick (Thermo-Electric Co., Saddle Brook, NJ, Thermocouple Style 502P).

NOTE 4: If the thermocouple is ordered with a bayonet length of 38.4 cm (15 1/8 inches) from the shoulder to the tip, the tip of the thermocouple will be in the same position as the end of the engine dipstick.

h. Thermocouple, closed tip, for determining oil-gallery temperature at front main bearing passage (Thermo-Electric Co., Style 5A02P or equivalent).
i. Thermocouple, closed tip, for measuring air-inlet temperature, installed in the location provided on the airflow measuring system No. 1 for the CLR engine.
j. Thermocouple, open, for measuring air-fuel mixture temperature installed as shown in Figure 1.
k. Fuel flow-rate measuring equipment (flowmeter and burette or weighing device).
1. Air-flow measuring system No. 1, for CLR engine (Meriam Instrument Co., Model 60AC02).
m. CRC Deposit Rating Scales (Coordinating Research Council, 30 Rockefeller Plaza, New York, NY 10020, Manuals No. 12 and 14).

5* MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Reference oil, AEL-O-112 (Naval Air Propulsion Center, Code PE33, Trenton, NJ 08628).

5.3 Gasoline, referee grade (CRC Designation RMF-215-59 or equivalent, Ashland Oil and Refinery Company, Ashland, KY) with sulfur content increased to 0.25 percent (by weight) by the addition of ditertiary butyl disulfide. [1,3,0].

5.4 Oil, engine assembly, nonaddictive oil AEL-0-64 (Naval Air Propulsion Center, Code PE33, Trenton, NJ 08625).

5.5 Solvent, dry cleaning (ASTM D 484, Type I). [0,2,0].

5.6 Cleaning compound, special (Penetone Corporation, 74 Hudson Avenue, Tenafly, New Jersey; Penetone ECS or equivalent), [u,u,u].

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6. PROCEDURE

6.1 Before each test, prepare the engine as follows:

a. Dismantle the power section of the engine in accordance with the manufacturer’s instructions.
b. Remove the oil pump, distributor, breather, and oil-pressure regulator from the crankcase side-cover plate. Disassemble the oil pump, breather, and oil-pressure regulator.
c. Soak all parts in the special cleaning compound for 12 hours.
d. After removing parts from the cleaning compound, rinse all parts first with hot water, then with dry cleaning solvent.

Carefully spray the oil pump oil-pressure regulator to remove all deposits. Clean oil passages with a fiber brush or swab, paying particular attention to the following:

Sludge trap and oil passages in the crankshaft.
Oil passages in the block.
Crankcase side-cover plate.
Timing-gear oiler jet.
Rating surfaces.
Rocker-shaft lubrication system (oil line, rocker arms, rocker shaft, and rocker-shaft supports).
Valve and valve seats.

CAUTION

Do not use a hone to break cylinder glaze.

e. Wire brush the water side of the cylinder liner to remove any rust or scale.
f. Immediately after cleaning each part, coat it with nonaddictive AEL-O-64 by spraying or dipping.
g. Install a new piston and pin assembly, weighed copper-lead connecting rod bearings, new gaskets, seals, and O-rings. Replace all other parts that do not permit maintenance of the operating clearances shown in Table I. Install three-cylinder barrel to crankcase gaskets (Labeco Part No. 8791) instead of a single gasket.
h. Rebuild the engine using the torque specifications recommended by the manufacturer.

6.2 Charge engine with 0.839 +0.009 kg (1.85 ±0.02 lb.) of test oil (approximately 0.9 L [2 pints]) and record weight.

6.3 Start engine and operate at 900 r.p.m. and 7.6 cm (3 inches) Hg manifold vacuum for 15 minutes. Adjust spark advance as specified in Table II.

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6.4 Shut down engine and immediately (within five minutes) adjust tappet clearances as specified in Table I.

6.5 Conduct a crankcase air leakage check using the following procedure:

a. Remove flapper valve disc (check valve plate) from crankcase breather tube.
b. Connect an air supply line through an air pressure regulator and flow-meter to the blowby outlet pipe above the flapper valve housing.
c. Apply an air pressure of 5.08 cm (2.0 inches) of water to the engine crankcase.
d. Measure air flow rate and seal crankcase leaks until the air flow rate is 14.2 L per hour (0.5 cfh) or less.

6.6 Operate the engine under the conditions prescribed in Table II. During the first hour record and adjust, if necessary, air-fuel ratio and spark advance. (Thereafter, record, and readjust if necessary, once every 10 hours.) Also record the following at hourly intervals:

a. Engine speed, r.p.m.
b. Fuel flow, kg/hr (lb/hr).
c. Air flow pressure drop, cm H_20 (inch H_20).
d. Engine load, bhp.
e. Gallery-oil temperature, °C (°F).
f. Sump-oil temperature, °C (°F).
g. Jacket-inlet coolant temperature, °C (°F).
h. Jacket-outlet coolant temperature °C (°F).
i. Oil pressure, gage Pa (psig).
j. Crankcase vacuum, cm (inches) of water.
k. Exhaust back pressure, cm (inches) of water.
l. Intake-air temperature, °C (°F).

TABLE I. Engine operating clearances.

Clearance	Measurement, cm	Measurement, inches
Valve-stem in guide, inlet	0.0051 - 000102	0.002 - 0.004
Valve-stem in guide, exhaust	0.0076 - 0.0127	0.003 - 0.005
Connecting-rod bearing clearance	0.0051 - 0.0076	0.002 - 0.003
Main bearing clearance	0.0051 - 0.0076	0.002 - 0.003
Camshaft bearing clearance	0.00305 - 0.0127	0.0012 - 0.005
Crankshaft journal out-of-round, max	- 0.0025	- 0.0010
Piston ring gaps-commpression rings, top and second-(as installed new)	0.071 - 0.081	0.028 - 0.032
Oil ring	0.038 - 0.051	0.015 - 0.020
Valve-rocker-arm on shaft	0.0038 - 0.0089	0.0015 - 0.0035

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TABLE I. Engine operating clearances. (Continued)

Clearance	Measurement, cm	Measurement, inches
Valve lifter assembly clearance	0.0033 - 0.0071	0.0013 - 0.0028
Piston top-land in cylinder	0.0635 - 0.074	0.025 - 0.029
Piston-skirt and other lands in cylinder	0.0025 - 0.0076	0.001 - 0.003
Piston pin in piston	0.00025 - 0.00076	0.0001 - 0.0003
Piston pin in connecting rod bushing	0.0010 - 0.0015	0.0004 - 0.0006
Crankshaft end play	0.018 - 0.046	0.007 - 0.018
Spark plug gap (Champion H-10)	0.076	0.030
Ignition breaker point gap	0.051	00020
Valve–tappet clearance, inlet	0.025 hot	0.010 hot
Valve-tappet clearance, exhaust	0.051 hot	0.020 hot

[a] Rod bearing clearance is to be determined from direct measurements of the crank pin and of the vertical diameter of the rod bearing installed in the rod after torquing the bearing cap bolts to 61 Nom (45 lb-ft). The clearance is calculated on the basis of the largest measured pin diameter and the vertical hearing diameter. The connecting-rod bearing bore must be clean and free from foreign particles to assure good bearing contact before installing the bearing for measurement.

[b] This clearance is to be based on direct measurement in the same manner as that indicated for the connecting rod-bearing in a. The main bearing diameter is to be measured after torquing the bearing blocks to 81 Nom (60 lb-ft). It is permissible to install either two standard main bearing halves, one standard (Part No. 8252) and one undersize bearing half (Part No. 8252-U) or two undersize bearing halves as is necessary to maintain the specified bearing clearance. For consistency, when using one standard and one undersize bearing half together, the standard half should be installed in the bearing cap.

m. Intake-manifold vacuum, cm (inches of mercury.
n. Blowby, L per hr (cfh).
o. Intake air humidity g of moisture per kg of dry air (grains of moisture per pound of dry air).

NOTE 5: When engine is first brought to test speed, oil pressure may fluctuate below 275 kPa (gage) (40 psig) particularly with the use of viscous oils. This is due to oil hangup on engine surfaces. When oil temperatures have stabilized at test conditions, control of oil pressure should be satisfactory.

6.7 After each 20 hours of test operation shut down engine. Rate each of the five engine parts listed below for sludge using the CRC Deposit Rating Scale (10 = clean) being careful to disturb deposits as little as possible.

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TABLE II. Test operating conditions.

Condition	Adjustment	Adjustment
Speed, rpm	1800 +10	
Load, bhp	Vary as needed.	
Fuel rate, kg/hr (lb/hr)	1.95 to 2.04	(4.30 to 4.50)
Air-fuel ratio	15.5:1	
Fuel mixture temperature, °C (°F)	79 +2.5	(175 +5)
Cooling water inlet, °C (°F)	46 +1.5	(115 +3)
Cooling water outlet, °C (°F)	52 ±1.5	(125 +3)
Oil gallery °C (°F)	Record (approx. 66° c)	Record (approx. 150° F)
Exhaust back pressure, cm (in.) water	2.5-10.2	(1.0-4.0)
Spark timing, deg. BTDC	10	
Crankcase vacuum, cm (in.) water	2.5 +1.3	(1.0 ±0.5)
Oil pressure kPa, (gage) (psig)	275 +96	(40 ±2)
Blowby, L per hr (cfh)	566 +28	(20 ±1)
Intake air humidity, g/kg (grains of moisture per lb. dry air)	11.4 +0.7	(80 ±5)

a. Push rod cover.
b. Rocker arm cover.
c. Lower cylinder.
d. Timing gear cover.
e. Crankcase side plate.

6.8 Average the five sludge ratings and plot the average against engine test hours, as shown in Figure 2. Connect the plotted points with straight lines.

NOTE 6: When operating on the reference oil (AEL-O-112), the average sludge rating line must intersect the 9.5 sludge rating line, point A in Figure 2, between 55 and 70 test hours. This severity level must be established on an engine before it is used for qualification testing and must be re-established each time a different cylinder liner is installed.

6.9 After the 20, 40, 60, and 80-hour inspections, reinstall the engine cover plates and conduct the crankcase air leakage check described in section 6.5.

6.10 After 40 and 80 hours of operation withdraw a 60 mL (2 oz) sample of crankcase oil and replace with 60 mL (2 oz) of fresh test oil. Record weight of oil withdrawn and oil added.

NOTE 7: Normally no other oil additions need be made. However, if external oil leaks develop and persist, low oil level will become apparent by a drop in oil pressure. To safeguard against mechanical failure, a low-pressure cutoff switch

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is recommended which should be set to stop engine when pressure falls below 138 gage kPa (20 psig). No more than 60 mL (2 oz) of fresh oil, in addition to that which is needed to replenish oil removed for samples, should be charged to the engine. If the specified oil pressure cannot be maintained with the extra 60 mL (2 oz) addition, the test is considered void. To prevent loss of test, oil leaks must be kept to a minimum.

6.11 End test at 100 hours. Drain oil while engine is hot with piston on top-dead-center position. Record weight of oil drain.

6.12 Obtain the following oil analyses:

	New oil	40 and 80 hours	100 hours	ASTM
Viscosity:				
SUS at 37.8 "C (100° F)	x		X	1/D 445
SUS at 98.9 "C (210° F)	x		X	1/D 445
Pentane insoluble		x		D 893
Fuel dilution			X	D 322

1/ Convert to SUS viscosity using ASTM D 2161.

6.13 Disassemble the engine and obtain deposit ratings of parts listed on sample report form shown in Figure 3. Determine weight loss of copper-lead bearings.

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Report the weight loss of the copper-lead bearings.

8.2 Report test results and summary of operating conditions on form similar to that shown in figure 3.

9. PRECISION

9.1 Precision data have not been developed for this method.

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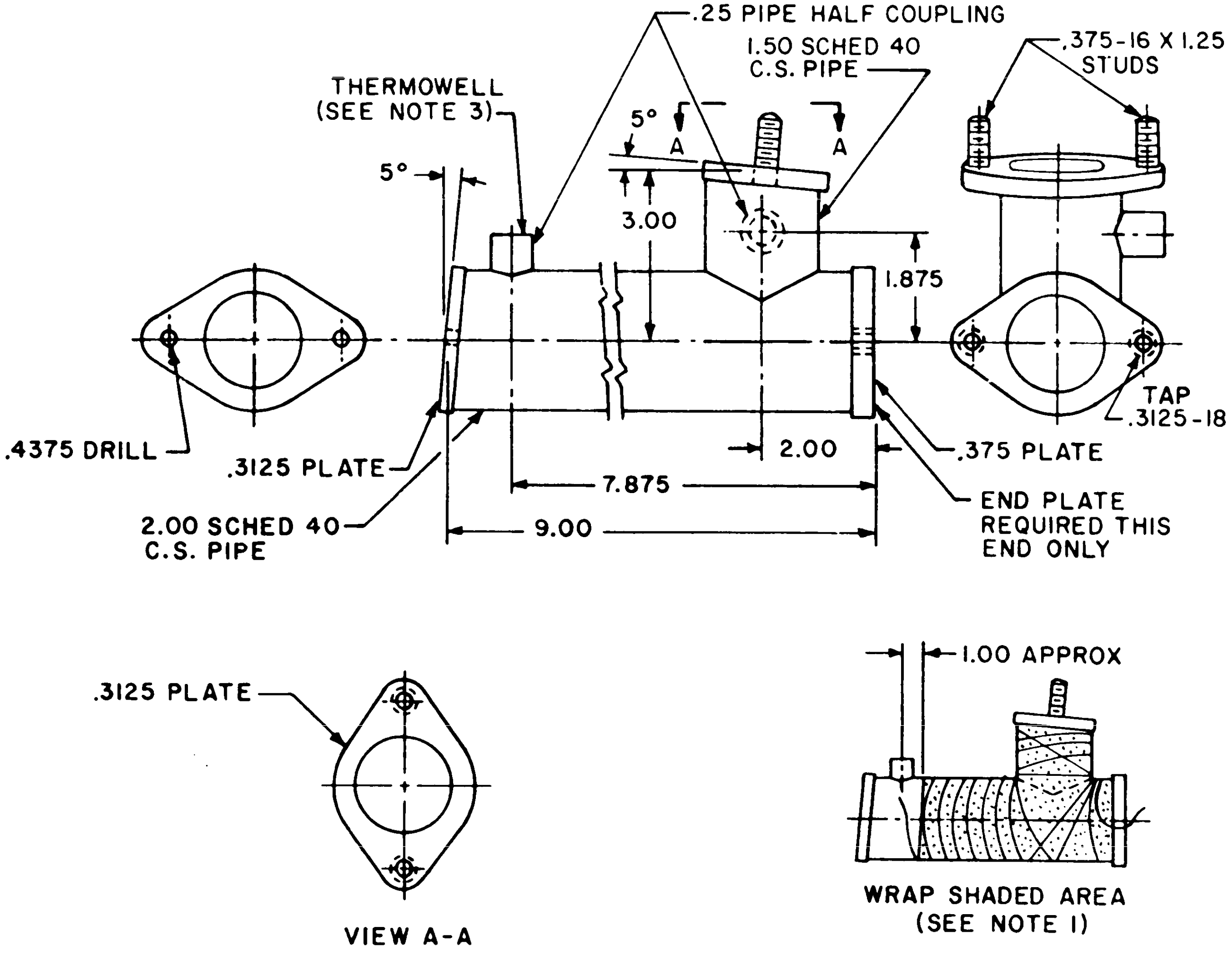

NOTES :

1. ELECTRIC HEATER:
   - A. WRAP ONE THICKNESS GLASS TAPE (SCOTCH NO.27).
   - 8. STRING CERAMIC BEADS (STUPAKOFF NO.75:8092)ON 19 FEET OF .040 DIA NICHROME WIRE (18 GAGE B & S) .406 OHMS/FT.
   - C. WRAP WIRE AROUND UNIT AS SHOWN.
   - D. WRAP TWO THICKNESSES ASBESTOS WEB , 1 INCH WIDE.
2. WELD ALL FLANGES AND JOINTS.
3. INSTALL THERMOCOUPLE (THE RMO-ELECTRIC, 5A02P) SO TIP IS ON CENTERLINE OF 2 INCH PIPE.
4. DIMENSIONS ARE IN INCHES.

FIGURE 1. Intake manifold and heater.

X-4345

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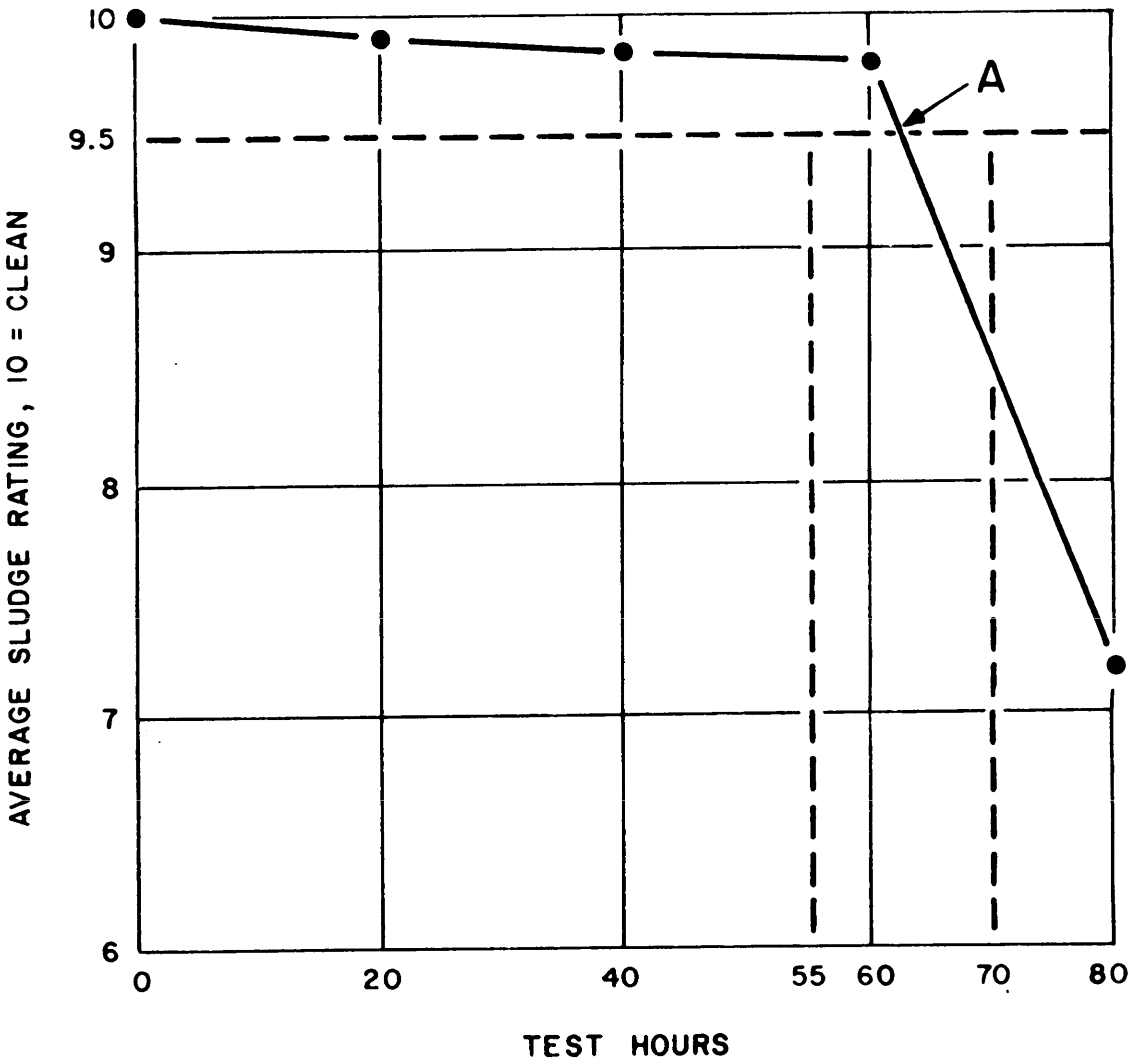

FIGURE 2. Average sludge rating vs. test hours.

X-4346

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SUMMARY OF TEST RESULTS

Low-Temperature Dispersancy Test

Test Oil ______ Sample No. ______ Test Fuel ______
Date ______ Engine No. ______ Run No. ______

SLUDGE RATINGS (CRC SCALE, 10 = CLEAN)

	Intermediate Inspection						End-of-Test
Test Hours:	20	40	60	80	____	____	100
Push Rod Cover	____	____	____	____	____	____	____
Rocker Arm Cover	____	____	____	____	____	____	____
Lower Cylinder	____	____	____	____	____	____	____
Timing Gear Cover	____	____	____	____	____	____	____
Crankcase Cover Plate	____	____	____	____	____	____	____
Average Sludge	____	____	____	____	____	____	____

OTHER INSPECITONS

(Sludge)		(Varnish)	
Oil Pan	____	Piston Skirt	____
Oil Screen	____	Rocker Arm Cover	____
Oil Screen Clogging, %	____	Cylinder Wall, BRT	____
Oil Ring clogging, Avg.	____	Oil Pan	____
Wide Slot Clogging, %	____	Cu-Pb Con. Rod Brg Wt Loss, mg	
Narrow Slot Clogging,%	____	Top	____
Sludge Trap Cup, %	____	Bottom	____
		Total	____

(Other)

Ring Sticking, Degrees ______ Top ______
2nd ______
Oil ______

Avg. Ring Rating (10 = No Sticking)* ______

FIGURE 3.

X-4316

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ENGINE OPERATING CONDITIONS

	Min.	Max.	Avg.
Engine Speed, rpm			
Fuel Flow, kg/hr (lb/hr)			
Dry Air Flow, kg/hr (lb/hr)			
Fuel-Air Ratio			
Load, bhp			
Blowby, L/hr (cfh)			
Absolute Humidity, g/kg (grains)			
Temperatures, C° (F°)			
Coolant In			
Coolant Out			
Inlet Mixture			
Gallery Oil			
Sump Oil			
Pressures			
Barometer, cm (in.) Hg (Dry)			
Manifold Vacuum, cm (in.) Hg			
Crankcase Vacuum, cm (in.) H-O			
Oil, gage kPa(psig)			

OIL ANALYSES

Test Hours	Viscosities, SUS 37.8 °C (100° F)	 98.9 °C (210° F)	Fuel Dilution, %	Pentane Insoulubles, %	Other
0					
40					
80					
100					

OIL CONSUMPTION DATA, LB

Test Hours	Fresh Oil Added	Oil Drained	Oil Consumed
0			
40			
80			
100			

Average Oil Consumption lb/hr

$$\text{*Average Ring Rating} = 10 - \left(\frac{\text{Sum of degrees stuck}}{108}\right)$$

Figure 3 - Continued.

X-4316

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Evaporation LOSS OF LUBRICATING GREASES AND OILS (HIGH TEMPERATURE)

1. SCOPE

1.1 This method describes the test procedure and apparatus for the determination of evaporation loss of lubricating greases and oils for applications where evaporation loss is a factor. Evaporation loss data can be obtained at any temperature in the range 99° C to 538° C (210° F to 1,000° F).

2. SUMMARY

2.1 The method consists of heating the oils or greases in containers vented with 2 L per minute of air in order to determine the percentage evaporation loss of the lubricant.

3. SAMPLE SIZE

3.1 Approximately 20 g of the grease or oil to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Evaporation cell and attachments conforming with the dimensional tolerances indicated in Figures 6 and 7. Other structural details are given below.

4.1.1 The body and cover of the cell shall be constructed of stainless steel and air-heating coil also of stainless steel.

4.1.2 The sample cups (recommended maximum weight 200 g each), hood, eduction tube, and orifice shall be constructed of stainless steel. A suitable material is an alloy steel conforming to grade S, type 304, of ASTM A 204. To facilitate removal and separation of the cup and hood for inserting the sample and weighing, the sample cup shall be threaded to the hood and this in turn to the eduction tube of the cover. The cover of the cell shall be made air tight.

4.2. Air supply system, capable of supplying to the cell the required flow of air free of mechanically entrained particles. A 61.0 cm (24-inch) length of 12.7 cm (5-inch) diameter pipe, reduced to 2.54 cm (l-inch) diameter at each end, packed with glass wool at each end, and filled with a suitable drying agent has been found satisfactory for filtering and drying. Means must be provided for filling the drying and filtering tube.

4.3 Heating blocks of cast aluminum with evaporation cells and air coils cast within. The heating block shall be heavily insulated and equipped with sufficient electric heating elements to maintain the test temperature. There shall be one thermocouple provided for each heating element. Figures 1, 2, and 3 show a satisfactory heating block.

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4.4 Temperature controller. A suitable temperature controller capable of maintaining temperatures between 99 °C to 538 °C +0.5 °C. A suitable temperature recorder shall also be provided.

4.5 Flowmeter. A rotameter calibrated to deliver air at a rate of 2.58+ 0.02 g per minute between 15.6° C to 29.4° C (60° F and 85° F) (2 L per minute at standard temperature and pressure). It shall be furnished with a needle valve and may be mounted as shown in Figure 7.

4.6 Evaporation tester stand. A suitable stand for supporting the test apparatus is shown in Figure 5.

5. MATERIAL

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled carefully. ‘Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 1,1,1-Trichloroethane (0-T-620), [2,1,0].

5.3 Tissue, Facial (UU-T-450).

6. PROCEDURE

6.1 Greases

6.1.1 Clean the grease-sample cup and hood thoroughly, using warm 1,1,1-trichloroethane (38°-540 C [100° F-130° F]) and facial tissues. Dry thoroughly in warm air.

NOTE 1. Caution. 1,1,1–trichloroethane is toxic. Use it only in a well ventilated area. Avoid contact with skin.

6.1.2 Weigh the clean grease-sample cup and hood to the nearest mg. Remove the hood and fill the cup with sample, taking care to avoid occulsion of air. Smooth the surface level with the rim of the cup with a straight edged spatula. Remove with a clean cloth any grease which may remain on the rim or threads of the cup. Thread the hood tightly onto the cup without disturbing the smoothed grease surface. Weigh the assembly and record the net weight of the sample to the nearest mg.

6.1.3 With cover in place, but without the hood and sample cup attached, allow the evaporation cell to acquire the temperature of the block (controlled to 1/2° C [+1° F]), at which the test is to be made. Allow the block to maintain the temperature of the test at least 1/2 hour before beginning the test. During this period, allow clean air to flow through the cell at the

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prescribed rate, 2.58 ±0.02 g per minute (2 L per minute at standard temperature and pressure), as indicated by the rotometer. Then remove the cover, thread the weighed hood and sample cup into place, and replace the cover. Tighten the three knurled cover-tightening screws securely to prevent air leakage under the cover. Pass clean air through cell for 22 hours ±5 minutes.

6.1.4 At the end of the 22 hour period, remove the assembled sample cup and hood from the cell, and allow to cool to room temperature. Determine the net weight of the sample to the nearest mg.

6.2 Oils.

6.2.1 Clean the oil-sample cup and hood as described in 6.1.1.

6.2.2 Weigh the clean oil-sample cup and hood to the nearest mg. Transfer, by means of a pipet, 10.00 ±0.05 g of sample to the cup. Assemble the cup and hood, being careful not to splash oil on the underside of the hood. Weigh the assembly and record the net sample weight to the nearest mg.

6.2.3 Evaporate the sample as described in 6.1.3 and 6.1.4.

7* CALCULATION

7.1 Calculate the evaporation loss of the sample as follows:

$$\text{Evaporation loss, percent by weight} = \frac{S - W}{S} \times 100$$

where:

S = Initial weight of sample, in grams.
W = Weight of sample, in grams, after the test.

8. REPORTING

8.1 Report the evaporation loss percentage.

9. PRECISION

9.1 Results should not differ from the mean by more than the following amounts:

Repeatability	Reproducibility
2.5 percent of mean	Not established

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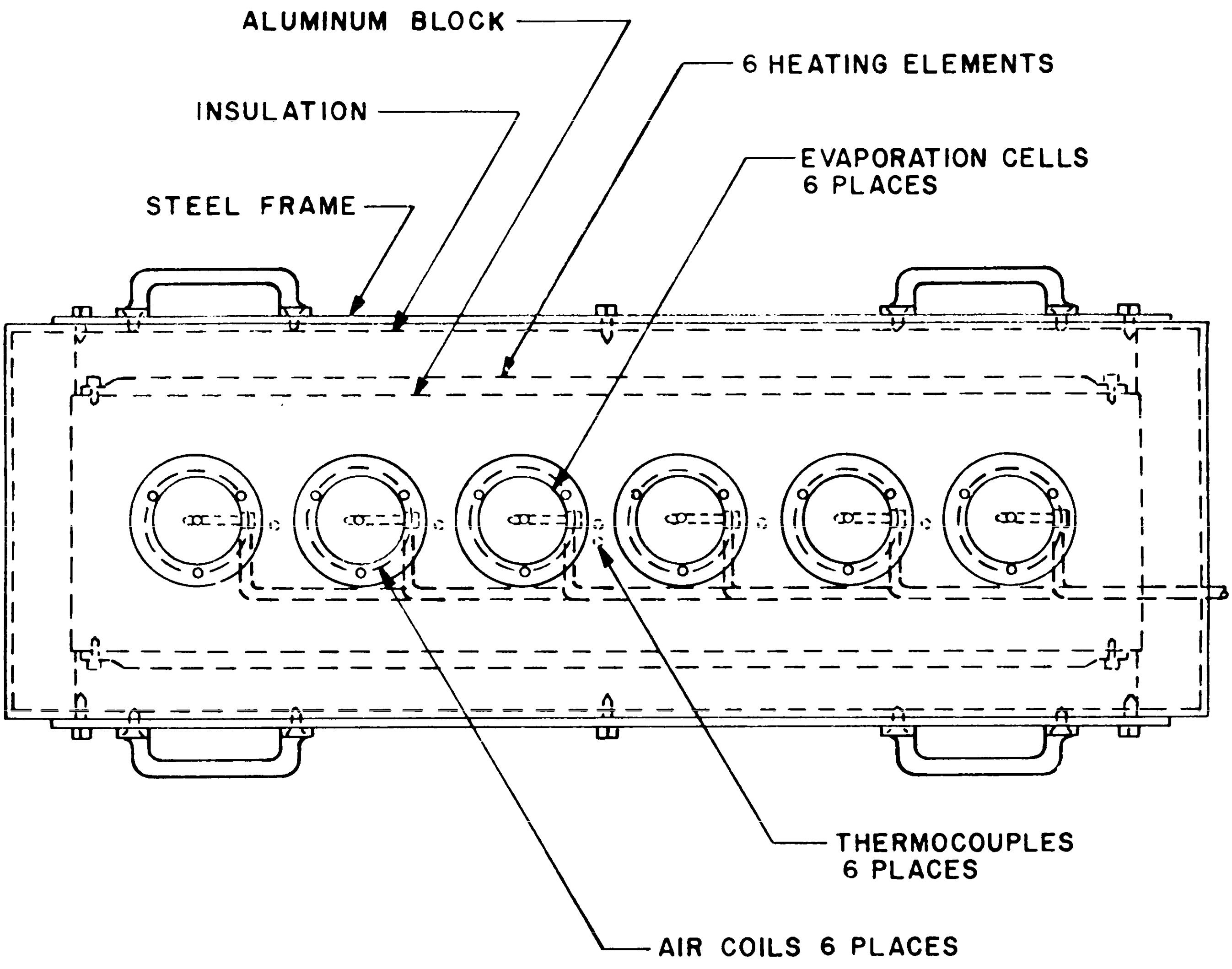

FIGURE 1. Top view high temperature evaporation tester.

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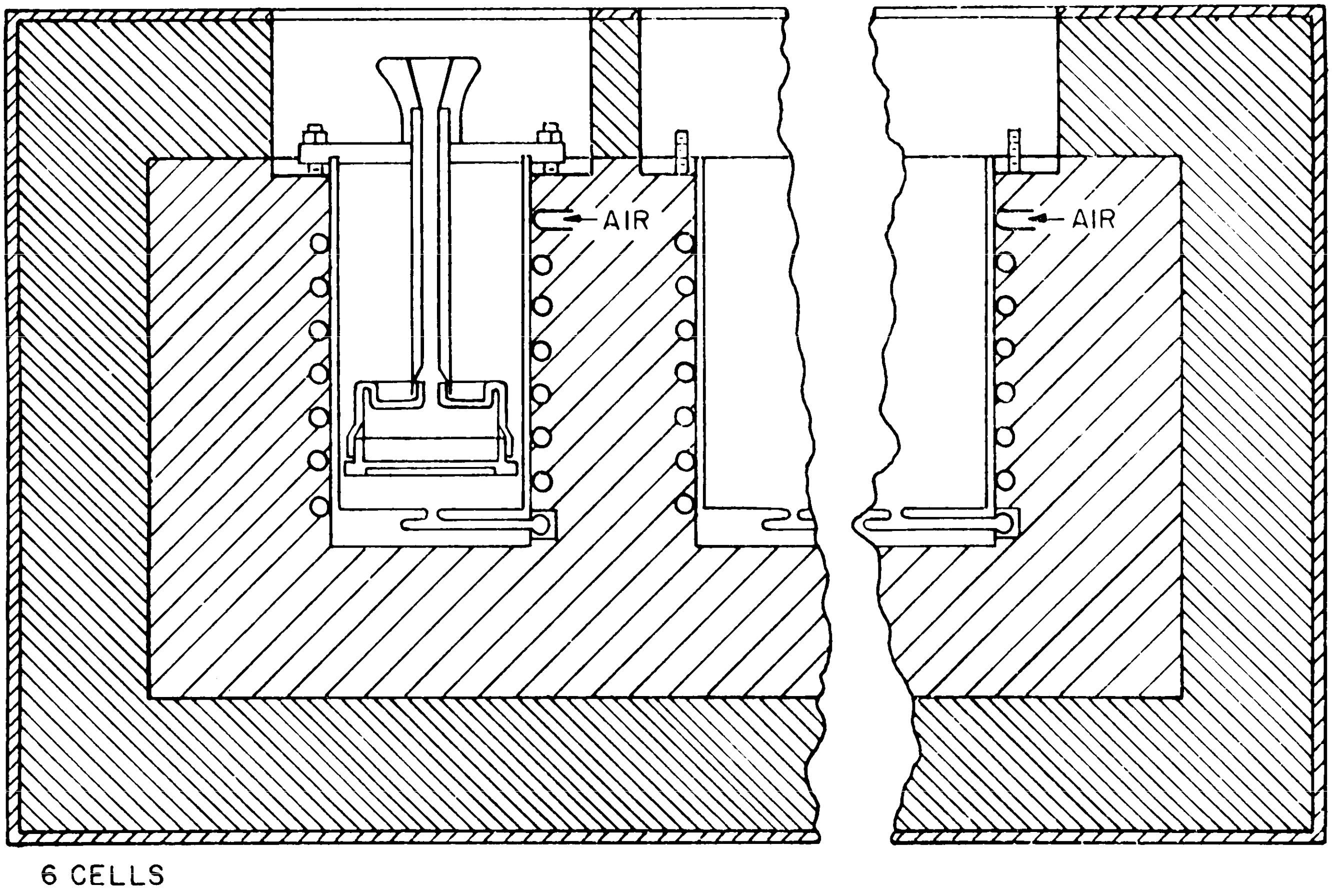

FIGURE 2. Side view high temperature evaporation tester.

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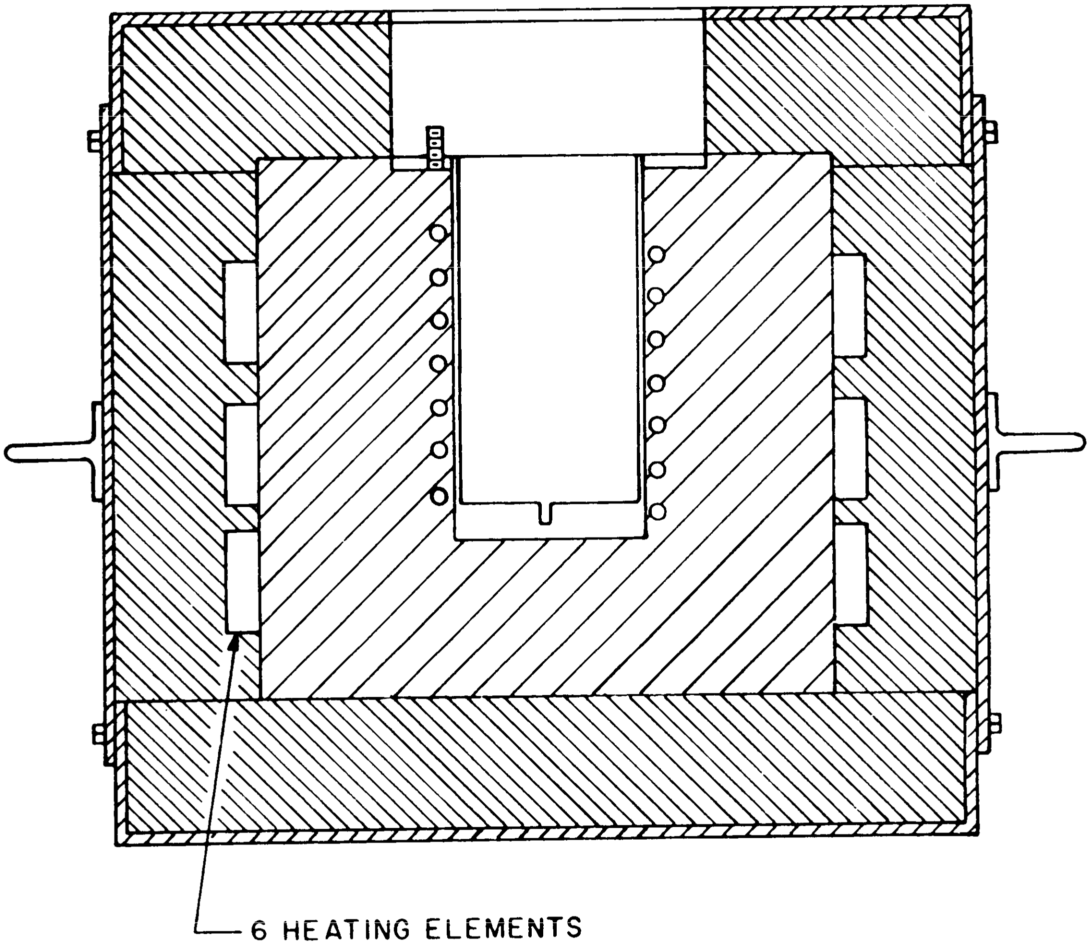

FIGURE 3. Cut end view high temperature evaporation tester.

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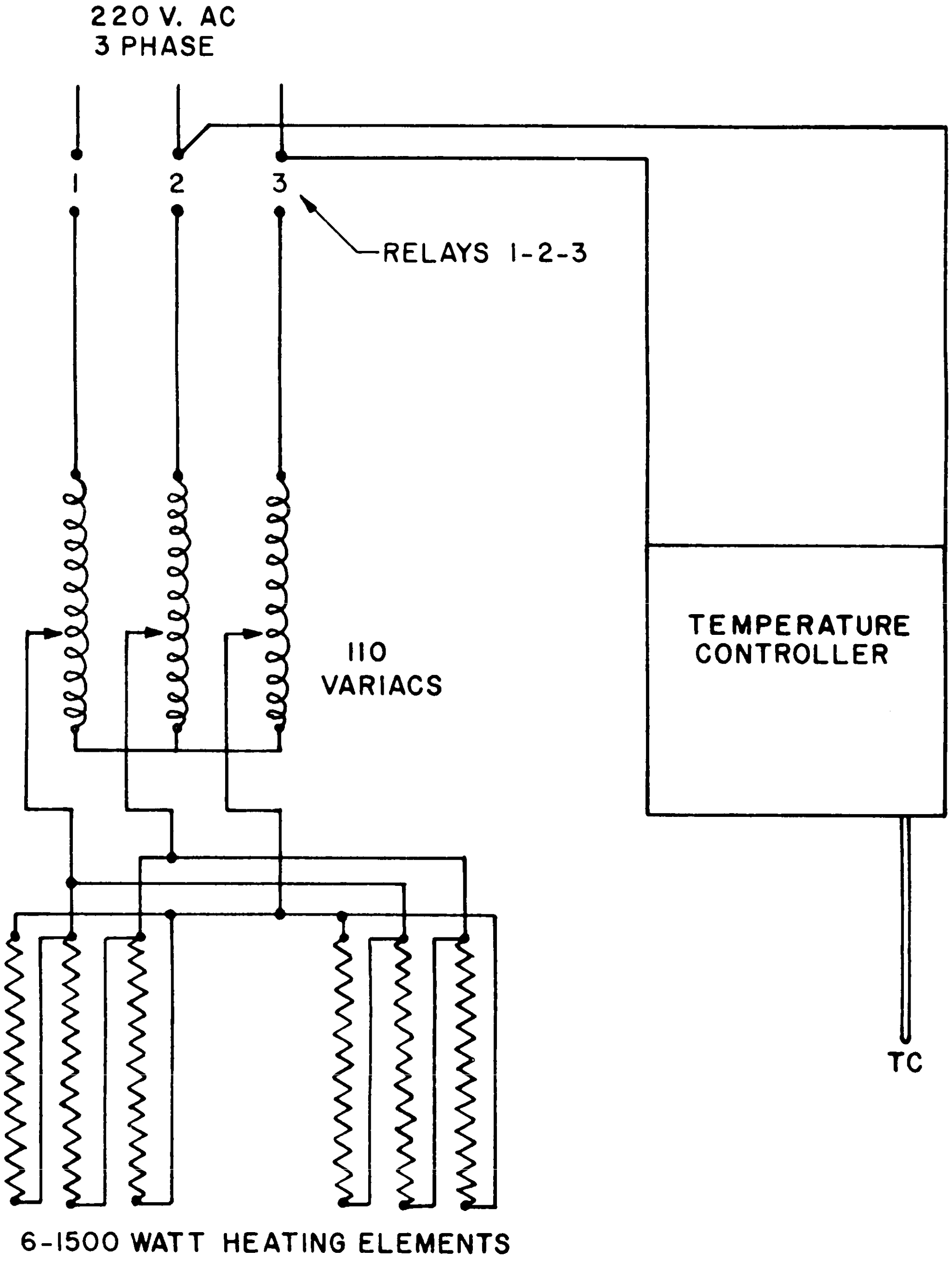

FIGURE 4. High temperature evaporation tester.

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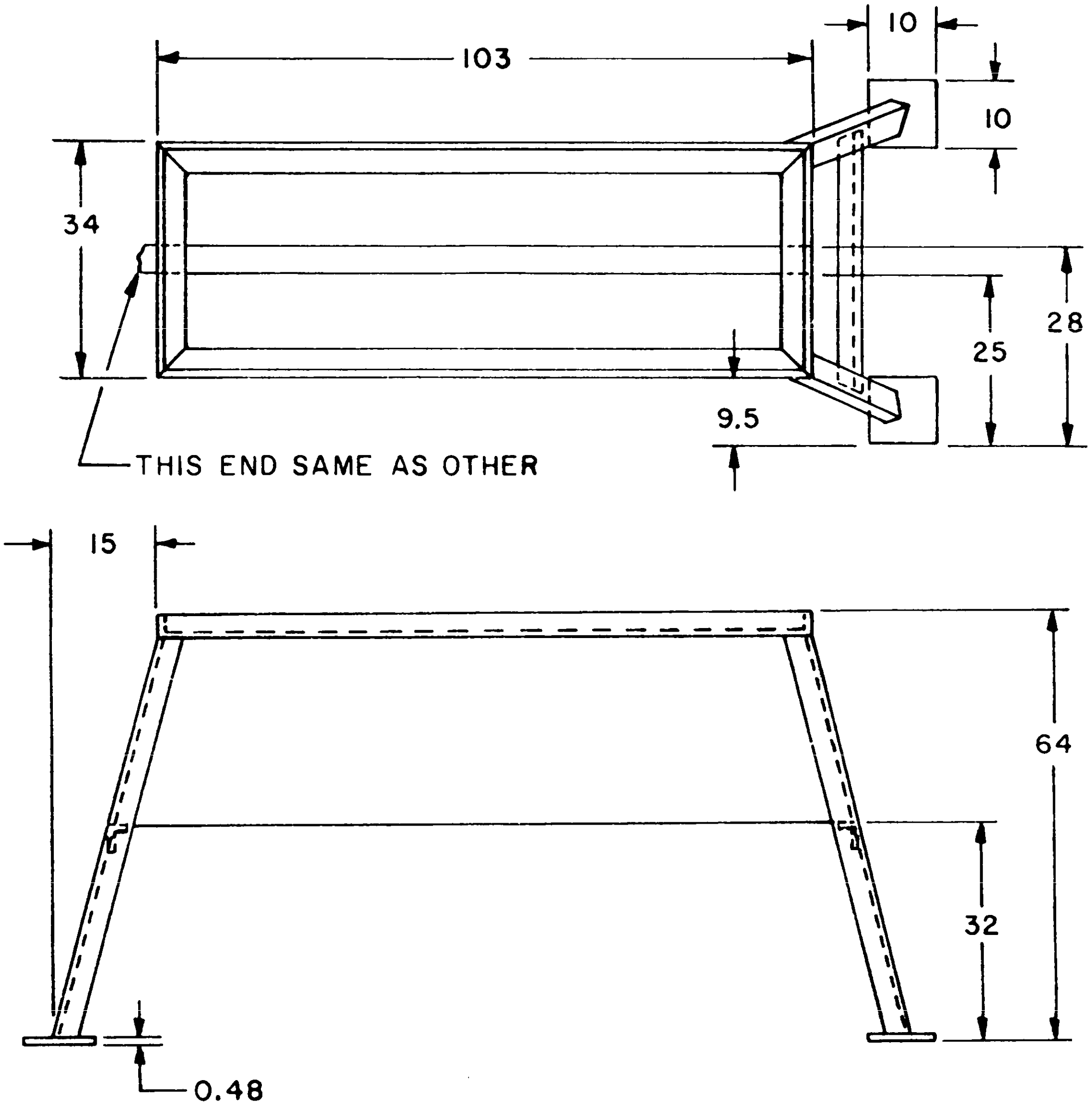

NOTE:
DIMENSIONS IN CENTIMETERS.

FIGURE 5. Evaporation tester stand.

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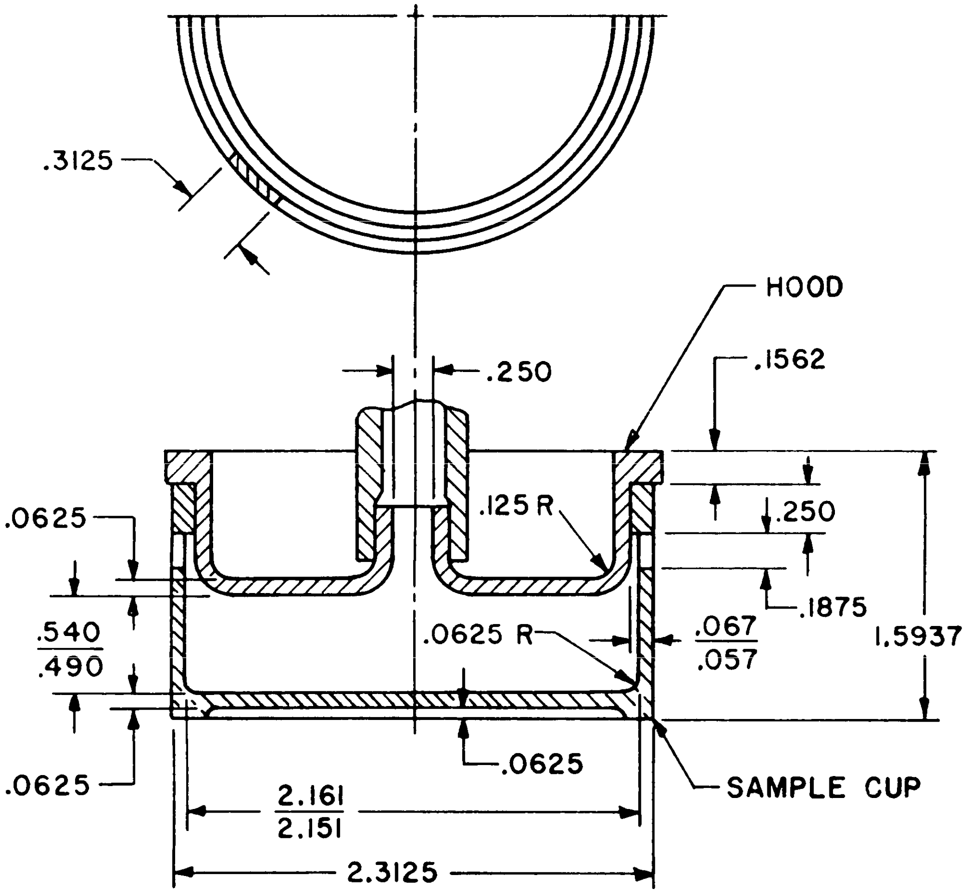

NOTE:
1. DIMENSIONS IN INCHES.
2. ALL DIMENSIONS ± .0156 UNLESS OTHERWISE SPECIFIED.

FIGURE 6. Oil sample cup.

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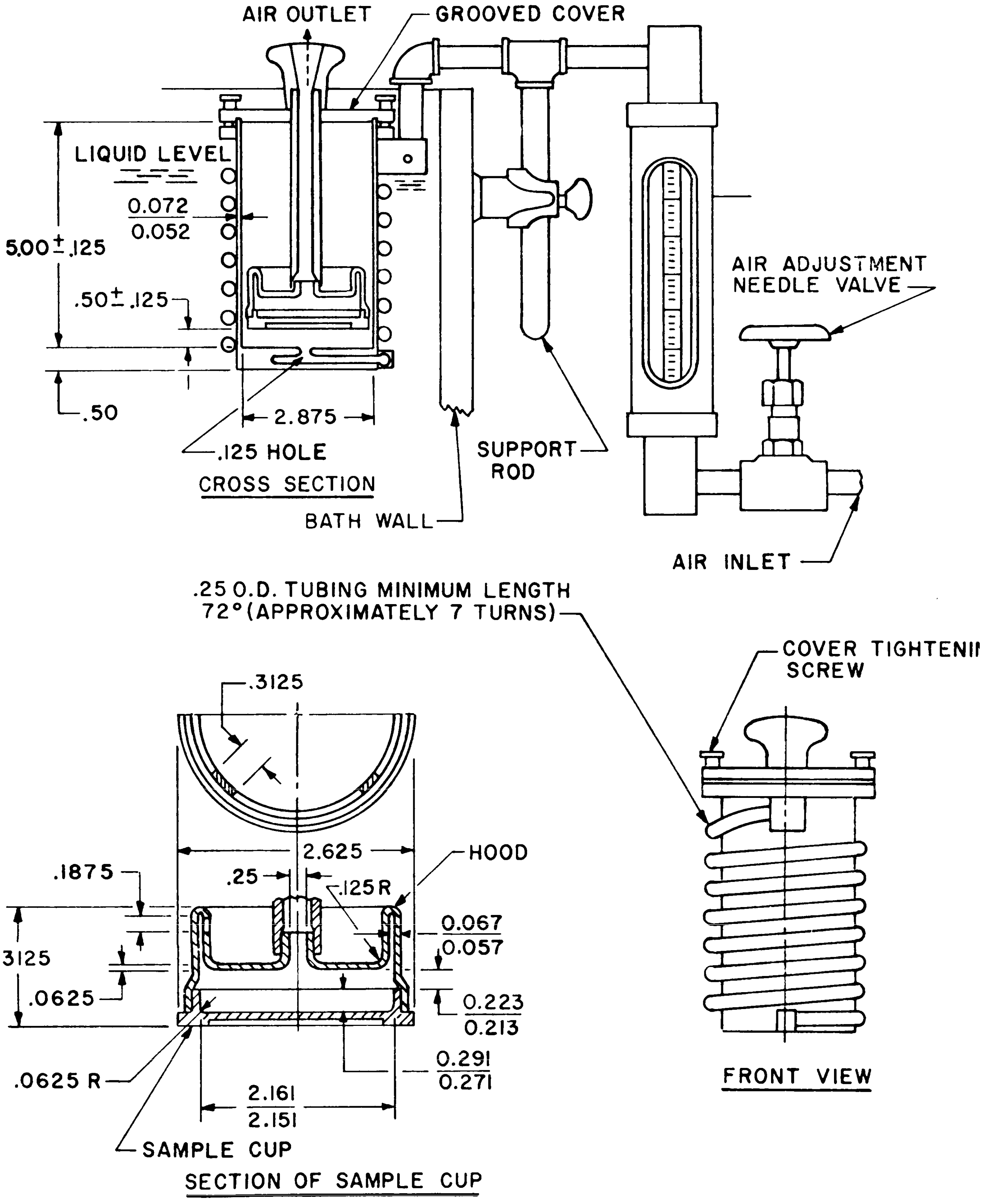

NOTES:
1. DIMENSIONS IN INCHES.
2. ALL DIMENSIONS ± .0156 UNLESS OTHERWISE SPECIFIED.

FIGURE 7. Evaporation test cell.

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METHOD 352.1
September 30, 1986

EFFECT OF EVAPORATION ON FLAMMABILITY

1. SCOPE

1.1 This method is used for determining the effect of evaporation on the flammability of a liquid petroleum product.

2. SUMMARY

2.1 It consists of checking the flammability of the liquid (by passing a sample-soaked pipe cleaner repeatedly through a flame and noting the number of passes required for ignition), storing the sample in an oven for the time and at the temperature required by the specification, and rechecking flammability.

3. SAMPLE SIZE

3.1 Approximately 30 mL of liquid to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Oscillating device (such as a windshield wiper), approximately 120-degree arc at 25 +2 cpm.

4.2 petri dish, approximately 9.0 cm diameter by 1.6 cm deep.

4.3 Oven, gravity-convection, capable of maintaining the specified temperature within 1° C (2° F).

4.4 Bunsen burner.

5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Pipe Cleaners (U.S. Tobacco Co., Dill’s or equal).

6. PROCEDURE

6.1 Cut at least 10 5.1 cm (2 inch) lengths of pipe cleaner.

6.2 Assemble a test setup (Figure 1) as follows:

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a. Mount a 5.1 cm (2 inch) piece of pipe cleaner in the arm of the oscillating device so that the end of the pipe cleaner describes an arc of approximately 120 degrees at a radius of 10.2 cm ±0.31 cm (4 ±1/8 inches).
b. Adjust the bunsen burner to provide a completely blue flame approximately 10 cm (4 inches) high, and without a sharp inner cone.
c. Position the bunsen burner so that the center of the 5.1 cm (2 inch) piece of pipe cleaner will pass through the center of the flame at the reversing point of the cycle.

6.3 Pour approximately 30 mL of the sample into the petri dish, and soak five 5.1 cm (2 inch) pieces of pipe cleaner in the sample for two minutes.

6.4 Drain off excess sample from one of the pieces of pipe cleaner, and mount cleaner in test apparatus as described in paragraph 6.2. Start the oscillating device, and record the number of cycles necessary for a self-sustained flame to appear on the pipe cleaner. Repeat this procedure with four other pieces of pipe cleaner.

6.5 Store the uncovered petri dish containing the sample in the oven, for the specified time.

6.6 At the end of this time, remove the dish from the oven. Place five 5.1 cm (2 inch) pieces of pipe cleaner in the dish.

6.7 Recheck flammability as specified in 6.4.

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Report the average number of cycles necessary for a self-sustaining flame to be achieved on the pipe cleaner both before and after partial evaporation.

9. PRECISION

9.1 Precision data have not been developed for this method.

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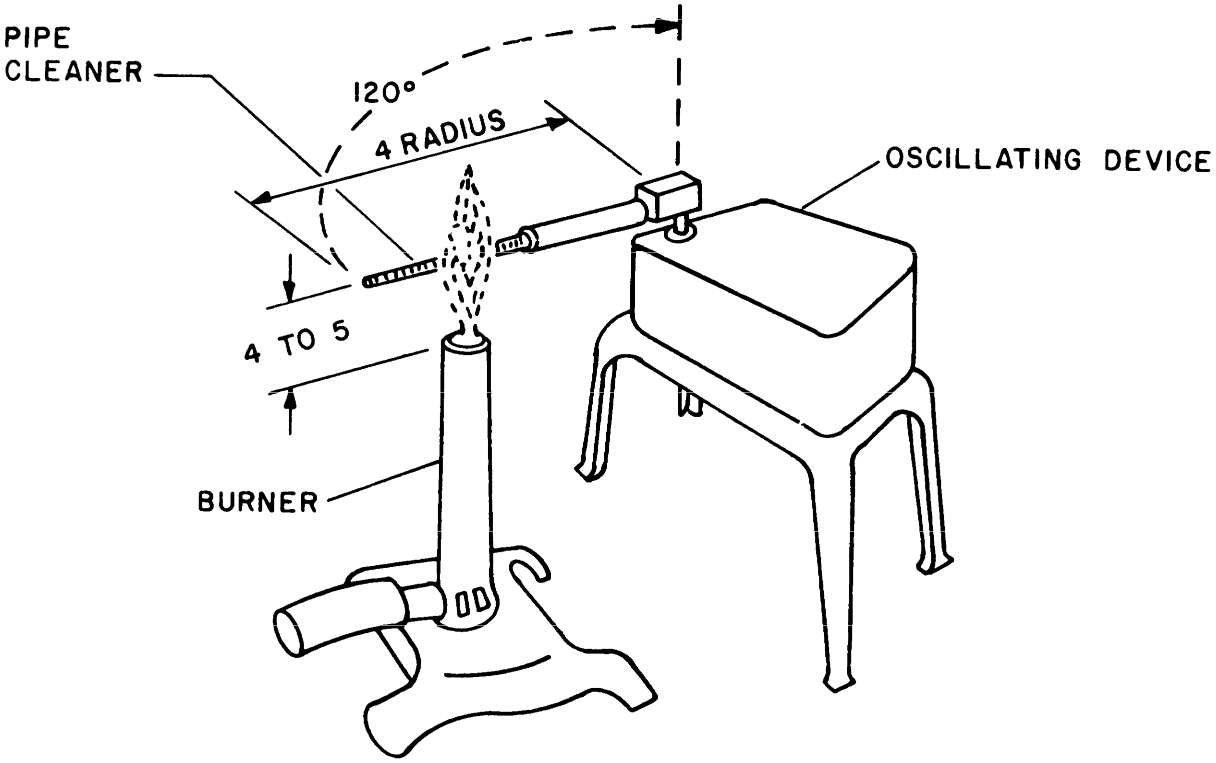

NOTE:
DIMENSIONS IN CENTIMETERS.

FIGURE I. Test setup.

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EVAPORATION

1. SCOPE

1.1 This method is used for determining the tendency of oil to form a hard or tacky residue upon evaporation.

2. SUMMARY

2.1 It consists of heating an oil-coated glass slide in an oven, at the temperature and for the time required by the specification, and reporting the condition of the residue.

3. SAMPLE SIZE

3.1 As needed, usually less than 100 mL.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Slide, microscope, glass.

4.2 Oven, gravity-convection, specified temperature within 1/2° C (±1° F).

4.3 Thread or wire, heat-resistant (for suspending slide in oven).

4.4 Beaker, 250-mL (for immersing the slide in the sample).

5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled carefully. Federal test Method 10000 > Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

6. PROCEDURE

6.1 Heat oven to specified temperature ±0.5° C (±1° F).

6.2 Cut notches near one end of slide so that it can conveniently be suspended by a thread or wire.

6.3 Immerse slide in oil at room temperature.

6.4 Remove slide from oil, and suspend it in oven for the specified time.

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6.5 After the specified heating period, remove slide from oven, and cool it to room temperature.

6.6 Observe the condition of oil residue on slide, paying particular attention to note the presence of any hard or tacky film.

7. cALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Report the condition of the oil residue on the slides, paying particular attention to the presence of any hard or tacky film.

9. PRECISION

9.1 Precision data have not been developed for this method.

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PERFORMANCE OF ARCTIC LUBRICATING OILS IN A TWO-CYCLE DIESEL ENGINE UNDER CYCLIC, TURBO-SUPERCHARGED CONDITIONS

1. SCOPE

1.1 This method is used for determining the effect of lubricating oils on wear, ring-sticking, and accumulation of deposits in a reciprocating internal combustion engine. Evaluation is based on: (a) the ability of the test engine to maintain performance throughout the cycle, (b) wear of critical engine components , (c) accumulation of fuel and lubricant related engine deposits, particularly in the piston ring zone areas, and (d) the physical and chemical condition of the lubricant monitored throughout the test.

2. SUMMARY

2.1 The test involves the operation of a militarized six-cylinder, fuel injected, turbo-supercharged, 2-stroke-cycle diesel engine under steady–state conditions for a total of 240 hours. Prior to test the engine is reconditioned as described herein. Evaluation is made by comparing the test oil performance to that of a reference oil of known quality.

3. SAMPLE SIZE

3.1 A minimum of 210 L (55 gallons) of test oil is required.

4. STANDARDS, REFERENCES, AND APPARATUS

4.1 References.

4.1.1 Coordinating Research Council Diesel Engine Rating Manual No. 5.

4.1.2 Proposed CRC Rating System for Diesel Engine Deposits, CRC, Inc., New York, NY, February 1973. This is a good reference but not mandatory.

4.1.3 Detroit Diesel Engine Series 53 Service Manual.

4.1.4 ASTM STP 509A Pt. 1.

4.1.5 ASTM committee D-2 Handout on 6V-53T rating.

4.2 Test Engine Systems.

4.2.1 Test engine. A Detroit Diesel 6V-53T Engine (Military Model 5063-5395), is specified for this method, with the following parts:

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Quantity	Detroit Diesel Part No.	Item
1	5133512	Flywheel
1	5126671	Scuff Plate
6	9409129	Bolt
1	5101431	Turbocharger
1	5133427	Heat Exchanger
1	8539953	Transmission Cooler (8 pi.)
1	8528885	Oil Cooler (16 pi.)
6	5140949	Connecting Rod
6	5228784	Fuel Injector (M70 or N70)
1	5199793	Overhaul Gasket Kit
2	Donaldson P12-1623	Air Filter
4	5107441	Hand Hole Gasket
1	AC-T552	Primary Fuel Filter
1	AC-TP540	Secondary Fuel Filter
2	AC-PF132W	Oil Filter
24	5197176	Exhaust Valves
6	5149315	Liner, Piston, Ring Set
1	5199734	Fuel Pump

4.2.2 Air intake system. A controlled-temperature air intake system is required for this method. The low temperature air-heater and primer assembly shall be removed from the engine.

4.2.3 Crankcase ventilation system. The crankcase breather system described herein shall be used for this method. The breather pipes are joined at a tee connection and connected to a short piece of l-1/4-inch rubber hose. The total gas flow is then piped by l-inch conduit to the blowby surge chamber from which the gas passes through a blowby meter and is discharged vertically. Appendix A illustrates the blowby surge tank. The airbox is drained from the left and right airbox drains through #49 orifices and into 3.8 L (1 gallon) collection cans. Filters may be placed before the orifices in order to prevent orifice plugging.

4.2.4 Cooling system. The coolant flow shall be from the thermostate housing cover outlet, through a 5 cm (2 inch) diameter transparent section of pipe into the coolant heat exchanger and back to the suction side of the coolant pump. A 3.8 L (1 gallon) cylindrical surge tank (16 cm [6-1/2 inches} diameter by 21 cm [8-1/2 inches long]) located to the side and above the coolant heat exchanger is provided as a settling vessel to insure coolant deaeration. During test the cooling system is operated with the pressure cap in the vented to atmospheric position. The engine thermostats are blocked in the full-open position for this test. Coolant heat exchanger shall be a BCF American Standard 5-030-06-024-006 or equal. System coolant capacity is 23 L (6 gallons). Coolant flow rate may be measured and reported.

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4.2.5 Fuel system. The primary and secondary fuel filter assemblies are relocated to a remote position off the engine and away from the heat of the exhaust gas. The same premium grade fuel lines (minimum length) and fittings supplied with the engine must be used when relocating the fuel filters. A water-to-fuel heat exchanger is employed to maintain fuel temperature. All lines must be lagged and secured to protect against vibration damage. Appendix B illustrates the fuel system.

4.2.6 Oil system. A special external oil cooler/filter assembly is used to control oil temperature. This assembly is available through Joe Brandes of Detroit Diesel. The 1/4 inch pipe plug in the front of the oil filter housing shall be removed and a sampling valve installed in its place. Appendix C illustrates the oil system. No additional oil cooling is allowed.

4.3 Instrumentation.

4.3.1 Load measurement. Appropriate engine speed and load-indicating devices, from which observed BHp can be determined, must be used in conjunction with suitable power-absorbing equipment. Engine or dynamometer speed shall be measured with an automatic electric revolution counter with synchronized time or suitable electronic speed measuring device. Accuracy of the load measuring device shall be ±4.07 N•m (±3 ft-lb).

4.3.2 Flow measurement.

4.3.2.1 Fuel flow. Provision shall be made for mass flow fuel measurement with a resolution of +0.045 kg/hr (+0.1 pound per hour). Average fuel temperature is determined at the fuel measuring device and fuel density is established. The fuel-flow measuring device shall be a properly installed mass flow meter.

4.3.2.2 Blowby flow. Blowby flow is indicated with the equipment described in 4.2.3 and Appendix A.

4.3.3 Temperature measurements. Provisions shall be made for thermocouple installation as shown below (total system accuracy shall be calibrated to ±1° C [±2° F]). Thermocouples shall be shielded and, unless specified, shall be immersed to the midstream.

Variable	Location
Exhaust gas before turbocharger	Left and right elbows, 6.9 cm (2-3/4 inches) from manifold.
Turbocharger exhaust exit	5.6 cm (2-1/4 inches) from turbocharger exit.
Cylinder jacket coolent-in 1/	3.8 cm (1.5 inch) above the inlet end of water pump inlet.

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Variable	Location
Cylinder jacket coolant-out 1/	In 1.3 cm (1/2 inch) pipe plug hole of thermostat housing deaeration dome.
Oil sump 1/	Sump drain plug 6.6 cm (2-5/8 inches) immersion from wall.
Oil gallery	Right front oil tap, 5.1 cm (2 inches) into block (after filter and coolers).
Fuel 1/	At secondary filter inlet.
Compressor inlet air 1/	Opposite air filter.
Airbox 1/	Left rear hand hole cover.
Wet bulb/dry bulb	Near air barrel inlet.

1/ All temperatures shall be recorded at not more than 2 minute intervals during the test.

4.3.4 Pressure measurements. Provision shall be made for measuring pressures as follows:

Variable	Location
Intake air vacuum	After air filter 10 cm (4 inches) from compressor inlet.
Exhaust back pressure	In 10 cm (4 inch) line, 7.5 cm (3 inches) after turbocharger exit.
Exhaust pressure before turbocharger	Right-hand elbow 7.5 cm (3 inches) from turbocharger Y connector.
Compressor discharge	Blower inlet housing (remove 0.625 cm [1/4 inch] pipe plug).
Airbox	Left rear hand hole cover.
Oil gallery	Left rear gallery top.
Fuel	Secondary filter outlet
Barometer	In vicinity.
Blowby	In blowby surge tank.

5 MATERIALS.

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical material listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life harzard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Fuel. Only fuels approved by the US Army Belvoir Research, Development, and Engineering Center, Material Fuels & Lubricants Laboratory, Ft. Belvoir, Virginia, and meeting the requirements set forth in part I of ASTM STP 509A [0,2,0].

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5.3 Reference oil. Reference engine oil REO-203 is to be used for standardizing engine operation as set forth herein. Orders for reference oil should be made out to Southwest Research Institute, P.O. Drawer 28510, San Antonio, Texas 78284 and sent to the ASTM Test Monitoring Center, 4400 5th Ave, Pittsburgh, PA, 15213, Attn: Mr. R. K. Nelson for transmittal to the supplier.

5.4 Dry cleaning solvent. ASTM D 484 Type I [0,2,0] or Exxon "Varsol" may be used to clean parts as described herein. D-Carb (Dubois Chemicals Co., Cincinnati, Ohio) may be used in vat cleaning the engine block [u,u,u].

5.5 Engine Coolant. Engine coolant will consist of a 50/5U volumetric mixture of ethylene glycol base antifreeze 2/ and potable water [0,0,0].

6. PROCEDURE.

6.1 Preparation for test.

6.1.1 Engine Disassembly. A systematic inspection and maintenance of the test engine shall be performed prior to each test run. New engines or engines being used for the first time in this test method and thereafter will be disassembled, reconditioned, and gauged before each test. Regardless of their condition, the following parts shall be replaced with new factory production items:

- Piston assemblies
- Piston ring sets
- Cylinder liners
- Fuel filters, oil filter, and air filters
- All gaskets and seals

The measurements prescribed in Appendix D (BEFORE AND AFTER TEST DATA SHEETS) shall be performed and recorded.

6.2 Cleaning procedure.

6.2.1 Engine block. If the engine is completely disassembled, the block shall be cleaned by spraying with solvent. Remove as much of the solvent as possible by rotating the block and blow drying with air.

6.2.2 Aluminum parts. Aluminum parts will be cleaned by spraying with solvent followed by air drying. If deposits are stubborn, the parts may be soaked in solvent for a period up to two hours at a temperature of 38°C or less. The solvent soak must be followed by a warm water wash and air drying.

6.2.3 Steel parts. All steel parts (i.e., rocker arm covers, oil pan, oil heat exchanger, cylinder head decks, oil pump, crankshaft, etc.), shall be

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2/ Prestone - mixing with other types not authorized.

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cleaned by spraying with solvent, air dried and lightly coated with' reference oil. Of particular concern are the fuel galleries in new heads; these should be flushed with diesel fuel and bottle brushed before use.

6.2.4 Fuel injectors. The fuel injectors are removed but not disassembled or adjusted. Only the tips should be lightly wire brushed to remove carbon particles. Should the operation of the engine indicate that their condition might be at fault, the units should be tested, adjusted, or replaced with new units.

6.2.5 Combustion chambers and valves. Exhaust valves are removed and the entire combustion chamber area of each cylinder is cleaned by wire brushing. Valves are only lightly refaced, if inspection shows pitting. Where the sealing surfaces (faces) are not pitted, the valves need be only lightly lapped prior to reassembly. If light refacing does not correct the seating condition, the valve shall be replaced. Regardless of their condition, valves should be replaced after three tests.

6.3 Engine disassembly.

6.3.1 The engine block is fitted with new parts as listed in sections 4.2.1 and 6.1.1. Complete measurements of the block bore, liners, pistons, rings, connecting rod journals, main bearing journals, connecting rod bearing inserts, and main bearing inserts are made prior to each rebuild. Connecting rods and piston pins will be inspected and replaced if not in good service condition. In addition, camshaft journals to bearings and oil pump clearances shall be checked against service limits during major rebuilds. These parts will be replaced as required to maintain service limits. The liner outside surfaces contacting the block bore shall be lightly coated with grease to reduce interface fretting corrosion. Other parts shall be coated with reference oil during assembly. Piston pin retainers shall be checked for leakage with KENT MOORE tool number J-23987-01.

6.3.2 The following critical rebuild measurements shall be maintained during engine assembly:

Engine part	Tolerance or Clearance, cm - (inches)	
Crankshaft main bearing clearance	0.00762-0.0127	(0.0030-0.0030)2/
Camshaft bearing clearance	0.0114-0.152	(0.0045-0.0060)
Connecting rod bearing clearance	0.002794-0.0104	(0.0011-0.0041)
Crankshaft end-play	0.0102-0.0279	(0.0040-0.0110)
Cylinder block bore		
Taper	0.0038	(0.0015) max
Out-of-round	0.0038	(0.0015) max

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Engine part	Tolerance or Clearance, cm - (inches) (cent)	
Inside diameter (bottom)	11.0655-11.0680 new, 11.073 max	(4.3565-4.3575) new, 4.3595 max.
Clearance liner to block (bottom)	0.00127-0.00762	(0.0005-0.0030)
Cylinder liners (installed or loose)		
Taper	0.0038	(0.0015) max 3/
Out-of-round	0.0038	(0.0015) max 7/
Inside diameter	9.8430-9.8468	(3.8752-3.8767)
Piston to liner fit	0.0155-0.0249	(0.0061-0.0098)
Piston skirt O.D.	9.8219-9.8275	(3.8669-3.8691)
#1 Fire Ring		
End gap	0.051-0.1016	(0.020-0.040)4/
Side clearance	0.008-0.01676	(0.003-0.0066)4/
#2 Compression ring		
End gap	0.051-0.1016	(0.020-0.040)4/
Side clearance	0.018-0.0267	(0.007-0.010573/
#3 Compression ring		
End gap	0.051-0.1016	(0.020-0.040)4/
Side clearance	0.013-0.0216	(0.005-0.0085)4/
#4 Compression ring		
End gap	0.051-0.1016	(0.020-0.040)4/
Side clearance	0.013-0.0216	(0.005-0.0065)3/
Upper Oil Rings		
End gap	0.025-0.0508	(0.010-0.020)4/
Side clearance	0.0038-0.01016	(0.001-0.004)7/
Lower		
End gap	0.0178-0.0432	(0.007-0.017)4/
Side clearance	0.00381-0.0140	(0.0015-0.0055)4/

3/ Using new cylinder liners in a used block.

4/ These are the latest specifications from Detroit Diesel and" should be reflected in future service manuals.

6.3.3 Engine assembly shall be in accordance with TM 9–2815-212-35 and the Detroit Diesel Engine Series 53 Service Manual. Reference must be made to these documents to determine the proper bolt torques, tightening sequences, and final injector timing and valve lash settings. Upper oil control rings and expanders (as a set) accompanying DD part number 5149315 should measure 19 - 22 pounds On a Dorsey Gage. Tensions for these rings should be reported on page D2.

6.4 Engine start-up and shut-down procedures.

6.4.1 Engine start-up and deaeration procedure. From a cold start, idle the engine for five minutes. Then warm up at 1200 rpm and l19N•m (88 lb-ft)

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dynamometer load (20 BHp) until oil sump temperature reaches 82° C (180° F) and coolant jacket-out temperatures reach 76.7° C (170° F). If the coolant system was drained by the previous shut-down, warm up at 1100 rpm and 98 N°m (72 lb-ft) load, 15 BHp, to insure deaeration of the coolant system. If the engine is started warm and the 82° C (180° F) oil sump and 76.7° C (170° F) coolant “ jacket-out temperatures are achieved, it is permissible to gradually accelerate the engine without delay to test conditions. The automatic controller set point for coolant-out temperature must remain at 74.7° C (170° F) during all start UPS.

6.4.2 Engine shut-down procedure. To shut down the engine from test conditions, slowly bring the engine to idle by turning the rack setting to the idle position. Allow the engine to idle for five minutes and then shut-down by actuating the idle cut-off. The automatic controller set point for coolant out temperatures must remain at 76.7° C (170° F) during all shut-downs.

6.4.3 Initial oil flush. Charge the engine oil sump with approximately 19 L (20 quarts) of reference oil (clean used oil permissible). Disconnect the turbo oil supply line at the turbo and crank the engine with the governor control in the fuel cut-off position until one pint of oil is pumped from the disconnected line. Reconnect the turbo line and crank the engine until the oil pressure stabilizes. Start and deaerate the engine as per 6.4.1. Drain the lubricant while still warm in order to remove any solvent retained in the engine.

6.5 Engine run-in procedure.

6.5.1 Oil charge. Charge the engine oil sump with approximately 23 L (24 quarts) of reference oil. Disconnect the turbo oil supply line at the turbo and crank the engine with the governor control in the fuel cut-off position until 475 mL (one pint) of oil is pumped from the disconnected line. Reconnect the turbo line and crank the engine until the oil pressure stabilizes.

6.5.2 Operating conditions. Start the engine in accordance with 6.4.1 and conduct the engine run-in according to the following schedule:

Engine Speed, rpm	Dynamometer Load. lb-ft	Power, Obs BHp	Time, min.
1800	88	30	15
2200	310	130	30
2500	420	200	30
2800	422	225	30

Coolant jacket-out temperature is maintained at 76.7° ±1° C (170° 2° F), and oil gallery pressure is 207kPa gage (30 psig) minimum. Coolant system deaeration (air free sight glass) must be established by the time the 2500 rpm sequence is completed.

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6.6 Interim Settings and Adjustments.

6.6.1 Immediately following the run-in, check, adjust and record the governor settings. Set the idle speed at 1000 rpm maintaining a minimum of 34 kPa gage (5 psig) gallery oil pressure. No-load speed maximum should be 2950-3030 rpm, and is adjusted per the Detroit Diesel Series 53 Service Manual.

6.6.2 Shut down the engine according to 6.4.2.

6.6.3 Five minutes after shut-down, check and reset the injector timing and exhaust valve clearance as follows:

Injector timing - 3.7084 ±0.0089 cm (1.4600 ±0.0035 inch)
Valve clearance - 0.0584 to 0.0635 cm (0.023 to 0.025 inch) hot

6.7 Initial power check. Power checks are made at 2200 and 2800 rpm in order to assure that the engine will produce the necessary power. Engine start-up is in accordance with 6.4.1. The engine is operated at the specified speed until the observed output has stabilized. A coolant jacket-out temperature of 76.7° C +1° c (170° F +2° F) is maintained during checks. The engine must produce at least 295 horsepower at 2800 rpm and at least 260 horsepower at 2200 rpm.

6.8 Oil flush run. Drain the reference oil and add 19 L (20 quarts) of test oil. Run the engine for 30 minutes at 1200 rpm and 40.7 NŽm (30 lb-ft) load. Oil flush is not necessary if the test oil is the reference oil.

6.9 Test procedure.

6.9.1 Oil drain. After oil flush shut-down, and while the oil is still warm, drain the oil and remove the oil filter. Perform the initial airbox inspection.

6.9.2 Oil charge. Weigh-in a new oil filter and sufficient test oil to bring the sump level to the full mark on the dipstick gage 23 L (approximately 24 qt). Crank the engine long enough to stabilize the oil pressure (approximately 10 seconds), wait five minutes and recheck the oil level.

6.9.3 Test duration. The test consists of 240 hours of operation at prescribed test conditions. Interim oil adjustments, airbox inspections, and oil samplings are made on the following schedule:

Operation	O	20	40	60	80	100	120	140	160	180	200	220	240
Oil Adjustments		X	x	x	x	x	x	x	x	k	x	x	-
Oil Sampled	X	x	x	x	x	x	x	X	x	x	x	x	x
Airbox Inspected*	x	-	-	x	-	-	x	-	-	x	-	-	-
Oil Change	x	-	-	-	-	-	x	-	-	-	-	-	-
Air Filter Change	-	-	-	-	-	-	As Needed						

X indicates adjustment, sampling or inspection to be performed at given test time.
* Additional inspections as needed.

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6.9.4 Test cycle description. The endurance test consists of repeating a four-mode, five-hour operating cycle four times daily for a total of 20 hours. The engine is then shut down for a period of four hours after which the daily cycle is repeated. The five-hour operating cycle (shown below) consists of: 0.5 hour at engine idle followed by 2.0 hours at maximum power, followed by 0.5 hour at engine idle followed by 2.0 hours at maximum torque. The 20-hour endurance cycle is conducted for 12 days without interruptions longer than three days. Ramping between operating conditions shall be as follows; 2 minutes maximum to come up to speed, followed by 8 minutes maximum to come up to load, 8 minutes maximum to come down to load, followed by 2 minutes maximum to come down to speed.

Endurance Test Operating Cycle

Period	Mode	Time, hrs	Load, %	Speed, rpm	Jacket-Out Temp, °C (°F)
1	Idle	0.5	0	675 ± 10	43 (110)
	Max Power	2	100	2800 ± 10	77 (170)
	Idle	0.5	0	675 ± 10	43 (110)
	Max Torque	2	100	2200 ± 10	77 (170)
2	Idle	0.5	0	675	43 (110)
	Max Power	2	100	2800	77 (170)
	Idle	0.5	0	675	43 (110)
	Max Torque	2	100	2200	77 (170)
3	Idle	0.5	0	675	43 (110)
	Max Power	2	100	2800	77 (170)
	Idle	0.5	0	675	43 (110)
	Max Torque	2	100	2200	77 (170)
4	Idle	0.5	0	675	43 (110)
	Max Power	2	100	2800	77 (170)
	Idle	0.5	0	675	43 (110)
	Max Torque	2	100	2200	77 (170)
5	Shutdown	4	0	0	- - -

6.9.5 Operating conditions. The engine shall be operated under the following conditions:

	Limits		
Operating Condition	Max Power Mode	Max Torque Mode	Idle Mode
Speed, rpm	2800 +10	2200 +10	675 +10
Fuel Flow, Kg/hr (lb/hr)	41 (90) min	34 (74) min.	NS
Obs BHp Output	235+5	207+5	NS
Jacket-out °C (°F)	76.7 (170 ±2)	76.±1 (170 +2)	43 (110)
Coolant T, °C (°F)	4 - 7 (8 - 12)	4 - 7 (8 -12)	NS
Inlet Air, °C (°F)	32 +2 (90 +5)	32 +2 (90 +5)	NS

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	Limits		
Operating Condition	Max Power Mode	Max Torque Mode	Idle Mode
Oil Sump, °C (°F)	121 (250) max	121 (250) max	NS
Oil Gallery, °C (°F)	35 ±1 (95 ±2)	35 ±1 (95 +2)	NS
Fuel Temp at Filter	35 1 (95 ±2)	35 ±1 (95 ±2)	
Fuel Pressure range, gage kPa (psig)	241– 483 (35 - 70)	241-- 483 (35 - 70)	NS
Compressor Suction, clean filter, cm (inches) water	20 (8) max	NS	NS
Compressor Suction, dirty filter, cm (inches) water	25 (10) max	NS	NS
Exhaust Back pressure (after turbo), cm (inches) Hg	3.0 - 5.1 (1.5 - 2.0)	3.0 - 5.1 (1.5 - 2.0)	NS
Blowby Pressure, cm (inches) water	10 (4.0) max*	NS	NS
Oil Pressure gage, kPa (psig)	207 (30) min	207 (30) min	34 (5) min

* = Blowby pressure greater than 10 cm (4 inches) of water constitutes test shutdown for inspection.
NS = Not Specified

6.9.6 Used oil sampling. Take a 240 mL. (8 fluid ounce) sample of oil at the oil filter housing according to the schedule specified in 6.9.3. This is done with the engine idling prior to the scheduled shut-down and oil adjustment. If fuel dilution (greater than 5 percent) is detected in the oil, the fuel leak should be repaired and the oil changed before the test continues.

6.9.7 Oil adjustment and oil change.

6.9.7.1 Shut down the engine according to 6.4.2. Note that oil samples must be taken during the 5 minute idling period (see 6.9.6).

6.9.7.2 Make oil adjustments according to the schedule of 6.9.3 by adding a weighed amount of test oil to the sump, bring the level to the full mark on the dipstick. Maintenance of an oil log sheet is required. If the oil level is below add halfway (10 hours) through the period, weight and add roughly 3.8 L (1 gallon) of oil so that the engine can finish the period safely. If oil temperature exceeds 121° C (250° F), remove and clean the oil heat exchanger. Oil consumption should not exceed 0.34 kg/hr (0.75 lb/hr) or the test shall be considered invalid.

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6.9.7.3 After the 120-hour oil sample is taken, the engine is shutdown according to 6.4.2. The oil is drained from the oil filter housing and the engine crankcase. A new charge of test oil and a new oil filter are installed per 6.9.2.

6.9.8 Airbox inspections. Four airbox inspections shall be made as specified in 6.9.3. The zero-hour inspection is made at the completion of the final power check and prior to the installation of test oil. Observations made at each airbox inspection must be recorded on a form similar to that on page D-13. The areas inspected, performance levels noted, and means of inspection shall be as follows:

Area inspected	Performance level noted	Means of inspection
Inlet Ports	Percent Plugging	Visual
Piston Skirt	Tinplate Melting Scoring Burning	Visual
Ring Lands	Carbon Deposits	Visual
Rings	Freedom Face Scuffing Face Burning	Blunt Probe and , Visual
Cylinder Liner	Scuffing 4/ Scoring Bridge Cracking 5/ Glazing	Illuminated and Magnifying Borescope Visual

4/ Scuffing shall be described in terms of degree (light, medium and heavy) and in terms of area (thrust, anti-thrust, front and rear).

5/ Bridge cracking constitutes a test shutdown or linear replacement as in 6.11.2.

6.9.9 Performance check. The last 2200 and 2800 rpm cycles shall be examined to assure that the engine meets horsepower requirements. A statement that the engine met horsepower requirements should be included in the test report.

6.9.10 Final oil drain. Shut down engine as outlined in 6.4.2. Let the engine stand for five minutes, then drain the crankcase and oil filter housing. Weigh and record the quantity of oil drained, the oil filter, and the blowby can.

6.9.11 Data recording.

6.9.11.1 The following data shall be recorded once during each idle mode and twice during each power and torque mode.

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Operator
Date
Time
Test Hours
Engine Speed, rpm
Load, N•m (lb-ft)
Fuel Rate, kg/hr (lb/hr)
BSFC, lb/bhp-hr
Observed Output, BHp
Temperatures, °C (°F)
  Exhaust Manifolds
  Turbocharger exit
  Coolant Jacket-in
  Coolant Jacket-out
  Oil Sump
  Fuel at Filter
  Compressor Inlet Air
  Airbox
  Ambient Air (wet/dry bulb)
Presures
  Intake vacuum, cm (in.) H_20
  Exhaust Turbocharger exit, cm (in.) Hg
  Exhaust Manifolds, kPa gage (psig)
  Compressor Discharge, kPa gage (psig)
  Blower Discharge, Airbox, kPa gage (psig)
  Transfer pump, kPa gage (psig)
  Oil Gallery, kPa gage (psig)
  Blowby, cm (in.) H_20
  Barometer, cm (in.) Hg

6.9.12 Problems encountered during test.

6.9.12.1 High blowby. Blowby pressure greater than 10 cm (4 inches) H_20 constitutes test shutdown for inspection. If the problem appears to be caused by lubricant-related ring wear, then the test should be terminated. Severe problems may be present by blowby pressures less than 10 cm (four inches) of water.

6.9.12.2 Liner scuffing-ring wear. Liner scuffing-ring wear is generally accompanied by high blowby pressures. During the test, in the case that one liner exhibits severe scuffing while all other exhibit normal wear, that liner-piston-ring set may be replaced and the test continued. The removed parts should be rated but not included in reported averages. Removed liners should exhibit 30 percent or greater overall scuffing. A fresh oil charge and full break–in should be used in this instance. Appropriate notations should appear in the test report. Engine oil iron content is also a good indication of ring wear and scuffing. If severe scuffing is observed before the test oil is

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introduced into the engine, that (those) cylinder(s) kit(s) may be changed out and a full break-in run. Measurements and ratings of the removed kits need not appear in the test report, but the test number suffix should reflect change outs as per section 8.5.

6.9.12.3 Visually observed scuffing. If severe liner scuffing is observed during the airbox inspections, and that scuffing is judged to be of a progressive nature, then the test should be terminated. Severe liner scuffing can lead to liner o-ring melting and subsequent catastrophic engine failure. Progressive liner scuffing is generally accompanied by high blowby and rapidly increasing engine oil iron content.

6.9.12.4 Fuel dilution. If a fuel concentration greater than five percent by weight is detected in the lubricant, the fuel leak should be repaired and the oil changed before the test continues. Fuel crossover lines are generally at fault in this case. Appropriate notations should appear in the test report.

6.9.12.5 Coolant dilution. If coolant is detected in the lubricant, the leak should be repaired and the oil changed before the test continues. Appropriate notations should appear in the test report. In order to avoid coolant dilution when cylinder heads are removed the following procedure should be used:

a. Drain lubricant.
b. Drain coolant.
c. Perform desired work taking care to minimize coolant drainage into sump.
d. Flush oil passages by pouring new oil down exposed oil drain holes.
e. Reinstall head(s).
f. Refill with original oil.
g. Refill coolant system.

6.9.12.6 High oil temperature. Oil sump temperatures greater than 121° C {250° F) generally indicate that the oil-water heat exchangers need cleaning. If after cleaning, the sump temperature remains high, then the test should be halted until the problem is corrected.

6.9.12.7 Loss of power.

6.9.12.7.1 Faulty injectors. poor engine performance during the test may be caused by worn, sticking, broken or leaking injectors Injectors may be replaced at any point in the test.

6.9.12.7.2 Valve distress. Poor engine performance caused by exhaust valve distress (burning) constitutes test termination. Exhaust valve replacement is allowed only in the case of valve stem breakage (this is not considered lubricant-related failure).

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6.9.12.7.3 Mechanical problems. Poor engine performance caused by faulty turbo chargers, blowers, misadjusted injectors, etc., may be corrected by component replacement or adjustment. Appropriate notations should appear in the test report.

6.9.12.7.4 High oil consumption. High oil consumption, 0.34 kg/hr (0.75 lb/hr), is generally caused by cracked piston pin retainers or worn oil control rings. Cracked piston pin retainers may be replaced at any point in the test. If the average oil consumption during the test is greater than 0.34 kg/hr (0.75 lb/hr), the test will be considered invalid.

6.9.12.7.5 Leaks. Lubricant or coolant leaks should be corrected during the course of the test.

6.9.12.7.6 Makeup of downtime. Minor downtime may be made up by reducing the soak periods to no less than 3 hours. Downtime that cannot be made up in this manner should be reported.

6.10 Evaluation of results.

6.10.1 Part ratings.

6.10.1.1 Preparation for rating. Pistons and cylinder liners are removed from the engine. Care must be taken to avoid disturbing engine deposits during disassembly. Pistons and cylinder liners are numbered on the thrust side. Using a band saw or cut-off saw, split the cylinder liners in half along a longitudinal plane separating the thrust and anti-thrust sides. Any engine not completing the full 240-hour test must be inspected for signs of disassembly before a failure may be termed "lubricant-related”.

6.10.1.2 Piston ratings. Using the terminology of 6.10.1.5, the CRC Diesel Engine Manual No. 5, and the proposed CRC rating system for Diesel Engine Deposits (first draft), and the latest ASTM committee D-2 handout on 6V-53T rating, rate the pistons for the following:

Ring groove carbon filling, percent ring supporting carbon, and Weighted Total Demerit (WTD)
Skirt lacquer
Ring sticking
Ring face condition

6.10.1.3 Cylinder liner ratings. Using the terminology of 6.10.1.5 and CRC Diesel Engine Rating Manual No. 5, and the latest ASTM committe D-2 handout on 6V-53T ratings, rate the cylinder liners for the following:

Intake Port Restriction
Scuffing (percent compression ring travel area, visual and mat methods)

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Bore Polishing (percent compression ring travel area, visual and mat methods)
Lacquer

6.10.1.4 Other ratings. Combustion chamber deposits in the cylinder head and in the piston crowns shall be rated in terms of texture and depth. Exhaust valves, camshaft lobes, rocker arms, tappets/roller-followers, exhaust valve bridges, crankshaft journals and main/connecting rod bearing inserts will also be rated. Crankshaft main bearing journals and bearings need only be rated at major rebuilds. Any unusual deposits or part condition shall be noted.

6.10.1.5 Rating terminology. Ratings shall be made using the CRC Diesel Engine Rating Manual No. 5 and the latest ASTM committee D-2 handout on 6V-53T ratings.

6.10.2 Lubricant analyses. Test lubricant degradation over the 240-hour test period shall be determined and reported as shown in Appendix F.

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Rating data. suitable forms for recording data are shown in Appendix E; all information shown on these forms shall be furnished with the test report. If one liner-piston-ring kit is changed during the course of the test, that rating data is reported but not included in the averages. If one cylinder kit was changed out during the test (as per 6.10.12.2), then that kit shall be the one dropped in the averages of five shown throughout Appendix E. If no kit was changed during the test, then the kit dropped in the averages of five shall be the kit exhibiting the higher of the following two numbers:

$$\text{Scuffing Dev. From Mean} = \frac{\dfrac{\text{Thrust + Anti-Thrust}}{2} - \text{Average of Six}}{\text{Average of six}}.$$

$$\text{\#2 and 3 Ring Demerits Dev. From Mean} = \frac{\dfrac{\text{\#2 + \#3 Demerits}}{2} - \text{Average of Six}}{\text{Average of six}}$$

8.2 Operating data. Mean and standard deviation operating data for the maximum power mode and the maximum torque mode shall be reported, together with the average oil consumption.

8.3 Build-up and wear measurement data. suitable forms for presenting the build-up and wear measurements are presented in Appendix G.

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8.4 Photographic data. Color photographs of each piston and split cylinder liner showing both thrust and anti-thrust sides shall be presented. All photographs shall be on a white background and shall be clearly marked giving cylinder number, right or left, and thrust or anti-thrust. Photographs of piston ring surfaces (opposite gap) and cylinder head deposits shall also be presented. Pictures shall be presented in the following order and manner:

a. Piston rings 1-L and 1-R shall be on the same page. Apparent ring diameter shall be equal to or greater than 10 cm (four inches). Rings shall be photographed with a space between each ring and in the top to bottom order of 1, 2, 3, 4, 5, 6, 7. Lighting should emphasize ring distress and attempts should be made to eliminate extraneous reflections from the ring surfaces.
b. Piston 1-L thrust and antithrust shall be presented on the same page. Apparent piston height shall be equal to or greater than 10 cm (4 inches). The thrust photograph should be the left most of the two photographs in all instances.
c. Piston 1-R thrust and antitrust shall be presented on the same page.
d. Liner 1-L thrust and antitrust shall be presented on the same page. Apparent liner height shall be equal to or greater than 15 cm (six inches).
e. Liner l-R.
f. Rings 2-L and 2-R.
g. Piston 2-L.
h. Piston 2-R.
i. Liner 2-L.
j. Liner 2-R.
k. Rings 3-L and 3-R.
1. Piston 3-L.
m. Piston 3-R.
n. Liner 3-L.
o. Liner 3-R.
p. The left and right cylinder heads shall be displayed on the same page. Apparent head length shall be equal to or greater than 13 cm (five inches). Heads shall be displayed horizontally with cam followers topmost. Combustion chambers should be labeled lR, 2R, etc.

8.5 Test number. The test number shall consist of the following: Stand-Stand Run number-Engine-Engine Run number-Suffix. Suffix denotes the number of attempts to reference (e.g., first attempt = number suffix, second attempt = A, third attempt = B, etc.).

9. PRECISION

9.1 A reference test is required when a new engine or a new test stand is put into service for the first time, or when an established facility re-installs a test stand. To maintain severity level, reference tests on each engine are

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required every thirteen tests. This implies that twelve candidate oils may be tested between reference runs on a single engine. An engine is defined as a block and any buildup constitutes a test. Each test stand must be referenced every ninth test or six months, whichever comes first. This implies that each stand may run eight candidate oils between reference tests or that six months may elapse between reference runs. Reporting of an engine's or stand's reference history is optional.

Method Prepared by:

Army - ME - 1986

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APPENDICES

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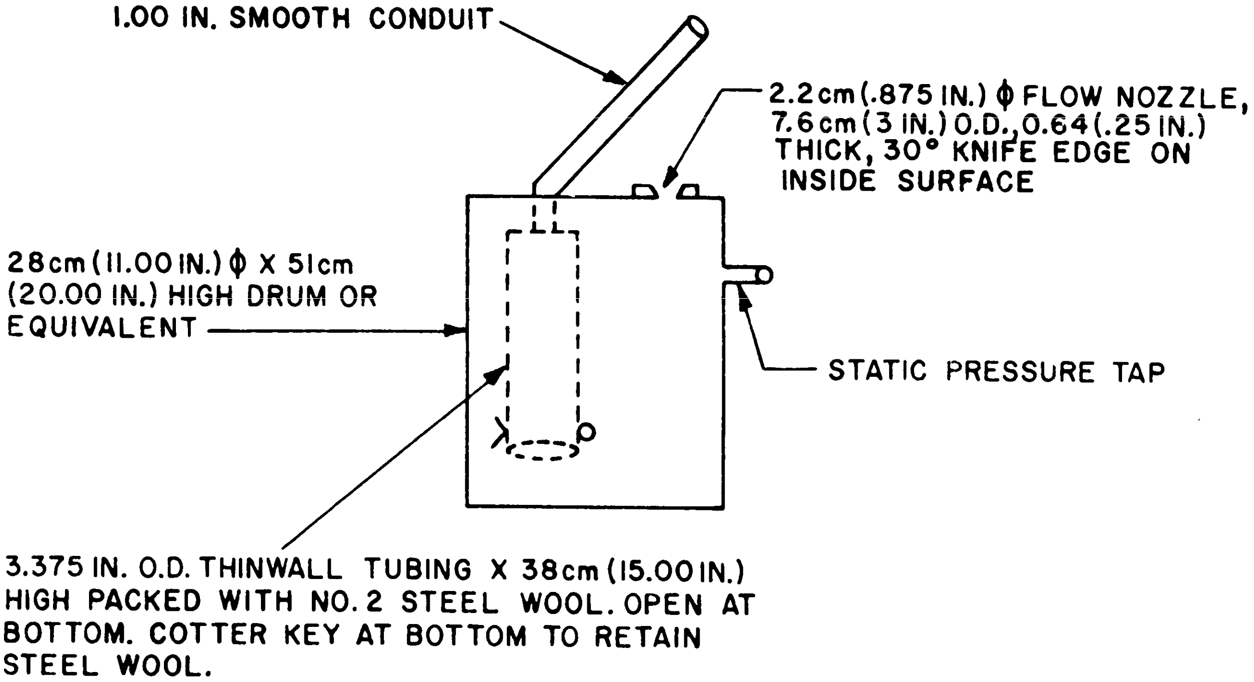
BLOWBY SURGE TANK



X-4355

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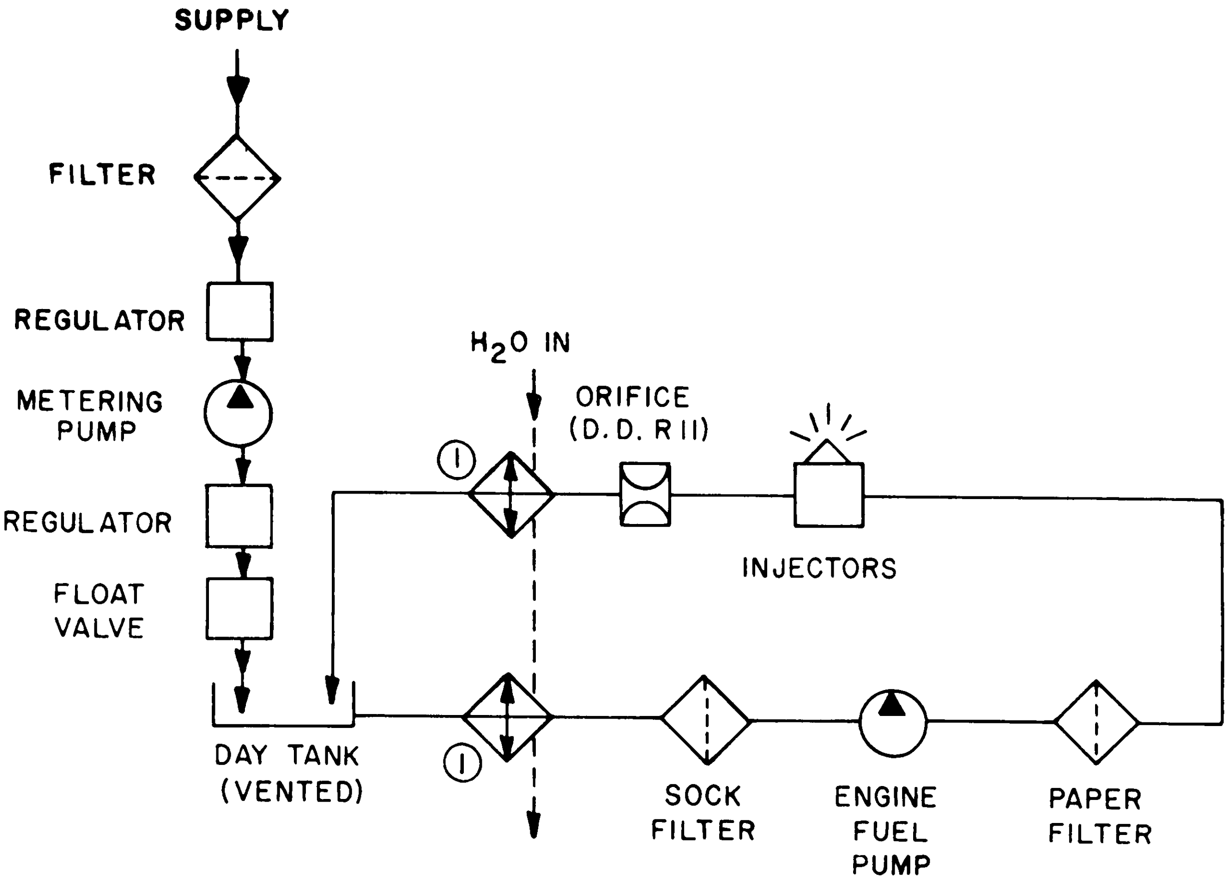
APPENDIX B

FUEL SYSTEM SCHEMATIC



① AMERICAN STANDARD BCF 5-030-03-014-003 HEAT EXCHANGERS OR EQUIVALENT.

X-4356

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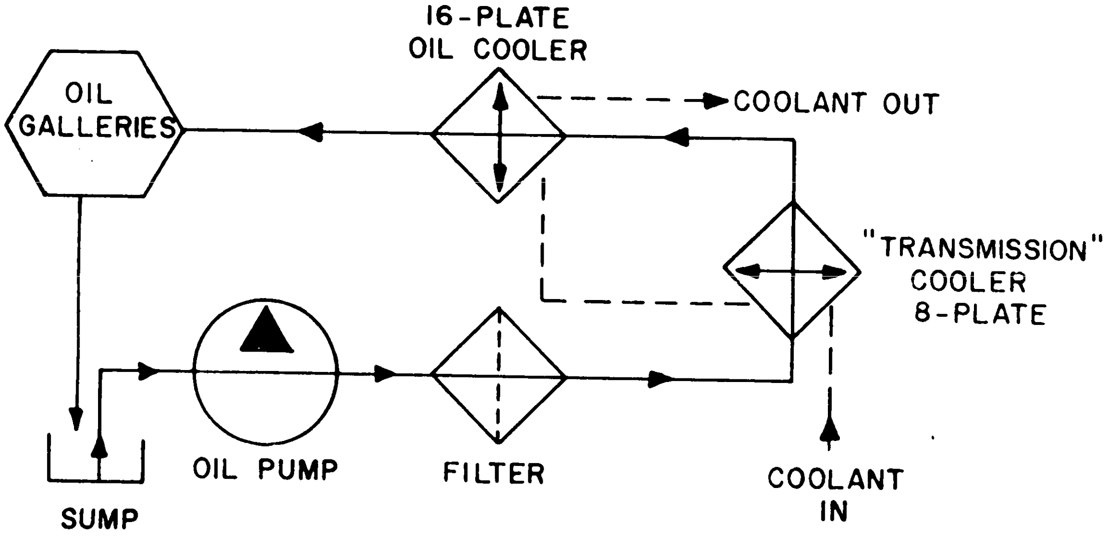
APPENDIX C

OIL SYSTEM SCHEMATIC



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APPENDIX D

BEFORE TEST AND AFTER TEST

DATA SHEETS

TEST NO. ____________________

BLOCK NO. ____________________

HEAD NO. ____________________ L

____________________ R

DATE STARTED ____________________

DATE FINISHED ____________________

LUBRICANT ____________________

FUEL ____________________

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DATE________________ TEST NO________________ TECHNICIAN________________

LUBRICANT________________ FUEL________________

6V-53T PISTON RING CLEARANCES

		BEFORE TEST		AFTER TEST
		End Gap*	Side	End Gap
1L	1			
	2			
	3			
	4			
	5			
UOCRT	6			
	7			
2L	1			
	2			
	3			
	4			
	5			
UOCRT	6			
	7			
3L	1			
	2			
	3			
	4			
	5			
UOCRT	6			
	7			

		BEFORE TEST		AFTER TEST
		End Gap	Side	End Gap
1R	1			
	2			
	3			
	4			
	5			
UOCRT	6			
	7			
2R	1			
	2			
	3			
	4			
	5			
UOCRT	6			
	7			
3R	1			
	2			
	3			
	4			
	5			
UOCRT	6			
	7			
	1			
INSTALLED	2			
@ __ HRS	3			
	4			
	5			
UOCRT	6			
	7			

Build-up Engine Measurement Specifications (inches)

	End Gap	Side Clearance
No. 1, Fire Ring	0.020-0.040	0.003-0.0066
No. 2, Compression Ring	0.020-0.040	0.007-0.0105
No. 3 & 4 Compression Rings	0.020-0.040	0.005-0.0085
Upper Oil Ring	0.010-0.020	0.001-0.004
Lower Oil Rings	0.007-0.017	0.0015-0.0055

---

*All end gap measurements taken in 3.8750" I.D. measuring jig.
UOCRT = Upper oil control ring tension.

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DATE__________________ TEST NO__________________ TECHNICIAN____________________

LUBRICANT____________________ FUEL_____________________

6V-53T CYLINDER LINER INSIDE DIAMETER (INSTALLED)

Measuring Gauge Set at 9.36625cm (3.8750 in.).
Numbers given are ten thousandths of a cm (inch).

			BEFORE TEST 6/			AFTER TEST		
			Top	Middle	Bottom	Top	Middle	Bottom
1L	T	AT						
	F	B						
2L	T	AT						
	F	B						
3L	T	AT						
	F	B						
1R	T	AT						
	F	B						
2R	T	AT						
	F	B						
3R	T	AT						
	F	B						

6/ 1.6 cm (5/8 in.), 13 cm (5 in.), and and 23 cm (9 in.) below block surface, respectively.

Installed @ ____HRS

Build-Up Engine Measurement Specification cm (inches).

Cylinder Liner (installed)	
Taper	0.0038 Max (0.0015)
Out-of Round	0.0038 Max (0.0015)
Inside Diameter	9.6875 - 9.6917 (3.8752 - 3.8767)

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DATE__________________ TEST NO__________________ TECHNICIAN____________________

LUBRICANT____________________ FUEL_____________________

BEFORE TEST

6V-53T PISTON - CYLINDER LINER CLEARANCE

All measurements are in cm (inches) unless otherwise indicated.

	CYLINDER LINER I.D.		PISTON SKIRT O.D.	CLEARANCE	
	MIN.	MAX.		MIN.	MAX
1L					
2L					
3L					
1R					
2R					
3R					

Build-Up Engine Measurement Specifications cm (inches).

Piston to Liner Fit	0.0152-0.0245	(0.0061-0.0098)
Piston Skirt O.D.	9.6672-9.6728	(3.8669-3.8691)
Cylinder Liner I.D. (installed or loose)	9.688-9.6918	(3.8752-3.8767)

Installed @ ____**HRS**

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DATE__________ TEST NO__________ TECHNICIAN__________

LUBRICANT__________ FUEL__________

6V-53T PISTON PIN TO PISTON BUSHING CLEARANCE

	BEFORE TEST			AFTER TEST		
	PIN	BUSHING	CLEARANCE	PIN	BUSHING	CLEARANCE
IL						
2L						
3L						
1R						
2R						
3R						

____Installed @ ____HRS

6v-53T PISTON PIN TO ROD BUSHING CLEARANCE

	BEFORE TEST			AFTER TEST		
	PIN	BUSHING	CLEARANCE	PIN	BUSHING	CLEARANCE
lL						
2L						
3L						
1R						
2R						
3R						

____Installed @ ____HRS

Rebuild Engine Measurement Specifications	cm	(inches).
Piston Pin Outside Diameter	3.4365-3.4375	(1.3746-1.3750)
Piston Bushing Inside Diameter	9.4375-3.4450	(1.3775-3.3780)
Pin-to-Piston Bushing Clearance	0.0062-0.0085	(0.0025-0.0034)
Rod Bushing Inside Diameter	3.4400-3.4412	(1.3760-1.3765)
Pin-to-Rod Bushing Clearance	0.0025-0.0048	(0.0010-0.0019)

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DATE__________ TEST NO__________ TECHNICIAN__________

LUBRICANT__________ FUEL__________

6V-53T BLOCK BORE DIAMETER

Measuring Gauge Set at 11.0642 cm (4.3560 inches).

Numbers given are ten thousandths of a cm (inch).

			BEFORE TEST	AFTER TEST
1L	T-AT	Top*		
		Bet**		
	F - B	Top		
		Bot		
2L	T-AT	Top		
		Bot		
	F - B	Top		
		Bot		
3L	T-AT	Top		
		Bot		
	F - B	Top		
		Bot		
1R	T-AT	Top		
		Bot		
	F - B	Top		
		Bot		
2 R	T-AT	Top		
		Bot		
	F - B	Top		
		Bot		
3R	A-AT	Top		
		Bot		
	F - B	Top		
		Bot		

____Installed @ ____HRS

Build-up Engine Measurement Specifications cm (inches)

Block Bore	
Taper	0.0038 Max (0.0015)
Out-of Round	0.0030 Max (0.0015)
Inside Diamenter	10.8915 - 10.8938 (4.3565-4.3575) New 10.8988 (403595) Max

*19.cm (7-1/2 in) below block surface

**21 cm (8-1/2 in) below block surface

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DATE__________________ TEST NO__________________ TECHNICIAN____________________

LUBRICANT____________________ FUEL_____________________

6v-53T VALVE DEPTH (BEFORE TEST)

LEFT SIDE			RIGHT SIDE		
1L	________	________	1R	________	________
	________	________		________	________
2L	________	________	2R	________	________
	________	________		________	________
3L	________	________	3R	________	________
	________	________		________	________

CRANKSHAFT THRUST WASHER THICKNESS (BEFORE TEST)

1	________	____________
2	________	____________
3	________	____________
4	________	____________

Crankshaft End Play (Before Test)______________

Oil Pump Clearances (Before Test)

Clearance Between Rotors__________________

Clearance Between Rotor and Housing________

Build-Up Engine Measurement Specifications cm (inches)

Valve Head Relation to Cylinder Head	Flush to 0.060 (0.024) Below Cylinder Head Surface
Crankshaft Thrust Washer Thickness	0.2975 to 0.3050 (0.1190 to 0.1220)
Crankshaft End Play	0.0100 to 0.0275 (0.0040 to 0.0110)
Oil Pump Clearance Between Rotors	0.0100 to 0.0275 (0.0040 to 0.0110)
Oil Pump Clearance Between Rotor and Housing	0.0025 to 0.0088 (0.0010 to 0.0035)

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DATE________________ TEST NO________________ TECHNICIAN________________

LUBRICANT________________ FUEL________________

6v-53T MAIN BEARING SHELL AND BEARING JOURNAL DIAMETERS AND CLEARANCES

Major rebuild only

	BEFORE TEST						AFTER TEST			
Bearin	Journals		Bearing Shells		Clearances		Bearing Journals		Bearing Shells	
	A*	B	F	BA	Min.	Max.	A	B	F	BA
1										
2										
3										

*A: Micrometer anvil parallel to weights
B Micrometer anvil perpendicular to weights

F: Front
BA: Back

6v-53T CONNECTING ROD BEARING SHELL AND BEARING JOURNAL DIAMETERS AND CLEARANCES

	BEFORE TEST						AFTER TEST			
Bearing	Journals		Bearing Shells		Clearances		Bearing Journals		Bearing Shells	
	A*	B	F	BA	Min.	Max.	A	B	F	BA
1L										
2L										
3L										
1R										
2R										
3R										

Build-Up Engine Measurement Specifications cm (inches)

	NEW	LIMIT
Main Bearing Journal Diameter	8.6225 to 8.7500 (3.4990 to 3.5000)	
Main Bearing Shell Inside Diameter (vertical axis)	8.7575 to 8.7600 (3.5030 to 3.5040)	
Main Bearing Shell to Journal Clearance	0.0076 to 0.0127 (0.0030 to 0.0050)	0.0150 (0.0060)
Connecting Rod Bearing Journal Diameter	6.8725 to 6.8750 (2. 7490 to 2.7500)	
Connecting Rod Bearing Shell Inside Diameter (vertical axis)	6.8778 to 6.8750 (2.7511 to 2.7500)	
Connecting Rod Bearing Shell to Journal Clearance	0.0028 to 0.0102 (0.0011 to 0.0041)	0.0150 (0.0060)

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DATE ____________ TEST NO ____________ TECHNICIAN ____________

LUBRICANT ____________ FUEL ____________

6V-53T CAMSHAFT BEARING SHELL AND BEARING JOURNAL DIAMETERS BEARING SHELL MEASURING GAUGE SET AT 5.435 cm (2.175 INCHES)

LEFT CAMSHAFT

		BEFORE TEST				AFTER TEST			
		Journal		Bearing		Journal		Bearing	
Major rebuild only	1								
	2								
	3								
	4								

RIGHT CAMSHAFT

		BEFORE TEST				AFTER TEST			
		Journal		Bearing		Journal		Bearing	
Major rebuild only	1								
	2								
	3								
	4								

Build-Up Engine Measurement Specifications	cm	(inches)
Camshaft Bearing Journal Diameter	5.4550-5.4562	(2.1820 to 2.1825)
Camshaft Bearing Shell Inside Diameter	5.4675-5.4700	(2.1870 to 2.1880)
Camshaft Bearing Shell to Journal	0.0113-0.0150	(0.0045 to 0.0060)

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TEST NO. ________

6v-53T 240-HOUR CHECKLIST

Initials	Task
	Fill out page 1 of Before Test and After Test Data Sheets.
	Measure and record ring end gap, side clearance, and upper oil control ring tensions.
	Measure and record cylinder liner inside diameter (installed).
	Measure and record piston-cylinder liner clearance.
	Measure and record piston pin-piston bushing clearance and piston pin-rod bushing clearance.
	Measure and record block bore diameter.
	Measure and record valve depth.
	Check valve clearances and replace valves and guides out of specification; replace valves after three runs.
	Measure and record connecting rod bearing shell and bearing journal diameters and clearances.
	For major rebuilds only - measure and record oil pump clearances, crankshaft thrust washer thickness and crankshaft end play.
	For major rebuilds only - measure and record main bearing shell and bearing journal diameters and clearances.
	For major rebuilds only – measure and record camshaft bearing shell and bearing journal diameters.
	Calibrate tachometer.
	Calibrate flowmeter.
	Calibrate load system.
	Calibrate temperature indicators.
	Calibrate pressure indicators.
	Deaerate engine and drain flush oil.
	Fill engine with reference oil.
	Break in engine.
	Adjust governor, injector timing, and valve clearance.
	Run and record initial power calibration check.
	Run shake down.
	Perform airbox inspection (optional).
	Drain oil and add 19 L (five gallon) flush oil.
	Run flush cycle - 30 minutes at 1200 rpm and 30 #FT.
	Drain oil.
	Perform airbox inspection.
	Weight new filter, blowby canisters, and initial fill.
	Run test cycle, weigh samples and adds.
	Perform after-test full load performance determination.
	Drain and weigh oil, filter, and blowby cans.
	Measure and record cylinder liner inside diameter.
	Disassemble engine stamping liners and pistons.

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Initials	Task
________	Measure and record piston pin to piston bushing clearance and piston pin to rod bushing clearance.
________	Measure and record connecting rod, bearing shell, and bearing rod journal clearances.
________	Major rebuild only - measure and record main bearing shell and bearing journal diameters and clearances.
________	Major rebuild only - measure and record camshaft bearing shell and bearing journal diameters.
________	Rate engine for deposits.
________	Measure and record ring end gap.
________	Photograph engine parts.

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6V-53T 240-HOUR ENDURANCE TEST LUBRICANT CONSUMPTION RECORD

Date Started ____________
Date Finished ____________

Test No. ____________

Fuel ____________
Lubricant ____________

Approximate Consumption kg (1b)

Weight of Initial Fill		____________
Weight of 120-hour Fill	+	____________
Total Weight of Additions	+	____________
Total Weight of Oil Added	=	____________
Weight of 120-hour Drain		____________
Weight of Final Drain	+	____________
Total Weight of Samples	+	____________
Total Weight of Oil Removed	=	____________

		0-120 hr	120-240
Weight of Used Oil Filter		______	______
Weight of New Oil Filter	-	______	______
Weight of Oil in Filter	=	______	______
Total Weight of Oil in Filters	=	______	______
After Test Blowby Can Weight		______	______
Before Test Blowby Can Weight	-	______	______
Total Weight of Oil in Blowby	=	______	______
Total Weight of Oil Added		______	______
Total Weight of Oil Removed	-	______	______
Total Weight of Oil in Filters	-	______	______
Total Weight of Oil in Blowby	-	______	______
Total Weight of Oil Consumed	=	______	______

Average Oil Consumption Rate ________ lbs/hr

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6V-53T 240-HOUR ENDURANCE TEST LUBRICANT CONSUMPTION RECORD
(DOES NOT INCLUDE INITIAL AND 120 HOUR FILLS)

Date Started ______________ Test No. ____________ Fuel ______________________
Date Finished _____________ Lubricant __________________

		Lubricant Additions			Lubricant Samples			Lubricants Consumed	
Test Hour	Technician	Col 1 Oil Before Add	Col 2 Oil After Add	Col 3 Change (Col 2 - Col 1)	Col 4 Bottle Wt	Col 5 Bottle & Sample Wt	Col 6 Oil Sample (5 - 4)	Oil Consumed (3 - 6)	Total Oil Consumed*
20									
40									
60									
80									
100									
120									
140									
160									
180									
200									
220									
240									

Ttl Wt Additions: ____________ Ttl Wt of Samples: ____________

*During test, average oil consumption is approximated by Total Oil Consumed divided by Test Hour.

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DATE ____________ TEST NO. ____________ TECHNICIAN ____________
LUBRICANT ____________ FUEL ____________ TEST HOURS ____________

6V-53T AIRBOX INSPECTION SHEET

	INTAKE PORTS	
	RING LANDS	
1L	RINGS	
	PISTON SKIRTS	
	CYLINDER LINER	
	INTAKE PORTS	
	RING LANDS	
2L	RINGS	
	PISTON SKIRTS	
	CYLINDER LINER	
	INTAKE PORTS	
	RING LANDS	
3L	RINGS	
	PISTON SKIRTS	
	CYLINDER LINER	
	INTAKE PORTS	
	RING LANDS	
1R	RINGS	
	PISTON SKIRTS	
	CYLINDER LINER	
	INTAKE PORTS	
	RING LANDS	
2R	RINGS	
	PISTON SKIRTS	
	CYLINDER LINER	
	INTAKE PORTS	
	RING LANDS	
3R	RINGS	
	PISTON SKIRTS	
	CYLINDER LINER	

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APPENDIX E

RATING SHEETS

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DETROIT DIESEL 6V-53T Evaluation

Rating of Engine Deposits and Parts Condition

Oil Code ____________________ Test Number ____________________
Fuel ____________________ Test Stand ____________________
End-of Test ____________________ Hours Completed ____________________

1. Cylinder Liners
   A. Intake Ports

INTAKE PORT PLUGGING

Cylinder No.	Percent Intake Port Restriction
1L	
2L	
3L	
1R	
2R	
3R	
Average 6	
Average w/o ____	
____ Changed Out @ ____ Hours	

B. Liner Scuffing

CYLINDER LINER

Percent of Total Ring Travel Area

Cylinder Number	Percent Scuffed		% Avg. Avea Scuffed	Percent Bore Polished		% Average Area Bore Polish
	T	AT		T	AT	
1L						
2L						
3L						
1R						
2R						
3R						
Average 6						
Average w/o ____						
____ Changed Out @ ____ Hours						

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6V-53T RING FACE DISTRESS

Test No. ____________________ Lubricant ____________________

Fuel ________________ Date ____________ Observer ____________

Cylinder No.	Ring No.	Heavy Distress (0.75)		Medium Distress (0.50)		Light Distress (0.25)		Total Demerits
		% Area	Demerit	% Area	Demerit	% Area	Demerit	
1L	1							
	2							
	3							
	4							
2L	1							
	2							
	3							
	4							
3L	1							
	2							
	3							
	4							
1R	1							
	2							
	3							
	4							
2R	1							
	2							
	3							
	4							
3R	1							
	2							
	3							
	4							
____ Changed Out @ ___Hrs	1							
	2							
	3							
	4							

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DETROIT DIESEL 6V-53T EVALUATION (Continued)

Rating of Engine Deposits and Parts Condition

II. Pistons

A. Ring Face Distress

Cylinder Number	Fire Ring No. 1	No. 2	No. 3	No. 4
1L				
2L				
3L				
1R				
2R				
3R				
Average 6				
Average 5 w/o ___				

Average 6 of Ring Nos. 2 and 3 ____________

Average 5 of Ring Nos. 2 and 3 ____________

____ Changed Out @ ___ Hrs ________ ________ ________ ________

Numbers denote demerits due to % of area exhibiting various levels of ring face distress.

B. Condition of Rings in the Groove

Cylinder Number	Fire Ring No. 1	No. 2	No. 3	No. 4
1L				
2L				
3L				
1R				
2R				
3R				
____ Changed Out				
@ ____ Hours				

Numbers denote % of ring circumference, Hot Stuck (HS), Cold Struck (CS), or Collapsed (C).

C. Piston Skirt Rating

Cylinder Number	Thrust	Anti-Thrust
1L		
2L		
3L		
1R		
2R		
3R		

Numbers denote % of area covered by scratching, scuffing, scoring or plate melt.

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CRC DIESEL RATING SYSTEM

6V-53T Computation Sheet for Piston Rating

Test Hours ______________ Rater __________ Date __________ Piston No. __________
Test Laboratory __________ Laboratory Test Number __________
Lubricant ______________

No. 1 Groove, Volume %

Piston WTD* Rating

Deposit Type		Deposit Factor	Grooves										Lands					
			No. 1		No. 2		No. 3		No. 4		No. 1		No. 2		No. 3		No. 4	
			A,%	Dem	A,%	Dem	A,%	Dem	A,%	Dem	A,%	Dem	A,%	Dem	A,%	Dem	A,%	Dem
Carbon	HC	1.00																
	MC	0.50																
	LC	0.25																
	Carbon Rating																	
Lacquer	BL	0.100																
	DBrL	0.075																
	AL	0.050																
	LAL	0.025																
	Lacquer Rating																	
CLEAN		0																
Zonal Rating																		
Location Factor																		
Weighted Rating																		

*Weighted Total Deposits

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EXHAUST VALVE SURFACE CONDITIONS

Test No. ________

Engine Model ____________________ Serial No. ____________________ Date ____________________

Fuel ____________________ Lubricant ____________________ Observer ____________________

	1L	2L	3L	1R	2R	3R
Freeness in Guide						
Head						
Face						
Seat						
Stem						
Tip						

See pages 1, 2, 16 through 23, and 54 through 65 of CRC Manual No. 5.

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VALVE AND COMBUSTION CHANGER DEPOSITS

Test No. ____________

Engine Model ____________ Serial No. ____________ Date ____________

Fuel ____________ Lubricant ____________ Observer ____________

		VALVE DEPOSIT RATING											
		1L		2L		3L		1R		2R		3R	
		Carb	Lacq	Carb	Lacq	Carb	Lacq	Carb	Lacq	Carb	Lacq	Carb	Lacq
Head*	EXH		---		---		---		---		---		---
Face	EXH		---		---		---		---		---		---
Tulip**	EXH		---		---		---		---		---		---
Stem	EXH												

Combustion Chamber Deposits (Abnormalities Only) ____________________________

____

____

* Carbon and Ash: Use Volume Factor Technique (Pages 5 and 40 through 47 of CRC Manual No. 5).

** Use Chart, Page 21 - indicate H, M, or S (Page 5).

Lacquer: Pages 4, 36, and 37.

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DETROIT DIESEL 6V-53T EVALUATION

Test No. ____________

Date ________________

Lubricant _________________________ Observer ___________________________

TAPPETS, CAMS AND ROCKER ARM CONDITION

(Abnormalities Only)

BEARING AND JOURNAL SURFACE CONDITION

(Abnormalities Only)

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CYLINDER LINER

Oil Code ____________ Test No. ____________ Liner No. ____________ Observer ________

Each line half = 100 %

THRUST HALF

Area % Scuffed = (S)

Area % Polished = (P)

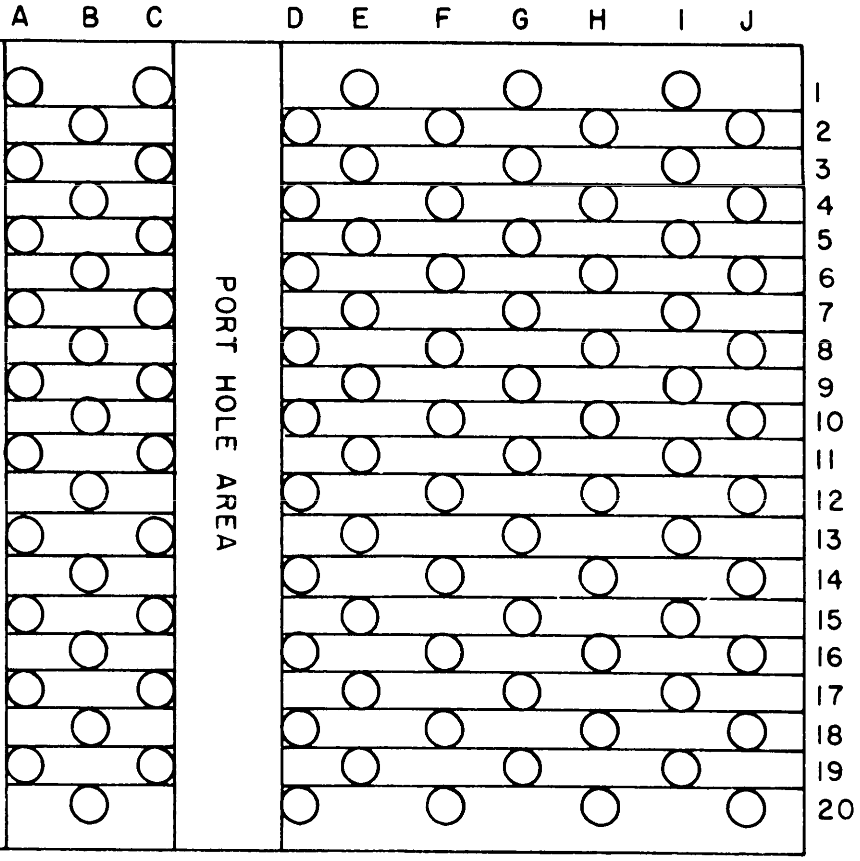
Area % Normal = (−)

Each rating area will be rated at the most severe level that is observed.

(S) = ____________

(P) = ____________

(−) = ____________



ANTI THRUST HALF

Area % Scuffed = (S)

Area % Polished = (P)

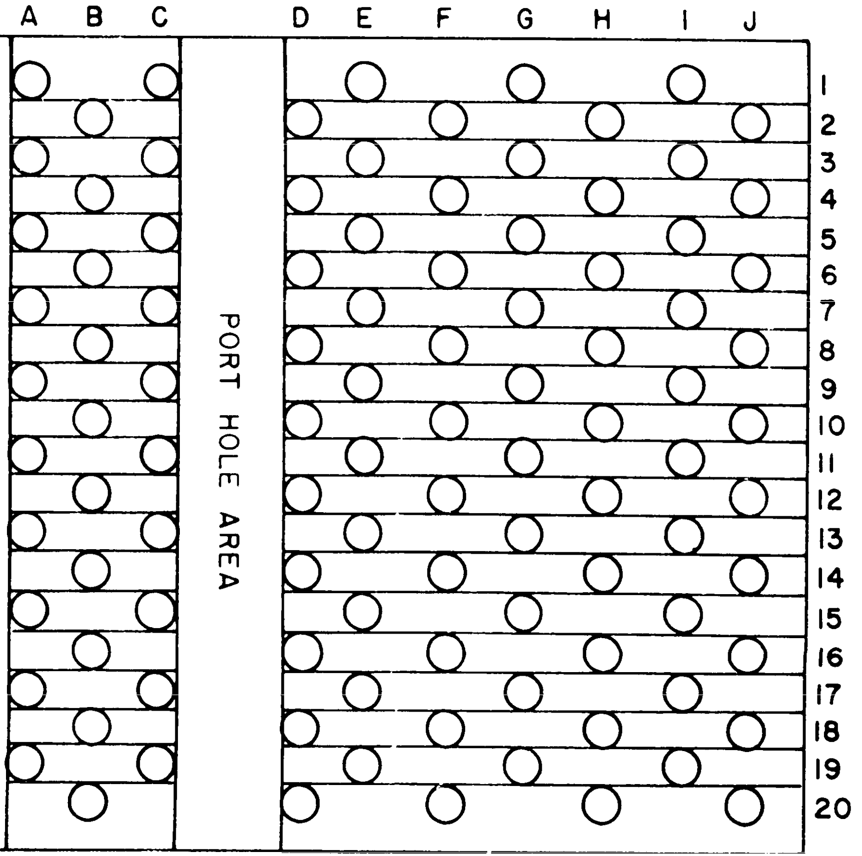
Area % Normal = (−)

Each rating area will be rated at the most severe level that is observed.

(S) = ____________

(P) = ____________

(−) = ____________



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APPENDIX F

LUBRICANT ANALYSIS

	Test Method	New Oil	Test Hour 20	40	60	80	100	120	140	160	180	200	220	240
Viscosity at 40° C	D 445	X			X			X			X			X
Viscosity at 100° C	D 445	X			X			X			X			X
TAN	D 664	X			X			X			X			X
TBN	D 664	X			X			X			X			X
Pentane B Isolubles	D 893	X			X			X			X			X
Toluene B Insolubles	D 893	X			X			X			X			X
Flash Point	D 92	X												X
Fuel Dilution	D 3524		X					X						X
Fe	a	X	X	X	X	X	X	X	X	X	X	X	X	X
Cu	a	X	X	X	X	X	X	X	X	X	X	X	X	X
Pb	a	X	X	X	X	X	X	X	X	X	X	X	X	X
Cr	a	X	X	X	X	X	X	X	X	X	X	X	X	X
Al	a	X	X	X	X	X	X	X	X	X	X	X	X	X

---

a = by any of the following methods: AA, XRF, emission spec.

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APPENDIX G
6V-53T
TEST NO.: ____________
LUBRICANT: ____________

WEAR MEASUREMENTS

Cylinder Liner Bore Diameter Change*

Cylinder Number

	1L		2L		3L	
	T-AT**	F-B	T-AT	F-B	T-AT	F-B
Top						
Middle						
Bottom						

Cylinder Number

	1R		2R		3R	
	T-AT**	F-B	T-AT	F-B	T-AT	F-B
Top						
Middle						
Bottom						

	Average Change		Changed Out @ ______ Hours	
	T-AT	F-B	T-AT	F-B
Top				
Middle				
Bottom				

Overall Average Change: ____________

Piston Ring End Gap Change

Ring Number	1L	2L	3L	1R	2R	3R	Average Change
1							
2							
3							
4							
5							
6							
7							

Overall Average Change: ____________

* All dimensions given are in cm (inches).

** T-AT = Thrust - Anti-Thrust Direction, F-B = Front-Back Direction.

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PERFORMANCE OF ENGINE LUBRICATING OILS IN A TWO-CYCLE DIESEL ENGINE UNDER CYCLIC, TURBO-SUPERCHARGED CONDITIONS

1. SCOPE

1.1 This method is used for determining the effect of lubricating oils on wear, ring-sticking, and accumulation of deposits in a reciprocating internal combustion engine. Evaluation is based on: (a) the ability of the test engine to maintain performance throughout the cycle, (b) wear of critical engine components, (c) accumulation of fuel and lubricant related engine deposits, particularly in the piston ring zone areas, and (d) the physical and chemical condition of the lubricant monitored throughout the test.

2. SUMMARY

2.1 The test involves the operation of a militarized six-cylinder, fuel injected, turbo-supercharged, 2-stroke-cycle diesel engine under cyclic conditions for a total of 240 hours. Prior to test the engine is reconditioned as described herein. Evaluation is made by comparing the test oil performance to that of a reference oil of known quality.

3. SAMPLE SIZE

3.1 A minimum of 210 L (55 gallons) of test oil is required.

4. STANDARDS, REFERENCES, AND APPARATUS

4.1 References.

4.1.1 Coordinating Research Council Diesel Engine Rating Manual No. 5.

4.1.2 Proposed CRC Rating System for Diesel Engine Deposits, CRC, Inc., New York, NY, February 1973. This is a good reference but not mandatory.

4.1.3 Detroit Diesel Engine Series 53 Service Manual.

4.1.4 ASTM STP 509A Pt. 1.

4.1.5 ASTM committee D-2 Handout on 6V-53T rating.

4.2 Test Engine Systems.

4.2.1 Test engine. A Detroit Diesel 6v-53T Engine (Military Model 5063-5395), is specified for this method, with the following parts:

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Quantity	Detroit Diesel Part No.	Item
1	5133512	Flywheel
1	5126671	Scuff Plate
6	9409129	Bolt
1	5101431	Turbocharger
1	5133427	Heat Exchanger
6	5140949	Connecting Rod
6	5228784	Fuel Injector (M70 or N70)
1	5199793	Overhaul Gasket Kit
2	Donaldson P12-1623	Air Filter
4	5107441	Hand Hole Gasket
1	AC-T552	Primary Fuel Filter
1	AC-TP540	Secondary Fuel Filter
2	25010971	Oil Filter
24	5197176	Exhaust Valves
6	5149315	Liner, Piston, Ring Set
1	5199734	Fuel Pump

4.2.2 Air intake system. A controlled-temperature air intake system is required for this method. The low temperature air-heater and primer assembly shall be removed from the engine.

4.2.3 Crankcase ventilation system. The crankcase breather system described herein shall be used for this method. The breather pipes are joined at a tee connection and connected to a short piece of l-1/4-inch rubber hose. The total gas flow is then piped by l-inch conduit to the blowby surge chamber from which the gas passes through a blowby meter and is discharged vertically. Appendix A illustrates the blowby surge tank. The airbox is drained from the left and right airbox drains through #49 orifices and into 3.8 L (1 gallon) collection cans. Filters may be placed before the orifices in order to prevent orifice plugging.

4.2.4 Cooling system. The coolant flow shall be from the thermostat housing cover outlet, through a 5 cm (2 inch) diameter transparent section of pipe into the coolant heat exchanger and back to the suction side of the coolant pump. A 3.8 L (1 gallon) cylindrical surge tank (16 cm [6-1/2 inches] diameter by 21 cm [8-1/2 inches long]) located to the side and above the coolant heat exchanger is provided as a settling vessel to insure coolant deaeration. During test the cooling system is operated with the pressure cap in the vented to atmospheric position. The engine thermostats are blocked in the full-open position for this test. Coolant heat exchanger shall be a BCF American Standard 5-030-06-024-006 or equal. System coolant capacity is 23 L (6 gallons). Coolant flow rate may be measured and reported.

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4.2.5 Fuel system. The primary and secondary fuel filter assemblies are relocated to a remote position off the engine and away from the heat of the exhaust gas. The same premium grade fuel lines (minimum length) and fittings supplied with the engine must be used when relocating the fuel filters. A water-to–fuel heat exchanger is employed to maintain fuel temperature. All lines must be lagged and secured to protect against vibration damage. Appendix B illustrates the fuel system.

4.2.6 Oil system. A special external oil cooler/filter assembly is used to control oil temperature. This assembly is available through Joe Brandes of Detroit Diesel. The 1/4 inch pipe plug in the front of the oil filter housing shall be removed and a sampling valve installed in its place. Appendix C illustrates the oil system. No additional oil cooling is allowed.

4.3 Instrumentation.

4.3.1 Load measurement. Appropriate engine speed and load-indicating devices, from which observed BHp can be determined, must be used in conjunction with suitable power-absorbing equipment. Engine or dynamometer speed shall be measured with an automatic electric revolution counter with synchronized time or suitable electronic speed measuring device. Accuracy of the load measuring device shall be ±4.07 N•m (±3 ft-lb).

4.3.2 Flow measurement.

4.3.2.1 Fuel flow. Provision shall be made for mass flow fuel measurement with a resolution of +0.045 kg/hr (±0.1 pound per hour). Average fuel temperature is determined at the fuel measuring device and fuel density is established. The fuel-flow measuring device shall be a properly installed mass flow meter.

4.3.2.2 Blowby flow. Blowby flow is indicated with the equipment described in 4.2.3 and Appendix A.

4.3.3 Temperature measurements. Provisions shall be made for thermocouple installation as shown below (total system accuracy shall be calibrated to ±1° C [±2° F]). Thermocouples shall be shielded and, unless specified, shall be immersed to the midstream.

Variable	Location
Exhaust gas before turbocharger	Left and right elbows, 6.9 cm (2-3/4 inches) from manifold.
Turbocharger exhaust exit	5.6 cm (2-1/4 inches) from turbocharger exit.
Cylinder jacket coolent-in 1/	3.8 cm (1.5 inch) above the inlet end of water pump inlet.

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Variable	Location
Cylinder jacket coolant-out 1/	In 1.3 cm (1/2 inch) pipe plug hole of thermostat housing deaeration dome.
Oil sump 1/	Sump drain plug 6.6 cm (2-5/8 inches) immersion from wall.
Fuel 1/	At secondary filter inlet.
Compressor inlet air 1/	Opposite air filter.
Airbox 1/	Left rear hand hole cover.
Wet bulb/dry bulb	Near air barrel inlet.

1/ All temperatures shall be recorded at not more than 2 minute intervals during the test.

,4.3.4 Pressure measurements. Provision shall be made for measuring pressures as follows:

Variable	Location
Intake air vacuum	After air filter 10 cm (4 inches) from compressor inlet.
Exhaust back pressure	In 10 cm (4 inch) line, 7.5 cm (3 inches) after turbocharger exit.
Exhaust pressure before turbocharger	Right-hand elbow 7.5 cm (3 inches) from turbocharger Y connector.
Compressor discharge	Blower inlet housing (remove 0.625 cm [1/4 inch] pipe plug).
Airbox	Left rear hand hole cover.
Oil gallery	Left rear gallery top.
Fuel	Secondary filter outlet
Barometer	In vicinity.
Blowby	In blowby surge tank.

5 MATERIALS.

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical material listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life harzard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Fuel. only fuels approved by the US Army Belvoir Research, Development, and Engineering Center, Material Fuels & Lubricants Laboratory, Ft. Belvoir, Virginia, and meeting the requirements set forth in part I of ASTM STP 509A [0,2,0].

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5.3 Reference oil. Reference engine oil REO-203 is to be used for standardizing engine operation as set forth herein. Orders for reference oil should be made out to Southwest Research Institute, P.O. Drawer 28510, San Antonio, Texas 78284 and sent to the ASTM Test Monitoring Center, 4400 5th Ave, Pittsburgh, PA, 15213, Attn: Mr. R. K. Nelson for transmittal to the supplier.

5.4 Dry cleaning solvent. ASTM D 484, Type I [0,2,0] or Exxon "Varsol" may be used to clean parts as described herein. D-Carb (Dubois Chemicals Co., Cincinnati, Ohio) may be used in vat cleaning the engine block [u,u,u].

5.5 Engine Coolant. Engine coolant will consist of a 50/50 volumetric mixture of ethylene glycol base antifreeze 2/ and potable water [0,0,0].

6. PROCEDURE.

6.1 Preparation for test.

6.1.1 Engine Disassembly. A systematic inspection and maintenance of the test engine shall be performed prior to each test run. New engines or engines being used for the first time in this test method and thereafter will be disassembled, reconditioned, and gauged before each test. Regardless of their condition, the following parts shall be replaced with new factory production items:

Piston assemblies
Piston ring sets
Cylinder liners
Fuel filters, oil filter, and air filters
All gaskets and seals

The measurements prescribed in Appendix D (BEFORE AND AFTER TEST DATA SHEETS) shall be performed and recorded.

6.2 Cleaning procedure.

6.2.1 Engine block. If the engine is completely disassembled, the block shall be cleaned by spraying with solvent. Remove as much of the solvent as possible by rotating the block and blow drying with air.

6.2.2 Aluminum parts. Aluminum parts will be cleaned by spraying with solvent followed by air drying. If deposits are stubborn, the parts may be soaked in solvent for a period up to two hours at a temperature of 38° C or less. The solvent soak must be followed by a warm water wash and air drying.

6.2.3 Steel parts. All steel parts (i.e., rocker arm covers, oil pan, oil heat exchanger, cylinder head decks, oil pump, crankshaft, etc.), shall be

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2/ Prestone - mixing with other types not authorized.

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cleaned by spraying with solvent, air dried and lightly coated with reference oil. Of particular concern are the fuel galleries in new heads; these should be flushed with diesel fuel and bottle brushed before use.

6.2.4 Fuel injectors. The fuel injectors are removed but not disassembled or adjusted. Only the tips should be lightly wire brushed to remove carbon particles. Should the operation of the engine indicate that their condition might be at fault, the units should be tested, adjusted, or replaced with new units.

6.2.5 Combustion chambers and valves. Exhaust valves are removed and the entire combustion chamber area of each cylinder is cleaned by wire brushing. Valves are only lightly refaced, if inspection shows pitting. Where the sealing surfaces (faces) are not pitted, the valves need be only lightly lapped prior to reassembly. If light refacing does not correct the seating condition, the valve shall be replaced. Regardless of their condition, valves should be replaced after three tests.

6.3 Engine disassembly.

6.3.1 The engine block is fitted with new parts as listed in sections 4.2.1 and 6.1.1. Complete measurements of the block bore, liners, pistons, rings, connecting rod journals, main bearing journals, connecting rod bearing inserts, and main bearing inserts are made prior to each rebuild. Connecting rods and piston pins will be inspected and replaced if not in good service condition. In addition, camshaft journals to bearings and oil pump clearances shall be checked against service limits during major rebuilds. These parts will be replaced as required to maintain service limits. The liner outside surfaces contacting the block bore shall be lightly coated with grease to reduce interface fretting corrosion. Other parts shall be coated with reference oil during assembly. Piston pin retainers shall be checked for leakage with KENT MOORE tool number J-23987-01.

6.3.2 The following critical rebuild measurements shall be maintained during engine assembly:

Engine part	Tolerance or Clearance, cm - (inches)	
Crankshaft main bearing clearance	0.00762-0.0127	(0.0030-0.0050) 4/
Camshaft bearing clearance	0.0114-0.152	(0.0045-0.0060)
Connecting rod bearing clearance	0.002794-0.0104	(0.0011-0.0041)
Crankshaft end-play	0.0102-0.0279	(0.0040-0.0110)
Cylinder block bore		
Taper	0.0038	(0.0015) max
Out-of-round	0.0038	(0.0015) max

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Engine part	Tolerance or Clearance, cm - (inches) (cent)	
Inside diameter (bottom)	11.0655-11.0680 new, 11.073 max	(4.3565-4.3575) new, 4.3595 max ‘
Clearance liner to block (bottom)	0.00127-0.00762	(0.0005-0.0030)
Cylinder liners (installed or loose)		
Taper	0.0038	(0.0015) max 3/
Out-of-round	0.0038	(0.0015) max 3/
Inside diameter	9.8430-9.8468	(3.8752-3.8767)
Piston to liner fit	0.0155-0.0249	(0.0061-0.0098)
Piston skirt O.D.	9.8219-9.8275	(3.8669-3.8691)
#1 Fire Ring		
End gap	0.051-0.1016	(0.020-0.040)4/
Side clearance	0.008-0.01676	(0.003-0.0066)4/
#2 Compression ring		
End gap	0.051-0.1016	(0.020-0.040)4/
Side clearance	0.018-0.0267	(0.007-0.0105)4/
#3 Compression ring		
End gap	0.051-0.1016	(0.020-0.040)4/
Side clearance	0.013-0.0216	(0.005-0.0085)4/
#4 Compression ring		
End gap	0.051-0.1016	(0.020-0.040)4/
Side clearance	0.013-0.0216	(0.005-0.0085)4/
Upper Oil Rings		
End gap	0.025-0.0508	(0.010-0.020)4/
Side clearance	0.0038-0.01016	(0.001-0.004)3/
Lowe r		
End gap	0.0178-0.0432	(0.007-0.017)5/
Side clearance	0.00381-0.0140	(0.0015-0.0055)4/

3/ Using new cylinder liners in a used block.
4/ These are the latest specifications from Detroit Diesel and should be reflected in future service manuals.

6.3.3 Engine assembly shall be in accordance with TM 9-2815-212-35 and the Detroit Diesel Engine Series 53 Service Manual. Reference must be made to these documents to determine the proper bolt torques, tightening sequences, and final injector timing and valve lash settings. Upper oil control rings and expanders (as a set) accompanying DD part number 5149315 should measure 19 - 22 pounds on a Dorsey Gage. Tensions for these rings should be reported on page D2.

6.4 Engine start-up and shut-down procedures.

6.4.1 Engine start-up and deaeration procedure. From a cold start, idle the engine for five minutes. Then warm up at 1200 rpm and 119 Nom (88 lb-ft)

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dynamomter load (20 BHp) until oil sump temperature reaches 82° C (180° F) and coolant jacket-out temperatures reach 76.7° C (170° F). If the coolant system was drained by the previous shut-down, warm up at 1100 rpm and 98 N•m (72 lb-ft) load, 15 BHp, to insure deaeration of the coolant system. If the engine is started warm and the 82° C (180° F) oil sump and 76.7° C (170° F) coolant jacket-out temperatures are achieved, it is permissible to gradually accelerate the engine without delay to test conditions. The automatic controller set point for coolant-out temperature must remain at 76.7° C (170° F) during all start ups.

6.4.2 Engine shut-clown procedure. To shut down the engine from test conditions, slowly bring the engine to idle by turning the rack setting to the idle position. Allow the engine to idle for five minutes and then shut-down by actuating the idle cut-off. The automatic controller set point for coolant out temperatures must remain at 76.7° C (170° F) during all shut–downs.

6.4.3 Initial oil flush. Charge the engine oil sump with approximately 19 L (20 quarts) of reference oil (clean used oil permissible). Disconnect the turbo oil supply line at the turbo and crank the engine with the governor control in the fuel cut-off position until one pint of oil is pumped from the disconnected line. Reconnect the turbo line and crank the engine until the oil pressure stabilizes. Start and deaerate the engine as per 6.4.1. Drain the lubricant while still warm in order to remove any solvent retained in the engine.

6.5 Engine run-in procedure.

6.5.1 Oil charge. Charge the engine oil sump with approximately 23 L (24 quarts) of reference oil. Disconnect the turbo oil supply line at the turbo and crank the engine with the governor control in the fuel cut-off position until 475 mL (one pint) of oil is pumped from the disconnected line. Reconnect the turbo line and crank the engine until the oil pressure stabilizes.

6.5.2 Operating conditions. Start the engine in accordance with 4.4.1 and conduct the engine run-in according to the following schedule:

Engine Speed, rpm	Dynamometer Load, lb-ft	Power, Obs BHp	Time, min.
1000	53 max	10 max	10
2800	19 max	10 max	30
1800	88	30	15
2200	310	130	30
2500	420	200	30
2800	422	225	30

Coolant jacket-out temperature is maintained at 76.7° ±1°C (170° +2° F), and oil gallery pressure is 207 kPa gage (30 psig) minimum. Coolant system deaeration (air free sight glass) must be established by the time the 2500 rpm sequence is completed.

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5.6 Interim Settings and Adjustments.

6.6.1 Immediately following the run-in, check, adjust and record the governor settings. Set the idle speed at 1000 rpm maintaining a minimum of 34 kPa gage (5 psig) gallery oil pressure. No-load speed maximum should be 2950-3030 rpm, and is adjusted per the Detroit Diesel Series 53 Service Manual.

6.6.2 Shut down the engine according to 6.4.2.

6.6.3 Five minutes after shut-down, check and reset the injector timing and exhaust valve clearance as follows:

Injector timing - 3.7084 ±0.0089 (1.4600 +0.0035 inch)
Valve clearance - 0.0584 to 0.0635 (0.023–to 0.025 inch) (hot)

6.7 Shake-down run. Immediately following the 2800 rpm power calibration check, the engine is operated for a period of five hours at 2800 rpm and 636 N•m (469 lb-ft) dynamometer load (250 BHp) maintaining a coolant jacket-out temperature of 76.7° +1° C (170° +2° F). The test parameter data list in 6.10.12.1 shall be recorded hourly during the shake-down run.

6.8 Initial power check. Power checks are made at 2200 and 2800 rpm in order to assure that the engine will produce the necessary power. Engine start-up is in accordance with 6.4.1. The engine is operated at the specified speed until the observed output has stabilized. A coolant jacket-out temperature of 76.7° C +1° C (170° F +2° F) is maintained during checks. The engine must produce at least 295 horsepower at 2800 rpm and at least 260 horsepower at 2200 rpm.

6.9 Oil flush run. Drain the reference oil and add 19 L (20 quarts) of test oil. Run the engine for 30 minutes at 1200 rpm and 40.7 N•m (30 lb-ft) load. Oil flush is not necessary if the test oil is the reference oil.

6.10 Test procedure.

6.10.1 Oil drain. After oil flush shut-down, and while the oil is still warm, drain the oil and remove the oil filter. Perform the initial airbox inspection.

6.10.2 Oil charge. Weigh-in a new oil filter and sufficient test oil to bring the sump level to the full mark on the dipstick gage 23 L (approximately 24 qt). Crank the engine long enough to stabilize the oil pressure (approximately 10 seconds), wait five minutes and recheck the oil level.

6.10.3 Test duration. The test consists of 240 hours of operation at prescribed test conditions. Interim oil adjustments, airbox inspections, and oil samplings are made on the following schedule:

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Operation	0	20	40	60	80	100	120	140	160	180	200	220	240
Oil Adjustments		X	x	x	x	x	x	x	x	x	x	x	-
Oil Sampled	X	x	x	x	x	x	x	X	x	x	x	x	x
Airbox Inspected*	x	-	-	x	-	-	x	-	-	x	-	-	-
Oil Change	x	-	-	-	-	-	x	-	-	-	-	-	-
Air Filter Change	-	-	-	-	-	-	As Needed						

X indicates adjustment, sampling or inspection to be performed at given test time.
* Additional inspections as needed.

6.10.4 Test cycle description. The endurance test consists of repeating a four-mode, five-hour operating cycle four times daily for a total of 20 hours. The engine is then shut down for a period of four hours after which the daily cycle is repeated. The five-hour operating cycle (shown below) consists of: 0.5 hour at engine idle followed by 2.0 hours at maximum power, followed by 0.5 hour at engine idle followed by 2.0 hours at maximum torque. The 20-hour endurance cycle is conducted for 12 days without interruptions longer than three days. Ramping between operating conditions shall be as follows; 2 minutes maximum to come up to speed, followed by 8 minutes maximum to come up to load, 8 minutes maximum to come down to load, followed by 2 minutes maximum to come down to speed.

Endurance Test Operating Cycle

Period	Mode	Time, hrs	Load, %	Speed, rpm	Jacket-Out Temp, °C (°F)
1	Idle	0.5	0	1000 + 10	77 (170) max
	Max Power	2	100	2800 ± 10	77 (170)
	Idle	0.5	0	1000 ± 10	77 (170) max
	Max Torque	2	100	2200 ± 10	77 (170)
2	Idle	0.5	0	1000	77 (170) max
	Max Power	2	100	2800	77
	Idle	0.5	0	1000	77 (170) max
	Max Torque	2	100	2200	77
3	Idle	0.5	0	1000	77 (170) max
	Max Power	2	100	2800	77 (170)
	Idle	0.5	0	1000	77 (170) max
	Max Torque	2	100	2200	77 (170)
4	Idle	0.5	0	1000	77 (170) max
	Max Power	2	100	2800	77 (170)
	Idle	0.5	0	1000	77 (170)
	Max Torque	2	100	2200	77 (170)
5	Shutdown	4	0	0	- - -

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6.10.5 Operating conditions. The engine shall be operated under the following conditions:

Operating Condition	Limits Max Power Mode	 Max Torque Mode	 Idle Mode
Speed, rpm	2800 +10	2200 +10	1000 ±10
Fuel Flow, Kg/hr (lb/hr)	53 (117) min	44 (96) min	NS
Obs BHp Output	300+5	265+5	20 +5
Jacket-out °C (°F)	76.7 ±1 (170 +2)	76.7 ±1 (170 ±2)	76.7 (170) max
Coolant T, °C (°F)	4 - 7 (8 - 12)	4 - 7 (8 -12)	NS
Inlet Air, °C (°F)	32 ±2 (90 +5)	32 +2 (90 ±5)	NS
Oil Sump, °C (°F)	121 (250) max	121 (250) max	NS
Oil Gallery, °C (°F)	100 ±1 (212 ±2)	95 ±1 (203 ±2)	79 ±1 (175 ±2)
Fuel Temp at Filter	35 ±1 (95 ±2)	35 ±1 (95 +2)	NS
Fuel Pressure, gage kPa (psig)	241- 483 (35 - 70)	241-- 483 (35 - 70)	NS
Compressor Suction, clean filter, cm (inches) water	20 (8) max	NS	NS
Compressor Suction, dirty filter, cm (inches) Hg	25 (10) max	NS	NS
Exhaust Back pressure (after turbo), cm (inches) Hg	3.0 - 5.1 (1.5 - 2.0)	NS	NS
Blowby Pressure, cm (inches) water	10 (4.0) max*	NS	NS
Oil Pressure, kPa (psig)	207 (30) min	207 (30) min	34 (5) min

* = Blowby pressure greater than 10 cm (4 inches) of water constitutes test shutdown for inspection.

NS = Not Specified

6.10.6 Used oil sampling. Take a 240 mL (8 fluid ounce) sample of oil at the oil filter housing according to the schedule specified in 6.10.3. This is done with the engine idling prior to the scheduled shut-down and oil adjustment. If fuel dilution (greater than 5 percent) is detected in the oil, the fuel leak should be repaired and the oil changed before the test continues.

6.10.7 Oil adjustment and oil change.

6.10.7.1 Shut down the engine according to 6.4.2. Note that oil samples must be taken during the 5 minute idling period (see 6.10.6).

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6.10.7.2 Make oil adjustments according to the schedule of 6.10.3 by adding a weighed amount of test oil to the sump, bring the level to the full mark on the dipstick. Maintenance of an oil log sheet is required. If the oil level is below add halfway (10 hours) through the period, weight and add roughly 3.8 L (1 gallon) of oil so that the engine can finish the period safely. If oil temperature exceeds 121° C (250° F), remove and clean the oil heat exchanger. Oil consumption should not exceed 0.34 kg/hr (0.75 lb/hr) or the test shall be considered invalid.

6.10.7.3 After the 120-hour oil sample is taken, the engine is shutdown according to 6.4.2. The oil is drained from the oil filter housing and the engine crankcase. A new charge of test oil and a new oil filter are installed per 6.10.2.

6.10.8 Airbox inspections. Four airbox inspections shall be made as specified in 6.10.3. The zero-hour inspection is made at the completion of the final power check and prior to the installation of test oil. Observations made at each airbox inspection must be recorded on a form similar to that on page D-13. The areas inspected, performance levels noted, and means of inspection shall be as follows:

Area inspected	Performance level noted	Means of inspection
Inlet Ports	Percent Plugging	Visual
Piston Skirt	Tinplate Melting Scoring Burning	Visual
Ring Lands	Carbon Deposits	Visual
Rings	Freedom Face Scuffing Face Burning	Blunt Probe and Visual
Cylinder Liner	Scuffing 4/ Scoring Bridge Cracking 5/ Glazing	Illuminated and Magnifying Borescope Visual

4/ Scuffing shall be described in terms of degree (light, medium and heavy) and in terms of area (thrust, anti-thrust, front and rear).

5/ Bridge cracking constitutes a test shutdown or linear replacement as in 6.11.2.

6.10.9 Performance check. The last 2200 and 2800 rpm cycles shall be examined to assure that the engine meets horsepower requirements. A statement that the engine met horsepower requirements should be included in the test report.

6.10.10 Final oil drain. Shut down engine as outlined in 6.4.2. Let the engine stand for five minutes, then drain the crankcase and oil filter housing. Weigh and record the quantity of oil drained, the oil filter, and the blowby can.

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6.10.11 Data recording.

6.10.11.1 The following data shall be recorded once during each idle mode and twice during each power and torque mode.

- Operator
- Date
- Time
- Test Hours
- Engine Speed, rpm
- Load, NŽm (lb-ft)
- Fuel Rate, kg/hr (lb/hr)
- BSFC, lb/hhp-hr
- Observed Output, BHp
- Temperatutes, ^{0}C (^{0}F)
  - Exhaust Manifolds
  - Turbocharger exit
  - Coolant Jacket-in
  - Coolant Jacket-out
  - Oil Sump
  - Fuel at Filter
  - Compressor Inlet Air
  - Airbox
  - Ambient Air (wet/dry bulb)
- Presures
  - Intake vacuum, cm (in.) H_20
  - Exhaust Turbocharger exit, cm (in.) Hg
  - Exhaust Manifolds, kPa gage (psig)
  - Compressor Discharge, kPa gage (psig)
  - Blower Discharge, Airbox, kPa gage (psig)
  - Transfer pump, kPa gage (psig)
  - Oil Gallery, kPa gage (psig)
  - Blowby, cm (in.) H_20
  - Barometer, cm (in.) Hg

6.10.12 Problems encountered during test.

6.10.12.1 High blowby. Blowby pressure greater than 10 cm (4 inches) H_20 constitutes test shutdown for inspection. If the problem appears to be caused by lubricant–related ring wear, then the test should be terminated. Severe problems may be present by blowby pressures less than 10 cm (four inches) of water.

6.10.12.2 Liner scuffing-ring wear. Liner scuffing-ring wear is generally accompanied by high blowby pressures. During the test, in the case that one liner exhibits severe scuffing while all other exhibit normal wear, that liner-piston-ring set may be replaced and the test continued. The removed parts should be rated but not included in reported averages. Removed liners should

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exhibit 30 percent or greater overall scuffing. A fresh oil charge and full break-in should be used in this instance. Appropriate notations should appear in the test report. Engine oil iron content is also a good indication of ring wear and scuffing. If severe scuffing is observed before the test oil is introduced into the engine, that (those) cylinder(s) kit(s) may be changed out and a full break-in run. Measurements and ratings of the removed kits need not appear in the test report, but the test number suffix should reflect change outs as per section 8.5.

6.10.12.3 Visually observed scuffing. If severe liner scuffing is observed during the airbox inspections, and that scuffing is judged to be of a progressive nature, then the test should be terminated. Severe liner scuffing can lead to liner o-ring melting and subsequent catastrophic engine failure. Progressive liner scuffing is generally accompanied by high blowby and rapidly increasing engine oil iron content.

6.10.12.4 Fuel dilution. If a fuel concentration greater than five percent by weight is detected in the lubricant, the fuel leak should be repaired and the oil changed before the test continues. Fuel crossover lines are generally at fault in this case. Appropriate notations should appear in the test report.

6.10.12.5 Coolant dilution. If coolant is detected in the lubricant, the leak should be repaired and the oil changed before the test continues. Appropriate notations should appear in the test report. In order to avoid coolant dilution when cylinder heads are removed the following procedure should be used:

a. Drain lubricant.
b. Drain coolant.
c. Perform desired work taking care to minimize coolant drainage into sump.
d. Flush oil passages by pouring new oil down exposed oil drain holes.
e. Reinstall head(s).
f. Refill with original oil.
g. Refill coolant system.

6.10.12.6 High oil temperature. Oil sump temperatures greater than 121° C (250° F) generally indicate that the oil-water heat exchangers need cleaning. If after cleaning, the sump temperature remains high, then the test should be halted until the problem is corrected.

6.10.12.7 Loss of power.

6.10.12.7.1 Faulty injectors. Poor engine performance during the test may be caused by worn, sticking, broken or leaking injectors. Injectors may be replaced at any point in the test.

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6.10.12.7.2 Valve distress. Poor engine performance caused by exhaust valve distress (burning) constitutes test termination. Exhaust valve replacement is allowed only in the case of valve stem breakage (this is not considered lubricant-related failure).

6.10.12.7.3 Mechanical problems. Poor engine performance caused by faulty turbo chargers, blowers, misadjusted injectors, etc., may be corrected by component replacement or adjustment. Appropriate notations should appear in the test report.

6.10.12.7.4 High oil consumption. High oil consumption, 0.34 kg/hr (0.75 lb/hr), is generally caused by cracked piston pin retainers or worn oil control rings. Cracked piston pin retainers may be replaced at any point in the test. If the average oil consumption during the test is greater than 0.34 kg/hr (0.75 lb/hr), the test will be considered invalid.

6.10.12.7.5 Leaks. Lubricant or coolant leaks should be corrected during the course of the test.

4.10.12.7.6 Makeup of downtime. Minor downtime may be made up by reducing the soak periods to no less than 3 hours. Downtime that cannot be made up in this manner should be reported.

6.11 Evaluation of results.

6.11.1 Part ratings.

4.11.1.1 Preparation for rating. Pistons and cylinder liners are removed from the engine. Care must be taken to avoid disturbing engine deposits during disassembly. Pistons and cylinder liners are numbered on the thrust side. Using a band saw or cut-off saw, split the cylinder liners in half along a longitudinal plane separating the thrust and anti-thrust sides. Any engine not completing the full 240-hour test must be inspected for signs of disassembly before a failure may be termed “lubricant-related”.

6:11.1.2 Piston ratings. Using the terminology of 6.11.1.5, the CRC Diesel Engine Manual No. 5, and the proposed CRC rating system for Diesel Engine Deposits (first draft), and the latest ASTM committee D-2 handout on 6V-53T rating, rate the pistons for the following:

Ring groove carbon filling, percent ring supporting carbon, and Weighted Total Demerit (WTD)
Skirt lacquer
Ring sticking
Ring face condition

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6.11.1.3 Cylinder liner ratings. Using the terminology of 6.11.1.5 and CRC Diesel Engine Rating Manual No. 5, and the latest ASTM committee D-2 handout on 6V-53T ratings, rate the cylinder liners for the following:

Intake Port Restriction
Scuffing (percent compression ring travel area, visual and mat methods)
Bore Polishing (percent compression ring travel area, visual and mat methods)
Lacquer

6.11.1.4 Other ratings. Combustion chamber deposits in the cylinder head and in the piston crowns shall be rated in terms of texture and depth. Exhaust valves, camshaft lobes, rocker arms, tappets/roller-followers , exhaust valve bridges, crankshaft journals and main/connecting rod bearing inserts will also be rated. Crankshaft main bearing journals and bearings need only be rated at major rebuilds. Any unusual deposits or part condition shall be noted.

6.11.1.5 Rating terminology. Ratings shall be made using the CRC Diesel Engine Rating Manual No. 5 and the latest ASTM committee D-2 handout on 6V-53T ratings.

6.11.2 Lubricant analyses. Test lubricant degradation over the 240-hour test period shall be determined and reported as shown in Appendix F.

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Rating data. Suitable forms for recording data are shown in Appendix E; all information shown on these forms shall be furnished with the test report. If one liner-piston-ring kit is changed during the course of the test, that rating data is reported but not included in the averages. If one cylinder kit was changed out during the test (as per 6.10.12.2), then that kit shall be the one dropped in the averages of five shown throughout Appendix E. If no kit was changed during the test, then the kit dropped in the averages of five shall be the kit exhibiting the higher of the following two numbers:

$$\text{Scuffing Dev. From Mean} = \frac{\underline{\text{Thrust + Anti-Thrust}} - \text{Average of Six}}{\text{Average of six}}$$

$$\begin{array}{l}\text{\#2 and 3 Ring Demerits} \\ \quad\text{Dev. From Mean}\end{array} = \frac{\underline{\text{\#2 + \#3 Demerits}} - \text{Average of Six}}{\text{Average of six}}$$

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8.2 Operating data. Mean and standard deviation operating data for the maximum power mode and the maximum torque mode shall be reported, together with the average oil consumption.

8.3 Build-up and wear measurement data. Suitable forms for presenting the build-up and wear measurements are presented in Appendix G.

8.4 Photographic data. Color photographs of each piston and split cylinder liner showing both thrust and anti-thrust sides shall be presented. All photographs shall be on a white background and shall be clearly marked giving cylinder number, right or left, and thrust or anti-thrust. Photographs of piston ring surfaces (opposite gap) and cylinder head deposits shall also be presented. Pictures shall be presented in the following order and manner:

a. Piston rings 1-L and 1-R shall be on the same page. Apparent ring diameter shall be equal to or greater than 10 cm (four inches). Rings shall be photographed with a space between each ring and in the top to bottom order of 1, 2, 3, 4, 5, 6, 7. Lighting should emphasize ring distress and attempts should be made to eliminate extraneous reflections from the ring surfaces.
b. Piston I-L thrust and antithrust shall be presented on the same page. Apparent piston height shall be equal to or greater than 10 cm (4 inches). The thrust photograph should be the left most of the two photographs in all instances.
c. Piston 1-R thrust and antithrust shall be presented on the same page.
d. Liner 1-L thrust and antitrust shall be presented on the same page. Apparent liner height shall be equal to or greater than 15 cm (six inches).
e. Liner l-R.
f. Rings 2-L and 2-R.
g. Piston 2-L.
h. Piston 2-R.
i. Liner 2-L.
j. Liner 2-R.
k. Rings 3-L and 3-R.
1. Piston 3-L.
m. Piston 3-R.
n. Liner 3-L.
0. Liner 3-R.
p. The left and right cylinder heads shall be displayed on the same page. Apparent head length shall be equal to or greater than 13 cm (five inches). Heads shall be displayed horizontally with cam followers topmost. Combustion chambers should be labeled lR, 2R, etc.

8.5 Test number. The test number shall consist of the following: Stand-Stand Run number-Engine-Engine Run number-Suffix. Suffix denotes the number of attemptS to reference (e.g., first attempt = number suffix, second attempt = A, third attempt = B, etc.).

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9. PRECISION

9.1 A reference test is required when a new engine or a new test stand is put into service for the first time, or when an established facility re-installs a test stand. To maintain severity level, reference tests on each engine are required every thirteen tests. This implies that twelve candidate oils may be tested between reference runs on a single engine. An engine is defined as a block and any buildup constitutes a test. Each test stand must be referenced every ninth test or six months, whichever comes first. This implies that each stand may run eight candidate oils between reference tests or that six months may elapse between reference runs. Reporting of an engine's or stand's reference history is optional.

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APPENDICES

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STROKING PROPERTIES OF HYDRAULIC BRAKE FLUIDS

1. SCOPE

1.1 This method describes a procedure for evaluating the stroking properties of brake fluids used in the hydraulic brake systems of automotive vehicles. This method, with slight modifications, may be used to evaluate hydraulic brake rubber cups against a standard brake fluid.

2. SUMMARY

2.1 The method utilizes standard Society of Automotive Engineers (SAE) hydraulic brake parts mounted in a manner similar to that of an automobile brake system. The test brake fluid is subjected to various stroking rates, pressures, and temperatures designed to evaluate the lubrication properties of the brake fluid. This method complements the chemical and physical tests required by the brake fluid specifications.

2.2 It is essential to have meaningful reference data before a significant interpretation of test results can be made. Reference data must include comparable test information on a brake fluid of known service performance characteristics.

3. SAMPLE SIZE

3.1 Approximately 3.8 L (one gallon) of the brake fluid to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 SAE Standard.

J 1703 - Motor Vehicle Brake Fluid

4.2 ASTM Standard.

D 2240 - Rubber Property-Durometer Hardness

4.3 Apparatus.

4.3.1 Wheel assemblies.[1] Four left front wheel brake assemblies.

4.3.1.1 Bearing assemblies. Four front outer bearing assemblies, and four front inner bearing assemblies, with bearing races and grease seals.

4.3.1.2 Hub and brake drum assemblies. Four left front wheel hub and brake drum assemblies.

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[1] An alternative to the wheel assemblies is described in section 4.12 of SAE J 1703.

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4.3.1.3 Helper springs. One helper spring per wheel assembly.

4.3.2 Brake pressure actuating mechanism. A suitable actulating mechanism for applying pressure to the master cylinder push rod to simulate, as closely as possible, the braking operation in a vehicle.

4.3.2.1 Type of actuating mechanism. The actuating mechanism shall be operated by suitable air pressure or hydraulic means. Mechanical actuation is not recommended.

4.3.2.2 Pressure application. The amount of pressure applied by the actuating mechanism shall be adjustable. The mechanism shall be capable of applying sufficient thrust to the master cylinder to create a minimum pressure of 6.9 gage MPa (1000 psig) in the simulated brake system.

4.3.3 Stroking rate and rate-of-load application. The actuating mechanism shall be designed to permit adjustable stroking rates ranging from 500 to 1,000 strokes per hour as desired. The ratio of percent time-of-load application to nonload application shall also be adjustable, from a minimum ratio 25/75 percent to a maximum of 60/40 percent per stroke cycle. (A "60/40 percent” ratio per stroke cycle indicates that pressure is applied during 60 percent of the duration of the stroke cycle, while the pressure is released, or not applied, during the remaining 40 percent of the cycle.)

4.3.4 Pressure gages. Two recording pressure gages of 0 to 6.9 gage MPa (O to 1000 psig) capacity with connecting tubing. One of the gages shall have a 24 hour cycle, while the other gage shall have a maximum cycle of 6 minutes. Each gage shall be provided with a shut off valve for removing air from the connecting tubing.

4.3.5 Revolution counter. A mechanical or electrical revolution counter with recording capacity for 500,000 strokes.

4.3.6 Tubing. Approximately 4.6 m (15 feet) of 0.63 cm (1/4 inch) o.d. copper or steel tubing with inverted flare nuts, connectors, adaptors, and fittings.

4.3.7 Stand. A stand or frame for mounting the four left front wheel assemblies as shown in Figure 1.

4.3.8 Cabinet or oven. A large cabinet or oven, of sufficient capacity to house the stand with the four mounted wheel assemblies, together with the master cylinder and necessary connections.

4.3.9 Temperature control. The cabinet or oven shall be insulated, and shall be equipped with suitable means of heating and cooling to provide the specified test temperatures. The temperatures shall be thermostatically controlled within ± 2.8° C (± 5° F) of the specified test temperature.

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4.3.10 Durometer, Type A-shore durometer. The description of the durometer, calibration, and application in testing rubber hardness may be found in ASTM D 2240.

5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Ethyl alcohol, (ACS) [0, 3, O].

5.3 Crocus cloth. Crocus cloth shall conform to the requirements of P-C-458.

5.4 Wheel cylinder assemblies. Four cast iron housing straight bore hydraulic brake wheel cylinders having a diameter of approximately 2.8 cm (1 1/8 in). SAE part number RM-14a.

5.5 Master cylinder assembly. One cast iron housing hydraulic brake master cylinder having a diameter of approximately 2.8 cm (1 1/8 in.) and fitted with an uncoated steel standpipe. SAE part number RM-15a.

5.6 Rubber cups. All wheel cylinder and master cylinder cups used in the test brake system shall be made of SBR type elastomer. SAE part numbers for wheel cylinders and master cylinders are RM-3, RM-4 and RM-5.

5.7 Wheel cylinder pistons. Unanodized aluminum pistons (SAE RM-12) made from SAE AA 2024 aluminum alloy are to be used.

5.8 Master cylinder piston. Use a SAE RM-13 piston made from SAE CA 360 copper-base alloy (half hard).

Note: All standard SAE parts are available from the Society of Automotive Engineers, Inc, 400 Commonwealth Drive, Warrendale, PA 15096.

6. PROCEDURE.

6.1 Preparation of the test appartus.

6.1.1 Inspection and cleaning of parts.

6.1.1.1 Wheel cylinder assemblies. The wheel cylinder assemblies shall be completely disassembled. All rubber parts, with the exception of the cylinder boots, shall be discarded. The expanders in the assembly shall also be discarded. All metal parts shall be cleaned with 95 percent ethyl alcohol to

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remove preservative oils, grease, and dirt, then dried in a stream of dry air, and examined for cuts, scores, galling, or pitting. Any part having any of these flaws shall be replaced. Light stains on the cylinder walls shall be removed by rubbing with crocus cloth and 95 percent etlyl alcohol. Any cylinder which cannot be freed of stains by this procedure shall be discarded.

6.1.1.2 Master cylinder assemblies. The master cylinder assemblies shall be completely disassembled. All rubber parts, including the piston washer if it forms an integral part of the primary cup, shall be discarded. The metal parts shall be cleaned, air-dried, examined for flaws, and light stains removed from the cylinder walls in the manner specified for the wheel cylinder assemblies (see 6.1.1.1). Any deficient parts shall be replaced. The cylinder’s relief and supply parts shall be inspected for burrs and wire–edge. If present, they may be removed with a burring tool or a jeweler’s file.

6.1.1.3 Rubber parts. The rubber parts to be used in the test shall be cleaned with a lint–free cloth and 95 percent ethyl alcohol to remove all dirt and grease, then dried in a stream of dry air and examined for cuts, molding flaws, or blisters. Any deficient part shall be discarded.

6.1.1.4 Tubing. The tubing used as brake fluid lines shall be flushed with 95 percent ethyl alcohol, and dried by blowing dry air through it, prior to connecting to the test apparatus.

6.2 Initial measurements and tolerance.

6.2.1 Cylinders. The internal diameter of the master cylinder and of each of the wheel cylinders shall be measured with a micrometer, to the nearest 0.0025 cm (0.001 inch). Four readings, approximately 45 degrees apart, shall be taken on each cylinder, and their average considered as the diameter of the cylinder. If the largest and smallest diametrical readings differ from each other by more than 0.0075 cm (0.003 inch), the cylinder in question shall be discarded.

6.2.2 Pistons. The external diameter of the master cylinder piston and of each of the wheel cylinder pistons shall be measured with a micrometer, to the nearest 0.0025 cm (0.001 inch). Two readings, at right angles to each other, shall be taken on each piston, and their average considered as the diameter of the piston. If the two readings differ from each other by more than 0.0025 cm (0.001 inch) the piston in question shall be discarded.

6.2.2.1 Clearance of piston in cylinder. Each piston shall be checked for clearance within the cylinder for which it is intended. If the clearance is less than 0.0075 cm (0.003 inch) or more than 0.0125 cm (0.005 inch), the cylinder or the piston shall be replaced by another similar part.

6.2.3 Rubber cups.

6.2.3.1 Base and lip diameters of the cups. The internal base and lip diameters of each rubber cup shall be determined with a micrometer, to the nearest 0.0025 cm (0.001 inch). The cups shall be placed on a flat surface for

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24 hours before measuring. In measuring the diameters of the cups, care should be taken that the micrometer does not extend more than 0.08 cm (1/32 inch) beyond the edges of the cup. If difficulty is encountered in measuring the diameter of the master cylinder secondary cup, the cup may be placed on a mandrel having a slight taper. Two readings at right angles to each other, shall be taken on the base and lip of each cup, and their average considered as the base and lip diameters of the cup. If the two readings on the base or the two readings on the lip differ by more than 0.0025 cm (0.001 inch) respectively, the cup in question shall be discarded.

6.2.3.2 Hardness of rubber. The durometer hardness of each cup shall be measured at four different points near the center of each cup. The average of the four readings shall be considered as the hardness of the rubber cup. For the sake of uniformity the durometer readings should be made as follows: The proper rubber anvil is inserted in the fixture, and the rubber cup placed on the anvil. The back edge of the durometer is placed on the shelf of the fixture, with the bottom surface of the durometer kept parallel to the surface of the base of the cup. The durometer is grasped between the thumb and the third and fourth fingers of one hand, with the index finger placed on the top of the depressor. The indenter point is lowered gently until it rests on the surface of the cup. With a minimum amount of rocking, pressure is then applied so that the pressure plate makes firm contact with the surface of the cup. the durometer reading is taken as soon as the dial needle comes to rest. If the needle does not come to rest, then the reading is taken at that moment when a definite change in the speed of the needle is observed, with the reading estimated to the nearest whole point of the dial scale.

6.2.3.2.1 Wheel cylinder cups. The average durometer hardness of the wheel cylinder cups shall be 60 ±3 points. Nonconforming cups shall be discarded.

6.2.3.2.2 Master cylinder cups. The average durometer hardness of the master cylinder cups shall be 63 ±3 points. Nonconforming cups shall be discarded.

6.3 Assembling, adjusting, and checking the apparatus.

6.3.1 Assembly of brake parts. After the required measurements have been taken and recorded, the wheel cylinders and the master cylinder shall be assembled for test. All parts with the exception of the cylinder housings and the rubber boots, shall be dipped in the hydraulic fluid under test when they are assembled. The assembled cylinders shall be checked for ease of operation, and then installed in their respective places in the simulated brake systems. Helper springs shall be installed in holes beneath the shoe flanges, pushed up and hooked over the flanges (see Figure 1).

6.3.2 Shoe clearance adjustment. The brake shall be adjusted to have a clearance of 0.102 ±0.0075 cm (0.040 ±0.003 inch) between the shoe and the drum, at the toe.

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6.3.3 Filling and bleeding the brake system. The assembled simulated brake system shall be filled with the fluid under test by means of a pressure pot, or by hand. If filled by hand the master cylinder shall he stroked several times to completely fill the system. All the wheel cylinders and the tubing connected to the pressure gages shall be bled to remove the entrapped air from the system.

4.3.4 Checking the system for leaks. After the system has been bled, a pressure of 6.9 gage MPa (1,000 psig) shall be applied to the system. The system shall be slowly stroked for 10 minutes, after which an inspection shall be made for leaks. The pressure shall be released, and the brake shoe clearance rechecked (6.3.2).

6.3.5 Fluid level. A constant level of test fluid shall be maintained at the master cylinder throughout the test. Accurate record shall be kept of the number of mL of the fluid added to the system during the test. It may be necessary to install special antisplash plugs on the master cylinder reservoir to avoid loss of the fluid due to splashing.

6.4 Test procedure.

6.4.1 Procedure A. Stroking properties at high temperatures.

6.4.1.1 Conditions of test.

6.4.1.1.1 Test temperature. Unless otherwise specified the test temperature shall be 120° + 3° C (248° + 5° F). The test shall be started at room temperature (23° + 5° C). The rise in temperature from room temperature to the test temperature–shall take place in not more than 8 hours from the start of the test.

6.4.1.1.2 Pressure. The initial stroking pressure in the simulated brake system shall be adjusted at room temperature (23° + 5° C), to 3.4 gage MPa (500 psig) and recorded. The pressure stroke pattern shall be adjusted at 60/40 percent stroke ratio 17 strokes per minute, with the aid of the short-cycle pressure recorder, so as to produce a relatively smooth curve (see Figure 2). Accurate record shall be kept of any pressure variations during the test. The pressure stroke pattern shall be compared with the initial pattern at intervals of 50,000 strokes during the test.

6.4.1.2 Brake-in or burnishing run. The stroking rate shall be adjusted at 1,000 ± 50 strokes per hour, using the 60/40 percent stroke ratio and the stroking pressure of 3.4 MPa gage (500 psig) applied at room temperature (23° + 5° C). While at room temperature, the system shall be stroked 16,000 + 500 strokes. At the end of this stroking period the system shall be checked for fluid level. The cylinder shall be filled to the given level, if necessary, and the test resumed.

6.4.1.3 Duration of test. The test shall be run until 94,000 strokes have been completed. The number of strokes given in the burnishing run (see 6.4.1.2) and in coming to test temperature (see 6.4.1.1.1) shall be included as part of

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total 94,000 strokes. The number of strokes required, if other then 94,000 shall be specified in the material specification.

6.4.2 Procedure B. Stroking properties at subzero temperatures.

6.4.2.1 Conditions of test.

6.4.2.1.1 Test temperature. The test temperature shall be minus 40° +3° c (-40° :5° F) or minus 55° +3° C (-67° +5° F), as specified. The test shall be started at room temperature (23° +5° C). The drop in temperature from room temperature to the specified test–temperature shall take place in from 8 to 24 hours, following the start of the test.

6.4.2.1.2 Pressure. The initial stroking pressure in the simulated brake system shall be adjusted at room temperature (23° +5° C) to 3.4 gage MPa (500 psig), and recorded. The pressure stroke pattern shall be adjusted at 60/40 percent stroke ratio, with the air of the short cycle pressure recorder so as to produce a relatively smooth curve (see Figure 2). Accurate record shall be kept of any pressure variations during the test.

6.4.2.2 Break-in or burnishing run. The stroking rate shall be adjusted at 1,000 +50 strokes per hour, using the stroking pressure of 3.4 gage MPa (500 +10 psig) applied at room temperature (23° ±5° C). While at room temperature the system shall be stroked 16,000 +500 strokes, at the end of which the system shall be checked for leaks, and proper brake shoe clearance and the master cylinder checked for fluid level. The cylinder shall be filled to the given level, if necessary The stroking rate shall then be adjusted to 720 +50 strokes per hour, using a 40/60 percent stroke ratio. The pressure-stroke pattern shall be adjusted, with the aid of the short-cycle pressure recorder, to give a relatively smooth curve (see Figure 3). Accurate record of observed pressure variations shall be compared with the initial pattern at approximately every 20,000 strokes. The stroking cycle, if other than that listed in this paragraph, shall be specified in the product specification.

6.4.2.3 Duration of test. The test shall be run until 94,000 strokes have been completed. The number of strokes given in the burnishing run (see 6.4.2.2) and in coming to the specified test temperature shall be included as part of the total 94,000 strokes. The number of strokes required, if other than 94,000, shall be specified in the product specification.

6.5 Observations.

6.5.1 Observations during test.

6.5.1.1 Pressure change. Observations at 12 hour intervals shall be made of the stroking pressure in the simulated system, to determine changes from the initial pressure.

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6.5.1,2 Functioning of wheel cylinder pistons. The functioning of the wheel cylinder pistons shall be observed. Improper functioning of the pistons, such as freezing of the piston in the cylinder, or failure of the brake shoe to be released from the brake drum, shall be recorded. However, very slight drag of the brake shoe on the drum, when the drum is rotated by hand, shall not be considered as improper functioning of the cylinder pistons. Mechanical defects of the brake mechanism may cause excessive pressure rise or improper functioning of the wheel cylinder pistons. If inspection of the malfunction shows this to be the case, the test shall he repeated using new parts.

6.5.1.3 Leakage (or evaporation). The leakage (or evaporation) loss of the hydraulic brake fluid at 24,000-stroke intervals shall be determined by the mL of the fluid required to maintain the constant fluid level in the master cylinder reservoir. The level of the fluid should be checked daily.

6.6 Observations and measurements at end of test.

6.6.1 Leakage. The equipment shall be allowed to come to room temperature within 16 hours following completion of the required number of strokes. The brake wheel cylinder shall be examined for evidence of excessive leakage. The assembly shall then be stroked an additional 100 strokes at 3.4 gage MPa (500 psig), and the cylinders again examined for evidence of excessive leakage.

6.6.2 Disassembly of cylinders. The wheel cylinders and the master cylinder shall be removed from the simulated system. The inlet ports of the cylinders shall be plugged or capped immediately upon removal to retain the fluid remaining therein. Each cylinder shall then be carefully disassembled. The fluid remaining in the cylinder shall be drained into a small screwcap jar, and saved for examination for evidence of sludging, jellinG, sedimentation, and grittiness.

6.6.3 Inspection. A visual inspection of the disassembled cylinder shall be made , and a record made of the type and quantity of dirt; gum deposition; rusty, scored , and galled areas on the surface of the pistons and on the cylinder walls; chipping, scoring, and general condition of the rubber cups. All parts shall then be cleaned with 95 percent ethyl alcohol, and dried in a stream of air. The metal parts shall then be re-exainined for evidence of corrosive action, such as pitting, etching, and severe stain.

6.6.4 Measurements.

6.6.4.1 Cylinders. The internal diameter of each wheel cylinder and of the master cylinder shall be measured as specified in 6.2.1.

6.6.4.2 Pistons. The external diameter of the master cylinder piston and of each wheel cylinder piston shall be measured as specified in 6.2.2.

6.6.4.3 Rubber cups. Measurements of the base and lip diameters of the rubber cups shall be made as specified in 6.2.3.1. Durometer hardness of the

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cups shall be determined as specified in 6.2.3.2. The diameter measurements and the hardness determinations shall be made within 1 hour following removal from the cylinder assembly.

7. CALCULATIONS

7.1 Change in cylinder and piston diameter:

$$C = c_1 - C_2$$

C = Change in cylinder diameter.
c_1 = Original cylinder bore diameter.
C_2 = Final cylinder bore diameter.

$$P = P_1 - P_2$$

P = Change in piston diameter.
P_1 = Original piston diameter.
P_2 = Final piston diameter.

7.2 Change in base and lip diameter of rubber cups.

$$B = B_2 - B_1$$

B = Change in rubber cup base diameter.
B_1 = Original base diameter.
B_2 = Final base diameter.

$$L = L_2 - L_1$$

L = Change in rubber cup lip diameter.
L_1 = Original lip diameter.
L_2 = Final lip diameter.

7.3 Lip diameter interference set.

$$LDIS = \frac{L_1 = L_2}{L_1 - C_1} = 100$$

LDIS = Lip diameter interference set percentage.
L_1 = Original lip diameter of rubber cup.
L_2 = Final lip diameter of rubber cup.
C_1 = Original cylinder bore diameter.

7.4 Change hardness of rubber cup.

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$H = H_2 - H_1$

H = Change in durometer hardness.
H_1 = Original hardness value.
H_2 = Final hardness value.

7.5 Change in fluid pressure.

$P = p_2 - P_1$

P = Change in system pressure.
P_1 = Original pressure value.
P_2 = Final pressure value.

7.6 Change in fluid volume

$V = V_2 - V_1$

V = Change in fluid volume.
V_1 = Original volume.
V_2 = Final volume.

8. REPORTING

8.1 Summary. A summary of the test conditions and the inspection results shall be made at the completion of the stroking test. Reports shall be made on the following:

a. Degree (slight, moderate, or excessive) of corrosion, scoring, and galling of metal parts.
b. Change in the initial diameter of the cylinders and pistons (see 7.1).
c. Change in the base and lip diameters of the rubber cups (see 7.2).
d. Percentage of lip diameter interference set (see 7.3).
e. Change in the durometer hardness of rubber cups (see 7.4).
f. Degree (slight, moderate, or excessive) of swelling, tackiness, scoring, scuffing, or blistering of the rubber cups.
g. pressure change in the system at end of each successive 12 hour interval (see 7.5).
h. Volume loss of fluid due to leakage or evaporation, at the end of each successive 24,000-stroke interval during the test (see 7.6).
i. Volume loss of the fluid at the end of the test (see 6.2.1 and 7.6).
j. Degree (slight, moderate, or excessive) of sludging, jelling, sedimentation, or grittiness of the fluid after testing (see 6.2.2).
k. Observed improper functioning of the wheel cylinder pistons.

9. PRECISION

9.1 Duplicate test runs should show the same general trend for a given hydraulic brake-fluid, particularly in the matter of leakage during and after test, excessive increase in the stroking pressure, and improper functioning of the wheel cylinder pistons.

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9.2 The test shall be repeated using new pacts if mechanical difficulties, which cannot be attributed to the fluid proper, are encountered during the test.

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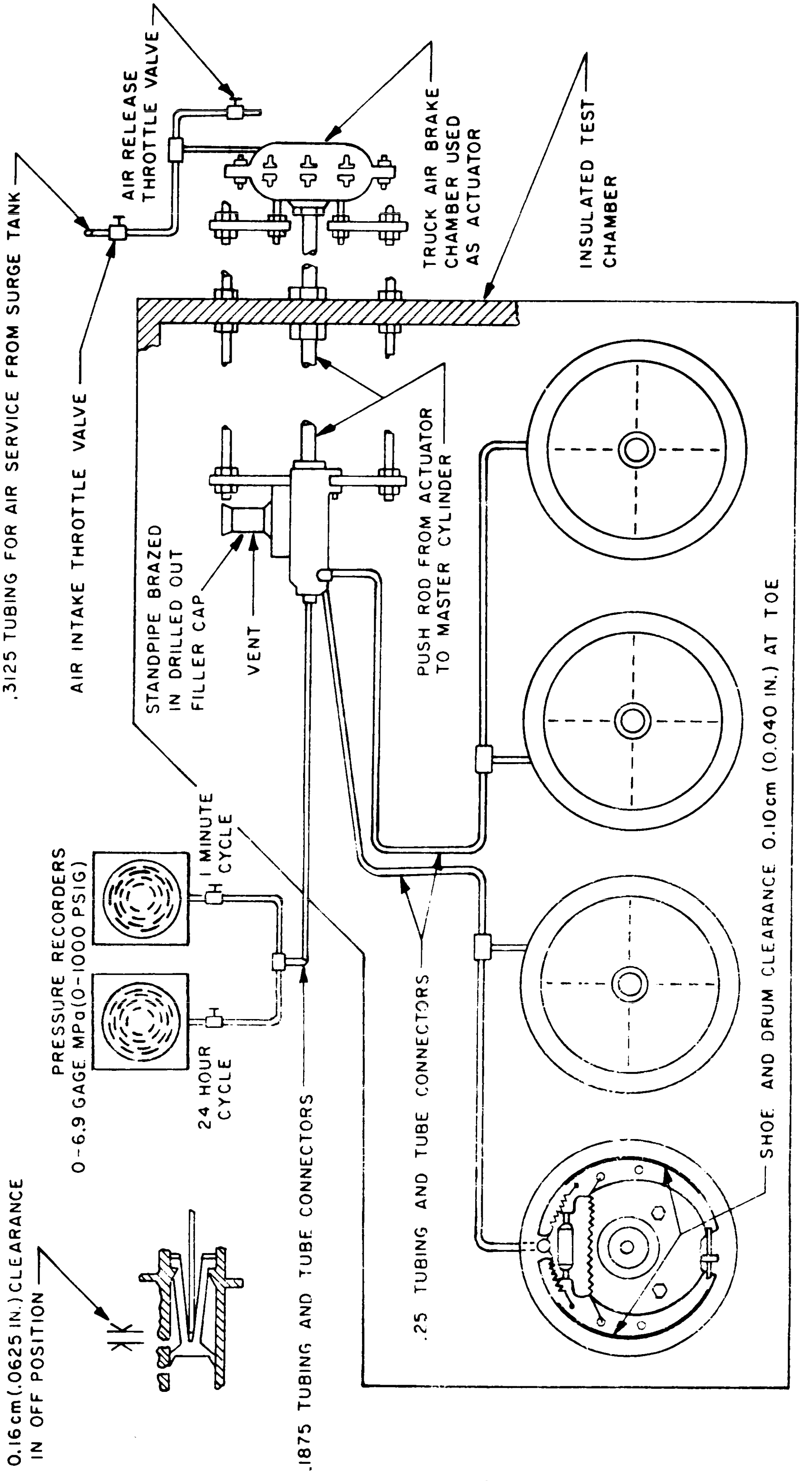

FIGURE 1. Diagrammatic sketch of suitable apparatus.

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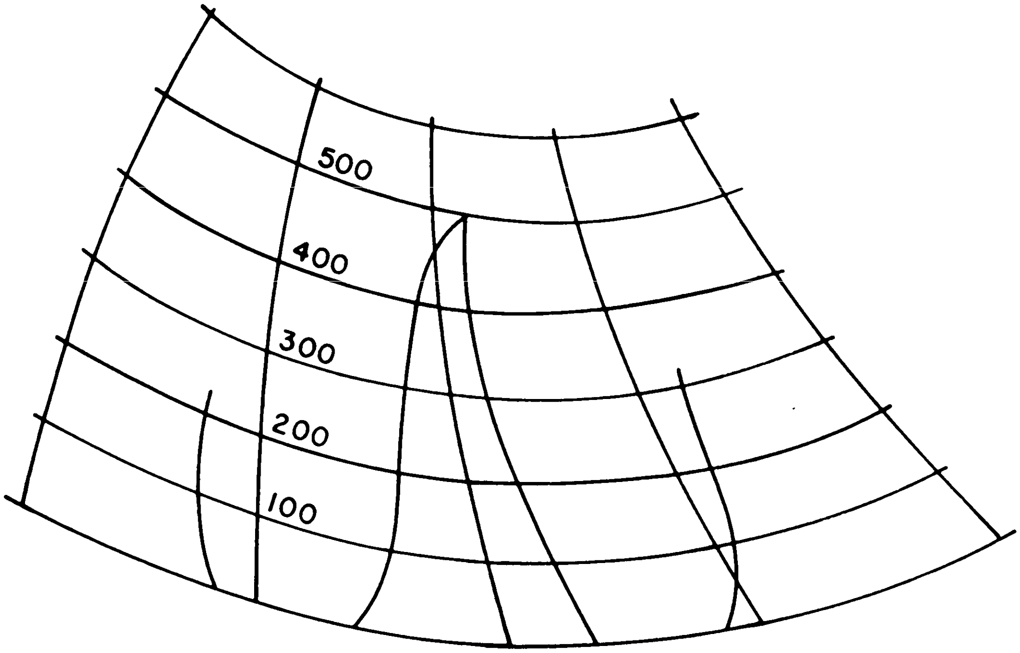

FIGURE 2. Pressure-stroke pattern 60/40 cam, 17 strokes per minute, chart speed - 1 rpm.

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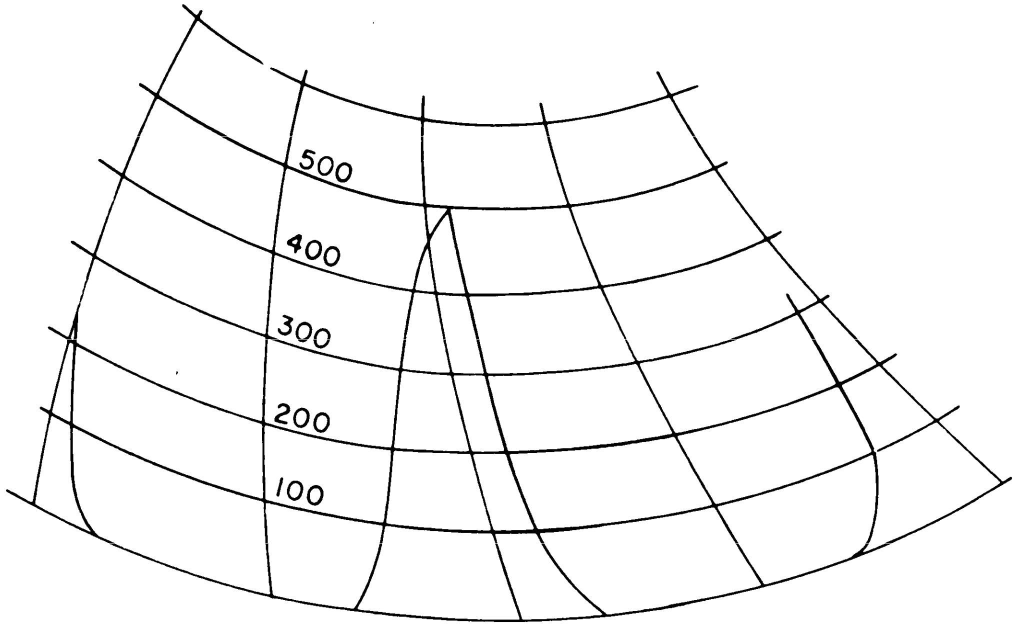

FIGURE 3. Pressure-stroke pattern 40/60 cam, 12 Strokes per minute, chart speed- 1 r. p.m.

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INDUCTION SYSTEM DEPOSIT (ISD) TENDENCIES OF MOTOR GASOLINE

1. SCOPE

1.1 This method is used for determining the tendencies of motor gasolines to form deposits in the induction systems region (intake manifold and intake valve regions) of spark-ignition engines.

2. SUMMARY

2.1 A gasoline sample from a reservoir is metered into a spray nozzle where it is mixed and expelled in a flat spray pattern across an open span of 7.5 cm onto a weighed deposit-collecting tube of aluminum heated to 190° C. The weight gain of the deposit tube obtained from 100 mL of gasoline is the ISD Index and is reported in mg/100 mL.

3* SAMPLE SIZE

3.1 Approximately 150 mL of the gasoline is required for each test run.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Induction System Deposit Apparatus (Figure 1) is available from Southwest Research Institute, San Antonio, Texas. However, detailed engineering drawings may be obtained from the Belvoir Fuels and Lubricant; Research Facility, (SwR1), P.O. Drawer 28510, San Antonio, TX 78284, for fabrication purposes. The apparatus consists of the following components:

a. Fuel Reservoir. A polytetrafluoroethylene (Teflon, Halon) bottle having a capacity of at least 200 mL and capable of withstanding pressures Up to 6.89 gage kPa (1 psig).
b. Fuel metering system, capable of metering fuel flow to 2 +0.1 mL/min.
c. Air metering system, capable of metering air flow to 15 ±0.5 L/min. at 83 gage kPa (12 psig).
d. Spray nozzle, using air to atomize the fuel into flat spray and directing the fuel onto the deposit-collecting tube.
e. Nozzle cooling jacket, permitting cooling of the nozzle to prevent fuel vaporization or vapor lock to occur in the nozzle.
f. Heating rod, having an OD which closely matches the ID of the deposit tube and is capable of operating at a wattage sufficient to produce tube temperatures up to 232° C.
g. Temperature controls, capable of controlling the heating rod output so that the depositing surface of the deposit tube can be maintained within ±1° C, in combination with a needle thermocouple accurate to ±1° C.

4.2 Deposit sample tube, made of type 6061-T6 aluminum tubing, containing a thermocouple probe hole, and of the dimensions shown in figure 2.

4.3 Desiccator, containing a desiccant.

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4.4 Oven, explosion-proof, capable of maintaining a temperature of 102° C.

4.5 Balance, with a sensitivity of 0.1 mg.

4.6 Millipore Filter apparatus, catalog No. XX1OO4700 with - a No. LCWPO4700, 10-micrometer, PTFE (Teflon) filter.

5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precuations, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 N-hexane, ACS Reaqent Grade [1,3,()].

5.3 Toluene, ACS Reagent Grade [2,3,0].

5.4 Acetone, ACS Reagent Grade [1,3,0].

6. PROCEDURE

6.1 Preparation of the deposit tube.

a. Rinse the deposit tube with n-hexane followed by toluene, then acetone. Place the clean tube in an oven maintained at 102° C for approximately one hour. (Note: After cleaning the tube, do not touch it with hare hands.)
b. Remove the tube from the oven and immediately place it in a desiccator to cool for at least two hours.
c. After the two-hour cool-down period, weigh the tube to the nearest 0.1 mg and then replace it in the desiccator.
d. Reweigh the tube after 10 minutes and repeat the weighing every 10 minutes until two consecutive weighings yield identical values. Record the weights and replace the sample tube in the desiccator until it is needed.

6.2 Preparation of Apparatus. Before each test, thoroughly clean the spray nozzle, fuel-flow meter, fuel lines, and reservoir with toluene and hexane and allow the components to air-dry as follows:

a. Close the fuel reservoir air valve and adjust the air-pressure regulator to 83 gage kPa.
b. Open the air flow meter until the float is centered on 15 L/rein on the flow meter scale, then close the fuel drain and spray nozzle valves.

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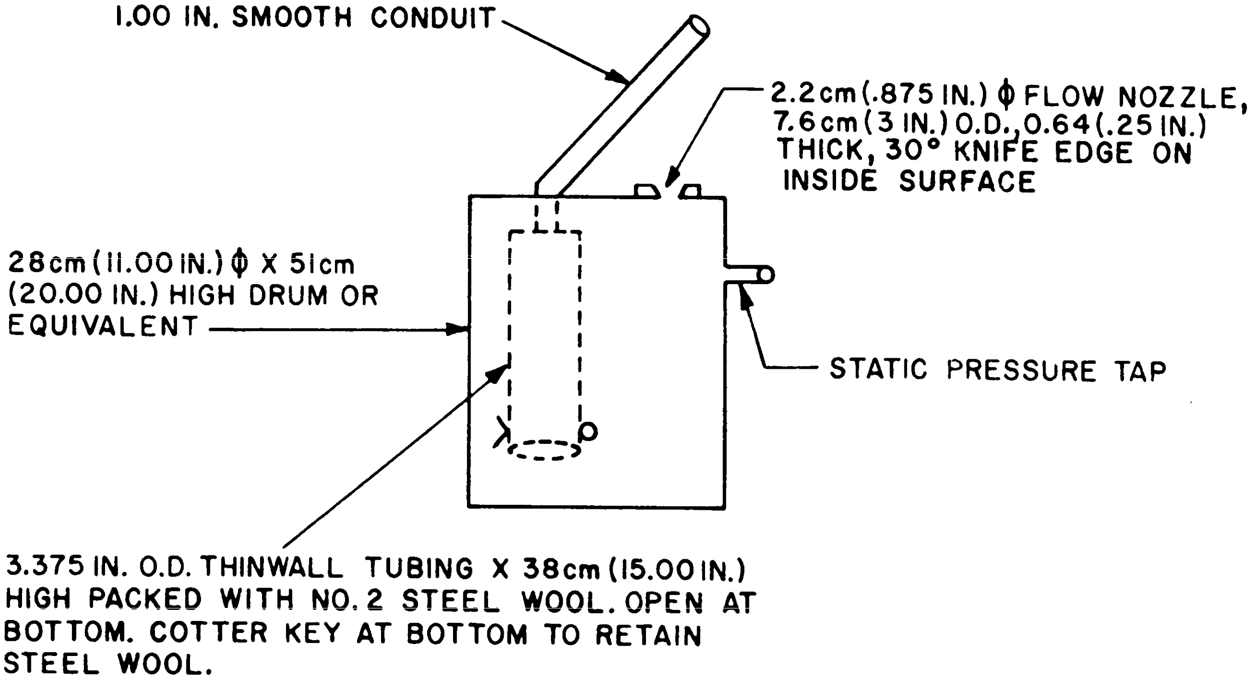
APPENDIX A

BLOWBY SURGE TANK



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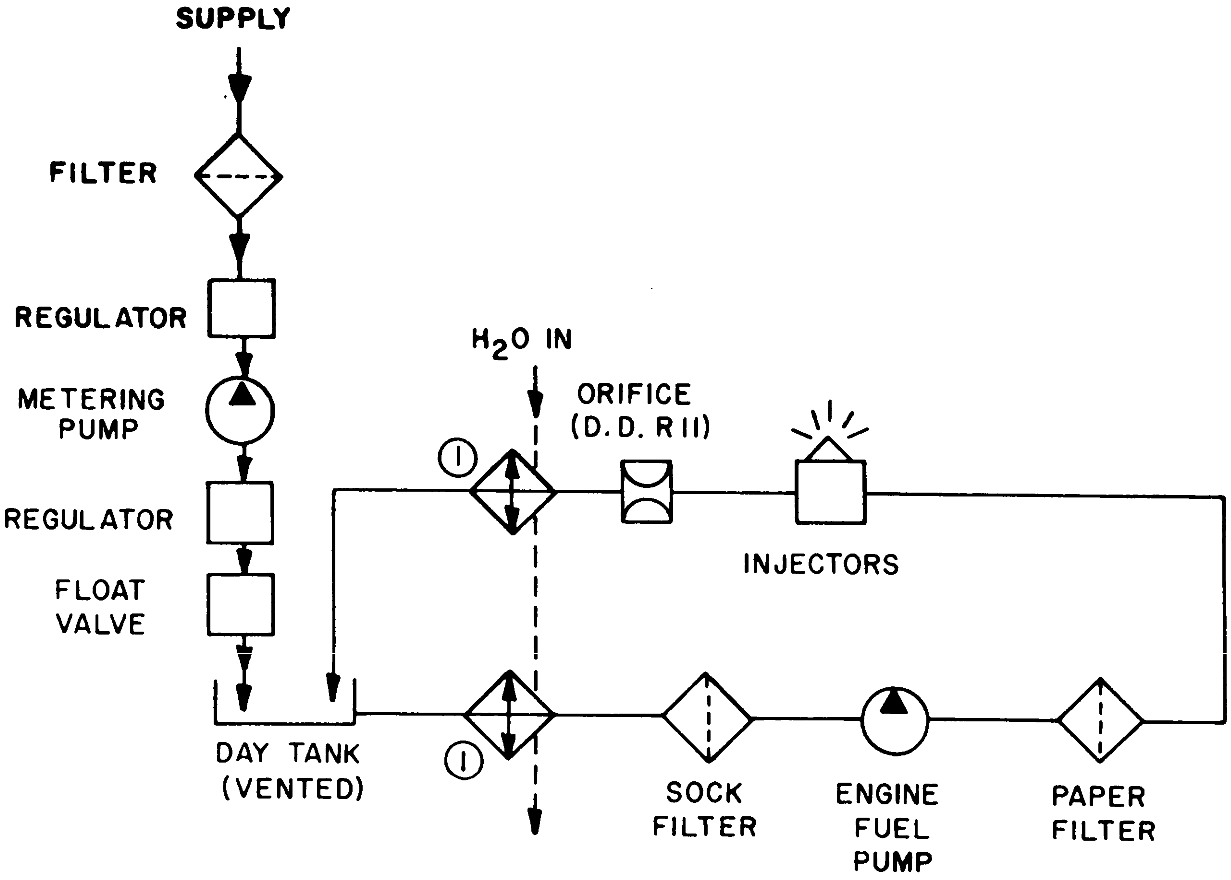
APPENDIX B

FUEL SYSEM SCHEMATIC



① AMERICAN STANDARD BCF 5-030-03-014-003 HEAT EXCHANGERS OR EQUIVALENT.

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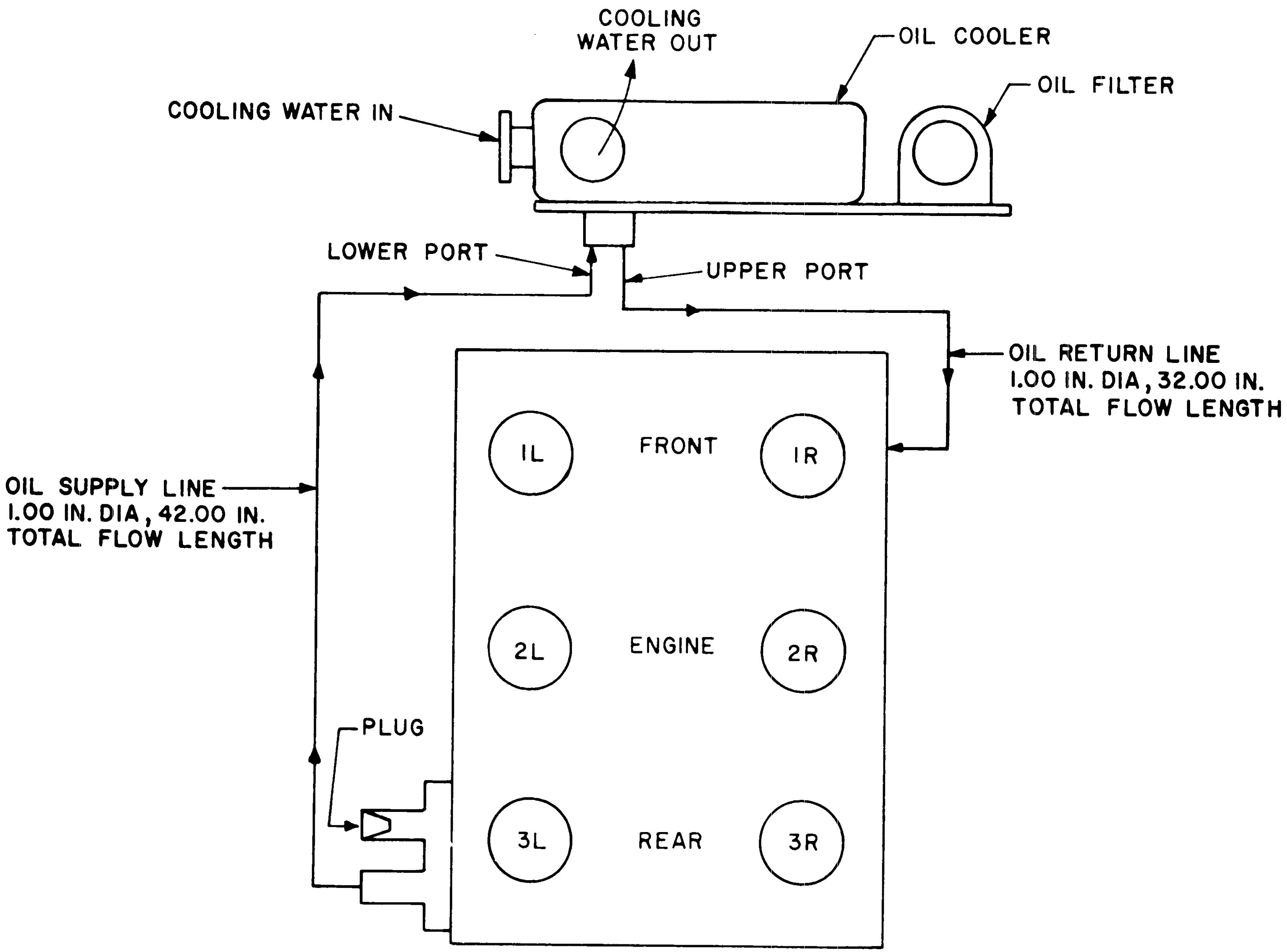
APPENDIX C

OIL TEMPERATURE CONTROL SYSTEM



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INSTALLATION NOTES FOR OIL COOLER

1. One freeze plug in the oil pump must be switched from the right side to the left side. Either drilling or a different size freeze plug may be necessary.

2. The front port of the existing remote oil filter manifold is plugged. The rear port supplies oil to the cooler/filter assembly.

3. One-inch oil lines (length specified in diagram) are used for supply and return lines.

4. Oil supply and return ports under the existing plate-type cooler housing (5133427) are plugged. The housing is retained as a support for the water pump.

5. Mounting holes on the special cooler will require plugging since this cooler is not designed for free standing.

6. Provisions for oil sampling from the port on top of the oil filter housing should be made.

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APPENDIX D

BEFORE TEST AND AFTER TEST

DATA SHEETS

TEST NO. ____________________

BLOCK NO. ____________________

HEAD NO. ____________________ L

____________________ R

DATE STARTED ____________________

DATE FINISHED ____________________

LUBRICANT ____________________

FUEL ____________________

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DATE________ TEST NO________ TECHNICIAN________

LUBRICANT________ FUEL________

6V-53T PISTON RING CLEARANCES

		BEFORE TEST		AFTER TEST
		End Gap*	Side	End Gap
1L	1			
	2			
	3			
	4			
	5			
UOCRT	6			
	7			
2L	1			
	2			
	3			
	4			
	5			
UOCRT	6			
	7			
3L	1			
	2			
	3			
	4			
	5			
UOCRT	6			
	7			

		BEFORE TEST		AFTER TEST
		End Gap	Side	End Gap
1R	1			
	2			
	3			
	4			
	5			
UOCRT	6			
	7			
2R	1			
	2			
	3			
	4			
	5			
UOCRT	6			
	7			
3R	1			
	2			
	3			
	4			
	5			
UOCRT	6			
	7			
	1			
INSTALLED	2			
@ __ HRS	3			
	4			
	5			
UOCRT	6			
	7			

Build-up Engine Measurement Specifications (inches)

	End Gap	Side Clearance
No. 1, Fire Ring	0.020-0.040	0.003-0.0066
No. 2, Compression Ring	0.020-0.040	0.007-0.0105
No. 3 & 4 Compression Rings	0.020-0.040	0.005-0.0085
Upper Oil Ring	0.010-0.020	0.001-0.004
Lower Oil Rings	0.007-0.017	0.0015-0.0055

---

*All end gap measurements taken in 3.8750" I.D. measuring jig.

UOCRT = Upper oil control ring tension.

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DATE ________ TEST NO ________ TECHNICIAN ________

LUBRICANT ________ FUEL ________

6v-53T CYLINDER LINER INSIDE DIAMETER (INSTALLED)

Measuring Gauge Set at 9.36625 cm (3.8750 in).
Numbers given are ten thousandths of a cm (inch).

		BEFORE TEST 6/			AFTER TEST		
		Top	Middle	Bottom	Top	Middle	Bottom
IL	T - A T						
	F - B						
2L	T - AT						
	F - B						
3L	T - A T						
	F - B						
lR	T - A T						
	F - B						
2R	T - A T						
	F - B						
3R	T - A T						
	F - B						

6/ 1.6 cm (5/8 in), 13 cm (5 in), and 23 cm (9 in) below block surface, respectively.

Installed @ ____HRS

Build-Up Engine Measurement Specification cm (inches).

Cylinder Liner (installed)

Taper	0.0038 Max (0.0015)
Out-of Round	0.0038 Max (0.0015)
Inside Diameter	9.6875 - 9.6917 (3.8752 - 3.8767)

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DATE__________ TEST NO__________ TECHNICIAN__________

LUBRICANT__________ FUEL__________

BEFORE TEST

6V-53T PISTON - CYLINDER LINER CLEARANCE

All measurements are in cm (inches) unless otherwise indicated.

	CYLINDER LINER I.D.		PISTON SKIRT O.D.	CLEARANCE	
	MIN.	MAX.		MIN.	MAX
IL					
2L					
3L					
lR					
2R					
3R					

Build-Up Engine Measurement Specifications cm (inches).

Piston to Liner Fit	0.0152-0.0245 (0.0061-0.0098)
Piston Skirt O.D.	9.6672-9.6728 (3.8669-3.8691)
Cylinder Liner I.D. (installed or loose)	9.688-9.6918 (3.8752-3.8767)

____Installed @ ____HRS

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DATE ____________ TEST NO ____________ TECHNICIAN ____________

LUBRICANT ____________ FUEL ____________

6V-53T PISTON PIN TO PISTON BUSHING CLEARANCE

	BEFORE TEST			AFTER TEST		
	PIN	BUSHING	CLEARANCE	PIN	BUSHING	CLEARANCE
IL						
2L						
3L						
lR						
2R						
3R						

____Installed @ ____HRS

6V-53T PISTON PIN TO ROD BUSHING CLEARANCE

	BEFORE TEST			AFTER TEST		
	PIN	BUSHING	CLEARANCE	PIN	BUSHING	CLEARANCE
IL						
2L						
3L						
lR						
2R						
3R						

____Installed @ ____HRS

Rebuild Engine Measurement Specifications cm (inches).

Piston Pin Outside Diameter	3.4365-3.4375	(1.3746-1.3750)
Piston Bushing Inside Diameter	9.4375-3.4450	(1.3775-3.3780)
Pin-to-Piston Bushing Clearance	0.0062-0.0085	(0.0025-0.0034)
Rod Bushing Inside Diameter	3.4400-3.4412	(1.3760-1.3765)
Pin-to-Rod Bushing Clearance	0.0025-0.0048	(0.0010-0.0019)

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DATE ________ TEST NO ________ TECHNICIAN ________

LUBRICANT ________ FUEL ________

6V-53T BLOCK BORE DIAMETER

Measuring Gauge Set at 11.0642 cm (4.3560 inches).

Numbers given are ten thousandths of a cm (inch).

			BEFORE TEST	AFTER TEST
lL	T-AT	Top*		
		Bet**		
	F - B	Top		
		Bot		
2L	T-AT	Top		
		Bot		
	F - B	Top		
		Bot		
3L	T-AT	Top		
		Bot		
	F - B	Top		
		Bot		
lR	T-AT	Top		
		Bot		
	F - B	Top		
		Bot		
2R	T-AT	Top		
		Bot		
	F - B	Top		
		Bot		
3R	A-AT	Top		
		Bot		
	F - B	Top		
		Bot		

____Installed @ ____HRS

Build-up Engine Measurement Specifications cm (inches)

Block Bore

Taper	0.0038 Max (0.0015)	*19 cm (7-1/2 in) below block surface
Out-of Round	0.0030 Max (0.0015)	**21 cm (8-1/2 in) below block surface
Inside Diamenter	10.8915 - 10.8938 (4.3565-4.3575) New 10.8988 (4,3595) Max	

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DATE ______________ TEST NO ______________ TECHNICIAN ______________

LUBRICANT ______________ FUEL ______________

6v-53T VALVE DEPTH (BEFORE TEST)

LEFT SIDE			RIGHT SIDE		
1L	________	________	1R	________	________
	________	________		________	________
2L	________	________	2R	________	________
	________	________		________	________
3L	________	________	3R	________	________
	________	________		________	________

CRANKSHAFT THRUST WASHER THICKNESS (BEFORE TEST)

Major rebuild only

1	______________	______________
2	______________	______________
3	______________	______________
4	______________	______________

Crankshaft End Play (Before Test) ______________

Oil Pump Clearances (Before Test)

Clearance Between Rotors ______________

Clearance Between Rotor and Housing ________

Build-Up Engine Measurement Specitications cm (inches)

Valve Head Relation to Cylinder Head	Flush to 0.060 (0.024) Below Cylinder Head Surface
Crankshaft Thrust Washer Thickness	0.2975 to 0.3050 (0.1190 to 0.1220)
Crankshaft End Play	0.0100 to 0.0275 (0.0040 to 0.0110)
Oil Pump Clearance Between Rotors	0.0100 to 0.0275 (0.0040 to 0.0110)
Oil Pump Clearance Between Rotor and Housing	0.0025 to 0.0088 (0.0010 to 0.0035)

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DATE________________ TEST NO________________ TECHNICIAN________________

LUBRICANT________________ FUEL________________

6V-53T MAIN BEARING SHELL AND BEARING JOURNAL DIAMETERS AND CLEARANCES

MAJOR REBUILD ONLY

	BEFORE TEST						AFTER TEST			
	Bearing Journals		Bearing Shells		Clearances		Bearing Journals		Bearing Shells	
	A*	B	F	BA	Min.	Max.	A	B	F	BA
1										
2										
3										
4										

*A: Micrometer anvil parallel to weights F: Front

B Micrometer anvil perpendicular to weights BA: Back

6V-53T CONNECTING ROD BEARING SHELL AND BEARING JOURNAL DIAMETERS AND CLEARANCES

	BEFORE TEST						AFTER TEST			
	Bearing Journals		Bearing Shells		Clearances		Bearing Journals		Bearing Shells	
	A*	B	F	BA	Min.	Max.	A	B	F	BA
1L										
2L										
3L										
1R										
2R										
3R										

Build-Up Engine Measurement Specifications cm (inches)

	NEW	LIMIT
Main Bearing Journal Diameter	8.6225 to 8.7500 (3.4990 to 3.5000)	
Main Bearing Shell Inside Diameter (vertical axis)	8.7575 to 8.7600 (3.5030 to 3.5040)	
Main Bearing Shell to Journal Clearance	0.0076 to 0.0127 (0.0030 to 0.0050)	0.0150 (0.0060)
Connecting Rod Bearing Journal Diameter	6.8725 to 6.8750 (2.7490 to 2.7500)	
Connecting Rod Bearing Shell Inside Diameter (vertical axis)	6.8778 to 6.8750 (2.7511 to 2.7500)	
Connecting Rod Bearing Shell to Journal Clearance	0.0028 to 0.0102 (0.0011 to 0.0041)	0.0150 (0.0060)

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DATE____________ TEST NO____________ TECHNICIAN____________

LUBRICANT____________ FUEL____________

6V-53T CAMSHAFT BEARING SHELL AND BEARING JOURNAL DIAMETERS
BEARING SHELL MEASURING GAUGE SET AT 5.435 cm (2.175 inches)

LEFT CAMSHAFT

		BEFORE TEST				AFTER TEST			
		Journal		Bearing		Journal		Bearing	
Major rebuild only	1								
	2								
	3								
	4								

RIGHT CAMSHAFT

		BEFORE TEST				AFTER TEST			
		Journal		Bearing		Journal		Bearing	
Major rebuild only	1								
	2								
	3								
	4								

Build-Up Engine Measurement Specifications	cm	(inches)
Camshaft Bearing Journal Diameter	5.4550-5.4562	(2.1820 to 2.1825)
Camshaft Bearing Shell Inside Diameter	5.4675-5.4700	(2.1870 to 2.1880)
Camshaft Bearing Shell to Journal	0.0113-0.0150	(0.0045 to 0.0060)

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TEST NO. ________

6V-53T 240-HOUR CHECKLIST

Initials	Task
________	Fill out page 1 of Before Test and After Test Data Sheets.
________	Measure and record ring end gap, and side clearance and upper oil control ring tensions.
________	Measure and record cylinder liner inside diameter (installed).
________	Measure and record piston-cylinder liner clearance.
________	Measure and record piston pin–piston bushing clearance and piston pin-rod bushing clearance.
________	Measure and record block bore diameter.
________	Measure and record valve depth.
________	Check valve clearances and replace valves and guides out of specification. Replace valves after three runs.
________	Measure and record connecting rod bearing shell and bearing journal diameters and clearances.
________	For major rebuilds only - measure and record oil pump clearances, crankshaft thrust washer thickness and crankshaft end play.
________	For major rebuilds only – measure and record main bearing shell and bearing journal diameters and clearances.
________	For major rebuilds only - measure and record camshaft bearing shell and bearing journal diameters.
________	Calibrate tachometer.
________	Calibrate flowmeter.
________	Calibrate load system.
________	Calibrate temperature indicators.
________	Calibrate pressure indicators.
________	Deaerate engine and drain flush oil.
________	Fill engine with reference oil.
________	Break in engine.
________	Adjust governor, injector timing, and valve clearance.
________	Run and record initial power calibration check.
________	Run shake down.
________	Perform airbox inspection (optional).
________	Drain oil and add 19 L (five gallon) flush oil.
________	Run flush cycle - 30 minutes at 1200 rpm and 30 #FT.
________	Drain oil.
________	Perform air box inspection.
________	Weight new filter, blowby canisters and initial fill.
________	Run test cycle, weigh samples and adds.
________	Perform after-test full load performance determination.
________	Drain and weigh oil, filter, and blowby cans.
________	Measure and record cylinder liner inside diameter.
________	Disassemble engine stamping liners and pistons.

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Initials	Task
________	Measure and record pistcn pin to piston hushing clearance and piston. pin to rod bushing clearance.
________	Measure and record connecting rod, bearing shell, and bearing rod journal clearances.
________	Major rebuild only - measure and record main bearing shell and bearing journal diameters and clearances.
________	Major rebuild only – measure and record camshaft bearing shell and bearing journal diameters.
________	Rate engine for deposits.
________	Measure and record ring end gap.
________	Photograph engine parts.

6V-53T 240-HOUR ENDURANCE TEST LUBRICANT CONSUMPTION RECORD

Date Started ____________ Test No. ____________ Fuel ________________

Date Finished ____________ Lubricant ________________

Approximate Consumption kg (lb)

Weight of Initial Fill		________
Weight of 120-hour Fill	+	________
Total Weight of Additions	+	________
Total Weight of Oil Added	=	________

Weight of 120-hour Drain		________
Weight of Final Drain	+	________
Total Weight of Samples	+	________
Total Weight of Oil Removed	=	________

		0-120 hr	120-240
Weight of Used Oil Filter			
Weight of New Oil Filter	-		
Weight of Oil in Filter	=		
Total Weight of Oil in Filters	=		
After Test Blowby Can Weight			
Before Test Blowby Can Weight	-		
Total Weight of Oil in Blowby	=		
Total Weight of Oil Added			
Total Weight of Oil Removed	-		
Total Weight of Oil in Filters	-		
Total Weight of Oil in Blowby	-		
Total Weight of Oil Consumed	=		

Average Oil Consumption Rate ________ lbs/hr

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6V-53T 240-HOUR ENDURANCE TEST LUBRICANT CONSUMPTION RECORD
(DOES NOT INCLUDE INITIAL AND 120 HOUR FILLS)

Date Started ______________ Test No. ______________ Fuel ______________

Date Finished ______________ Lubricant ______________

		Lubricant Additions			Lubricant Samples			Lubricants Consumed	
Test Hour	Technician	Col 1 Oil Before Add	Col 2 Oil After Add	Col 3 Change (Col 2 - Col 1)	Col 4 Bottle Wt	Col 5 Bottle & Sample Wt	Col 6 Oil Sample (5 - 4)	Oil Sample Consumed (3 - 6)	Total Oil Consumed*
20									
40									
60									
80									
100									
120									
140									
160									
180									
200									
220									
240									

Ttl Wt Additions: ______________ Ttl Wt of Samples: ______________

*During test, average oil consumption is approximated by Total Oil Consumed divided by Test Hour.

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DATE ____________ TEST NO. ____________ TECHNICIAN ____________
LUBRICANT ____________ FUEL ____________ TEST HOURS ____________

6V-53T AIRBOX INSPECTION SHEET

INTAKE PORTS
RING LANDS
lL RINGS
PISTON SKIRTS
CYLINDER LINER

INTAKE PORT'S
RING LANDS
2L RINGS
PISTON SKIRTS
CYLINDER LINER

INTAKE PORTS
RING LANDS
3L RINGS
PISTON SKIRT'S
CYLINDER LINER

INTAKE PORTS
RING LANDS
lR RINGS
PISTON SKIRTS
CYLINDER LINER

INTAKE PORTS
RING LANDS
2R RINGS
PISTON SKIRTS
CYLINDER LINER

INTAKE PORTS
RING LANDS
3R RINGS
PISTON SKIRTS
CYLINDER LINER

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APPENDIX E

RATING SHEETS

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DETROIT DIESEL 6V-53T EVALUATION

Rating of Engine Deposits and Parts Condition

Oil Code ______________________ Test Number ______________________
Fuel ______________________ Test Stand ______________________
End-of Test ______________________ Hours Completed ______________________

I. Cylinder Liners

A. Intake Ports

INTAKE PORT PLUGGING

Cylinder No.	percent Intake Port Restriction
lL	
2L	
3L	
1R	
2R	
3R	
Average 6	
Average w/o ____	
____ Changed Out @ ____ Hours	

B. Liner Scuffing

CYLINDER LINER

Percent of Total Ring Travel Area

Cylinder Number	Percent Scuffed T	Percent Scuffed AT	% Avg. Avea Scuffed	Percent Bore Polished T	Percent Bore Polished AT	% Average Area Bore Polish
1L						
2L						
3L						
1R						
2R						
3R						
Average 6						
Average w/o						
____ Changed Out @ ____ Hours						

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6v-53T RING FACE DISTRESS

Test No. ______________________ Lubricant ______________________

Fuel ______________________ Date ______________ Observer ______________

Clinder No.	Ring No.	Heavy Distress (0.75)		Medium Distress (0.50)		Light Distress (0.25)		
		% Area	Demerit	% Area	Demerit	% Area	Demerit	Total Demerit:
1L	1							
	2							
	3							
	4							
2L	1							
	2							
	3							
	4							
3L	1							
	2							
	3							
	4							
lR	1							
	2							
	3							
	4							
2R	1							
	2							
	3							
	4							
3R	1							
	2							
	3							
	4							
________ Changed Out @ ____Hrs	1							
	2							
	3							
	4							

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DETROIOT DIESEL 6V-53T EVALUATION (Continued)

Ratings of Engine Deposits and Parts Condition

II. Pistons

A. Ring Face Distress

Cylinder Number	Fire Ring No. 1	No. 2	No. 3	No. 4
1L				
2L				
3L				
1R				
2R				
3R				
Average 6				
Average 5 w/o				
Average 6 of Ring Nos. 2 and 3				
Average 5 of Ring Nos. 2 and 3				
____ Changed out @ Hrs.				

Number denote demits due to % of area exhibiting various levels of ring face distress.

B. Condition of Rings in the Groove

Cylinder Number	Fire Ring No. 1	No. 2	No. 3	No. 4
1L				
2L				
3L				
1R				
2R				
3R				
_ Changed Out @ ____ Hours				

Numbers denote % of ring circumference, Hot Stuck (HS), Cold Struck (C S), or Collapsed (C).

C. Piston Skirt Rating

cylinder Number	Thrust	Anti-Thrust
1L		
2L		
3L		
1R		
2R		
3R		

Numbers denote % of area covered by scratching, scuffing, scoring or plate melt.

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CRC DIESEL RATING SYSTEM

6V-53T Computation Sheet for Piston Rating

Test Hours ______________ • Rater ____________ Date ____________ Piston No. ____________
Test Laboratory ______________ Laboratory Test Number ____________
Lubricant ______________

No. 1 Groove, Volume % ____________
Piston WTD* Rating ____________

Deposit Type	Deposit Factor	Grooves								Lands							
		No. 1		No. 2		No. 3		No. 4		No. 1		No. 2		No. 3		No. 4	
		A,%	Dem	A,%	Dem	A,%	Dem	A,%	Dem	A,%	Dem	A,%	Dem	A,%	Dem	A,%	Dem
HC	1.00																
MC	0.50																
LC	0.25																
Carbon Rating																	
BL	0.100																
DBrL	0.075																
AL	0.050																
LAL	0.025																
Lacquer Rating																	
CLEAN	0																
Zonal Rating																	
Location Factor																	
Weighted Rating																	

*Weighted Total Deposits

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EXHAUST VALVE SURFACE CONDITIONS

Test No. ____________

Engine Model ____________ Serial No. ____________ Date ____________

Fuel ____________ Lubricant ____________ Observer ____________

	1L	2L	3L	1R	2R	3R
Freeness in Guide						
Head						
Face						
Seat						
Stem						
Tip						

See pages 1, 2, 16 through 23, and 54 through 65 of CRC Manual No. 5.

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VALVE AND COMBUSTION CHANGER DEPOSITS

Test No. ____________

Engine Model ____________________ Serial No. ____________________ Date ____________________

Fuel ____________________ Lubricant ____________________ Observer ____________________

		VALVE DEPOSIT RATING											
		1L		2L		3L		1R		2R		3R	
		Carb	Lacq	Carb	Lacq	Carb	Lacq	Carb	Lacq	Carb	Lacq	Carb	Lacq
Head*	EXH		---		---		---		---		---		---
Face	EXH		---		---		---		---		---		---
Tulip**	EXH		---		---		---		---		---		---
Stem	EXH												

Combustion Chamber Deposits (Abnormalities Only) ____

____

____

* Carbon and Ash: Use Volume Factor Technique (Pages 5 and 40 through 47 of CRC Manual No. 5).

** Use Chart, Page 21 - indicate H, M, or S (Page 5).
Lacquer: Pages 4, 36, and 37.

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DETROIT DIESEL 6V-53T EVALUATION

Test No. ____________

Date ________________

Lubricant ____________________________ Observer ____________________________

TAPPETS, CAMS AND ROCKER ARM CONDITION
(Abnormalities Only)

BEARING AND JOURNAL SURFACE CONDITION
(Abnormalities Only)

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APPENDIX F

LUBRICANT ANALYSIS

	Test Method	New Oil	Test Hour											
			20	40	60	80	100	120	140	160	180	200	220	240
Viscosity at 40° C	D 445	X			X			X			X			X
Viscosity at 100° C	D 445	X			X			X			X			X
TAN	D 664	X			X			X			X			X
TBN	D 664	X			X			X			X			X
Pentane B Isolubles	D 893	X			X			X			X			X
Toluene B Insolubles	D 893	X			X			X			X			X
Flash Point	D 92	X												X
Fuel Dilution	D 3524		X					X						X
Fe	a	X	X	X	X	X	X	X	X	X	X	X	X	X
Cu	a	X	X	X	X	X	X	X	X	X	X	X	X	X
Pb	a	X	X	X	X	X	X	X	X	X	X	X	X	X
Cr	a	X	X	X	X	X	X	X	X	X	X	X	X	X
Al	a	X	X	X	X	X	X	X	X	X	X	X	X	X

---

a = by any of the following methods: AA, XRF, emission spec.

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APPENDIX G
6V-53T

TEST NO.: ____________

LUBRICANT: ______________

WEAR MEASUREMENTS

Cylinder Liner Bore Diameter Change*

Cylinder Number

	1L		2L		3L	
	T-AT**	F-B	T-AT	F-B	T-AT	F-B
Top						
Middle						
Bottom						

Cylinder Number

	1R		2R		3R	
	T-AT**	F-B	T-AT	F-B	T-AT	F-B
Top						
Middle						
Bottom						

	Average Change		Changed Out @ ______ Hours	
	T-AT	F-B	T-AT	F-B
Top				
Middle				
Bottom				

Overall Average Change: ____________

Piston Ring End Gap Change

Ring Number	1L	2L	3L	1R	2R	3R	Average Change
1							
2							
3							
4							
5							
6							
7							

Overall Average Change: ____________

* All dimensions given are in cm (inches).

** T-AT = Thrust - Anti-Thrust Direction, F-B = Front-Back Direction.

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c. Remove the fuel reservoir cap, pour approximately 30 mL of toluene into the reservoir, and replace the cap.
d. Open the fuel pressure shutoff valve and adjust the fuel pressure regulator to 6.9 gage kPa.
e. After placing a suitable receptacle under the fuel drain spout, open the fuel drain valve and allow approximately 15 mL of solvent to flow out, then close the valve.
f. Open the spray nozzle valve and allow the remaining solvent to flow through the fuel flow meter and the spray nozzle.
g. Repeat steps a through f using n-hexane.
h. Following step g open the fuel drain valve and permit air to flow through the entire system for at least five minutes.
i. After completing the procedure of step h, close the following valves: fuel drain, spray nozzle, fuel pressure, air flow meter, and cooling water.

6.3 Preparation of the fuel sample. Using a standard millipore filter setup, filter 150 mL or more of the fuel sample through the 10-micrometer PTFE (Teflon) membrane (No. LCWP04700) without using a vacuum. (Note: The primary purpose of filtration is to remove fuel contamination larger than 10 microns which can cause spray nozzle plugging.)

6.4 Evaluation of the Fuel Sample. Complete all the steps listed under 6.2 before evaluating the fuel sample.

a. Remove the fuel reservoir cap and introduce approximately 30 mL of the pre-filtered gasoline sample into the reservoir and reinstall the reservoir cap.
b. Adjust the air pressure regulator to 83 gage kPa and open the air flow meter valve until the float is centered on the flow meter scale.
c. Open the fuel pressure shutoff valve and adjust the fuel pressure regulator to 6.9 gage kPa.
d. Open the fuel drain valve. After 10 mL of gasoline have passed through, close the valve.
e. Open the spray nozzle valve until the fuel flow meter indicates a flow of 100. After 10 mL of fuel have passed through close the spray nozzle valve.
f. Reopen and close the fuel drain valve momentarily to remove any remaining air.
g. Close the fuel pressure shutoff valve and remove the fuel reservoir cap.
h. Add a sufficient quantity of the gasoline sample to the reservoir to bring the level up to the 100 mL mark on the reservoir and replace the fuel reservoir cap.
i. Open the fuel pressure shutoff valve and adjust the fuel pressure regulator to 6.9 gage kPa.

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j. Place the deposit tube balder in the deposit chamber.

k. Remove the tared aluminum deposit tube from the desiccator and carefully position the tube in the deposit chamber taking care not to touch the tube with bare hands.

l. After connecting the heating rod to the receptacle, insert the rod into the aluminum deposit tube until it barely contacts the tube holder on the other end.

m. Install the spray nozzle and deposit tube thermocouples in the appropriate jacks and probe holes. (Note: The deposit tube thermocouple probe hole must be facing the spray nozzle.)

n. Turn on the main power switch and adjust the temperature control so that deposit tube temperature of 190° +3° C is established, then open the cooling water valve to insure that the spray nozzle temperature will not exceed 24° C.

o. After the deposit tube temperature has stabilized at 190° +3° C, open the spray nozzle valve until the proper flow rate of 2 mL/min is obtained. (Note: This flow rate is extremely critical since the total test duration must not exceed 50 +3 min for a valid test.) Record as the starting time for the test the moment when the spray nozzle valve is opened.

p. Carefully maintain the air, fuel, and tube-temperature levels until the 100 mL portion of the gasoline sample has been expended. Then close the spray nozzle valve and record the time of closure as the end of the test.

q. Maintain the temperature of the deposit tube at 190° +3° C for an additional 10 minutes, then turn off the power switch. Allow the temperature to fall to 120° C or less.

r. After removing the deposit-tube thermocouple and heating element, replace the thermocouple in the deposit tube to permit monitoring of the tube temperature down to 38° C. Then remove the thermocouple from the deposit tube.

Carefully remove the deposit tube and its holder from the deposit chamber, then dip the deposit tube consecutively in two separate beakers of n-hexane for 15 seconds each. (Note: This hexane rinse will remove any fuel dyes or other napththa-soluble residue that sould not be used in the total ISD value.)

t. Place the deposit tube in an oven maintained at 100° +3° C for at least 15 minutes.

u. Remove the deposit tube from the oven and place it in a desiccator for at least four hours.

v. Remove the deposit tube from the desiccator and weigh it. Then replace the tube in the desiccator. Repeat the procedure until two consecutive weighings yield identical values.

7. CALCULATIONS

7.1 Calculate the ISD Index as follows:

$$ISD_T = W_f - W i$$

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Where:

ISD_T = Induction System Deposit at test temperature (T) in mg/100 mL

W_f = Final weight of the deposit tube in mg

W_i = Initial weight of the deposit tube in mg

8. REPORTING

8.1 Report the ISD Index as mg/100 mL.

9. PRECISION

9.1 Repeatability - The results should not vary more than +2 mg within lab.

9.2 Reproducibility - Not yet determined.

Method Prepared by:

Army - ME - 1986

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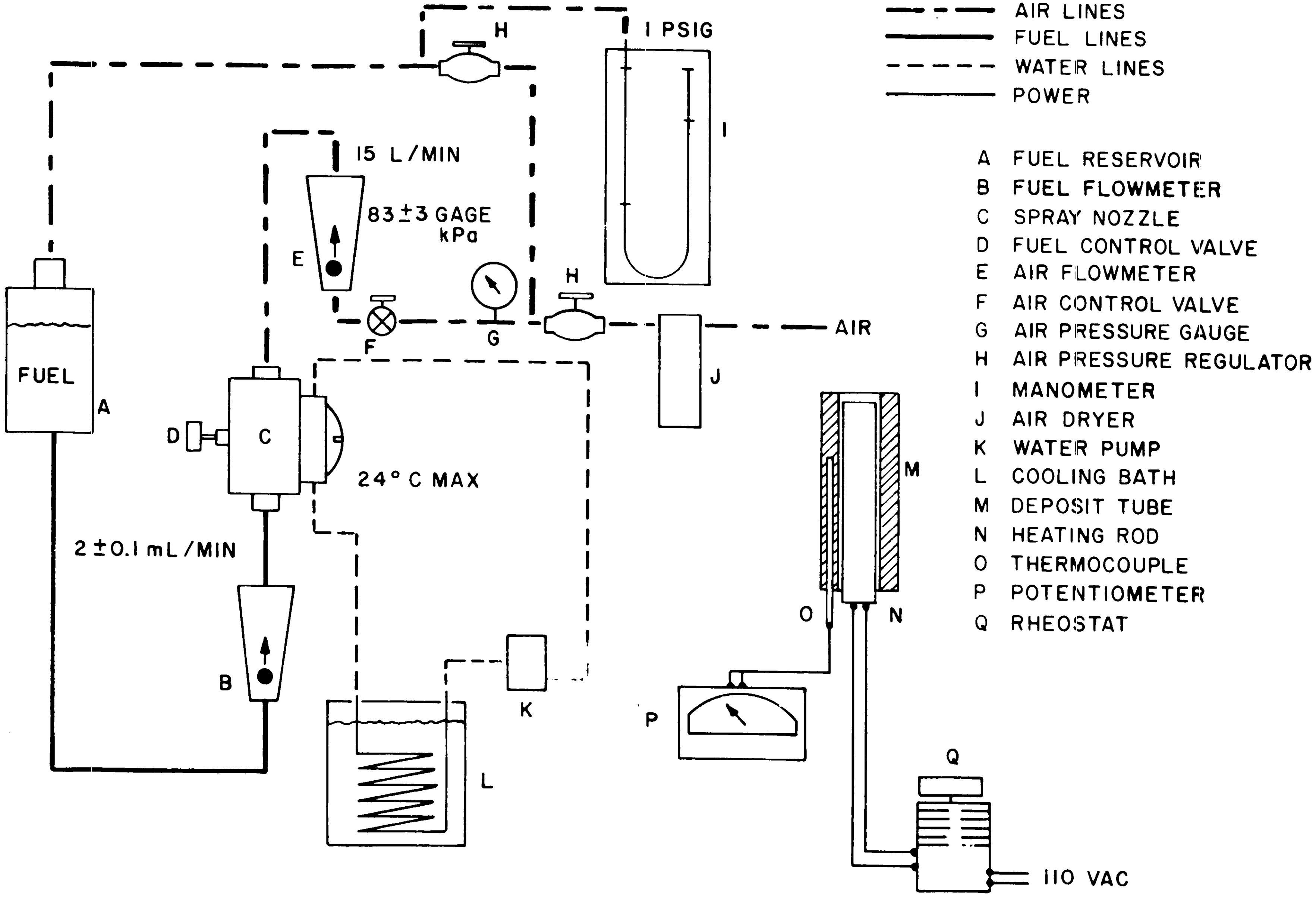
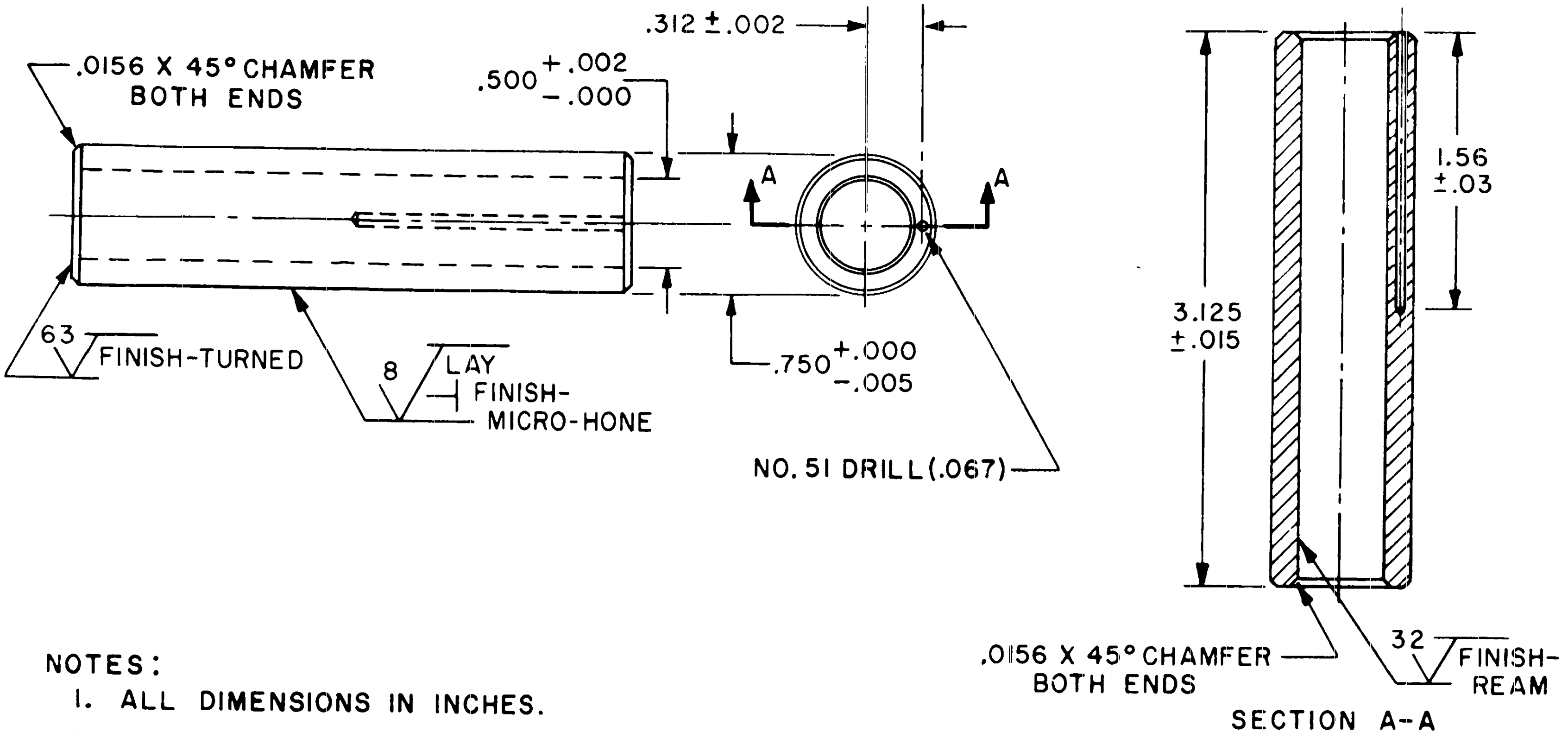


FIGURE 1. Schematic of ISD apparatus plumbing and power.

X-4363



NOTES:

1. ALL DIMENSIONS IN INCHES.
2. MATERIAL: S.A.E. 6061-T6 ALUMINUM.
3. FINISH: ALL SURFACES FINISHED AS INDICATED BY A.S.A. B-46.1 FINISH NOMENCLATURE-PART TO BE FREE FROM BURRS, SCRATCHES AND OTHER SURFACE IMPERFECTIONS.
4. SHIPPING: PART TO BE INDIVIDUALLY PACKED FOR SHIPMENT IN A CLEAR PLASTIC TUBE.
5. DEPOSIT BAR: SUB-ASSEMBLY OF INDUCTION SYSTEM DEPOSIT BENCH APPARATUS.

FIGURE 2. Deposit sample tube.

X-4364

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EMULSIFICATION TENDENCIES OF PETROLEUM FUELS BY MULTIPLE CONTACT EXTRACTIONS

1. SCOPE

1.1 This method is used for determining the emulsification tendencies of petroleum fuels resulting from contact with the water bottoms usually found in fuel storage environments.

2. SUMMARY

2.1 A sample composed of water and test fuel is placed in a sealed bottle and subjected to a cycle consisting of shaking, settling, rating, siphoning, and addition of fresh fuel. The appearance of the fuel-water interface is reported after the settling period. A total of ten complete cycles is required.

3. SAMPLE SIZE

3.1 Approximately 1.1 L of the fuel to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Bottle, oil sample, 125-mL capacity (Kimble No. 60520L or equal), with No. 24 plastic screw cap.

4.2 Gasket material, fluorocarbon vulcanizate (Viton or equal), 0.16 cm thick sheet stock, cut to the I.D. of the No. 24 screw cap (approximately 2.1 cm).

4.3 Syringe, B.D., Luer-Lok, 100-mL capacity.

4.4 Syringe needle, Teflon (or equal), with Kel-F (or equal) hub, 16-gauge, 30.5 cm (12-in.) length (Hamilton No. KF16TF or equal).

4.5 Mechanical reciprocating shaker device (Equipoise Heavy-Duty or equal).

4.6 Graduated cylinder, 100–mL capacity.

5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammabilitY, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Cleaning solution glass. Concentrated sulfuric acid [3,0,2] saturated with technical grade potassium bichromate [1,0,1].

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5.3 Distilled or deionized water.

6. PROCEDURE

6.1 Immerse the oil sample bottle in the acid-bichromate cleaning solution, rinse it with tap water followed by distilled or deionized water, and allow it to drain until dry. If the bottle is still not clean, soak it in hot cleaning solution for 30 minutes. Rinse it with tap water followed by distilled or deionized water, and allow it to drain until dry.

6.2 Pour 10 mL of distilled or deionized water into the sample bottle. Carefully add 100 mL of the fuel to be tested and seal the bottle with the screw cap lined with a Viton gasket.

6,.3 Place the sample bottle in the mechanical shaker in an upright position and shake it for 15 minutes. Remove the bottle and allow it to remain at 25° + 3° C, undisturbed in darkness for 24 hours (or 72 hours during a weekend period).

6.4 After positioning the sample bottle on a flat surface with adequate lighting, rate and report the condition of the fuel-water interface in accordance with Table 1.

TABLE 1. <u>Appearance of interface</u>.

Rating	Appearance
0	Clean break at fuel-water interface.
1	Very slight “skin” at fuel-water interface.
2	Skin at fuel-water interface, heavier than #1.
3	First sign of white emulsion forming at fuel-water interface.
4	Emulsion occurring at interface and starting into water layer.
5	Slightly more emulsion than #4 and with thin film on sides of bottle.
	Emulsion on bottom layer, water still visible-
7	Semi–solid emulsion with bubbles (assuming a sponge–like configuration).
8	Same emulsion as #7, but smaller bubbles.
9	Almost a solid emulsion.
10	Solid emulsion resembling mayonnaise.

6.5 After rating the condition of the fuel-water interface, carefully remove approximately 95 mL of the fuel using the 100-mL syringe fitted Teflon needle. (Note: In removing the fuel, be careful not to disturb the fuel-water interface or the water bottom.)

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6.6 Carefully add a fresh 95 mL sample of the fuel to be tested and seal the sample bottle with the plastic screw cap as before.

6.7 Repeat the shaking, settling, rating, and siphoning steps as described in 6.3 through 6.6 until ten cycles (or extractions) have been performed.

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Report interface ratings as measured above. A rating of 3 or greater, denoting the presence of water-reactive impurities is considered unsatisfactory. The initial formation of these stable interracial emulsions are indicative of potential filter–plugging and storage problems.

9. PRECISION

9.1 Precision data have not been developed for this method.

Method Prepared By:

Army - ME - 1986

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QUENCHING SPEED

1. SCOPE

1.1 This method is used to determine the quenching speed or rate of heat removal provided by quenching oils.

2. SUMMARY.

2.1 The test consists of immersing heated steel test bars in samples of the test quench oil. From temperatures recorded during the test procedure the quenching speed of the oil is calculated.

3. SAMPLE SIZE.

3.1 Approximately 4.5L (1.2 gal) of quenching oil to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 One electric timer, graduated in 1/10 seconds.

4.2 Two containers, insulated with 5.1 cm (2 inches) of insulation, approximately 30.5 cm (12-inches) deep and 11.4 cm (4-1/2 inches) wide (inside dimensions).

4.3 One stirrer, electric, of proper size to stir contents of containers.

4.4 One thermometer, 0°-1000 C, with 1/10 degree graduations.

4.5 One furnace, controlled atmosphere, capable of being controlled at 816° +14° C (1500° ±25° F).

4.6 One hook, steel, approximately 0.64 cm (1/4-inches) diameter by approximately 1.2 m (4 foot) long (to lift and carry test bars).

5* MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Five steel test bars, made from steel meeting the requirements of QQ-S-631, Steel No. 1050, approximately 2.5 cm (1 inch) diameter by 6.4 cm (2-1/2-inches) long, with loop on one end, scale free, weighing 250 ±5 g.

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5.3 Abrasive paper, 280 grit (P-P-l2l).
5.4 1,1,1-Trichlorethane (0-T-620) [2,1,0].
5.5 Facial tissue (UU-T-450).

6. PROCEDURE

6.1 Polish all five steel test bars with 280 grit abrasive paper to a uniform finish. Place the five test bars in the furnace and permit them to remain for at least one hour. The atmosphere in the furnace must be so controlled as to prevent the formation of carbon smut or scale. Clean the inside of the two insulated containers with 1, 1, 1-trichlorethane and facial tissue. Place 2000 ±10 mL of the quenching oil under test in each of the containers. The oil must Be at the temperature of the furnace room. Number the containers 1 and 2. Place the stirrer in container 1 and stir until the oil has reached a constant temperature. Record the temperature of the oil in this container. Turn off the stirrer. Remove one of the test bars from the furnace using the hook and vertically immerse the test bar beneath the surface of the oil. Start the stirrer and record the highest temperature obtained.

6.2 Place the stirrer in position in the second container and stir until the oil has reached a constant temperature. Record the temperature of the oil in this container and turn off the stirrer. Remove 1 test bar from the furnace and plunge it vertically beneath the surface of the unagitated oil. Hold the test bar in the oil for 5 ±0.10 seconds. Remove the bar from the oil and start the stirrer. Operate the–stirrer for approximately 15 seconds. Stop the stirrer and plunge the third test bar into the oil. Repeat this sequence until all of the test bars have been quenched. Record the total rise in temperature for the 4 test bars. The total rise in temperature produced by the four test bars quenched in container 2, divided by 4 gives the average temperature rise for each 5 second test.

Note 1. Speed and timing are essential in order to avoid heat losses. Stirring should note be violent, only sufficient to produce a uniform temperature.

7. CALCULATIONS.

7.1 Calculate the quenching speed of the oil by the following formula:

$$\text{Quenching speed} = \frac{a \text{X} 100}{b}$$

where: a = the average rise in temperature produced by the four test bars quenched in container 2.
b = temperature rise produced by the fully quenched test bar (quenched in container 1).

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8. REPORTING

8.1 Report the calculated quenching speed of the test oil.

9. Precision

9.1 Precision data have not been developed for this method.

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METHOD 1151.2
September 30, 1986

EXPLOSIVE VAPORS IN BOILER FUEL OIL

1. SCOPE

1.1 This method is used for determining the approximate percent explosiveness of gas and vapor mixture given off by fuel oil.

2. SUMMARY

2.1 The test consists of measuring the explosiveness of fuel-oil vapors produced under specified conditions, using a hot-wire type combustible-gas indicator that has been calibrated against a hydrocarbon gas of known explosiveness.

3. SAMPLE SIZE

3.1 Approximately 1 L (1 quart) of oil representative of the lot to be tested.

CAUTION

The one sample is to have been immediately stoppered (allowing a minimum of air space) upon removal from the lot.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Indicator, combustible-gas, hot-wire (Explosimeter Model No. 2, Mine Safety Appliances Co., Pittsburgh, Pa., or equivalent).

4.2 Flask, volumetric, 2-L, with 2-hole rubber stopper.

4.3 Graduated cylinder, 100-ML.

4.4 Tank, water (deep enough to accommodate 2-L volumetric flask and 100-mL graduated cylinder.).

4.5 Tube, drying, containing anhydrous calcium chloride.

4.6 Bulb, aspirator.

4.7 Vapor generating apparatus (Figure 1), consisting of:

a. Bottles (2), glass, l-quart widemouth.
b. Stopper, rubber, 2-hole (for l-quart bottle).
c. Stopper, rubber, 3-hole (for l-quart bottle).
d. Thermometer, 40° to 82° c (100° tO 180° F) (ASTM E 1).
e. Tube, outlet, copper, approximately 3/16-inch OD, sealed at one end with approximately l/8-inch hole, 1/2 inch from sealed end.

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f. Tubing, glass and rubber, as required.
g. Clamp, screw (for rubber tubing). Bath heating, water, 66° to 69° c (150° to 155° F).

4.9 Compressed-air supply.

5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Gas, hydrocarbon, with known lower limit of explosiveness (in volume percentage of gas concentration).

6. PROCEDURE

6.1 Prepare the 2-hole rubber stopper (for the volumetric flask) by inserting a short length of glass tubing in one hole and the sealed end of the copper outlet tube, used in figure 1, in the other hole. Position the outlet tube so that the stopper seals the side opening of the tube; seal the outside end of the glass tube with a short length of rubber tubing and a screw clamp.

6.2 Prepare an air-gas mixture of 50 percent explosiveness (for use in calibrating the combustible-gas indicator), as follows:

a. Compute the volume of hydrocarbon gas (see. 5.2) required to produce a 2-L air-gas mixture of 50–percent explosiveness.
b. Place approximately 500 mL of water in the 2-L volumetric flask, and invert in the water tank.
c. Measure the required amount of hydrocarbon gas, using an inverted waterfilled 100-mL graduated cylinder supported in the water tank so it will contain the computed volume of gas when the water levels in the graduate and the tank are the same.
d. Transfer the gas to the volumetric flask by carefully raising the lip of the graduate beneath the neck of the submerged flask.
e. Add air to the volumetric flask until the water levels (inside and outside) are at the graduation mark.
f. Insert the prepared 2-hole stopper (see 6.1) into the volumetric flask taking care to maintain the water seal of the gas mixture. Remove the flask from the tank and invert several times.

6.3 Calibrate the combustible-gas indicator by passing the air-gas mixture through the indicator and noting the reading as follows:

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a. Fill one of the quart bottles about half full of water, and insert its 2-hole stopper (and tubing) as indicated for bottle A of Figure 1.
b. Connect the water-filled bottle to the rubber tubing on the volumetric flask.
c. Connect the copper outlet tube to the drying tube, and the drying tube to the combustible-gas indicator. Adjust the indicator needle to zero.
d. Reposition the copper outlet tube so that its side opening is exposed to the air-gas mixture, and apply low–pressure air to the water-filled bottle.
e. Adjust the screw clamp to produce a uniform flow of water of approximately 500 mL in 20 seconds, and record reading at which the indicator becomes stable.

6.4 Prepare the sample as follows:

a. Fill one of the quart bottles (bottle B) half full of test sample.
b. Insert the 3-hole stopper with its inlet tube, outlet tube, and thermometer. position the outlet tube so that its side opening is covered by the stopper. Seal the inlet tube with a short length of rubber tubing and a screw clamp. Position the thermometer so that its bulb is approximately centered in the test sample.
c. Immerse the bottle (containing the sample) in the heating bath so that the level of the sample is below the level of the bath, and allow the sample to reach approximately 52° C (125° F). During the immersion (approximately 5 minutes) shake occasionally to insure even heating.

6.5 Test the explosiveness of the gas and vapor mixture of the sample as follows:

a. When the temperature of the sample reaches 52° C (125° F), remove the bottle and shake vigorously for a total of 5 minutes, with periodic immersions of the bottle in the water bath to maintain the fuel oil temperature at 52° C (125° F).
b. Fill bottle A approximately one–half full of water at about 52° C (125° F) and as soon as bottle B has been shaken for 5 minutes, connect the two bottles as shown in Figure 1.
c. Connect the outlet tube to the combustible-gas indicator, zero the indicator needle, and push the copper outlet tube down to expose its opening to the vapors in the bottle.
d. Apply low-pressure air to bottle A. Then while observing the indicator needle, slowly open and adjust the screw clamp to permit the water to flow into the sample-filled bottle at a uniform rate over a period of approximately 20 seconds. When the reading becomes constant, stop the flow, and record the reading.

CAUTION

Do not allow fuel oil to flow into the combustible-gas indicator.

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7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Report the sample as having passed if its combustible-gas indicator reading does not exceed the reading for the hydrocarbon gas.

9. PRECISION

9.1 Precision data have not been developed for this method.

Method Prepared By:

Navy - SH - 1986

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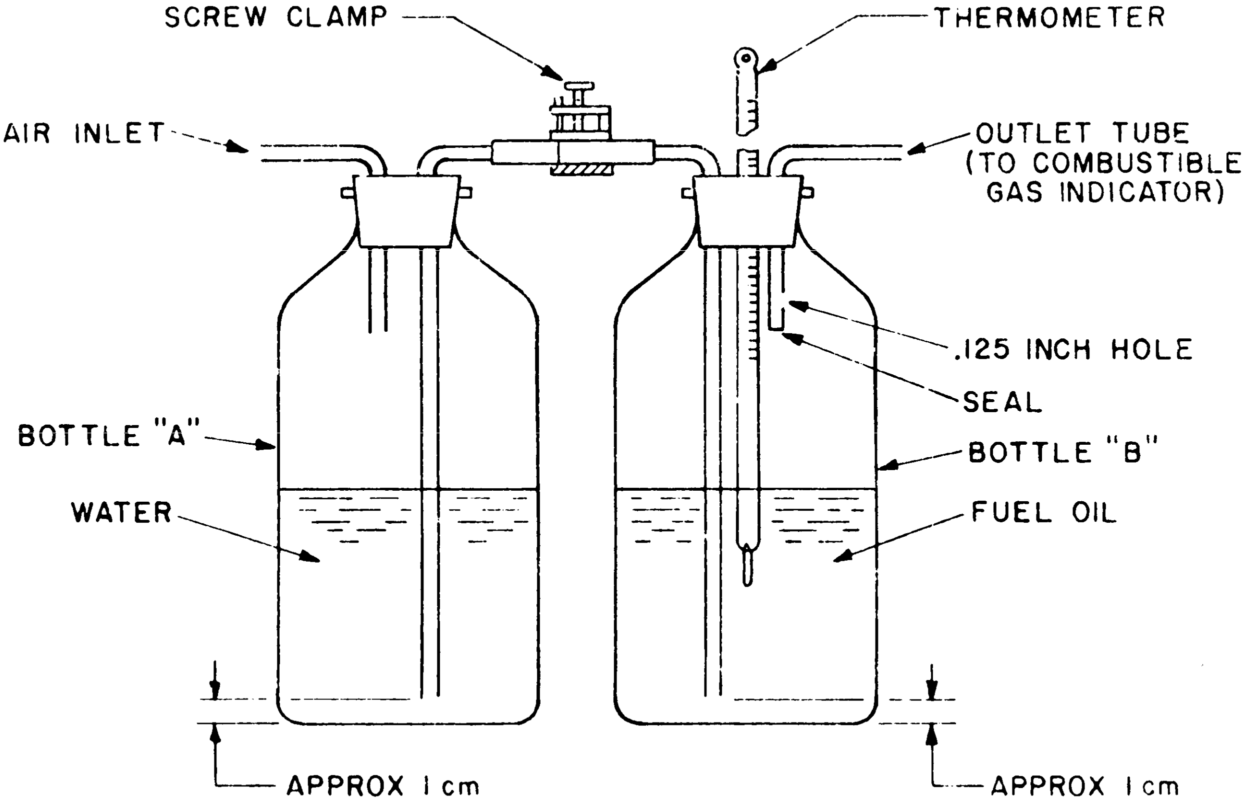

FIGURE 1. Vapor generating apparatus,

X-4365

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FLOCK POINT

(Refrigerant Compressor Oil)

1. SCOPE

1.1 This method is used for determining the temperature (flock point) at which wax or solids in refrigerant compressor oil will precipitate (form flock).

2 SUMMARY

2.1 The test consist of cooling the specimen to -35° C (-300 F), mixing it with refrigerant, allowing it to warm until the mixture is homogeneous, then retooling it until flocculent material forms.

3. SAMPLE SIZE

3.1 Approximately 1 mL of oil to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Test tube, borosilicate, 15-mL, 0.1 mL graduations fitted with one-hole cork stopper.

4.2 Cooling bath, approximately -73° C (-100° F) (dry ice in denatured ethyl alcohol).

4.3 Thermometer, low cloud and pour (ASTM E 1).

5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Refrigerant, Freon-12 or equivalent [u,u,u].

6. PROCEDURE

6.1 Fit thermometer into hole in stopper.

6.2 Place 1.0 mL of sample into clean, dry test tube, and insert stopper so that thermometer bulb is immersed in sample.

6.3 Cool sample to -35° C (-30 F).

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6.4 Unstopper tube, and add refrigerant to the 10.1-mL graduation. Restopper tube, and wrap it in several layers of toweling as a precautionary measure.

6.5 Allow tube to warm until the mixture becomes homogeneous, venting occasionally.

6.6 Remove toweling, and cool sample at approximately 5.6° C (10° F) per minute while checking for flocculent material at 1 minute intervals.

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Report the temperature at which flocculent material is first observed (flock point).

9. PRECISION

9.1 Precision data have not been developed for this method.

Method Prepared By:

NAVY - SH - 1986

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METHOD 2508.1
September 30, 1986

THERMAL STABILITY OF LUBRICATING AND HYDRAULIC FLUIDS

1. SCOPE

1.1 This method describes a procedure for determining the thermal stability of fluids.

2. SUMMARY

2.1 In this method, the volatile decomposition products are in continuous contact with the fluid during test. To eliminate possible catalytic metal effects, the fluid is confined in a glass apparatus. To remove the variables of oxidation and hydrolysis, air and moisture are removed by heating and shaking under vacuum prior to the initiation of the test. This method will not measure the thermal stability threshold (the temperature at which volatile oil fragments begin to form), but will indicate bulk fragmentation occurring at a specified temperature and testing period.

3. SAMPLE

3.1 Approximately 20 mL of the lubricant to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Test cell. A borosilicate glass test cell having the dimensions given in Figure 1 is recommended as the sample container. Any heavy walled borosilicate glass closed end tube of the proper O.D. having sufficient capacity to hold 20 mL of fluid and of sufficient length to permit heating and drawing the tube to a sealed end reasonably above the fluid level should be satisfactory.

4.2 Pester. Aluminum block with at least two openings of the proper diameter (approximately 2 cm) and depth (approximately 21 cm) so that the sealed test cell is completely immersed in the heater. A suitable heating bath may be used in place of the aluminum block heater if desired. The temperature of either the aluminum block or the bath shall be capable of being controlled within ±1° C (+2° F) at the the test temperature. The temperature gradient between fluid sample and the aluminum block or bath shall be kept at a minimum (less than 1° C [2° F] is recommended).

4.3 Test cell holder. When a heating bath is used a heavy walled steel sample holder of the proper size to contain the test cell shall be provided for safety reasons.

4.4 Becton, Dickinson and Co. Yale Luer-Lok (20 YL) or equal 20 mL hypodermic syringe equipped with a No. 14 square tip needle approximately 21 cm long.

4.5 Vacuum pump, capable of reducing the pressure to at least 1.0 mm of mercury.

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4.6 Water bath, Capable Of maintaining a temperature of 80° C ±2° C (175° F ±5° F) and sufficient size to contain the test cell.

4.7 Laboratory safety shield, constructed of either safety glass or wire reinforced plastic.

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Cleaning solution glass (concentrated sulfuric acid [3,0,2] saturated with potassium bichromate, tecnhical grade).

5.3 Detergent for cleaning glassware [u,u,u].

6. PROCEDURE

6.1 Cleaning test cell. Clean the test cell by scrubbing with a suitable detergent and rinse with distilled water. Prior to the introduction of the sample into the test cell, the cell shall be rinsed in hot potassium bichromate-sulfuric acid cleaning solution, thoroughly rinsed in distilled water, and dried in an oven at 107° C ±2.5° C (225° F +5° F) for one hour.

6.2 Preheat and adjust heater temperature to 260° C ±1° C (500° F ±2° F).

6.3 Perform duplicate test procedures of 6.4 through 6.13.

6.4 Filter the sample through a nominal 10 micrometer filter paper to remove particle contaminants.

6.5 Introduce 20 mL of the filtered sample below the constricted area of the test cell with the aid of the hypodermic syringe.

NOTE: This syringe is capable of delivering 20.0 +0.5 mL of sample which is within the accuracy required by this test procedure.

6.6 Connect the filled test cell to the vacuum pump and degas the cell and its contents, while shaking gently for at least 5 minutes or until foam no longer persists.

6.7 Place the test cell, while still connected to the operating vacuum pump, in a water bath maintained at 80° C ±2° C (175° F ±5° F) for 5 minutes. Remove

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the cell from the bath, shake gently for a minute or two, and return the cell to the water bath. Continue this heating and shaking sequence for at least 4 cycles or until there is no longer evidence of foaming.

NOTE: Ester base as well as certain other type synthetic lubricants are hydrolytically unstable at 260° C (500° F). Therefore, it is necessary that dissolved as well as occluded water be removed before sealing the cell. Each 0.01 percent by weight moisture consumed by hydrolysis produces sufficient acid to raise the neutralization number by 0.31.

6.8 Seal off the constricted area of the test cell while the cell is under vacuum. Weigh the test cell to the nearest mg.

6.9 Insert the, test cell in the heater (preheated to 260° C ±1° C [500° F +20 F]) for a period of 24 hours. If a heating bath is used insert the test cell in the steel holder and place the assembly in the bath.

NOTE: A safety shield should be used as a safety precaution when placing the test cells in the heater, removing the cells from the heater, and opening the cells.

6.10 At the conclusion of the heating period, remove the test cell from the heater and permit it to cool to room temperature. Visually observe the sample for evidence of insoluble, phase separation, or other change. A difference in color between the duplicate tests will necessitate retesting since color differences indicate improper preparation of one or both combustion tubes.

6.11 Reweigh the test cell and calculate the percent evaporation loss (see 7.1). If the evaporation loss is more than 0.05 percent by weight, repeat the test since a weight loss in excess of this amount indicates leakage of the test cell.

6.12 Remove the sample from the test cell. This may be accomplished by file scratching the cell near the top and applying a hot glass rod to the scratch mark.

6.13 Determine the following characteristics on a portion of both the original untreated sample and the heated sample in accordance with the test methods listed in Table I:

TABLE I. Characterisitcs of test methods.

Characteristic	ASTM Method
Viscosity (Kinematic) at 37.8° C (100° F)	D 445
Acid and base numbers	D 664

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7. CALCULATIONS

7.1 To calculate evaporation loss, use the following formula:

$$\text{percentage loss} = \frac{W_b - W_a}{W_b} \times 100$$

W_b = Weight of sample before heating.
W_a = Weight of sample after heating.

8. REPORTING

8.1 Report the following:

a. Visual appearance of fluid and test cell.
b. Average change of acid or base numbers of the duplicate tests.
c. Average change in kinematic viscosity at 37.8° C (100° F) of the duplicate tests.

9. PRECISION

9.1 Precision data have not been developed for this method.

Method prepared by:
Navy - KAPC - 1986

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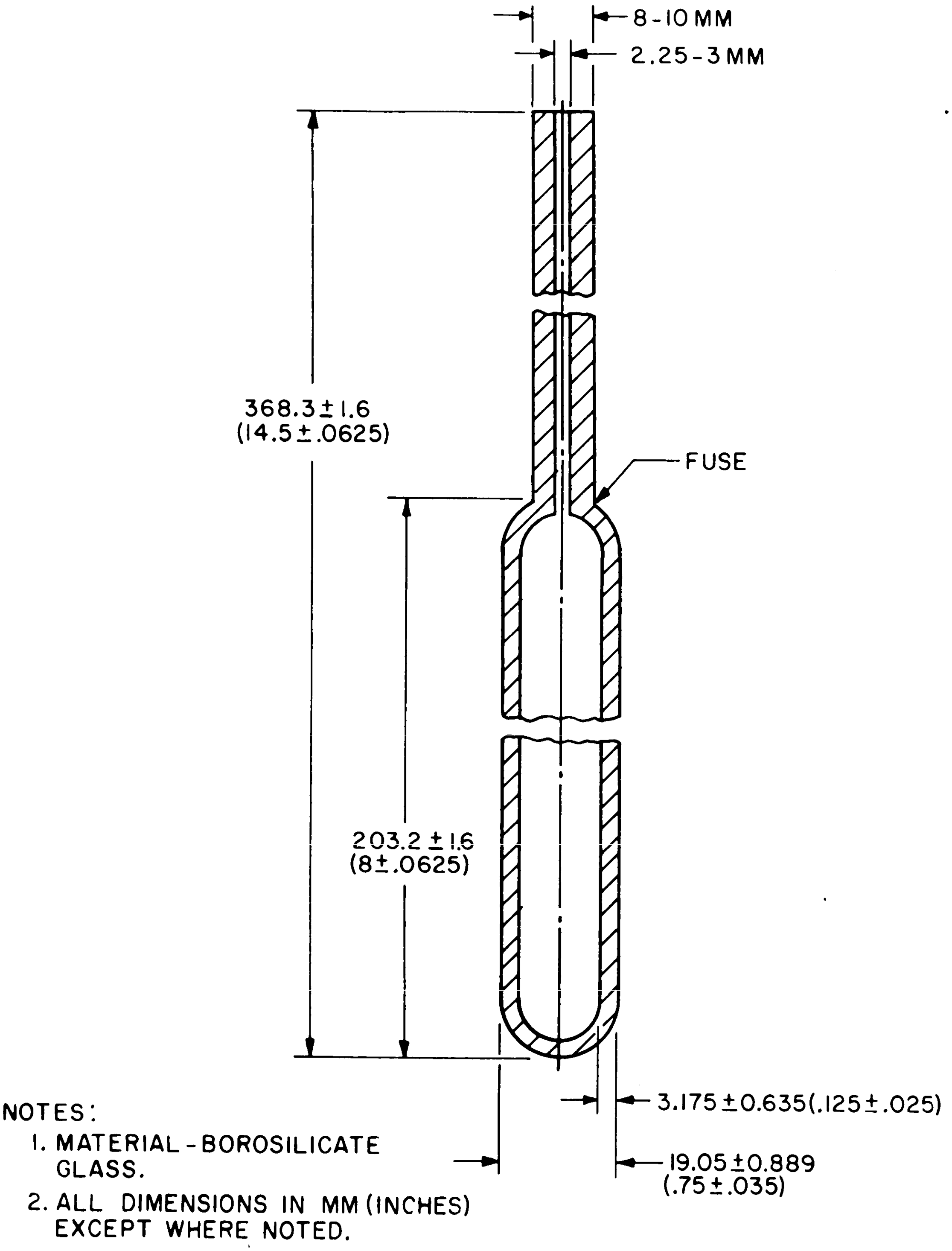

NOTES:

1. MATERIAL - BOROSILICATE GLASS.
2. ALL DIMENSIONS IN MM (INCHES) EXCEPT WHERE NOTED.

FIGURE 1. Test cell.

X-4448

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DIRT CONTENT OF GREASE

1. SCOPE

1.1 This method is used for determining the size and concentration of foreign particles in lubricating greases.

2. SUMMARY

2.1 The test consists of applying a known quantity of grease to a microscope slide, and examining the slide with a microscope to determine the size and number of particles present.

3. SAMPLE SIZE

3.1 Approximately 1 ml. of grease to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Microscope, mechanical stage, 60 diameter magnification, with eyepiece micrometer (not filar) calibrated against suitability ruled, stage micrometer.

4.2 Slide, microscope, approximately 2.5 by 5.0 cm with cover glass.

4.3 Template (Fig. 1), steel (shim stock), 0.01 cm thick, approximately 2.5 x 5.0 cm, slotted from one end for a distance of approximately 2.0 cm with a slot width of approximately 1.0 mm. The template thickness and slot width are accurately measured so that the end area of the slot can be calculated. (A hemacytometer may be used in place of the template). See Note 1.

Note 1. Calculation of test results will be simplified if the template is ground to such thickness, or the slot width is adjusted so that the end area of the slot is 0.01 square cm.

4.4 Vacuum chamber, 1.0 cm of mercury (absolute), or lower (to accommodate microscope slide).

4.5 Spatulas (2)

5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

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6. PROCEDURE

6.1 Compute the cross sectional area of the end of the slot (see 7.1).

6.2 Clean template, microscope slide and cover glass, and spatulas.

6.3 Prepare the sample for examination as follows:

a. Open a fresh container of grease to be tested, and with a clean spatula, scrape off and discard the surface layer.
b. Hold the template by the unslotted end, and place it against the clean microscope slide. Using another clean spatula fill the slot with the test grease. Make sure the corners are filled and the surface of the grease is level with, or slightly above the sides of the slot. Then press the side of the slot firmly against the slide.
c. Place the slide and template in the vacuum chamber for 10 to 15 minutes to remove bubbles or voids from the grease in the slot. (See Note 2).

Note 2. Vacuum exposure may be omitted if the grease is free from entrained air.

d. Slide the clean cover glass onto the template to shear off surplus grease . Then press the cover glass firmly against the template until it is parallel to the microscope slide.

6.4 Mount the assembled slide on the stage of the microscope. Adjust the illumination so that light passes straight up through the grease in the slot, as well as straight across the surface of the grease.

6.5 Determine the size and number of opaque particles.

a. Adjust the stage and micrometer eyepiece so that the micrometer scale coincides with one side of the slot, and so that one end of the scale coincides with one corner of the slot.
b. Move the stage slowly, so that the slot passes across the field of view. Count each opaque inclusion having a size of 25 micrometers or more. Particle size is determined by measuring along the largest dimension of the particle.
c. Record the count in three columns headed: “25 to 75 micrometers”, “75 to 125 micrometers”, and “over 125 micrometers”.
d. When the micrometer scale has reached the opposite side of the slot, move the stage along the axis of the slot for a distance equal to the length of the scale. (Use a minor irregularity on the wall of the slot, or a specific particle in the grease, as a point of reference.) Scan this section completely across the slot.

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e. Continue scanning successive sections in the slot until approximately three-quarters of the area (1 x 1.5 cm) of the slot has been inspected.

f. Record the number of sections scanned, and the total number of particles according to size.

7 CALCULATIONS

7.1 Calculation of slot cross sectional area.

$T = D - W$
T = End area of template slot.
D = Depth or thickness of template (cm).
W = Width of slot (cm).

7.2 Compute the number of particles per cubic centimeter of grease, using the following formulas:

25 micrometers or larger: $\frac{(A + B + C)}{TSN}$

75 micrometers or larger: $\frac{(B + C)}{TSN}$

Over 125 micrometers: $\frac{C}{TSN}$

A = Total number of particles 25 to 75 micrometers.
B = Total number of particles 75 to 125 micrometers.
C = Total number of particles 125 micrometers or larger.
N = Number of sections of grease scanned.
S = Length of micrometer scale, cm.
T = End area of template slot, sq cm.

Note 3. If dirt in excess of specification limits is not found in the first run, the grease shall meet the requirements of the test.

If dirt in excess of the specification limits is found in first run, two more runs shall be conducted. If dirt in excess of specification limits is found in one or both of these runs, the grease shall fail the test.

8. REPORTING

8.1 Report the number of particles in the following ranges:

25-75 micrometers
75-125 Micrometers
125 or larger micrometers

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9. PRECISION

9.1 Precision data have not been developed for this method.

Method Prepared By:

Navy - NADC - 1986

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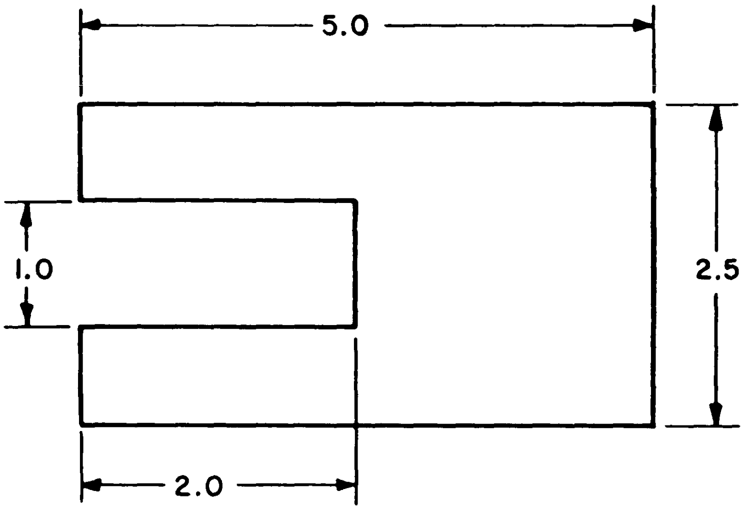

NOTE:
DIMENSIONS IN CENTIMETERS.

FIGURE 1. <u>Template.</u>

X-4366

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CONTAMINATION IN ENGINE OIL

1. SCOPE

1.1 This method is used for determining the degree of contamination caused by Foreign solid material in engine oil.

2. SUMMARY

2.1 It consists of passing the sample through a sieve, and determining the increase in weight of the sieve.

3. SAMPLE SIZE,

3.1 Approximately 15 L (4 gallons) of oil to be tested.

4. REFERENCES, STANDARDS AND APPARATUS

4.1 Sieve, 200-mesh.

4.2 Oven 100° C ±3° C (212° F ±5° F).

4.3 Desiccator, containing desiccant.

4.4 Balance, sensitivity 1 mg.

4.5 Container 38 L (10 gallon).

4.6 Microscope 10X power.

4.7 Tweezers, sharp-pointed.

4.8 Membrane filter, watch glass or suitable holder.

5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Naphtha (TT-N-95). [1,4,0].

5.3 Unleaded Gasoline [1,3,0].

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5.4 Iso-octane (technical grade), [0,3,0].

6. PROCEDURE

6.1 Clean sieve thoroughly, using naphtha or unleaded gasoline. Dry sieve in oven at 100° C ±2.8° C (212° F ±5° F), cool to room temperature in desiccator, and weigh to the nearest milligram. Repeat to constant weight.

6.2. Mix sample with 15 L (4 gallons) of naphtha, iso-octane or unleaded gasoline in a clear 38 L (10 gallon) container, and filter mixture through sieve. Solvent should be particle free. The metal sieve should be grounded to prevent build-up of static electricity.

6.3 Thoroughly rinse container with naphtha, iso-octane or unleaded gasoline, and filter washings through sieve.

6.4 Remove any residual oil from sieve by rinsing it with naphtha, iso-octane, or unleaded gasoline. Care should be taken to remove all residual oil from the creases and crevasses in the sieve. Dry sieve in oven at 100° C ±3° C (212° F ±5° F). Cool sieve to room temperature in desiccator, and weigh to nearest mg. Repeat to constant weight.

6.5 Determine increase in weight of sieve. This value is the weight of foreign solid material in the sample.

6.6 Place the screen under a microscope, 10 power, and carefully remove the fibrous material with a pair of sharp-pointed tweezers. Place the fibers on a pre-weighed membrane filter, watch glass or other suitable holder. Determine the increase in weight of the holder. This value is the weight of the fibrous material in the sample.

7. CALCULATIONS

A = weight of screen and contaminant in g.
B = weight of screen in g.
C = L of test oil used.

$$\text{mg of contaminant per L of test oil} = \frac{(A - B) \times 1000}{C}$$

D = weight of holder and fibrous material in g.
E = weight of holder in g.

$$\text{mg of fibrous material per L of test oil} = \frac{(D - E) \times 1000}{C}$$

8. REPORTING

8.1 Report the weight in mg of the foreign solid material per L of test oil sample.

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8.2 Report the weight in mg of the fibrous material per L of test oil sample.

8.3 Report the visual appearance of the remaining material on the screen, as observed under the 10-power microscope.

9. PRECISION

9.1 Precision data have not been developed for this method.

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Navy - NAPC - 1986

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WATER DISPLACEMENT AND WATER STABILITY

1. SCOPE

1.1 This method is used to determine the water-displacing ability of corrosion preventive oils and their stability in the presence of water.

2. SUMMARY

2.1 Steel test panels are immersed in distilled water and then either the test oil or a water emulsion of the test oil. After exposure in a static humidity chamber the panels are examined for the presence of rust.

3. SAMPLE SIZE

3.1 Approximately 60 mL of the test oil.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Standards

4.1.1. ASTM D 1748, Rust Protection by Metal Preservative In The Humidity Cabinet.

4.2 Static humidity chamber (a desiccator containing some distilled water).

4.3 Oven, forced draft, 54° ±l°C (130° +2° F).

4.4 Desiccator, containing an indicating desiccant.

4.5 Panel hook, stainless steel (for handling panels during processing).

4.6 Erlenmeyer flasks, 125-mL.

4.7 Beakers, tall-form 500mL.

4.8 Petri dishes, 10 cm in diameter and 2 cm in height.

4.9 Controlled atmosphere (to provide 25° +3° C [77° ±5° F]) and a maximum of 50 percent relative humidity.

4.10 Shaded fluorescent light. (A 15-watt balance illuminator type that will permit the panel to be viewed from all angles at a distance of 3 inches)).

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000,

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Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Test panels, FS 1009 steel, 5.1 X 7.6 X 0.16 cm (2 X 3 X 1/16 inch), fabricated from open hearth “killed” type low carbon, No. 4 soft temper cold rolled sheet or strip conforming to QQ-S-698. Cold drawn bar stock is not satisfactory.

5.3 Naphtha, aliphatic (TT-N-95) [1,4,0].

5.4 Methyl alcohol (O-M-232) [1,3,0].

5.5 Distilled water.

5.6 Silica sand, white dry, sharp. The size shall be such that it meets the following sieve requirements RR-S-366:

a. 100 percent must pass through a No. 10 sieve.
b. Minimum of 90 percent must pass through a No. 20 sieve.
c. Maximum of 10 percent permitted to pass through a No. 50 sieve.

5.7 Surgical gauze.

5.8 Absorbent tissue.

5.9 Emulsion, water and oil prepared as follows:

a. Place 50 mL of the test sample and 5 mL of distilled water in a 125 mL Erlenmeyer flask.
b. Shake mixture thoroughly and store overnight in an oven a 54° ±l°C (130° +2° F).
c. Remove from oven and cool at 25 ±3°C (77° +5° F) for testing.
d. Shake the mixture immediately prior to placing in the petri dish.

6. PROCEDURE

6.1 Clean the steel panels as follows:

a. Round the edges and ream out the suspension holes in accordance with ASTM D 1748.
b. Wipe the surfaces with solvent soaked rags and scrub with surgical gauze swabs in a beaker of hot naptha.
c. Rinse in a beaker of hot methyl alcohol.
d. Cool the panels in a desiccator until further processing.
e. Test panels must be handled with a panel hook at all times, avoiding contact with any type of contaminated surface.

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f. Maintain the solvents at a temperature high enough to keep the temperature of the panels above the dew point during the cleaning operation.

6.2 Sandblast the panels as follows:

a. Sandblast the edges and lightly sandblast the back of the panels with silica sand.
b. Sandblast the unnumbered side, or test surface, of the panels to a fresh, uniformly abraded surface.
c. Immediately after sandblasting, place the panels in a beaker of anhydrous methyl alcohol.
d. Heat the methyl alcohol so that the solvent will evaporate from the panels immediately upon withdrawal from the solvent.
e. Remove remaining residue by holding the panels in a rack at 20 degrees from the vertical and spraying downward with naptha.
f. Spray the test surface, then the back of the panel and the test surface again.
g. Rinse the panels in hot naphtha and hot methyl alcohol and store in a desiccator until cool.
h. Panels are to be used the same day as prepared.

Note 1. Caution. Methyl alcohol and naphtha are both toxic and flammable. Do not permit them to come in contact with the skin or breathe their fumes. Use only in a well ventilated area. Keep all flames away from these materials.

6.3 Three test panels are processed with the original oil as follows:

a. Dip the panels into distilled water, momentarily, and drain in a vertical position for not more than 5 seconds, with the bottom edge in contact with absorbent tissue.
b. Immerse the panels horizontally, and without agitation, for 15 seconds in a petri dish containing 50 mL of the test sample maintained at 25° +3° C (7.70 +5° F) and 50 percent maximum relative humidity.
c. Drain the panels momentarily and place in the static humidity chamber for 1 hour at 25° +3° C (77° +5° F).
d. At the completion of the static humidity exposure, remove the panels and rinse in methanol.
e. Examine the test surfaces for the presence of rust, mottling, or other abnormal surface stains. The outer 0.32 cm (1/8 inch) edge of the panels and 0.32 cm (1/8 inch) around the holes is excluded from the evaluation.

6.4 Three test panels are processed with the oil-water emulsion in accordance with the procedure outlined in paragraph 6.3 and similarly examined.

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

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8. REPORTING

8.1 Follow the specification requirements.

9. PRECISION

9.1 Precision data have not been developed for this method.

Method Prepared By:
Army - AR - 1986

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Method 3009.3
September 30, 1986

SOLID-PARTICLE CONTAMINATION IN HYDRAULIC FLUIDS

1. SCOPE

1.1 This method is used for determining the amount of solid particle contamination in hydraulic fluids.

2. SUMMARY

2.2 The method consists of determining the length of time required to filter the hydraulic fluid through a single membrane filter, and then examining the filter under a microscope to determine the number and sizes of solid particles.

3. SAMPLE SIZE

3.1 Approximately 100 mL of hydraulic fluid to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Microscope, mechanical stage, 100X and 45X magnifications, with micrometer eyepiece calibrated (for both magnifications) against a suitably ruled, stage micrometer.

4.2 Filter holder, Pyrex (Millipore Corporation, Bedford, Mass. 01730, No. XX10–047-00; also Gelman Instrument Co., 600 S. Wagner Road, Ann Arbor, Mich., No.1200WP).

a. Fritted-glass base and rubber stopper (No. XX10-047-02).
b. Holding clamp, spring action (No. XX10-047-03).
c. Funnel , graduated, 250-mL (No. XX10-047-04).

4.3 Cover, plastic (for graduated funnel) equipped with membrane filter to minimize contamination of test filter by air.

4.4 Flask, filter, side-tube (to accommodate filter holder, par. 4.2.2), 1000-mL.

4.5 Vacuum source, 36 to 43 cm (14 to 17 inches) of mercury.

4.6 Slides (4), glass 5.0 x 7.5 cm (2 x 3 inches).

4.7 Bottles (3), sample, with ground-glass stoppers, 1000-mL.

4.8 Forceps, stainless-steel, plastic tipped.

4.9 Petri dish, with cover (for four 5.0 x 7.5 cm glass slides).

4.10 Tongs, stainless-steel.

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5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled care fully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Distilled water.

5.3 Alcohol, isopropyl (TT-I-735) [1,3,0].

5.4 Petroleum ether (O-E-751) [1,4,0].

5.5 Detergent, water-soluble, commercial.

5.6 Cleaning solution, glass (concentrated sulfuric acid [3,0,2] saturated with potassium or sodium bichromate [1,0,1], technical grade).

5.7 Tape, transparent , pressure-sensitive.

5.8 Filters, cellulose membrane, 0.45 + 0.02 micrometer pores, 4.7-cm diameter, white, 0.308-cm grid, capable Of filtering 200 mL Of distilled water per square cm per minute at 69 kPa (10 psi) differential pressure and at 25° C. (Available from Millipore Corp., Gelman Instrument CO., or Decontamination, Inc.)

6. PROCEDURE

6.1 Clean the filter flask, filter holder, graduated funnel cover, and three sample bottles and stoppers as follows:

6.1.1 Wash in hot tap water and detergent.

6.1.2 Rinse with tap water.

6.1.3 Soak in hot glass-cleaning solution until clean.

6.1.4 Rinse with tap water.

6.1.5 Rinse with distilled water.

6.2 Prepare filter solvents as follows:

6.2.1 Insert a new membrane filter into the filter holder, and filter three 100 mL portions of distilled water to rinse the filter flask. Discard the rinsings.

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6.2.2 Continue filtering enough distilled water to rinse each of the three prepared sample bottles (see 6.1 through 6.1.5) and stoppers with three 100 mL portions, and to fill one of them with filtered distilled water; stopper them immediately.

6.2.3 Replace the used filter with a new one, and using the cleaned filter flask, filter enough isopropyl alcohol to rinse the two clean sample bottles and stoppers with three 100 ml. portions and to subsequently fill one with filtered alcohol; stopper them immediately.

6.2.4 Using a new filter, filter enough petroleum ether to rinse (with three 100 mL portions) and subsequently fill the last sample bottle; stopper immediately.

4.2.5 Remove the filter holder from the filter flask, and discard the used filter.

6.3 Using tongs to handle them, prepare two glass slides as follows:

6.3.1 Soak in hot glass-cleaning solution until clean.

6.3.2 Rinse with filtered, distilled water.

CAUTION

Immediately re-stopper the sample bottles
after each use to avoid contamination.

6.3.3 Rinse with filtered isopropyl alcohol.

6.3.4 Rinse with filtered petroleum ether and allow to air dry.

Note 1: Caution. Isopropyl alcohol and petroleum ether are flammable. Use only in a well ventilated area. Keep all flames away from these materials.

6.3.5 When dry, immediately hinge the two slides together, using transparent tape, and store them in a clean covered petri dish.

6.4 Using tongs, prepare the filter holder for the filtration of the sample as described in 6.4.1 through 6.4.3.

6.4.1 Rinse the filter holder and the funnel cover, first with filtered distilled water, then with filtered, distilled isopropyl alcohol, and finally with filtered petroleum ether.

6.4.2 Using clean forceps to grip the edge, rinse a new membrane filter with filtered petroleum ether, and install it (grid side up) on the fritted glass surface of the filter holder. Also, install a filter in the cover for the graduated funnel.

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6.4.3 Install and clamp the funnel to the filter holder. Ground the clamp (to prevent buildup of static electricity while filtering).

6.5 Filter the sample as follows:

6.5.1 Measure 100 ml. of the sample into the funnel and cover the funnel.

6.5.2 If filtration time only is being determined, proceed to 6.5.2.1 and Stop. If particle count is to be measured, proceed to 6.5.2.2 and continue.

6.5.2.1 Within one minute after pouring the sample into the funnel, apply suction of 36 to 43 cm (14 to 17 inches) of mercury to the filtration apparatus and start the timer. When the first dry spot appears on the membrane filter, stop the timer, and disconnect the suction source.

6.5.2.2 Within one minute after pouring the sample into the funnel, start timer and apply suction of 36 to 43 cm (14 to 17 inches) of mercury to the filtration apparatus. Disconnect the suction source and stop timer when the fluid level is 0.5 cm above the filter membrane, then add the rinse from 6.5.3 before the last of the hydraulic fluid has passed through the filter.

Note 2: If the time of filtration is more than 8 percent of the filtration time requirement, repeat the test using the filtration procedure in 6.5.2.1.

6.5.3 Wash the graduated cylinder with 50 mL of filtered petroleum ether. Remove the cover from the funnel, pour the washings into the funnel, replace the cover, and apply suction. Perform this washing operation once again, disconnecting the suction source between washings.

6.5.4 Allow suction to continue until the filter is dry.

6.6 Prepare the test filter for microscopic counting as follows:

6.6.1 Using clean forceps, remove the filter from the filter holder, and sandwich it between the cleaned glass slides (see 6.3).

6.6.2 (Using transparent tape, seal the remaining unsealed edges of the slides.

6.7 Prepare a blank for analysis, using a fresh test filter and substituting filtered petroleum ether for the sample, as specified in 6.4, 6.5, and 6.4.

6.8 Place the slide under the microscope (45X), and scan the entire filter to ascertain that the particle distribution on the filter paper is uniform. If the distribution is not uniform; discard the filter and repeat the test.

6.9 Estimate the number of particles presert in the filter grid area (100 squares), listing the numbers of particles by sizes according to the six size ranges given in Table I.

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TABLE I. Size ranges and counting magnifications.

Particle size range (largest dimension), mircometer	Counting magnifications diameters
5 to 15 --	100
15 to 25 --	100
25 to 50 --	100
50 to 100 --	100
over 1001/ (length-width ratio under 10:1) -----------	45
Over 1001/ (length-width ratio over 10:1) ------------	45

1/ Fibers.

6.10 For each size range, determine sampling area and calibration factor on the basis of the estimate. If the estimated number of particles of that size was 5000 or less, use sampling area and factor shown in Table II. If the estimated number was more than 5000, determine area and factor as follows:

6.10.1 Select a sampling area consisting of at least 10 sections (chosen at random), each of which is one grid length long (0.308 cm), and narrow enough to contain no more than 50 particles (of that size range under consideration). (See Figure 1.)

6.10.2 Using the micrometer eyepiece, measure the width of each unit area, and determine the sum or the widths. Compute the calibration factor (see 7.1).

6.11 For each size range, count the particles within the sampling area, using the counting magnification specified in Table I. (See Figure 2). Include in the tally those particles lying on the upper and left boundary lines of the area as well as those within the areas selected. (Particles on the lower and right boundary lines are tallied with those in the square below or to the right.)

TABLE II. Calibration factors.

Estimated number of particles	Sampling area	Calibration factor
1 to 50 -----------------	100 squares (total area) - - - -	1
51 to 1000 --------------	20 squares (at random) - - - - -	5
1001to 5000-------------	10 squares (at random) - - - - -	10
More than 5000 - - - - - - -	10 sectionsl/ - - - - - - - - - -	

1/ See paragraph 6.10.

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7. CALCULATIONS

7.1 Compute calibration factor:

$$\text{Calibration factor} = \frac{960}{3.08A} = \frac{317}{A}$$

A = Sum of widths of unit areas, cm.

8. REPORTING

8.1 For each size range, multiply the results by the calibration factor (see 6.10), subtract the values obtained for each size range for the blank from those obtained on the specimen filter and report the results as the total number of particles (of the size range) present (see Figure 2). Also, report the total filtration time and subparagraph from which it was obtained.

9. PRECISION

9.1 Precision data have not been developed for this method.

Method Prepared By:

Army - ME - 1986

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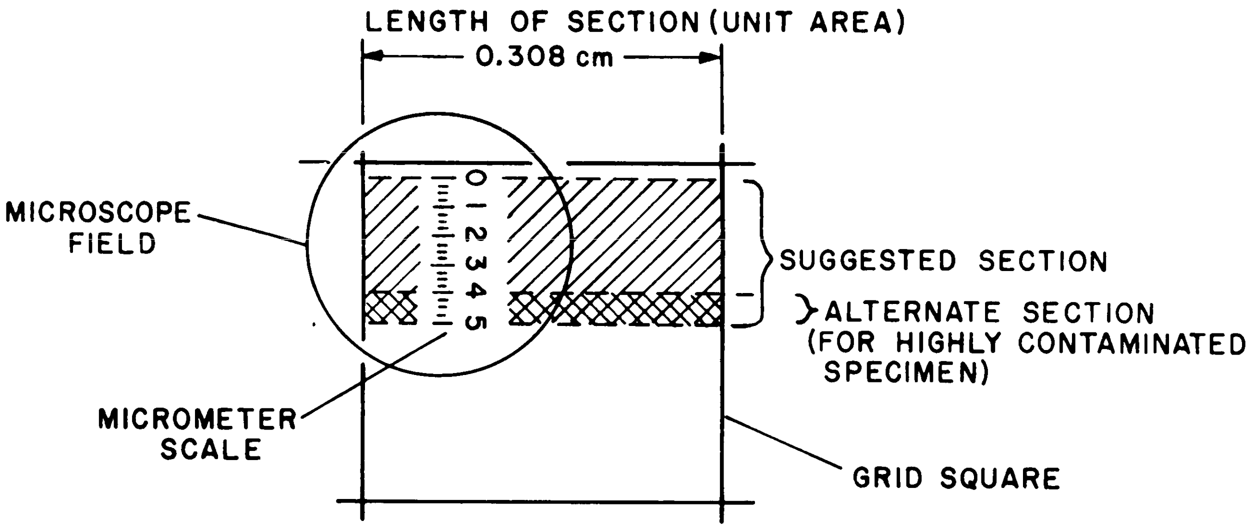

FIGURE 1. Typical sampling section.

X-4367

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Size Range, Micrometers	Estimated Total	Sample Count	Calibration Factor	Total Particles
5 to 15	60	11	5	55
15 to 25	400	86	5	430
25 to 50	1500	132	10	1320
50 to 100	600	113	5	565
More than 100	50	52	1	52
More than 100 (fibers)	30	28	1	28

FIGURE 2. Typical tally sheet.

X-4315

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SOLID PARTICLE CONTAMINATION IN AIRCRAFT TURBINE FNGINE LUBRICANTS (GRAVIMETRIC PROCEDURE)

1. SCOPE

1.1 This method describes a gravimetric procedure for the determination of solid particle contamination in packaged aircraft turbine lubricants and related fluids.

2. SUMMARY

2.1 A known volume of fluid is filtered through a pre-weighed membrane filter. The increase in filter weight is determined after washing and drying and reported as total contaminant. The test filter is ashed and the inorganic material remaining is reported as ash.

3. SAMPLE SIZE

3.1 Approximately 1 L (1 quart) of turbine engine lubricant.

3.2 The sample must be thoroughly representative of the material to be tested. This requires vigorous agitation of the fluid before sampling. The importance of sampling cannot be too strongly emphasized. All suspected sediment must be homogeneously suspended in the oil. When packaged liter (quart) samples are available the entire liter (quart) should be used.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Membrane filters, white, plain, 4.7 cm diameter, pore size 1.2-micrometer and 0.22-micrometer.

4.2 Filter holder, 4.7 cm.

4.3 Analytical balance, sensitivity 9.1 mg.

4.4 Petri dishes, 5.0 cm in diameter.

4.5 Oven, non-circulatory air, capable of maintaining a temperature of 90° C (200° F)

4.6 Forceps, flat-bladed with underrated tips.

4.7 Vacuum system.

4.8 Muffle furnace capable of maintaining a temperature of 810° C (1500° F).

4.9 Crucibles, 30 mL capacity, squat form.

4.10 Desiccator, with desiccant.

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5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Isopropyl alcohol, reagent grade [1,3,0].

5.3 Petroleum ether, reagent grade, boiling point range 30° to 60° C [1,4,0].

6. PROCEDURE

6.1 Preparation of apparatus and containers.

6.1.1 All components of the filtration apparatus and containers must be washed with hot tap water containing detergents.

6.1.2 Rinse with hot tap water.

6.1.3 Rinse with distilled water.

6.1.4 Rinse with filtered isopropyl alcohol.

6.1.5 Rinse with filtered petroleum ether.

6.1.6 place clean plastic film or clean aluminum foil over containers and filtration apparatus.

NOTE 1: Rinse a sufficient number of times to completely remove the previous solvent.

6.2 preparation of reagents.

6.2.1 Filter the petroleum ether, and isopropyl alcohol, through a 0.22-micrometer membrane filter. Discard the first 50 mL of each and filter enough solvents to complete testing of samples to be filtered. Containers used for filtered reagents must be cleaned initially as described in Section 6.1.

NOTE 2: Ground the filter mechanism when filtering flammable solvents to prevent buildup of static electricity.

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6.3 All equipment used for handling samples must be cleaned as described in Section 6.1. Precaution must be taken to minimize apparatus contamination from all sources including airborne particles.

6.3.1 Duplicate tests should be performed whenever more than 1 L (1 quart) of lubricant from the same lot or batch is available.

6.4 Preparation of test filters.

6.4.1 Identify each filter by marking the rim with a ballpoint pen, or by marking the petri dishes that will contain them. Place each filter separately in petri dish and dry it for 1/2 hour in an oven regulated to 90° C (194° F). The petri dishes are then placed in a desiccator and moved to the balance room in the vicinity of a balance on which weighings are to be made. Allow 1 hour for the closed desiccator and contents to come to equilibrium with ambient temperature. Use forceps to place the test membrane on the balance pan by handling the edge only.

6.4.2 An air ionizer must be kept permanently on the base of the balance adjacent to the pan to eliminate weighing errors due to electrostatic charge effects. Make all weighings to the nearest 0.1 mg.

6.5 Laboratory filtration and contamination determination.

6.5.1 Thoroughly clean outside of sample container in the region to be opened by washing with detergent and water and rinsing with tap water and filtered isopropyl alcohol. Shake the 1 L (1 quart) sample of lubricant for 15 minutes. Cautiously open can so as to prevent the introduction of metal chips into the sample.

6.5.2 To keep airborne contaminants on the membrane surface to a minimum, pour some of the sample into the filter funnel before applying vaccuum. Filter the entire contents of the 1 L (1 quart) sample and thoroughly wash down the inside of the sample can with filtered petroleum ether, passing the washings through the filter.

6.5.3 Wash down the inside of the filter funnel. This will complete the transfer of the contaminant to the filter membrane. With the vacuum applied, carefully remove the funnel. Wash the periphery of the membrane by directing a gentle stream of petroleum ether from the edge toward the center, taking care not to wash any contaminant from the surface of the membrane.

6.5.4 Carefully remove the test membrane from the filter base, using clean flat forceps, and place it in a covered petri. dish. Dry and reweigh as described in Section 6.4, taking care not to wash any contaminant from the surface of the membrane.

NOTE 3: For greater accurancy, control membranes may be used as described in ASTM D 2276 (Particulate Contaminant in Aviation Turbine Fuels).

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6.6 Determination of non-Combustible contamination or ash.

6.6.1 Clean crucibles with hot detergent, wash and rinse with tap and distilled waters and dry. Place crucibles in a muffle furnace maintained at 810° C (1500° F) for 1/2 hour. Remove and place crucibles in a desiccator. Allow closed desiccator and contents to cool and come to equilibrium with the atmosphere in the vicinity of the balance for 2 hours. Handle crucibles with clean tongs. Weigh crucibles to the nearest 0.1 mg. Repeat this procedure until constant weight is obtained.

6.6.2 Handling the membrane filter only with clean forceps, lay it, contaminant side upwards, in the center of the crucible. Wet it with filtered isopropyl alcohol and push it gently into the crucible.

6.6.3 Cover the crucible containing the filter membrane with a porcelain lid and place it in a cold muffle furnace. Start the furnace and allow to come to 810° C (1500° F). Hold at this temperature for 1/2 hour. Remove and place crucibles in a desiccator. Allow closed desiccator and contents to cool and come to equilibrium with the atmosphere in the vicinity of the balance for 2 hours. Handle crucibles with clean tongs. Weigh crucibles to the nearest 0.1 mg. Repeat this procedure until constant weight is obtained. Increase in weight is inorganic material or ash.

NOTE 4: An alternate method is to place the crucible in a triangle and put a porcelain cover over it. Place a small flame under the crucible to one side. When dry, char the filter membrane, being careful not to ignite. Increase the burner flame until all organic matter is distilled from the filter. Place the crucible in a preheated muffle furnace 810° C (1500° F) for 1/2 hour. Weigh as in 6.6.3.

70 CALCULATIONS

$$\text{Contaminant, mg per L oil} = \frac{A - B}{C}$$

A = Final weight of the membrane filter with the material collected in filtration, mg.
B = Initial weight of the test membrane, mg.
C = Volume of sample in L filtered through the test membrane.

$$\text{Ash, mg per L oil} = \frac{D - B}{C}$$

D = Final weight of the crucible and noncombustible material, ash, mg.
B = Initial weight of the crucible, mg.
C = Volume of sample in L filtered through the test membrane.

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8. REPORTING

8.1 Contamination, mg per L of oil.

8.2 Ash, mg per L of oil.

9. PRECISION

9.1 Precision data have not been developed for this method.

Method prepared by
Navy - NAPC - 1986

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METHOD 3011.1
September 30, 1986

PARTICULATE CONTAMINATION IN AEROSPACE HYDRAULIC FLUIDS USING THE HIAC PARTICLE COUNTER

1. SCOPE

1.1 This method is used to determine particulate matter in aerospace hydraulic fluids using the HIAC particle counter.

2. SUMMARY

2.1 The test consists of using the HIAC particle counter to determine the number of particles within 5 diameter ranges from 5 to 150 micrometers.

3. SAMPLE SIZE

3.1 Approximately 300 mL are required.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Particle counter, HIAC automatic particle counter, with a minimum of five channels, fitted with a sensor suitable for counting in the 5-150 micrometer range. Other accessories, such as timers and print-outs may be used.

4.2 Compressed gas supply, a source of air or nitrogen, free from oil and water, capable of delivering the gas at a pressure of up to 202 gage kPa (2 atmospheres). The gas shall be filtered through a 0.45 micrometer membrane filter.

4.3 Sample bottles, round glass bottle fitted with a polypropylene threaded cap forming a seal with the bottle without the use of any insert. The dimensions of the bottle will depend on the type of sample holding facilities with the HIAC counter but should be between 150 and 500 mL capacity. The bottle should be flat-bottomed to facilitate the use of a magnetic stirrer.

4.4 Solvent dispensers, suitable dispenser fitted with a 0.45 micrometer membrane filter at the outlet.

5* MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Detergent, liquid, water soluble, commercial grade.

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5.3 Isopropyl alcohol (TT-I-735) [1,3,0].

5.4 Trichlorotrifluoroethane (MIL-C-81302) [u,u,u].

5.5 Petroleum ether, 100/120° C (Note 1) [1,4,0].

Note 1: Trichlorotrifluoroethane is the preferred solvent because of the flammability hazard with petroleum ether.

5.6 Primary calibration standard, HIAC certified field calibration kit consisting of MIL-H-5606 hydraulic fluid containing known number and size ranges of suspended latex spheres.

6. PROCEDURE

6.1 Sample bottle preparation (Note 2).

a. Wash thoroughly with warm tap water containing detergent.
b. Rinse with warm tap water.
c. Rinse with distilled or deionized water.
d. Rinse with filtered isopropyl alcohol.
e. Rinse with the filtered solvent specified in 5.4 or 5.5.
f. Drain the bulk of the solvent, leaving approximately 1 mL in the bottle to create a small positive pressure. This negligible amount need not be drained prior to taking the sample.
g. Fit the cap, cleaned as in 6.1 a. to 6.1 e.
h. Check 1 in 10 bottles for cleanliness, using the filtered solvent specified in 5.4 or 5.5. Maximum count allowable 1000 particles per 100 mL greater than 5 micrometers.

5.2 Glassware preparation, all glassware used in connection with the method shall be cleaned by the procedure given in 6.1 a. to 6.1 e.

6.3 Sample preparation before counting.

a. Bottle sample.
   1. Fluid samples submitted in bottles, cleaned as above, shall be rejected if visibly contaminated with water or excessive solids.
   2. Using the filtered solvent specified in 5.4 or 5.5, thoroughly clean the outside of the bottle particularly in the region of the cap, to prevent extraneous contamination entering the fluid sample.
   3. Shake by hand for one minute.

Note 2: Alternative methods of sample bottle preparation may be used provided the requirements of 6.1 h. are met. The standard method must be used for referee purposes.

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b. Sealed containers of new fluid.
   1. Thoroughly clean with lint free cloth and then with the filtered solvent specified in 5.4 or 5.5 the top of the container to prevent extraneous contamination entering the fluid.
   2. Thoroughly shake by hand for one minute.
   3. Puncture the cleaned surface with a cleaned and solvent rinsed tool, making a hole no larger than is necessary.
   4. Remove the required quantity of fluid using a solvent cleaned and rinsed syringe or pipette, taking the sample from approximately the middle of the container.
   5. Transfer the sample to a cleaned glass counting vessel for insertion in the HIAC apparatus.

6.4 Preparation of sample for counting.

a. After carefully removing the cap from the sample bottle, place the bottle or the counting vessel in the HIAC pressurized bottle sampler equipment or connect to the sensor assembly.
b. Apply a vacuum of at least 53 gage kPa (400 mm Hg) for 30 seconds to remove air bubbles.
c. If counting is not commenced within 2 minutes after shaking has ceased , the sample shall be stirred for 2 minutes using the standard HIAC magnetic stirrer equipment with a glass coated non-magnetized bar. This shall be followed by application of vacuum as in 6.4 b.
d. Flush sensor with a small amount of the test sample.
e. Commence counting. The sample shall not be stirred during counting.

6.5 Calibration procedure.

a. The primary calibration of the instrument shall be carried out using the “Procedure for Field Calibration of the HIAC Solid State Automatic Particle Counter with Latex Spheres in MIL-H-5606 Hydraulic Fluid: 5-150 Micrometers Sensor”. This procedure is supplied with each calibration kit.
b. The fluid flow rate shall be 60 +2 mL per minute.
co The calibration shall be carried–out at least annually or when any change is made to the sensor.

6.6 Instrument calibration check.

a. The following procedure shall be carried out at least monthly if the instrument is left switched on permanently or daily if the instrument is switched off between counts. A period of at least two hours of warm-up should be allowed before check is commenced.
b. Check the instrument strictly in accordance with the HIAC manual provided with the instrument, using the calibration numbers obtained as in 6.5.

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6.7 Counting procedure.

a. The counting procedure shall be carried out in the delta mode, in accordance with the HIAC manual provided with the instrument.
b. Ensure that the counter has been switched on long enough (30 minutes minimum) to obtain a steady meter reading with the calibrate/operate switch in the null check position. Balance to zero if necessary.
c. The fluid flow rate shall be 60 +2 mL per minute.
d. The volume counted shall be 2 x 50 mL, the two results being added together, if they agree within 10 percent for the 5--15 micrometer size range.
e. After each test, remove the bottle or counting vessel. and flush the sensor with the filtered solvent specified in 5.4 or 5.5.

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Report to not more than three significant figures, the number of particles per 100 mL in the following size ranges:

a. 5-15 micrometer.
b. Above 15 to 25 micrometer.
c. Above 25 to 50 micrometer.
d. Above 50 to 100 micrometer.
e. Above 100 to 150 micrometer.

9. PRECISION

9.1 Precision data have not been developed for this method.

Method Prepared By:

Air Force - SFTL - 1986

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6. PROCEDURE

6.1 Sample bottle preparation.

6.1.1 Wash sample bottle thoroughly with warm tap water containing detergent.

6.1.2 Rinse with warm tap water.

6.1.3 Rinse with distilled or deionized water.

6.1.4 Rinse with filtered isopropyl alcohol.

6.1.5 Rinse with filtered trichlorotrifluoroethane.

6.1.6 Dry the bottle inverted. Wash bottles that permit inverted rinses are more efficient.

6.1.7 Clean the cap as in 6.1.1 through 6.1.6.

6.1.8 Cap the dry bottle.

6.1.9 Check the bottle for cleanliness using filtered trichlorotrifluoroethane. Maximum count allowed per 100 mL is as follows:

Particle size range Micrometer	National Aerospace Standard 1638 Class 00, Number of Particles
5 to 15	125
15 to 25	22
25 to 50	4
50 to 100	1
over 100	0

6.1.10 Fill the bottle approximately half full, shake and count the particles. Trichlorotrifluoroethane tends to boil. Adjust the valve near the sensor to obtain more backpressure to diminish the difficulty.

6.2 Glassware preparation.

6.2.1 All glassware used with the method shall be cleaned as directed in 6.1.1 through 6.1.5.

6.3 Sample preparation before counting.

6.3.1 Bottle sample.

6.3.1.1 Fluid samples shall be rejected if visibibly contaminated with water or excessive solids.

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6.3.1.2 Using the filtered solvent specified in 5.5.2, thoroughly clean the outside of the bottle, particularly in the region of the cap.

6.3.1.3 Place the sample in the ultrasonic bath for one minute to loosen the particles that have become struck to the bottle wall.

6.3.1.4 Shake by hand for one minute immediately before counting. Counting is to be completed in less than 5 minutes after shaking.

6.3.2 Sealed containers of new fluid.

6.3.2.1 Using the filtered solvent specified in 5.5.2, thoroughly clean the outside of the container, particularly on the top where it will be opened.

6.3.2.2 Place the container in the ultrasonic bath for one minute to loosen the particles that have become stuck to the container wall.

6.3.2.3 Shake by hand for one minute.

6.3.2.4 Puncture the cleaned surface with a cleaned and rinsed tool, making a hole that is no larger than necessary. For other containers, remove the closure and clean the lip.

6.3.2.5 Using a cleaned and rinsed syringe or pipette, take the sample from the middle depth of the container.

6.3.2.6 Transfer the sample to a cleaned glass bottle and cap it.

6.3.2.7 Shake the bottle by hand for one minute immediately before counting.

6.4 Preparation of sample bottle for placing in the counter.

6.4.1 After carefully removing the cap from the sample bottle, place the bottle in an ultrasonic bath.

6.4.2 Apply a vacuum of at least 47.8 kPa (535 millibars) for 30 seconds to remove air bubbles.

6.4.3 Remove bottle from ultrasonic bath.

6.4.4 Turn off the vacuum source.

6.4.5 Place sample bottle in automatic counter sampler for counting.

6.5 Calibration procedure.

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6.5.1 The primary calibration of the instrument shall be carried out in accordance with procedures provided by the manufacturer using a certified distribution of AC Fine Test Dust (ACFTD) dispersed in H-515 hydraulic fluid as the automatic counter is fitted with a 5 to 150 micrometer sensor.

6.5.2 The calibration shall be carried out at least annually or when any change is made in the automatic counter.

6.6 Calibration procedure using ACFTD.

6.6.1 When AC Fine Test Dust is dispersed in a particle free fluid at a concentration of 1 mg/L this is the total count:

Diameter (micrometer)	Number of particles per milliliter greater than diameter
5	516.688
15	55.230
25	13.254
50	1.290
100	0.0798

For sources of the ACFTD suspension in fluid see 5.2.

6.6.2 Six bottles of known ACFTD concentration are used to calibrate the automatic particle counter.

5.7 Preparation of known standards.

6.7.1 Place an accurately (±0.1 mg) weighed amount (for example 100 mg) of dried ACFTD in a clean sample container and add clean filtered hydraulic fluid (for example 1 L). Replace the cap on the bottle.

6.7.2 Disperse and suspend the dust in this concentrated mixture by violent agitation (for example, 5 minutes in a paint shaker, 30 seconds in the ultrasonic bath, and 15 minutes in a paint shaker). It is sometimes useful to soak the ACFTD in the fluid overnight, then disperse the next day.

6.7.3 Prepare a calibration standard by diluting a portion of the concentrated standard with filtered H 515 to obtain a concentration of less than 4 mg/L. This concentration is well below the saturation level of the 5-15 micrometer count.

6.7.4 Shake this diluted calibration standard by hand for 30 seconds. Remove air bubbles by ultra-sonics and apply a minimum vacuum of 47.8 kPa (535 mm Hg) for at least 30 seconds.

6.8 Calibration of the automatic particle counter.

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6.8.1 Adjust the first five channels of the particle counter thresholds to some valve (manufacturer's suggested or previously determined) for the ranges of greater than 5, 15, 25, 50, 100 micrometer.

6.8.2 Obtain 5 particle counts from the bottle of known ACFTD within 5 minutes in total count or threshold mode. Calculate the arithmetic mean of the five counts and record it. Call this value A.

6.8.3 Calculate the average particle count per mL per mg ACFTD per L and call it A. Calculate A for each channel. Using A for the average count, B for the gravimetric concentration of the calibration suspension, C for the sample volume in milliliters used for the count and this expression:

A = A/(B X C)

6.8.4 A bar values can then be directly compared with the expected values in 6.6. Alternatively, a log-log plot of A against channel threshold settings can be constructed and a true calibration setting can be obtained from the intersection of the calibration curve with the threshold settings.

Note: Linear regression may be used to obtain the best linear graph when this technique is applied to automatic particle counters which incorporate AC amplifiers.

6.8.5 Adjust the channel thresholds to the values determined in 6.7.8.

6.8.6 Repeat 6.7.6 through 6.7.9 on two more bottles of known bottles of ACFTD standard. This completes the threshold calibration.

6.8.7 Count the particles in two more bottles of known ACTFD standard. The results should agree within +10 percent of the expected count.

6.8.8 Record the tl~resholds that have been determined. To use this calibration for other sizes, prepare a calibration curve on log-log paper of threshold settings in millivolts versus particle size. (Particle size as the horizontal axis [abcissa] permits comparison to HIAC curves more readily).

6.9 Instrument thresholds check.

6.9.1 The following procedure shall be carried out monthly if the instrument is left switched on permanently. If the instrument is switched off between counts a period of two hours should be allowed for warm up before making any change in the threshold settings.

6.9.2 Check the instrument threshold settings strictly in accordance with the manual provided with the instrument, using the calibration settings obtained in 6.8.

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6.10 Counting procedure.

6.10.1 Counting procedure shall be carried out in accordance with the manual provided with the instrument, in the window or delta mode.

6.10.2 Ensure that the counter has been switched on long enough (30 minutes). For instruments that do not automatically compensate for opacity additional adjustment may be needed to be made before counting begins.

6.10.3 Fluid flow rate shall be as recommended by the manufacturer.

6.10.4 The sample shall be counted in at least two equal volumes (each shall have a minimum flow time of 20 seconds).

6.10.5 A small amount of sample may be used to flush the sensor as an alternative, first count may be disregarded by not recording it.

6.10.6 After all of the tests are completed, flush the sensor with filtered solvent as described in 5.5.1 and 5.5.2.

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Report to no more than three significant figures, the number of particles per 100 mL in the following size ranges: (DELTA mode).

5 to 15 micrometer
16 to 25 micrometer
26 to 50 micrometer
51 to 100 micrometer
over 100 micrometer

9. PRECISION

9.1 Precision data have not been developed for this method.

Method Prepared By:

SFTL - 1986

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DETERMINATION OF PARTICULATE CONTAMINATION IN SYNTHETIC TURBINE ENGINE LUBRICANTS

1. SCOPE

1.1 This method describes a gravimetric procedure for the determination of particulate contamination in synthetic turbine engine lubricating oils.

2. SUMMARY

2.1 A known volume of oil is filtered through a pre-weighed membrane filter. The increase in filter weight is determined after washing and drying and is considered particulate contaminant. Particulate contaminant per liter of oil is calculated from the volume of oil filtered and the weight of particulate contaminant.

3. SAMPLE

3.1 Approximately one L of the oil to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Membrane filters, 4.7 cm diameter, absolute pore size of 3 micrometers and 0.45 micrometers. Filters must be compatible with the required reagents and with MIL-L-7808 lubricants at elevated temperatures. Millipore MF filters or equivalent shall be used.

4.2 Filter holder, 4.7 cm diameter.

4.3 Analytical balance, sensitivity 0.1 mg.

4.4 Petri dishes, 10.0 cm diameter with covers.

4.5 Oven, non-circulatory air, capable of maintaining temperature of 90°C.

4.6 Forceps, flat-bladed with unserrated tips.

4.7 Vacuum system, 62.5 cm Hg or better.

4.8 Laboratory wash bottle.

5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hzardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handing and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

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5.2 Isopropyl alcohol, reagent grade [1,3,0].

5.3 Petroleum ether, 30 to 60°C boiling range, reagent grade [1,4,0].

6 . PROCEDURE

6.1 Sampling

6.1.1 The sample must be representative of the material to be tested. When samples represent packaged quart containers, the entire contents must be filtered. When samples represent packaged 8-ounce containers, the entire contents of at least two, but no more than four, of the 8-ounce containers must be filtered. When the material is packaged in containers larger than 1 quart, a representative 1L, (1 quart) sample must be taken in a clean container for the filtration test. The entire contents of these samples must be filtered.

6.2 Preparation of apparatus and containers.

6.2.1 Wash all components of the filtering apparatus with hot water and detergent.

6.2.2 Rinse with hot tap water.

6.2.3 Rinse with distilled water.

6.2.4 Rinse with filtered isopropyl alcohol.

6.2.5 Rinse with filtered petroleum ether.

6.2.6 Place clean plastic wrap or aluminum foil over the filtering apparatus when not in use.

6.3 Preparation of reagents.

6.3.1 Filter the isopropyl alcohol and petroleum ether through a 0.45 micrometer membrane filter. Discard the first 50 mL of each solvent filtered. Filtering equipment and storage containers for the solvents must be cleaned as described in 6.2.

NOTE: Ground the filter mechanism to prevent build-up of static electricity.

6.4 Preparation of test filters.

6.4.1 place a 3-micrometer membrane filter in a petri dish and dry for 30 minutes in an oven regulated to 90°C with petri dish lid ajar. Remove petri dish and with lid closed, place in vicinity of balance on which weighings are to be

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made. Allow filters to cool for 30 minutes and weigh to the nearest 0.1 mg. Use forceps to handle the test membranes. An air ionizer must be utilized during all weighings to eliminate errors due to electrostatic charge effects.

6.5 Filtering of test sample.

6.5.1 Inspect visually the top of the sample container for dust and dirt. If present, wash top of container using laboratory wash bottle containing filtered petroleum ether.

6.5.2 Shake sample mechanically for 5 minutes prior to test. Puncture small opening in top of container (vent in case of screw cap containers) and heat to a maximum of 60°C to facilitate filtering. Lubricant formulations which filter readily (30 minutes or less per L [quart]) need not be heated.

6.5.3 Cautiously open containers so as to prevent the introduction of metal particles into the sample. Pour approximately 50 mL of sample into the assembled filtering apparatus containing the pre-weighed filter and apply vacuum. Filter entire contents of the sample container and record filtering time in minutes. All of the sample must be filtered through one filter. Thoroughly wash down the inside of the sample container with filtered petroleum ether, passing the washings through the filter.

6.5.4 Wash down the inside of the filter funnel using laboratory wash bottle containing filtered petroleum ether. With vacuum still applied, carefully remove the funnel. Wash the periphery of the membrane by directing a gentle stream of filtered petroleum ether from the edge toward the center, taking care not to wash any contaminant from the surface of the membrane.

6.5.5 Carefully remove the test membrane from the filter base and place it in a petri dish. Dry and reweigh as described in 6.4.1.

7. CALCULATIONS

7.1 Calculate particulate contaminant per liter of oil from the initial and final weight of the test filter and the volume of sample filtered.

$$\text{Particulate contaminant, mg/liter of test} = \frac{A - B}{C}$$

A = Final weight of test filter in mg.
B = Initial weight of test membrane in mg.
C = Volume of sample measure in litres passed through the filter.

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8. REPORTING

8.1 Report the contaminant in mg/L and filtering time in minutes.

9. PRECISION

9.1 Precision data have not been developed for this method.

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Air Force - AFWAL/POSL - 1986

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METHOD 3110.1
September 30, 1986

FATTY OIL IN CUTTING FLUIDS BY INFRARED SPECTROPHOTOMETRY

1. SCOPE

1.1 This method of analysis is intended for the determination of fatty oil in sulfurized fatty mineral and sulfurized, chlorinated fatty mineral cutting fluids. The method is based on the assumption that the fatty oil will consist entirely of lard oil. The method is not applicable to the fatty oil analysis of cutting oils which contain oxidized oils or compounds containing carbonyl groups which also absorb at 1743 cm^{-1}, the point in the spectrum upon which this analysis is based. Sulfur- and chlorine–containing compounds which often interfere with the conventional fatty oil analysis do not interfere with this method.

2. SUMMARY

2.1 The total concentration of fatty oil in a cutting fluid is determined by measuring the absorbance at the carbonyl absorption band at 1743 cm-l by means of infrared spectrophotometry. A curve showing the relationship between fatty oil content and absorbance at 1743 cm-l is used to determine the percent of fatty oil in the cutting fluid.

3. SAMPLE SIZE

3.1 Approximately 100 mL. of the oil to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 An infrared spectrophotometer capable of producing a distinct carbonyl absorption band at 1743 cm^{-1}. The Perkin-Elmer Infrared Spectrophotometer, Model 621, has been found satisfactory. A sealed liquid cell with sodium chloride or potassium bromide windows may be used. It is recommended that the path length used be approximately 0.025 mm.

5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Spectrophotometric standards of MIL-F-46148 Fatty Oil in VV-O-241 Mineral Oil ranging from 0.0 to 15.0 percent.

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6. PROCEDURE

6.1 Calibrate the spectrophotometer in accordance with the manufacturer's instructions. Prepare a series of at least five standards consisting of mixtures of fatty oil meeting the requirements of MIL-F-46148 and mineral oil meeting the requirements of VV-0-241, type II, such that the percent of fatty oil in the standards ranges from 0.0 to 15.0 percent. If the sample being analyzed contains more than 15 percent fatty oil, dilute it with sufficient mineral oil which meets the requirements of VV-0-241, type II, to reduce the fatty oil content below 15 percent so that the standards prepared above can be utilized. Determine the absorbance values of the standards in accordance with 5.2 and plot the percent fatty oil against the absorbance values at 1743 cm^{-1}.

6.2 Thoroughly mix the sample but avoid producing air bubbles. Fill the cavity in the sealed cell, avoiding any air inclusion. Samples suspected of containing any moisture should not be used as the moisture will fog the sodium chloride or potassium bromide windows or change the effective path length of the cell. Place the filled cell in the beam of the infrared spectrophotometer and scan between 2000 and 1500 cm^{-1}. Determine absorbance of the band at 1743 cm^{-1}. Determine absorbance of the band at 1743 cm-1 using the Base Line Mehtod. This method consists of drawing the base line as nearly parallel as possible to the radiant energy background as shown in Figure 1. The absorbance is then calculated from the equation in Section 7.1. Determine the percent fatty oil in the sample from the plot prepared from the standards (see 5.2). It is suggested that standards bracketing the expected fatty oil concentration be run concurrently with the sample undergoing test to check the previously prepared plot prepared from the standards and to compensate for any variability in equipment operation. If the absorbance of these standards do not agree with the previously prepared plot, prepare a new working curve prior to analyzing the sample.

7. CALCULATIONS

7.1 Calculation of absorbance of 1743 cm^{-1} band:

$$A = \log_{10} \frac{T_B}{T_P}$$

where A = absorbance, T_B = the distance from the zero line to the base line, and Tp = the distance from the zero line to the selected absorption peak.

8. REPORTING

8.1 Report the percent of fatty oil found in the cutting fluid.

9. PRECISION

9.1 Use the following criteria as a basis for judging the acceptability of results (95 percent confidence):

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a. Repeatability. Duplicate results by the same operator should be considered suspect if they differ by more than 0.2 percent.
b. Reproducibility. The results submitted by each of two laboratories should be considered suspect if they differ by more than 0.3 percent.

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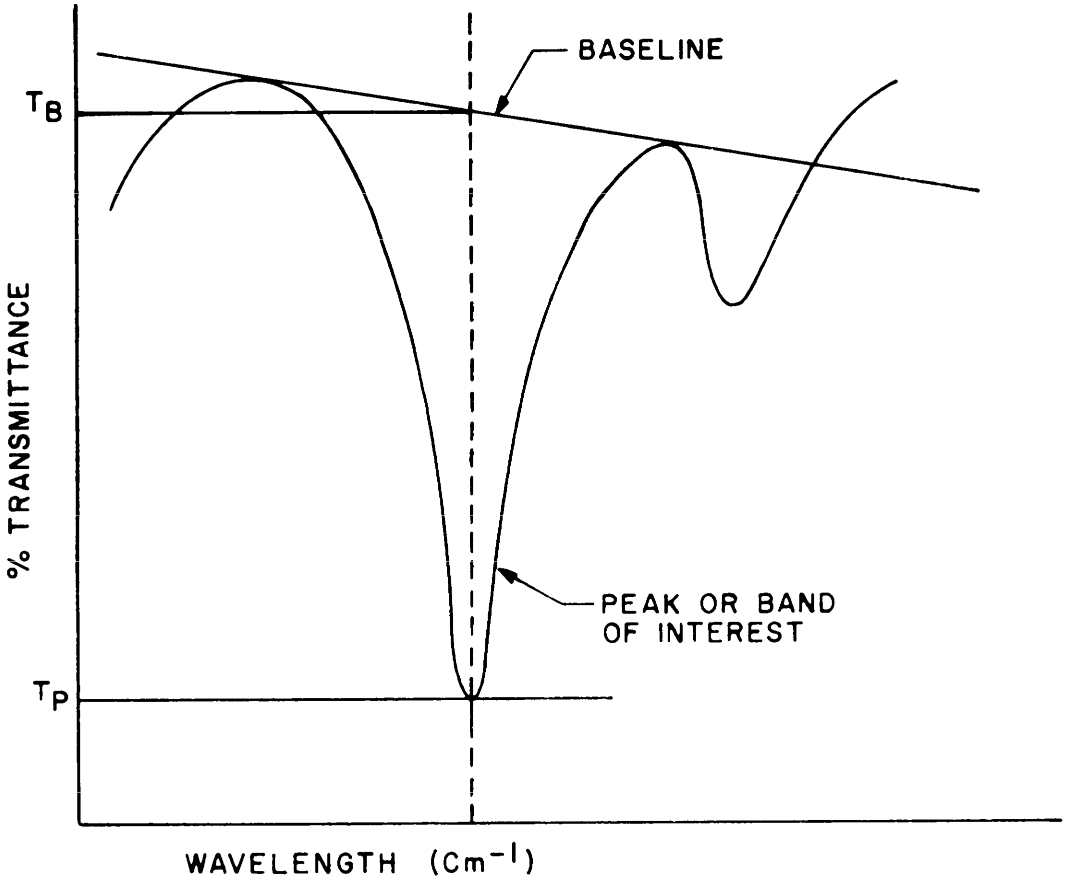

FIGURE 1. Base line method for determination of absorbance.

X-4368

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SULFUR IN CUTTING FLUIDS (ACTIVE AND TOTAL)

1. SCOPE

1.1 This method is used for the determination of active and total sulfur in cutting fluids. It is used in conjunction with ASTM D 129.

2. SUMMARY

2.1 Total sulfur content of the fluid is determined in accordance with ASTM D 129 with the noted exceptions. Active sulfur content is determined by first reacting the fluid with some copper powder, determining the sulfur content of the reacted fluid and then subtracting this sulfur content from the total sulfur content.

3. SAMPLE SIZE

3.1 Approximately 45 mL of the cutting fluid to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Standards

4.1.1 ASTM Method D 129, Sulfur in Petroleum Products by the Bomb Method.

4.2 Beaker, lipless, tall-form, 250-mL capacity.

4.3 Auger stirrer blade, 1..0 cm wide and 7.5 cm high.

4.4 Thermometer, 177° C (350° F), range of 150 to 200 “C.

4.5 Bomb, minimum capacity 300 mL, electrically fired (see ASTM D 129).

4.6 Sample cup, platinum or nickel (see ASTM D 129).

5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Copper powder, ACS. Baker Chemical Company Catalog No. 1728, Copper, Purified Powder, has been found satisfactory.

5.3 Nitric acid, 5 percent [2,0,0].

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5.4 Acetone, ACS [1,3,0].

5.5 Isooctane, knock test grade [0,3,0].

5.6 Filter paper, Whatman No. 4 and No. 42 or equivalent.

5.7 Firing wire, iron, approximately 26 B&S gage.

5.8 Blue litmus paper.

5.9 Materials required for ASTM D 129.

6. PROCEDURE

6.1 Preparation of copper powder. Place approximately 20 g of copper powder in a 250-mL beaker and add 5 percent nitric acid until all the powder is covered. Heat the beaker and contents gently until the surface of the copper powder begins to react. Allow the reaction to continue for about one minute or until the copper powder is free of oxides. Add sufficient distilled water to stop the reaction. Decant and discard supernatent liquid. Wash the copper powder on a No. 4 Whatman or equivalent filter paper with distilled water until the wash water shows no trace of nitric acid when tested with blue litmus paper. When all the nitric acid has been removed, wash the copper powder with sufficient acetone to remove all traces of water. If not ready to proceed with the test, the dried copper powder may be stored under knock test grade isooctane.

Note 1. Caution. Isooctane is flammable. Do not use isooctane near an open flame.

6.2 Sulfur determinations.

6.2.1 Active sulfur. Place 20 +1 g of the sample fluid in a 250-mL, tall-form lipless beaker and add approximately 2.0 ±0.1 g of the dried copper powder prepared in 6.1. place the beaker and contents on a hot plate and heat the mixture to 149° +3° C (300° +5° F) while stirring at 1750 rpm for at least one hour. At the end of the hearing and stirring period, cool the mixture to room temperature and filter through a Whatrnan No. 4 or equivalent filter paper. Determine the sulfur content of the filtrate (the reacted fluid) in accordance with ASTM D 129 with the following exceptions:

a. paragraphs 3.2, 3.3: A nickel cup and iron wire may be used.
b. Paragraph 5.1: Place 15 mL of sodium carbonate solution in the bomb in place of the prescibed 5 mL.
c. Paragraph 5.5: After removing the beaker containing the barium sulfate from the hot plate, permit the barium sulfate to settle for a minimum of four hours, preferably overnight.
d. Paragraph 5.5: After the barium sulfate has settled for a minimum of four hours, filter the supernatant liquid through a Whatman No. 24 or

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equivalent filter paper and wash with hot water until all traces of barium chloride are removed. The active sulfur content of the cutting fluid is equivalent to the difference between the total sulfur content of the cutting fluid (as determined in 6.2.2) and the sulfur content of the reacted cutting fluid.

6.2.2 Total sulfur. Determine the total sulfur content of the cutting fluid in accordance with ASTM D 129 with the exceptions listed in paragraph 6.2.1.

7. CALCULATIONS

7.1 Weight percent of sulfur as calculated in 6.1 of ASTM D 129.

7.2 Active sulfur content = Total sulfur content - sulfur content of reacted fluid.

8. REPORTING

8.1 Report active and total sulfur contents to the nearest 0.01 percent.

9. PRECISION

9.1 Reference paragraph 8.1 of ASTM D 129 for percent sulfur contents.

9.2 No precision data available for sulfur content of reacted fluids.

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EMULSION (PETROLEUM AND PETROLEUM-LIKE PRODUCTS)

1. SCOPE

1.1 This method is used for determining the emulsifying tendency of petroleum and petroleum-like products.

2. SUMMARY

2.1 The test consists of stirring the sample and its emulsifying agent at a specified temperature, allowing the emulsion to remain undisturbed at the test temperature for the time required by the specification, and examining the emulsion for any separation.

3. SAMPLE SIZE

3.1 Approximately 40 mL of the oil or fluid to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Graduated cylinder, 100-mL (approximately 28.6 mm [1-1/8 inch] ID).

4.2 Heating bath (oil or water) 54° ±0.5° C (130° +1° F) (unless otherwise specified) deep enough to cover 85 mL mark of the graduated cylinder.

4.3 Stirring mechanism (figure 1) consisting of:

a. Paddle, copper strip, 12.1 (4-3/4) by 1.9 (3/4) by 0.16 cm (1/16 inch).
b. Shaft, stirring, with means for attaching paddle long enough to immerse paddle to approximately 0.64 cm (1/4 inch) from bottom of graduated cylinder.
c. Motor, stirring, approximately 1500 rpm, for rotating shaft,and paddle.

4.4 Thermometer (range to suit requirements of specification).

4.5 Wooden stick or rubber policeman.

5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical' are explained.

5.2 Emulsifying agent (distilled water, sodium-chloride solution, or synthetic seawater) as required by the specification.

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6. PROCEDURE

6.1 Secure paddle to shaft and connect shaft to stirring motor.

6.2 Preheat and regulate bath to maintain test temperature.

6.3 Pour approximately 40 mL each of sample and emulsifying agent into graduated cylinder. Immerse cylinder in bath to 85 mL mark, and allow contents of cylinder to reach test temperature.

6.4 Lower paddle into cylinder so that bottom of paddle is approximately 0.64 cm (1/4 inch) from bottom of cylinder. Start stirring motor and allow it to rotate paddle at approximately 1500 rpm for 5 minutes ±15 seconds.

6.5 Stop motor, raise paddle from cyliner, and remove emuslion from paddle with stick or rubber policeman. Return as much of the emulsion as possible to cylinder.

6.6 Allow emulsion to remain undisturbed at the test temperature for the time required by the specification.

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Examine emulsion for any separation, and report whether end product conforms to specification.

9. PRECISION

9.1 Precision data have not been developed for this method.

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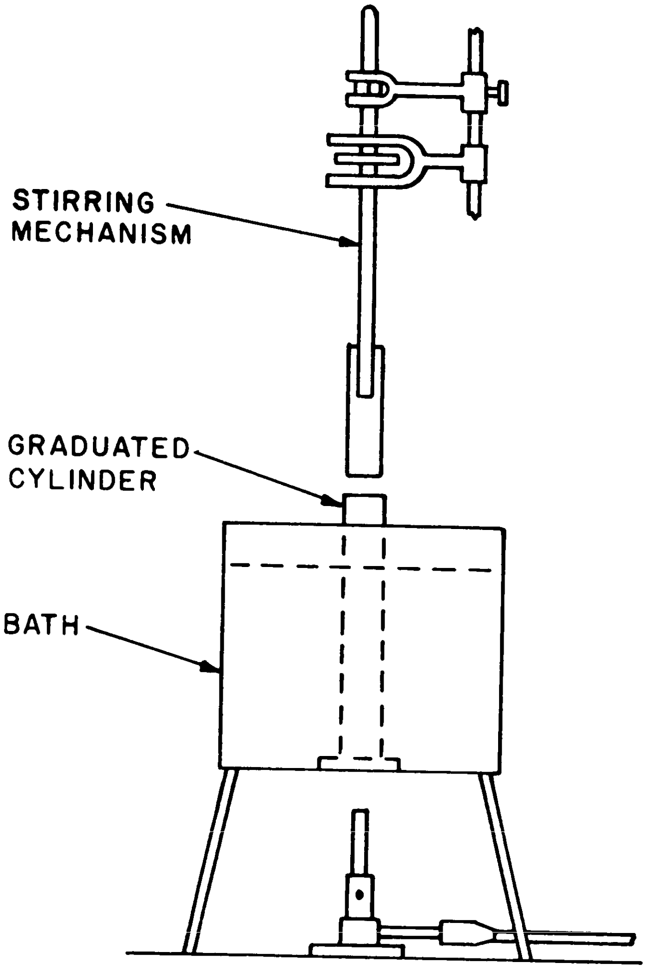

FIGURE 1. Stirring mechanism.

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EMULSION (SOLUBLE CUTTING OILS)

1. SCOPE

1.1 This method is used for determining the emulsifying tendency of soluble cutting oils.

2. SUMMARY

2.1 The test consists of shaking a mixture of sample oil and water, allowing the mixture to stand, and examining for evidence of separation and for air bubbles.

3. SAMPLE SIZE

3.1 Approximately 5 mL of oil to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Sample bottle 120-mL (4 oz.), with stopper.

5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Distilled water.

6. PROCEDURE

6.1 Pour 95 mL of distilled water into sample bottle and add 5 mL of test oil. Shake vigorously for 1 minute.

6.2 Let bottle stand for 1 hour at 21° to 32° C (70° to 90° F). At end of this period, examine for evidence of separation.

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Report the sample as acceptable if no separation is apparent and as unacceptable if separation occurs.

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9. PRECISION

9.1 Precision data have not been developed for this method.

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FOAMING CHARACTERISTICS OF AIRCRAFT TURBINE LUBRICATING OILS (STATIC FOAM TEST)

1. SCOPE

1.1 This method is used to determine the foaming characteristics of aircraft turbine lubricating oils under specified temperature and air flow conditions.

2. SUMMARY

2.1 This static foam test is basically the ASTM D 892 foam test modified to be substantially more severe. Ratings of synthetic lubricant foaming tendencies using this method have been consistent with existing operational turbine engine experience. The modifications primarily involve the use of a 500 mL rather than the 1000 mL. graduated cylinder and a greatly increased air flow rate.

3. SAMPLE

3.1 Approximately 300 mL of the material to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Foam Test Apparatus; ASTM D 892 (Model 430 or Model 430A, Koehler Inst. Co., 1595 Sycamore Ave., Bohemis L.I., New York 11716 or equivalent).

The apparatus consists of an air inlet device, 2.54 cm diameter spherical gas diffusion stone (Norton CO., Worcester, Mass., No. ME-46239, p2180 grade or equivalent) , and a liquid bath equipped with heater, stirrer and temperature controller. The bath must be capable of maintaining a bath temperature of 80° ±1°C throughout a test cycle. Maximum stone pore diameter shall not be greater than 80 micrometers. Stone permeability at a water pressure of 250 mm shall be 3000 to 6000 mL of air/min. Refer to ASTM D 892 for maximum pore diameter and permeability test procedures.

4.2 Cylinder, graduated; 500-mL (Standard glass laboratory ware with pouring spout). Corning No. 3022 or equivalent.

4.3 Stopper, rubber; fitted for air tube.

4.4 Flowmeter; capable of delivering 1000 +20 mL air/min as measured at 20° C (68° F) and 101 gage kPa (760 mm Hg).

4.5 Timer; 1 sec graduations, accurate to 1 sec or better.

4.6 Thermometer; 1° C increments, accuracy of 1° C or better. An ASTM 12C (-20 to +102° C) thermometer is suitable.

4.7 Oven, drying; standard laboratory equipment.

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5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS . The materials references and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precuations, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Solvents, cleaning; dry cleaning solvent (Astm D 484,type I) or petroleum distillate [0,2,0].

5.3 Toluene conforming to ASTM D 892 specifications [2,3,0].

5.4 Petroleum ether (Boiling Range 30 to 60° C), ACS [1,4,0].

“WARNING: Toluene is toxic and flammable. Keep away from open flames. Avoid breathing vapors and contact with skin. Use in a laboratory hood or with adequate ventilation.”

6. PREPARATION OF APPARATUS

6.1 The graduated cylinder, air inlet tube and diffuser stone must be cleaned thoroughly after each test. Between tests, these items must be stored in a clean, dust-free area.

6.1.1 The cylinder shall be cleaned by rinsing with dry cleaning solvent or petroleum distillate, then another- rinse with toluene followed by washing with detergent and water. Rinse thoroughly with distilled water and dry in oven.

6.1.2 Clean stone and air tube by rinsing with dry cleaning solvent or petroleum distillate. Then immerse stone in toluene and, using vacuum and air pressure, flush the solvent back and forth at least 5 times. Finally, rinse stone with petroleum ether and dry using clean air. Wipe the outside of the air tube with a clean cloth moistened with toluene followed by a clean dry cloth.

6.2 PROCEDURE

6.2.1 Measure 200 mL of lubricant into clean cylinder. Immerse the cylinder in bath maintained at 80 +1° C (bath liquid above 500 mL cylinder mark). Install air tube and stone so that the stone just touches the bottom of the cylinder and is approximately at the center of circular cross section. Allow 15 minutes for lubricant to reach thermal equilibrium. Make all air supply connections. Adjust air flow to 1000 ±20 mL/min.

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6.2.2 Record the maximum foam volume generated during the thirty minute test period. Foam volume is defined as the foam-air interface (mL) minus the foam-liquid interface. If no foam-liquid interface is discernible, the foam-air interface measured in mL shall be defined as the foam volume. At the end of the test period, disconnect the air supply. Record the time required for the foam to collapse to no more than a single ring of bubbles at the lubricant surface periphery, or record volume of foam remaining after 5 minutes, whichever occurs first. Disassemble and clean apparatus.

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Report the following:

Maximum Foam Volume, mL________________
Foam Collapse Time, sec________________
Foam Volume Remaining after 5 min mL________________

9. PRECISION

9.1 Repeatability. The repeatability of the method depends upon the level of the result. Limited test data indicates the following test repeatability:

Foam Volume	Repeatability
50 mL	10
150 mL	20
250 mL	25

9.2 Reproducibility. This has not been established.

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Air Force - AFWAL/POSL - 1986

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FOAMING CHARACTERISTICS OF AIRCRAFT TURBINE LUBRICATING OILS (DYNAMIC FOAM TEST)

1. SCOPE

1.1 This method describes a test procedure for determining the foaming characteristics of aircraft turbine lubricating oils at specified temperatures and aeration rates. Although the test rig described in this method permits the determining of foaming characteristics under simulated altitude conditions (reduced pressures), this method describes testing at ground level (atmospheric pressure) conditions.

2. SUMMARY

2.1 The test oil is heated and circulated through a foam test rig consisting primarily of a test oil loop, oil pump, oil heater, air injection orifice, foam test cell and associated control and measuring units. The test cycle for each sample consists of determining the foaming characteristics at temperatures of 80° C and 110° C with air flows of 1000 mL/min, 1500 mL/min and 2000 mL/min at each temperature. Test oil flow rate is 4.5 to 5.7 L/rein and is controlled by the oil pump pressure and an oil line orifice. (Reference Figure 1.)

3. SAMPLE SIZE

3.1 Approximately 1200 mL of material to be tested.

4. APPARATUS

4.1 Dynamic foam test rig. Drawings of this test rig are available from the Air Force Aero-Propulsion Laboratory/SFL, Wright-Patterson AFB, Ohio 45433. Description of this test rig is given in technical report AFAPL-TR-71-83, "Dynamic Foam and Aeration Test Apparatus", dated June 1972 and is available from the Defense Documentation Center, Cameron Station, Alexandria, Virginia 22314.

4.2 Timer, graduated and accurate to 1 second or better.

5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

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5.2 Desiccant, indicating Drierite ^{R} or equivalent for air purifiers.

5.3 Trichlorotrifluoroethane cleaning solvent, in accordance with MIL-C-81302 type 1 or type 2 (u.u.u).

6. PROCEDURE

6.1 Preparation of test rig.

6.1.1 Prior to test rig assembly, thoroughly clean all parts with trichlorotrifluoroethane and air dry.

"Warning: Halogenated solvents should be used with adequate ventilation.”

6.1.2 Assemble all parts, taking care to ensure against leaks at all fittings. Position air injector so that the direction of air flow is perpendicular to the oil flow.

6.1.3 Check test system for leaks by evacuating test system to an absolute pressure of 34.5 absolute kPa (5 psia) and closing all valves. System pressure should not increase above 41.4 absolute kPa (6 psia) after two hours. If leaks are present, location of such can be accomplished by pressuring the system and using a bubble-type detector solution. However, it is important to ensure that none of the detector solution enters the test system.

6.1.4 Check desiccant in air drier and change if necessary.

6.1.5 Turn on water for oil vapor trap.

6.2 Test operation.

6.2.1 Flush of system.

6.2.1.1 Prior to test, flush the system with the test oil by placing drain valve in a beaker containing 600 mL of the test oil. Open drain valve, close atmospheric vent valve, turn on vacuum pump and open test system vacuum valve. When beaker is empty, open and close atmospheric vent valve momentarily *to* cause oil to rise to the top of foam chamber. Leave vent valve open and close drain valve. Close vacuum valve and turn off vacuum pump. Turn on circulation pump and regulate oil pressure to 758 absolute kPa (110 psia). Turn on oil heater and heat oil to approximately 80° C. Turn off oil heater and drain flush oil with circulation pump.

6.2.2 Test phase I.

6.2.2.1 Charge the system with 600 mL of test oil as outlined in paragraph 7.1.1. With atmospheric vent valve closed, vacuum valve closed and vacuum pump

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off, start oil circulation pump and adjust pump speed to obtain an oil pressure of 758 absolute kPa (110 psia). Set aeration valve to bypass and turn on air flow and adjust to 1000 mL/min (20° C and 101 absolute kPa [1 atm]). Turn on oil heater and set temperature control to 80° C. After test oil has reached 80° C, adjust control as needed to maintain an oil temperature of 80° C. With operating temperature and pressure established, open drain valve until 500 mL of oil is indicated in the test chamber. Turn aeration valve to "aerate" and adjust flow meter for 1000 mL/min (20° C and 101 absolute kPa [1 atm]) and start timer. (Note: Some oils exhibit a large change in foaming values for small changes in air flow. Therefore, for air flows measured under conditions other than 20° C and 101 absolute kPa [1 atm] appropriate corrections must be made.) Continue aeration for 30 minutes. At the end of each 5 minute period, record oil pressure decrease and oil volume increase. Also record the maximum volume of foam reached during the 5 minutes period. At the end of 30 minutes and after recording the foam, oil pressure and volume measurements, turn aeration valve to bypass. Record time required for first patch of clear surface to appear and remain exposed or record volume of foam remaining after 5 minutes, whichever occurs first.

6.2.2.2 With test oil still being at 80° C and a pressure of 758 absolute kPa (11O psia), turn aeration valve to “aerate” and adjust air flow to 1500 mL/min (20° C and 101 absolute kPa [1 atm]). Continue test for 30 minutes taking readings as outlined in 6.2.2.1.

6.2.2.3 With test oil still being at 80° C and a pressure of 758 absolute kPa (110 psia), turn aeration valve to "aerate" and adjust air flow to 2000 mL/min (20° C and 101 absolute kPa [1 atm]). Continue test for 30 minutes taking readings as outlined in 6.2.2.1.

6.2.3 Test phase II.

6.2.3.1 Adjust temperature control to 110° C. After test oil has reached this temperature, adjust control as needed to maintain an oil temperature of 110° C. Open drain valve until 500 mL of oil is indicated in the test chamber. Set aeration valve to bypass and turn on air flow and adjust to 1000 mL/min (200 C and 101 absolute kPa [1 atm]). Turn aeration valve to “aerate” and re-adjust flow to 1000 mL/min (20° C and 101 absolute kPa [1 atm]). Continue testing as outlined in 6.2.2.1, 6.2.2.2, and 6.2.2.3.

6.2.4 Cleaning procedures.

6.2.4.1 Turn off oil heater and circulate oil until temperature is below 80° C. Open drain valve and drain oil by slowly rotating the oil circulation pump. place drain valve in a beaker containing 600 mL of trichlorotrifluoroethlane solvent. Open drain valve, close atmospheric vent valve, turn on vacuum pump and open test system vacuum valve. When beaker is empty, open and close atmospheric vent valve momentarily to cause cleaning solvent to rise to the top of foam chamber. Leave vent valve open and close drain valve. Close vacuum valve and turn off vacuum pump. Turn on oil circulation pump and drain 25 mL of

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cleaning solvent through drain on pulsation damper. Close pulsation damper rain and circulate the cleaning solvent through the system at a low pressure (about 276 absolute kPa [40 psia]) for 2 minutes. Open drain valve and turn off oil pump as soon as unit is empty. Close drain valve, open pulsation damper drain and apply vacuum to the system to remove residual cleaning solvent from the chemical seal.

6.2.4.2 Repeat flushing outlined in 6.2.4.1 two additional times or until the trichlorotrifluoroethane solvent shows no discoloration from test oil.

6.2.4.3 With pulsation damper drain open, system drain valve closed and atmosphric vent valve closed, apply vacuum and dry for 30 minutes.

6.2.4.4 Open drain valve, close pulsation damper drain and continue drying for 30 minutes. Open atmospheric vent valve and shut off vacuum system. Remove oil pump and disassemble in accordance with manufacturer^{s} instructions. Clean all parts with cleaning solvent and then dry. Coat all parts including seal with a qualified MIL-L-7808 oil. Assemble pump in accordance with manufacturer’s instruction. Replace pump on test unit ensuring alignment of oil pump and motor. Test rig is now ready for next test. (Note. Since some lubricants change foaming characteristics in storage, care should be taken in selecting oil for wetting oil pump after cleaning with trichlorotrifluoroethane solvent).

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Report maximum foam volume, oil pressure decrease and oil volume increase recorded during each of the three aeration rates at each temperature. Report foam collapse time or foam volume remaining after five minutes, at the end of each of the three aeration periods at each temperature.

9. PRECISION

9.1 Repeatability. The repeatability of the method depends upon the level of result. Limited test data indicates the following test repeatability.

Foam Volume	Repeatability
100 mL	30 mL
250 mL	50 mL
500 mL	75 mL

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9.2 Reproducibility. This has not been established.

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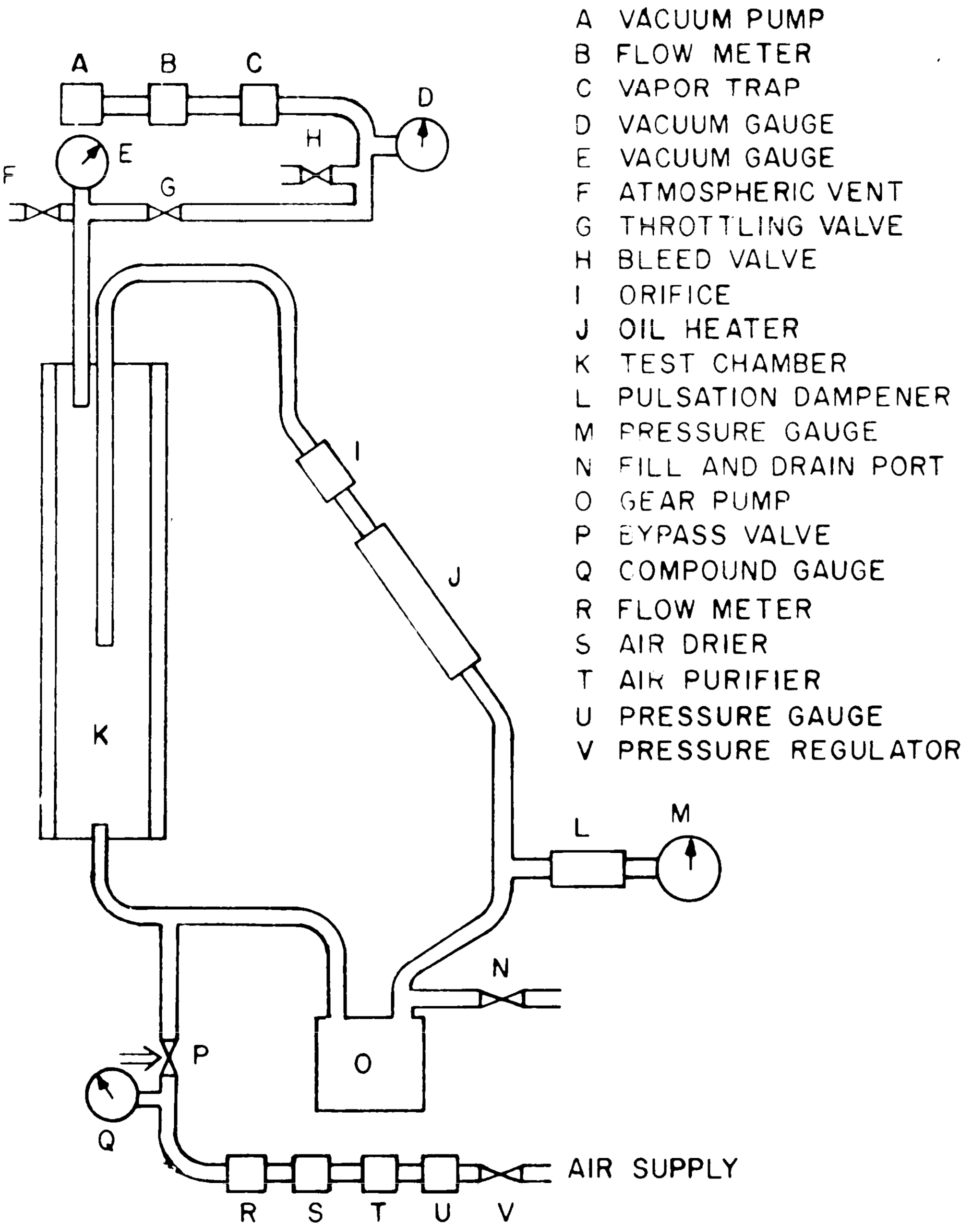

FIGURE 1. Schematic of foam and aeration apparatus.

X-4370

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TOTAL SOLIDS IN WATER FOR AIRCRAFT INJECTION SYSTEMS

1. SCOPE

1.1 This method described the gravimetric determination of total solids in water which is to be used in water-alcohol mixtures and water injection systems of reciprocating and jet engine aircraft.

2. SUMMARY

2.1 This method recognizes that total solids may include both dissolved solids and undissolved solids (suspended particles) in water samples. An alternate method for determining the weight of suspended particles is provided. An option to clean weighing dishes with a detergent solution instead of the sulfuric acid cleaning solution is also allowed if detergent cleaning provides satisfactory results.

3. SAMPLE SIZE

3.1 A sample of about 500 mL water should be taken at sampling. A minimum of 100 mL is required for the test.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Hot plate, electric, capable of boiling water.

4.2 Analytical balance, sensitive to 0.1 mg.

4.3 Oven, drying, must maintain a temperature of 110 ±2° C.

4.4 Pyrex glass evaporating dish 5 cm high and 9 cm diameter.

4.5 Watch glass, ribbed, 10 cm diameter.

4.6 Desiccator, with cover.

4.7 Glass plate for desiccator.

4.8 Crucible tongs for transporting evaporating dish.

4.9 Graduated cylinder, 100-mL.

4.10 Graduated cylinder, 500-mL.

4.11 Thermometer for temperature measurement at 85° C and 100° C.

4.12 Safety face mask.

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4.13 Safety gloves.

4.14 Apron.

4.15 Glass tongs.

4.16 containers, with covers, suitable for cleaning glassware and storing the detergent cleaning solution.

4.17 Funnel, borosilicate.

4.18 Filter paper, Whatman #42, 11 cm, diameter.

4.19 Beaker, borosilicate, 250-mL.

4.20 Filtration apparatus for liquid samples with the following component parts.

4.20.1 Filter holders, standard millipore.

4.20.2 Millipore filters, type SM (5-micrometer pore opening) 4.7 cm diameter.

4.20.3 Petri disk, 8.0-cm ID with covers.

4.21 Filtering flask.

4.22 Vacuum system, either aspirator or pump.

4.23 Forceps, flat-bladed, underrated for handling filters.

5. MATERIALS

5.1 CAUTIION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Distilled water (demineralized water may be used as a substitute except in the final rinse of the cleaning procedures).

5.3 Cleaning solution, glass (concentrated sulfuric acid saturated with potassium or sodium dichromate,technical grade) [3,0,2].

5.4 Sulfuric acid, concentrated, tech grade (NSN 6810-00-146-7520) [3,0,2].

5.5 Detergent concentrate (a suggested product is “Micro Detergent” manufactured by International Products Corp., PO Box 118, Trenton NJ or equal).

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5.6 Steel Wool, grade 1 (NSN 5350-00-242-4404, grade 1).

5.7 Indicating desiccant (NSN 6850-00-664-6654).

6. PROCEDURE

6.1 Preparation of detergent cleaning solutions.

6.1.1 Place 25 mL of detergent concentrate in a suitable container. Add 1000 mL of distilled water and stir to mix.

6.1.2 This solution should be discarded and a fresh solution made monthly. During its use, a small volume of water will be lost due to evaporation, add enough distilled water to bring the volume back to its original size and continue to use. The detergent solution may become cloudly when cold; however, this will not effect the cleaning ability.

6.2 Cleaning Glassware.

6.2.1 Laboratory conditions will dictate the required cleaning solution to be used. If glassware appears dirty, cloudy or experiences large weight changes during test conditions, then the glassware must be cleaned by using the glass cleaning solution. Under normal conditions, the preferred procedure will be cleaning with detergent solution. Detergent cleaning will avoid the potential dangers and possible hazardous conditions that can arise using the acid cleaning solution. All new glassware should be cleaned using glass cleaning solution before use. Evaporating dishes used for test should be wiped with a small piece of steel wool on the internal surface to remove dried salts by its abrasive action. The dishes should then be rinsed with tap water before proceeding to the cleaning solution to be used.

6.2.2 Detergent Cleaning. Immerse the glassware in the detergent solution for at least 30 minutes. While using the solution for cleaning, it must be maintained at a temperature of 85° +5° Co Rinse all glassware with tap water at least three times and then rinse with distilled water at least six times. Insure that the final rinses with distilled water are thorough. Dr the glassware in a dust free oven for at least two hours at a temperature of 11 ±2° C. After removal from the drying oven, place the glass dishes in a desiccator for a minimum of two hours prior to use. Glass dishes may be maintained in this condition, ready for test, as long as the indicating dessicant maintains its color.

4.2.3 Acid cleaning. Immerse glassware to be used in the acid cleaning solution for approximately four hours. Handle glassware with glass tongs, make sure the evaporating dishes are not in contact with the hands during any part of the procedure after they have been immersed in the cleaning solution. Rinse, dry and store the glassware according to the same steps as listed in 6.2.2 above.

6.3 Total Solids Test Procedure.

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6.3.1 Weigh two glass evaporating dishes to the nearest 0.1 mg. Record the weights and use the lightest dish as the control for determining the blank value.

6.3.2 Shake the sample to insure it is homogeneous. Using a 100-mL graduated cylinder, pour 100 mL of sample into a tared dish. Using tongs, place the dish on the hot plate. Cover with the ribbed watch glass. Cover the control dish with a watch glass and place on the desiccator plate (not in the desiccator).

6.3.3 Apply heat to the sample and allow the water to slowly vaporize until approximately 5 mL remain in the dish. Never allow the water to boil vigorously. Never allow the water to evaporate to dryness in the dish on the hot plate. Place the test and control dish in the drying oven for two hours at a temperature of 110° +2° C. Any splashing or bumping which allows drops of water to hit the watch glass will necessitate a retest.

6.3.4 After two hours, remove the dishes from the oven and allow to cool in a desiccator for a minimum of two hours.

6.3.5 Reweigh the dishes and record the weights.

6.4 Determine the total solid content (see 7.1 and 7.2).

6.5 Suspended solids test procedure.

6.5.1 If the water sample contains excessive large particles of visible sediment which settle quickly after the sample is shaken, pipetting a sample does not give a representative sample and the following procedure must be used.

6.5.2 Record volume of entire sample.

6.5.3 Filter entire water sample through a previously dried and weighed 5 mircometer pore opening millipore filter, dry filter and reweigh. Calculate the sediment collected in terms of ppm (g suspended solids X 10000 = ppm).

6.5.4 Determine total solids as outlined in 6.3 to 6.4.

6.5.5 Add total solids value (see 6.3 thru 6.4) to suspended solids value to yield total solids value of samples with visible suspended sediment.

NOTE 1. A more accurate method but which requires considerably longer time is to evaporate entire sample and calculate the total solids from the volume of sample and weight of evaporated residue.

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7. CALCULATIONS

7.1 Total solid content in PPM is:

$$[(D-C) - (B-A)] \times 10{,}000 = PPM$$

A = Initial weight of control dish in g.
B = Final weight of control dish in g.
C = Initial weight of test dish in g.
D = Final weight of test dish in g.

7.2 If the value (B-A) exceeds plus or minus 0.0003 g (0.3 mg), then the testing conditions and technique used should be suspect and the sample retested.

8. REPORTING

8.1 Report results in parts per million (ppm) total solids; number shall be rounded off to the nearest whole ppm.

9. PRECISION

9.1 Precision data have not been developed for this method.

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COMPATIBILITY OF TURBINE LUBRICATING OILS

1. SCOPE

1.1 This method is used for determining the compatibility of aircraft turbine lubricants with specific referee lubricants.

2. SUMMMARY

2.1 This method consists essentially of preparing mixtures of the sample lubricant and referee lubricant in three concentrations, maintaining the mixtures at a fixed temperature for seven days, and then centrifuging them for ten-minute intervals until the volumes of sediment becomes constant.

3. SAMPLE SIZE

3.1 Approximately 300 mL of the aircraft turbine lubricant to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Oven, gravity-convection 105° C ±1° C (221° F ±2° F) (to accommodate three 250-mL flasks).

4.2 Erlenmeyer flasks, (3), Pyrex, 250-mL with glass stoppers.

4.3 Centrifuge tubes, cone-shaped, 100-mL (see ASTM D 2273).

4.4 Centrifuge, capable of spinning two or more centrifuge tubes, and applying a relative centrifugal force of 600 to 700 at the tips of the tubes.

4.5 Bath, hot water, 93° C ±3° C (200° F ±5° F) (for simultaneous heating of centrifuge tubes to be spun).

5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Referee lubricant (in accordance with lubricant specification), 300 mL.

5.3 1,1,1-Trichloroethane (0-T-620) [2,1,0].

5.4 Cleaning solution, glass (concentrated sulfuric acid [2,0,2] saturated with potassium or sodium bichromate [1,0,1], technical grade).

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6. PROCEDURE

6.1 Clean all flasks and centrifuge tubes as follows:

a. Thoroughly rinse with 1,1, 1-trichloroethane in hood, and allow to air dry in hood.

NOTE 1: Caution. 1,1,1-trichloroethane is toxic. Do not breathe its fumes nor allow it to come in contact with the skin.

b. Immerse in glass cleaning solution for at least two hours.
c. Rinse first with tap water, then with distilled water, and dry in an oven 105° C (220° l?).

6.2 Prepare three 200 mL mixtures, in 250-mL Erlenmeyer flasks, using the following proportions:

a. Sample, 180 mL; referee lubricant, 20 mL.
b. Sample, 100 mL; referee lubricant, 100 mL.
c. Sample, 20 mL; referee lubricant, 180 mL.

6.3 Stopper with a cork stopper, and identify each flask.

6.4 Manually shake each flask vigorously for one minute.

6.5 Loosen the stoppers, and heat the flasks in an oven for 168-hours at 105° C ±3° C (221° F ±5° F).

6.6 After the 168-hour period, remove the flasks, and allow them to cool to room temperature.

6.7 Manually shake each flask (one at a time) vigorously one minute, and immediately fill two clean centrifuge tubes to the 100 mL mark with its contents. Identify the contents of each tube.

NOTE 2: Do not fill more pairs of tubes than can be spun by the centrifuge at one time. Allow the remaining filled flasks to stand until the first set of tubes have been completely centrifuged.

6.8 Process the centrifuge tubes as follows:

a. Heat the tubes for five minutes in a hot-water bath at 93° C ±3° C (200° F +5° F).
b. Mount the tubes opposite each other in the centrifuge, being careful to locate the tubes to achieve proper balance of the centrifuge.
c. Turn on the centrifuge, and increase the speed until the relative centrifugal force at the tips of the tubes is 600 to 700. Run the centrifuge for ten minutes.

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d. After the ten minute period, record the amount of sediment in each tube to the nearest 0.001 mL.
e. Repeat the 10-minute centrifuging and sediment readings until the amount of sediment remains constant for three consecutive readings.

7. CALCULATIONS

7.1 Compute the average sediment volume to the nearest 0.001 mL of each tube pair.

8. REPORTING

8.1 Report the average volume of sediment in each pair of centrifuge tubes.

9. PRECISION

9.1 Precision data have not been developed for this method.

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OXIDATION AND THERMAL STABILITY OF AIRCRAFT ENGINE LUBRICATING OILS (CLR ENGINE)

1. SCOPE

1.1 This method is used for determining the relative performance of aircraft reciprocating-engine oils based upon the amount of deposits formed in the piston zone of the CLR Oil Test Engine under high-temperature operating conditions.

2. SUMMARY

2.1 This 40-hour test measures primarily the oxidation characteristics and thermal stability of the oil and is patterned after the L-38 Test Method developed by the Coordinating Research Council.

3. SAMPLE SIZE

3.1 Approximately 12 L of test oil.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Test Engine, single-cylinder; 3.8-inch bore, 3.75-inch stroke, 42.5–cubic inch displacement, spark-ignition (Laboratory Equipment Corporation [Labeco], Mooresville, Indiana), modified as follows:

a. Machine cylinder barrel in lower portion to accommodate a special O–ring, to include a l/16-inch diameter groove between new and existing sealing ring grooves, and to provide a drain passage from the groove to the outside of the engine as shown in Figure 1.
b. provide auxiliary oil supply to upper bearing of oil pump shaft. (See Figure 2.)
c* Drill passages in cylinder barrel and liner to accommodate two spring-loaded thermocouples 136 degrees apart as shown in Figure 3.

4.2 Standard engine parts.

a. Connecting rod and main bearings, babbitt Labeco Part NO. 8273 and 8252, respectively).

NOTE 1: Undersize babbitt rod and main bearing (Labeco Part No. 8273–U and 8252-U, respectively) should be used if necessary to permit uniform control of bearing clearances.

b. Crankshaft thrust washers, babbitt (Labeco part No. 8292).
c. Camshaft bearings, babbit (Labeco Part No. 8231).
d. Camshaft thrust washers, aluminum, (Labeco Part NO. 8405).

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e. Carburetor, modified Stromberg type BXV-2 (Labeco Part No. 9651).
f. Distributor (Labeco Part No. 9667).
g. Spark plug (Champion H-8 or equivalent).
h. Valve tappet assembly (Labeco Part No. 8202).
i. Aluminum piston and pin (Labeco Part No. 2405).
j. Piston ring set (Labeco Part No. 4948).
k. Crankcase breather assembly (Labeco Part No. 9781).
l. Exhaust system, wet or dry.

4.3 Special engine parts and equipment.

a. O-ring seals, Viton A (Dupont) in accordance with Table I.
b. Fret ring, oversize (0.003 in. thicker), installed under top flange of cylinder liner (Labeco Part No. 8371) to insure against glycol leakage to combustion chamber.
c. CLR intake heater housing (Figure 4), installed in place of original intake manifold equipped with a Chromalox bayonet-type heater (E.L. Weigard CO., pittsburgh, PA, part No. DFM 110; 115v, 1000w, or equivalent) controlled by a variable voltage transformer (Variac or equal).
d. Cooling system, diethylene glycol, positive-circulating, with means for heating and cooling. (See Figure 5.)
e. Oil cooler, external, (modified Mark II oil heater, Labeco Part No. 2431-A). (See Figure 6.)

TABLE 1. Special seals required.

Location	Labeco part No.
Barrel to liner (special)	(a)
Barrel to liner	3310
Oil passage to timing gear plate	3315
Oil passage barrel to head	3315
Oil pump to side cover	3315
Push-rod passage	3318
Barrel to head, inside B.C.	3316
Barrel to head, outside B.C.	3317
Sludge trap in crankcase	3319

[a] Special O-ring (Viton A), 4-1/4 x 4-5/8 x 3/16 inches (available from Labeco) to be installed in special groove machined in cylinder barrel. (See Figure 1.)

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4.4 Measuring and recording equipment.

a. Power absorbing equipment, a 15-hp, 220-v, 3-phase 1700-rpm induction motor. (A 17.8 cm [7-inch] 3-groove pulley installed on the drive shaft of the engine accessory case and a 30.5 cm [12-inch] pulley on the* motor will provide an engine speed of 3100 rpm.)
b. Thermocouples (2), spring-loaded (Figure 7) for measuring cylinder-liner temperature, 136 degrees apart and 2.5 cm (one inch) below top deck of cylinder barrel as shown in Figure 3.
c. Temperature indicators (2), recording (Leeds and Northrup, Speedomax, or equivalent) for measuring cylinder liner temperatures.
d. Pyrometer indicating proportioning controller (West, Model JP, or equivalent) for automatic regulation of cylinder–wall temperature as shown in Figure 5.
e. Air-flow (load) measuring system, 566 L per minute (20-CFM) laminar flowmeter with a 102 cm (40–inch) inclined manometer (Merian Instrument Co., Model 60AC02).
f. Fuel-flow rate measuring equipment (flow-meter, buret, or weighing device).
g. Water manometer, for measuring crankcase vacuum, connected to hole in crankcase breather pipe.
h. Mercury manometer, for measuring intake manifold vacuum, connected to l/4-inch pipe collar located below carburetor on heater housing. (See Figure 4.)
i. Oil-pressure gage, to be installed at the point indicated in Figure 6.
j. Dry-gas meter for measuring crankcase blowby. (Measurements are to be taken on the outlet side of crankcase breather assembly).
k. Valve, oil sampling, to be installed in lower l/2–inch hole of oil pan.
1. Thermocouples for determining jacket–coolant inlet and outlet temperatures, to be located within 10.2 cm (4 inches) of the inlet and outlet bosses of the engine.
m. Thermocouple for measuring gallery oil temperature, to be inserted in a hole to a depth of 1.9 cm (3/4-inch) in the oil gallery plate. (This hole is located in the main oil gallery below and to the left of the oil pressure regulator.)
n. Thermocouple to measure manifold fuel-air mixture temperature, located in the l/4-inch pipe collar on heater housing near flange that bolts to engine. (See Figure 4.)
o. CRC Deposit Rating Scales (Coordinating Researth Council, 30 Rockefeller Plaza, New York, NY 10020, Manual No. 14).

5. MATERIALS

5. CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms,

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life hazard, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Reference oil (AEL-0-64) Naval Air Propulsion Center, Code PE33, Trenton, NJ 08628.

5.3 Test fuel (MIL-G-55720), grade 115, 145 commercial aviation gasoline with 12 to 15 percent aromatic content containing 4.6 mL TEL as aviation mix. [1,3,0].

5.4 Oil, SAE 20, noncompounded, having a minimum viscosity index of 75.

5.5 Solvent, dry-cleaning (ASTM D 484), type II. [0,2,0].

5.6 Cleaning compound, special (Penetone ECS; penetone Corporation, 74 Hudson Avenue, Tenafly, New Jersey 07670, (201) 567-3000 or equivalent). [u,u,u].

5.7 Diethlylene glycol (Union Carbide and Chemical or equivalent) as coolant. [1,1,0].

6. PROCEDURE

6.1 Before each test, prepare the engine as follows:

a. Dismantle the power- section of the engine in accordance with the manufacturer’s instructions.
b. Remove the oil pump, distributor, breather, and oil-pressure regulator from the crankcase side-cover plate.
c. Soak all parts in the special cleaning compound for 12 hours.
d. After removing parts from the special cleaning compound, rinse first with hot water, then with dry-cleaning solvent. Carefully spray the oil pump and oil-pressure regulator to remove all deposits. Clean all oil passages with a fiber brush or swab, paying particular attention to the following:

Sludge trap and oil passages in the crankshaft.
Camshaft oil passages.
Crankcase side cover plate.
Timing gear oiler jet.
Rating surfaces.
Rocker-shaft lubrication system (oil line, rocker arms, rocker shaft, rocker shaft support, orifice in block).
Valve and valve seats. (Recondition if necessary.)

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DETERMINATION OF PARTICULATE MATTER IN AEROSPACE HYDRAULIC FLUIDS

1. SCOPE

1.1 This method describes the determination of particulate matter in aerospace hydraulic fluids with an automatic particle count/size analyzer working on the light interupt principle. This document when cited in product specifications becomes a mandatory test requirement.

2. SUMMARY

2.1 This method utilizes HIAC/ROYCO particle counters such as the 60HZ model for CONUS use (NSN 6635-01-073-5455, Part No. PC-321-2-1-4 w/BS-3-3311 and SK-10) or the 50 HZ model (NSN 6635-01-078-3252, Part NO. PC-321-2-2-4 w/BS-3-3312 and SK-18). HIAC automatic particle counters will be calibrated with AC Fine Test Dust (ACFTI) since this standardized material is most like the kind of contaminant materials encountered in aerospace hydraulic fluid.

3. SAMPLE SIZE

3.1 Minimum sample size for analysis is 120 mL (4 oz). Sizes of sample bottles accepted by automatic counters are described in 4.4.

4. REFERENCES, STANDARDS AND APPARATUS

4.1 HIAC Particle Counter. A minimum of 5 channel counters fitted with a sensor suitable for counting in the 5-150 micrometer size range. Other accessories such as printouts may be used.

4.2 Manufacturer's operating instructions. These shall be obtained from:

HIAC/ROYCE Instrument Division
PACIFIC SCIENTIFIC CORPORATION
141 Jefferson Drive
Menlo Park, CA 94025
(415) 325-7811

4.3 Compressed Gas Supply. A source of air or nitrogen, free from oil or water , capable of delivering the gas at 240 kPa (30 psig). The gas shall be filtered through a 0.45 micrometer membrane filter. Most automatic counters have an air pump that operates at the required pressure.

4.4 Sample bottles. Round glass bottles fitted with a threaded cap with a polystyrene liner forming a seal without an insert. Capacity of bottle should be 118 to 475 mL (4 to 16 oz). Bottles shall be cleaned in accordance with 6.1.

4.5 Solvent dispenser. Suitable dispensers fitted with 0.45 micrometer membrane filters at the outlet. Pressurized dispensers permit inverted bottle rinses.

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4.5 Timer. Timer that is accurate to the second.

5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 AC Fine Test Dust (ACFTD). This dust is used to calibrate the particle counter and it is available from:

In 10 gram packages
Particle Information Services, Inc.
4914 NOW. David Road
Bremerton, WA 98312
(206) 479-9912

In 8 pound packages
AC Spark Plug Division Laboratory
General Motors Corporation
Phoenix, AZ

5.3 Primary calibration standard. A certified field calibration kit consisting of H-515 hydraulic fluid containing a known suspension of ACFTD. This kit is available in 1 mg/liter suspension at no charge to US Government agencies from:

Energy Management Laboratory, OL/SFTLE
Vandenberg AFB CA 93437
Autovon 276-6263 Commercial (803) 866-6263

Suspension concentrations are available from HIAC/ROYCO CO and from:

National Fluid Power Association
4444 Mayfair Road
Milwaukee, WI 53222

5.4 Detergent. Liquid, water soluble, commercial grade.

5.5 Solvents.

5.5.1 Isopropyl alcohol [1,3,0].

5.5.2 Trichlorotrifluoroethane (MIL-C-1302) [u,u,u].

5.5.3 H-515 Hydraulic fluid.

Note: All solvents shall be filtered through a 0.45 micrometer filter before use.

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e. Immediately after cleaning each part, coat it with noncompounded SAE 20 oil by spraying or dipping.

f. Clean the oil-cooler case and inner cartridge by filling the housing (with the cartridge in place) with the special cleaning compound, and allowing it to soak for a short time. Then remove the cartridge from the housing and wipe clean.

g. Build up engine, installing a set of new rings, new piston and pin, and new gaskets, seals, and O-rings. Replace all other parts that do not permit maintenance of the operating clearances shown in Table 11.

TABLE II. Engine clearance adjustments.

Clearance	Measurements centimeters	Measurements inches
Valve-tappet, inlet (hot)	0.025	0.010
Valve-tappet, exhaust (hot)	0.051	0.020
Valve-stem in guide, inlet	0.0051-0.0102	0.0020-0.0040
Valve-stem in guide, exhaust	0.0076-0.0127	0.0030-0.0050
Connecting-rod bearing[1/]	0.0051-0.0076	0.002-0.003
Main bearing[2/]	0.0051-0.0076	0.0020-0.0030
Crankshaft journal out-of-round, max.	0.0025	0.0010

1/ Rod bearing clearance is to be determined from direct measurements of the crank pin and of the vertical diameter of the rod bearing installed in the rod after torquing the bearing cap bolts to 61 N•m (45 lb-ft). The clearance is calculated on the basis of the largest measured pin diameter and the vertical bearing diameter. The connecting-rod bearing bore must be clean and free from foreign particles to assure good bearing contact before installing the bearing for measurement.

2/ This clearance is to be based on direct measurement in the same manner as that indicated for the connecting rod-bearing in Note a. The main bearing diameter is to be measured after torquing the bearing blocks to 81 N•m (60 lb-ft). It is permissible to install either two standard main bearing halves, one standard (Part No. 8252) and one undersize bearing half (Part No. 8252-U) or two undersize bearing halves as is necessary to maintain the specified bearing clearance. For consistency, when using one standard and one undersize bearing half together, the standard half should be installed in the bearing cap.

h. Replace cylinder liner when piston-to-cylinder clearances exceed limits indicated in Table III. (If the liner must be replaced, drill two holes in new liner to as accommodate spring-loaded thermocouples as shown in Figure 7.)

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TABLE III. Manufacturing tolerances and clearances.

Engine Parts	Tolerance or Clearance centimeters	Tolerance or Clearance inches
Valve-guide press in cylinder head, inlet	0.00127-0.00330	0.0005-0.0013 tight
Valve–guide press in cylinder head, exhaust	0.00127-0.00330	0.0005-0.0013
Valve-insert shrink in cylinder head, exhaust	0.0051-0.0102	0.002-0.004
Valve-spring load at 1.80 inches height	285-311 N	64-70 lb
Valve-sprins load at 1.47 inches height	592-654 N	133-147 lb
Valve-rocker-arm clearance on shaft	0.0038-0.0089	0.0015-0035
valve-lifter assembly clearance	0.0033-0.0071	0.0013-0.0028
Piston top-land clearance in cylinder	0.06145-0.0729	0.0242-0.0287
Piston-skirt and other land clearance in cylinder	0.0030-0.00635	0.0012-0.0025
Piston-ring gaps-all rings (as installed new)	0.038-0.0508	0.015-0.020
Pistcn-pin clearance in piston	().00025-0.00076	0.0001-0.0003
Piston-pin clearance in connecting-rod bushing	0.0010-0.0015	0.0004-0.0006
Crankshaft end play	0.018-0.046	0.007-0.018
Camshaft clearance in bearings	0.0030-0.013	0.0012-0.0052
Camshaft end play	0.023-0.081	0.009-0.032
Camshaft bearing press in (crankcase	0.0064-0.014	0.0025–0.0055 tight
rider sleeve in cylinder frel clearance	0.0025-0.0076	0.001-0.003
it in bearing bore in the crank-case, with bearing cap torqued in place at 81 N-m (60 lb-ft)	7.4701-7.4727	2.941-2.942
Main bearing journal diameter	6.9812-6.98246	2.7485-2.7490
Connecting- rod bore in the rod, with bearing cap torqued in place at 61 N•m (45 lb-ft)	5.7823-5.7836	2.2765-2.2770
Connecting -rod bearing journal	5.3937-5.3950	2.1235-2.1240
cylinder barrel in crankcase clearance	0.0051-0.0178	0.002-0.007

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i. Rebuild the engine using the torque specification shown in Table IV.

TABLE IV. Engine torque adjustments.

Adjustment	NŽm	Torque lb-ft
Connecting-rod bearing cap	61	45
Main bearing block	81	60
Cylinder hold down	95	70
Drive plate	54	40
Cylinder-barrel hold down	68	50
Accessory cover cap screws1/	27	20
Auxiliary cover cap screws1/	14	10

1/ These specifications are not considered rigid; however they should serve as a guide to prevent damage to the cap screws.

j. Inspect the clearances shown in Table 111 to insure proper tolerances.

6.2 Before the test engine is used for the first time and after a new cylinder liner is installed, conduct the test, using the reference oil. The results must conform to Table V.

NOTE 2: The purpose of the reference-oil test is to insure maintenance of a uniform test severity level.

TABLE V. Reference-oil- test requirements.

Inspection Area	CRC Rating 1/	
	AEL-O-64 (Reference Oil)	AEL-O-112
Piston skirt	6.0 max	6.5 min
Pin boss area	6.0 max	7.5 min
Piston underside	6.0 max	7.5 min
Ring grooves	2.0 max	4.0 min
Oil-ring plugging, percent	50 min	20 max
Ring sticking	5.0 max	8.5 min

1/ 10 = clean

6.2.1 Before the engine is used for assessing the relative performance of aircraft reciprocating engine oils and after the requirements of 6.2 have been satisfied, conduct the test using a second reference oil, AEL-0-112. The results must conform to the appropriate column in Table V.

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NOTE 3: The purpose of the AEL-0-112 test is to insure maintenance of a satisfactory test severity level and fair assessment of a test oil.

6.3 Break in the engine as follows:

a. Charge engine with 1.9 L (2 quarts) of weighted test oil.
b. Charge cooling system with diethylene glycol. Start glycol circulating pump, and turn on heater (4000 Watts). Allow glycol to circulate for 1 hour to preheat engine.
c. Start and operate the engine without load for 1 hour under the following conditions: Speed, 1500 rpm; spark advance, 30 degrees (BTDC); oil-gallery temperature 107° C (225° F) max; and cylinder-liner temperature, 190° C (375° F) max.
d. At the end of 1 hour, stop the engine, set piston at top dead center, and allow the engine to rest for .5 minutes. Then measure oil level, and add oil if necessary to bring to 1.9 L (2–quart) level. (Weigh oil additions.)

6.4 While engine is warm commence test operations as follows:

a. Start engine and motor to bring speed to 3100 rpm. Open throttle to give 23.6 +0.45 kg/hr (52 +1 lb/hr) dry-air flow.
b. During the–first half hour: adjust the engine to test conditions shown in Table VI. Start test time when the average cylinder-liner temperature stabilizes at 190° C (375° F).

TABLE VI. Test operating conditions.

Condition	Adjustment	
Engine speed, rpm	3100 +25	3100 +25
Load, dry–air flow	23.6 ±45 kg/hr	52 ±1–lb/hr
Manifold vacuum, mercury	25.4 cm	10 in. approx.
Fuel-air ratio	0.085 ±0.001	0.085 +0.001
Fuel flow	Set	Set
Ignition timing, (btdc), deg.	30	30
Manifold-mixture temperature	54° C ±2.50 C	130° F +5° F
Coolant in temperature, °C (°F)	Record	Record
Average cylinder-liner temperature	190° C +2.5° C	375° F +5° F
Difference between front and rear cylinder-liner temperature	5.5° C max	10° F max
Jacket-outlet temperature	171° C approx.	340° F approx.
Oil-gallery temperature	107° C ±2.5° C	225° F +5° F
Oil pressure	414 ±14 gage kPa	60±2psig
Crankcase vacuum, water	2.5-5.1 cm	1-2 in.
Blowby	Record	Record
Oil consumption, max	0.034 kg/hr	0.075 lb/hr

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6.5 Record the following data during test:

a. At l-hour intervals:

Engine speed.
Fuel flow.
Air flow.
Front, rear, and average cylinder-liner temperatures.
Jacket-outlet coolant temperature.
Manifold-mixture temperature.
Oil-gallery temperature.
Intake-air temperature.
Oil pressure.
Crankcase vacuum.
Intake-manifold vacuum.

b. At 2-hour intervals:

Blowby.

c. At 10-hour intervals:

Fuel-air ratio.
Spark advance.

6.6 Oil samples are to be taken every 20 hours of test time using the following procedure:

a. Idle engine for 10 minutes at 1500 rpm, no load, with coolant heater turned off.
b. Stop engine, and set piston on top dead center for 5 minutes.
c. Obtain a weighed 60 mL (2 ounce) oil sample.
d. Weigh and add 60 mL (2 ounces) of new oil. Do not add additional oil. Check oil level. If oil level is 0.94 L (1 quart) or below, end test since oil consumption is too high.
e. At the end of test stop engine in the same manner as indicated above, drain crankcase and oil cooler, weigh and take a 120 mL (4 ounce) sample for analysis.

6.7 The test shall end at 40 test hours.

6.8 Analyze the oil samples in accordance with Table VII.

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TABLE VII. Lubricant analysis schedule.

Test	New and 40 hours	20 hours	ASTM
Viscosity:			
SUS at 37.8° C (100° F)	x	x	D 445
SUS 98.9° C (210° F)	x	x	D 445
Acid and base number	x	x	D 664
N. pentane insolubles	x		D 893
Ash content	x		D 482
Carbon residue, percent	x		D 524

a. Piston skirt (major and minor thrust sides).
b. Piston sides perpendicular to pin.
c. Piston underside (top and sides).
d. Piston-ring lands.
e. Piston-ring grooves.
f. Piston rings.
g. Degree of ring sticking.
h. Oil-ring plugging, percent (Erdco ring rater).
i. Rocker-arm cover.
j. Oil pan.
k. Oil-pump screen.
1. Crankcase.
m. Timing-gear cover.
n. Sludge trap (percent full).
o. Connecting rod.

6.10 The following photographs may be obtained:

a. Colored slides (2 by 2 inch) of:

Piston with rings showing skirt and portion of pin-boss area.
Underside of piston.
Oil pan.
Oil screen and sludge cup.
Rocker box.
Any unusual engine deposits.

b. Black-and-white photographs (8 by 10 inch) of piston and rings (angle shot). Any unusual engine deposits.

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6.11. Inspect rings and bore for scuffing.

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Report as required by specification.

9. PRECISION

9.1 Precision data have not been developed for this method.

Method prepared by:
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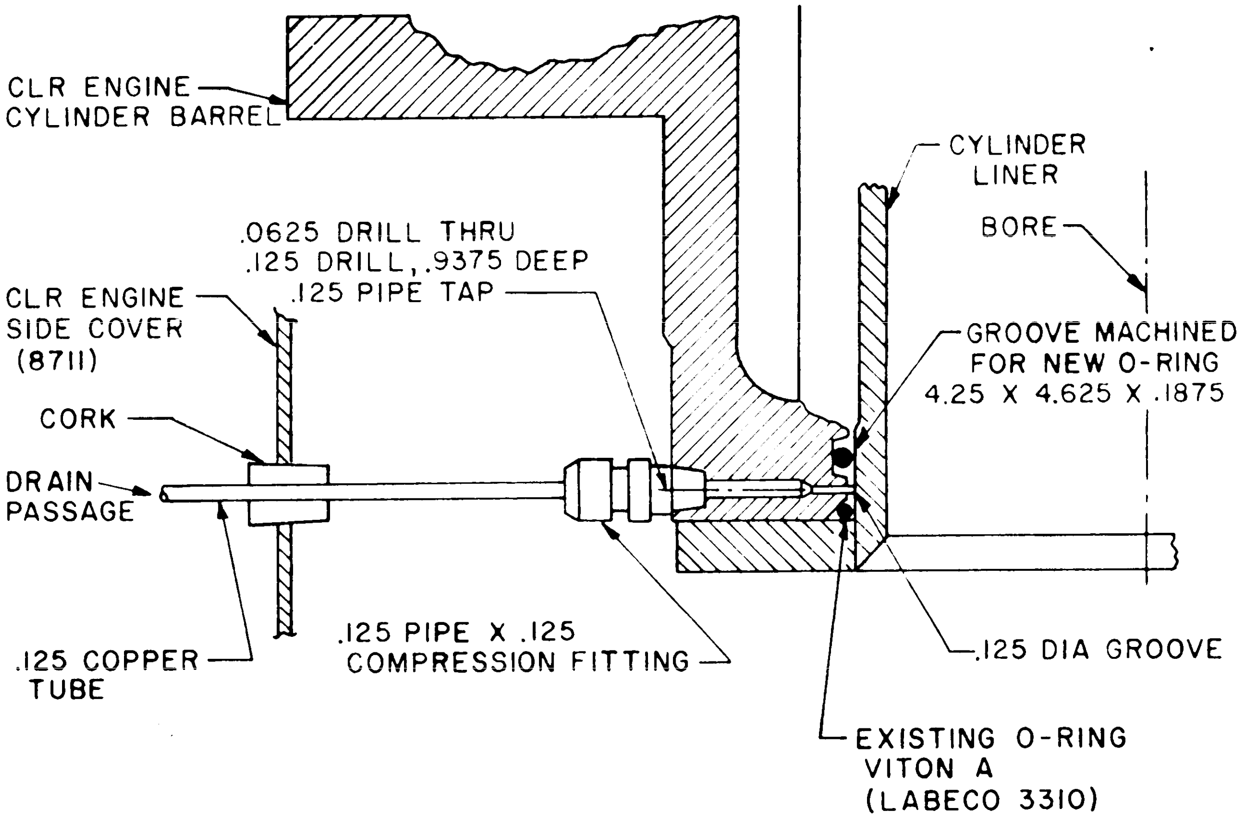

NOTE:
DIMENSIONS IN INCHES.

FIGURE 1. Sealing ring and drain installation.

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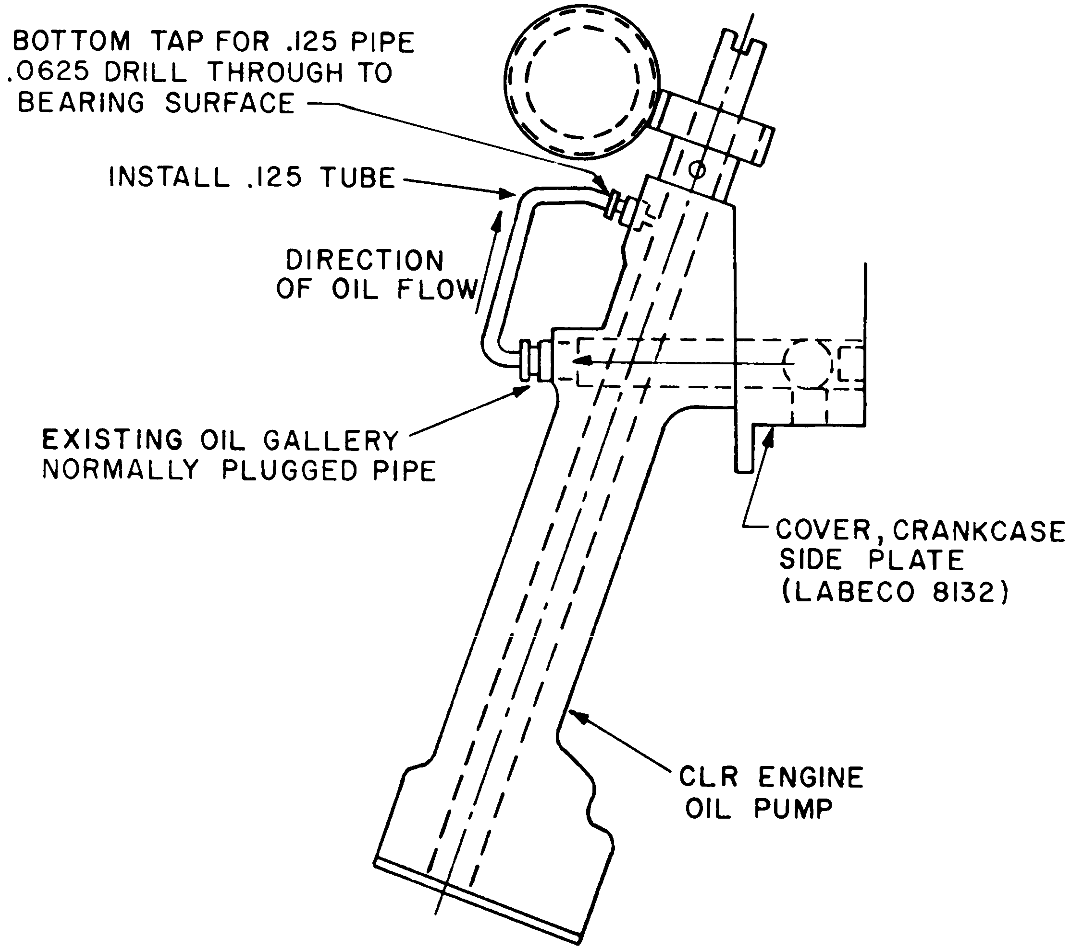

NOTE:
DIMENSIONS IN INCHES.

FIGURE 2. Auxiliary oil supply installations.

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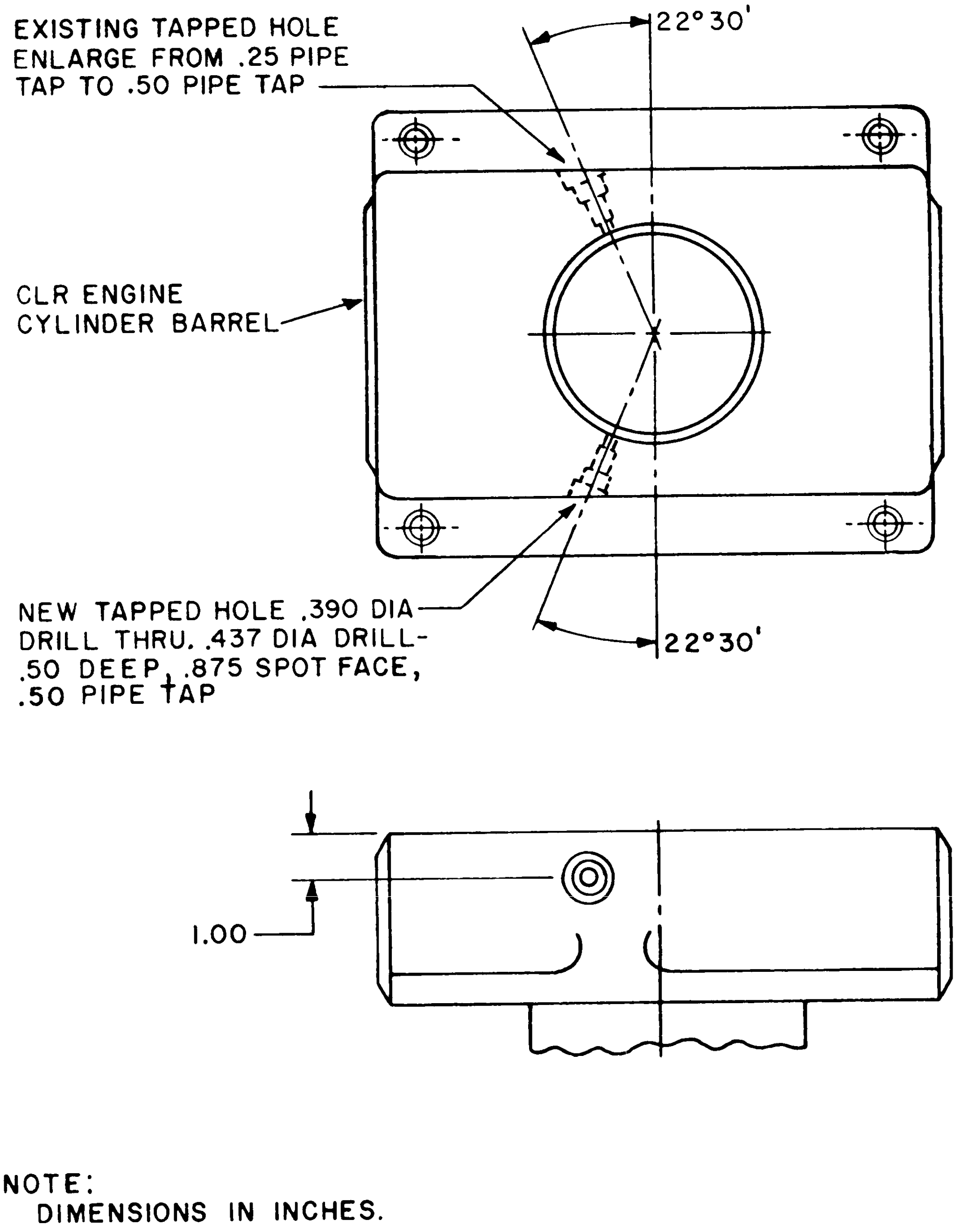

FIGURE 3. Cylinder barrel thermocouple installation.

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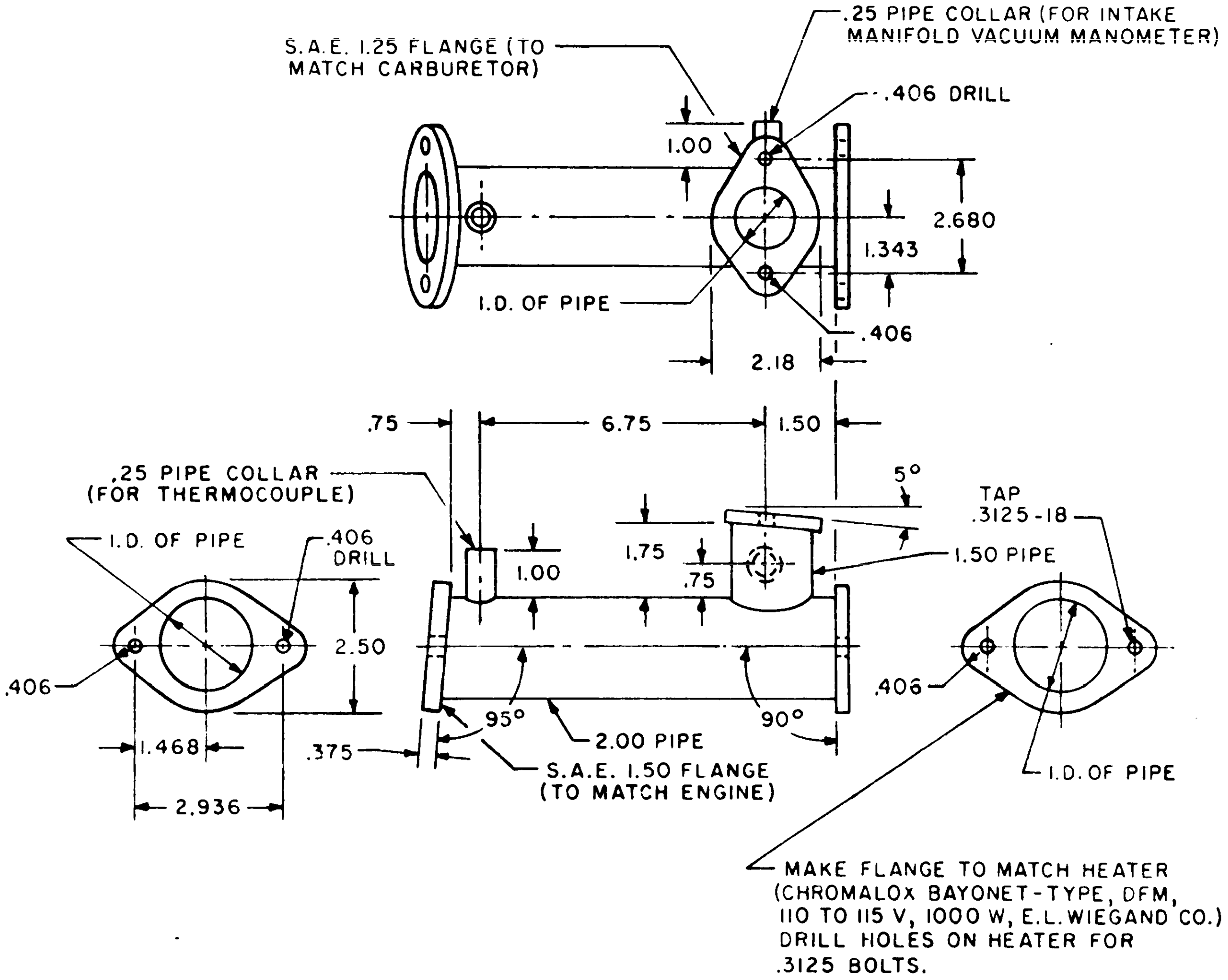

FIGURE 4. CLR intake heater housing.

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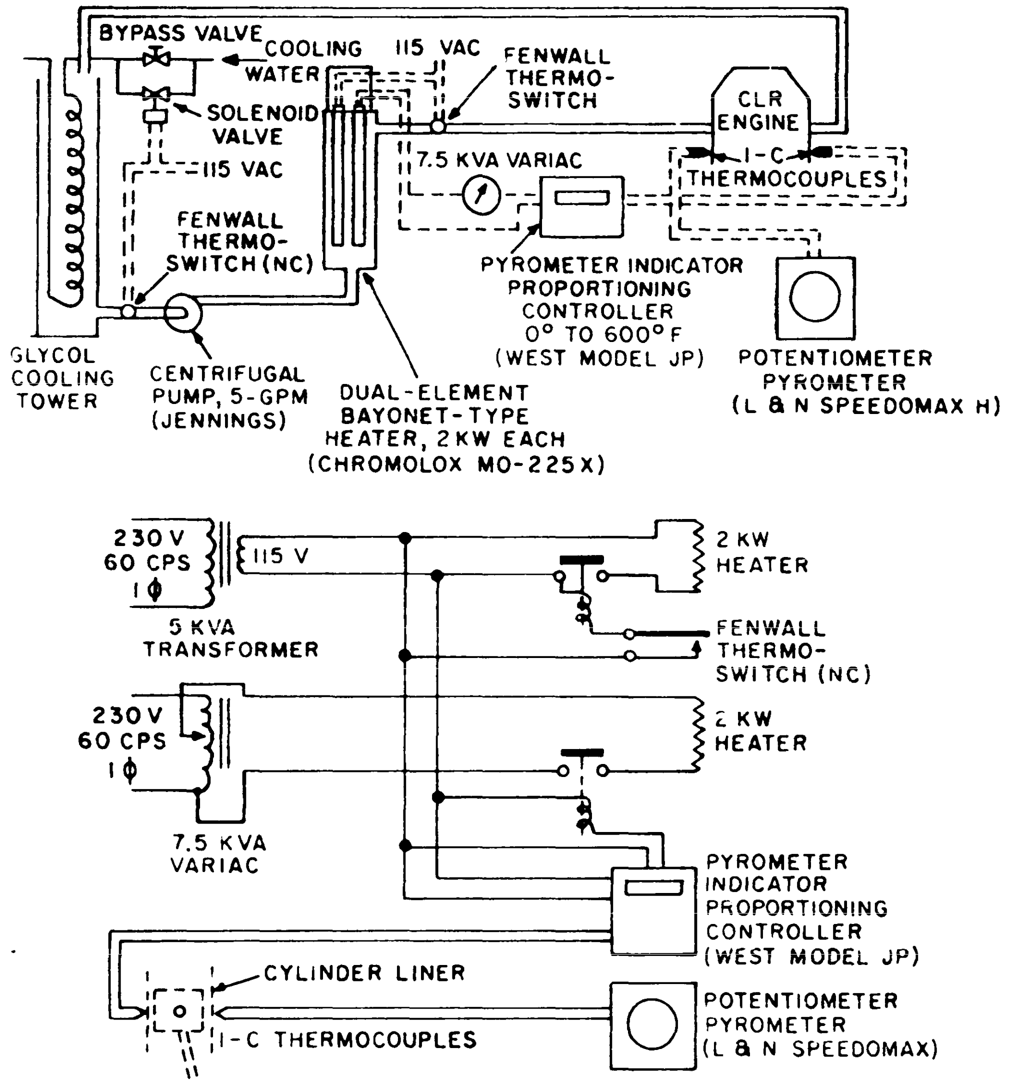

FIGURE 5. Typical cooling system.

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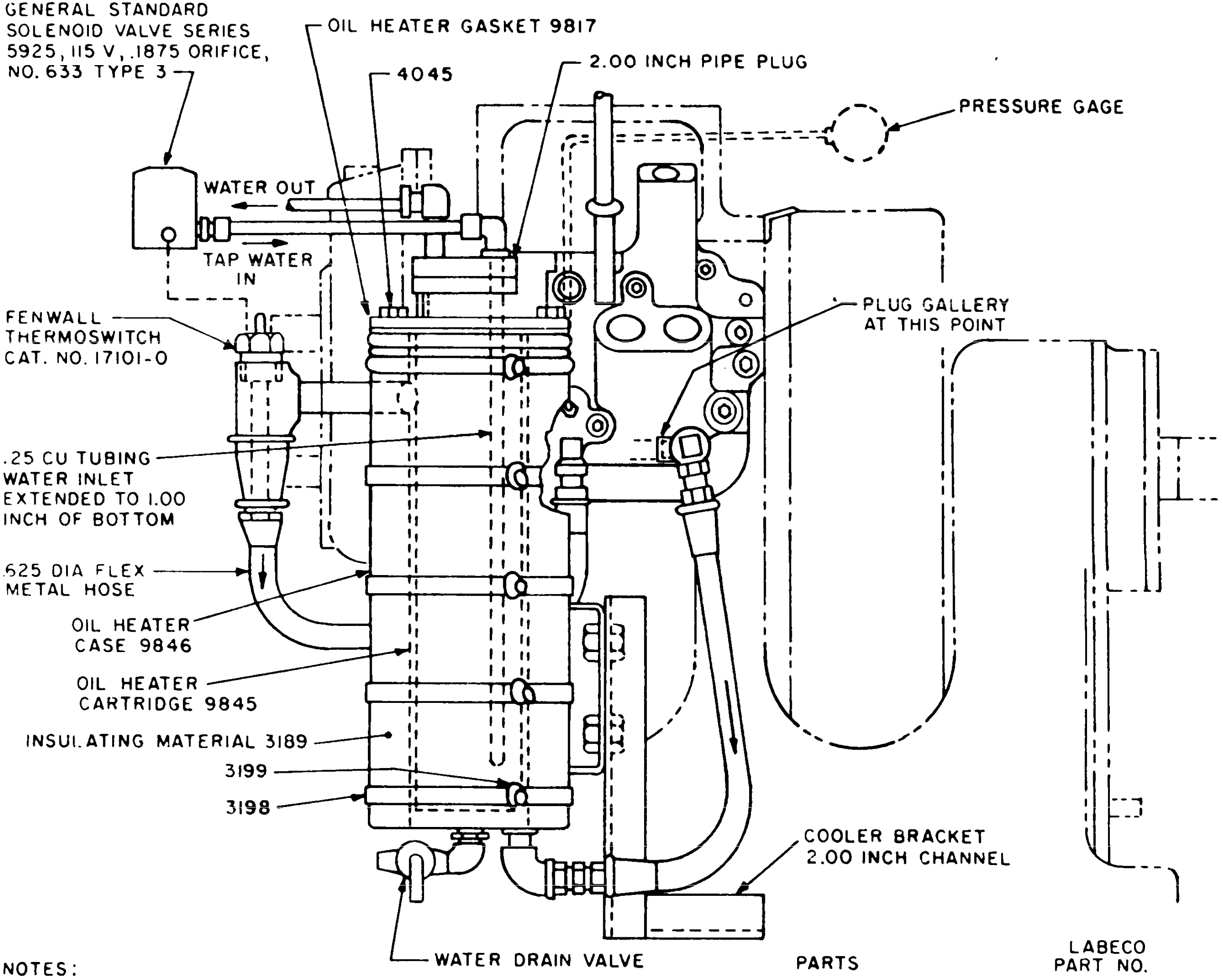

NOTES:

1. DIMENSIONS IN INCHES.
2. COOLER IS MOUNTED VERTICALLY. OIL CAPACITY 425-475 mL INCLUDING HOSE AND FITTINGS. LABECO PART NOS. SHOWN IF AVAILABLE.

PARTS	LABECO PART NO.
CASE, OIL HEATER	9846
CARTRIDGE, OIL HEATER	9645
GASKET, OIL HEATER	9847
INSULATING MATERIAL	3189
.375 WIDE BAND, 20.00 LONG, 5 EACH	3198
.375 WIDE BAND CLIP, 5 EACH	3199
.375-16 X .875 CAP SCREW, HEX. HD, 6 EACH	4045

FIGURE 6. Oil cooler installation.

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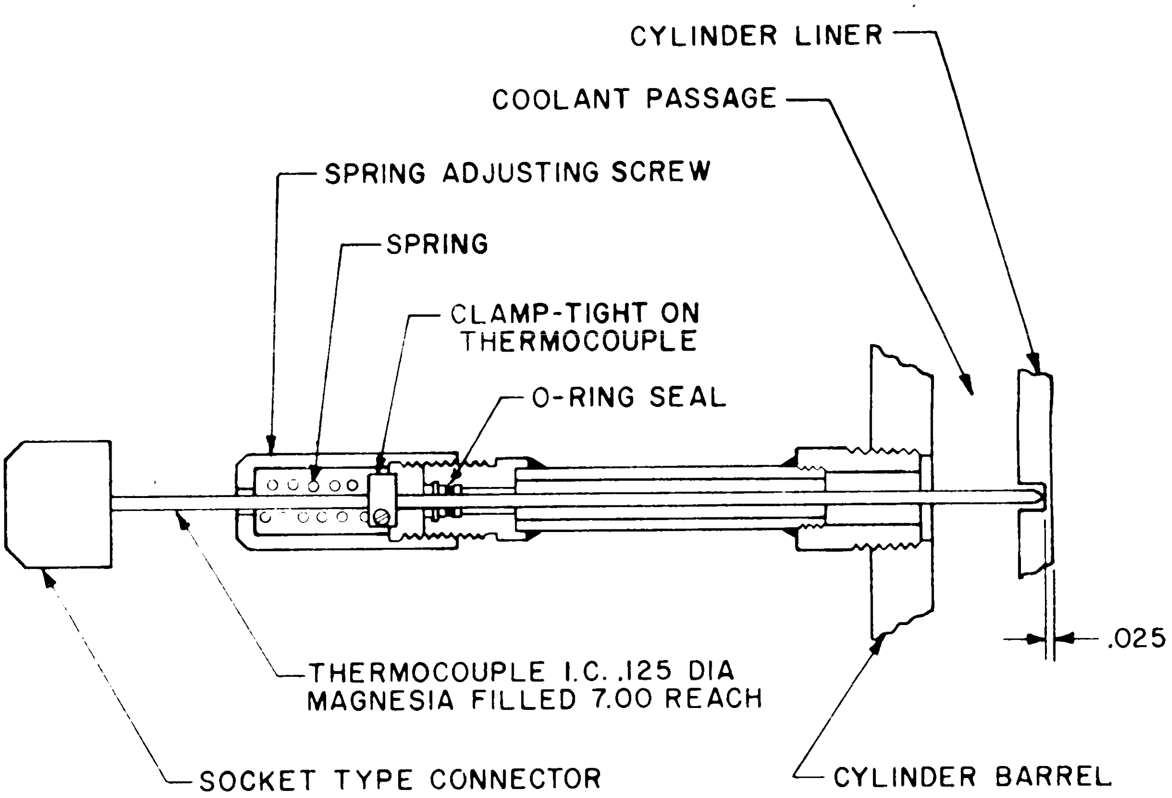

NOTE:
DIMENSIONS IN INCHES.

FIGURE 7. Cylinder barrel thermocouple assembly.

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METHOD 3410.1
September 30, 1986

HIGH TEMPERATURE DEPOSIT AND OIL DEGRADATION CHARACTERISTICS OF AVIATION TURBINE OILS

1. SCOPE

1.1 This method describes procedures used to evaluate the thermal stability characteristics of turbojet lubricants under varying levels of severity.

2. SUMMARY

2.1 Sample of the lubricant is subjected to one of the severity levels (type 1, 1–1/2, or 2) for a controlled number of hours. At periodic intervals during the test and at the end of test, samples of the oil are examined for both physical and chemical changes when compared to the sample of new oil. A visual inspection is made at the end of test of the accumulated deposits on the bearing and bearing housing. A weighted numerical rating system is used for rating individual areas as well as for obtaining an overall rating. Additional data on relative sludge forming tendencies on oils are obtained by weighing a 100-mesh filter element and a 40-mesh filter element.

3. SAMPLE SIZE

4. REFERENCES, STANDARDS AND APPARATUS

4.1 The apparatus used in this method is the Erdco high temperature bearing head mounted on a suitable drive test stand, similar to the Erdco universal test stand. It is not mandatory to use the “universal drive” to power the bearing. The support oil system and the test oil system are separate units and of special design for the Erdco high temperature bearing head.

4.1.1 Erdco high temperature bearing head. The bearing head is divided internally into two main sections. The front or test section with its separate test oil system houses the unshielded 100-mm straight roller test bearing. The temperature of the test bearing is controlled by supplying heat to the outer race of the bearing. The outer race is secured in a bearing mount assembly containing wound Calrod heating elements packed in aluminum oxide for even heat distribution. The rear or support section of the bearing head houses the externally loaded, main shaft support bearing, together with a separate oil system. The test and support sections of the modified bearing head are separated by a screw thread seal to prevent mixing of the test and support oil. Details covering the bearing head and screw thread seal assembly are shown in Figure 1.

4.1.1.1 Test oil jet. A standard No. 60 drill size jet located at 12 o’clock on a 0.13335 m (5.250–inch) diameter should be used. The size of the jet should be checked with a No. 60 drill and a visual check of axial straightness made with the drill inserted in the jet. Corrections for orifice size and axial straightness should be made by silver soldering the orifice end of the jet tube and redrilling.

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4.1.2 Test bearing. An unshielded 0.10-m straight roller bearing is mounted on the free end of the shaft in the test oil compartment of the bearing head. The test bearing is loaded radially by the slight downward displacement of the free end of the shaft caused by a straight downward force from the loading piston acting on the outer race of the main support ball hearing shown in Figure 1. The test bearing is lubricated by a single jet located at 12 o'clock which supplies essentially a solid stream of oil midway between the I.D. of the outer race and the O.D. of the retainer on the top or unloaded position of the test bearing.

4.1.3 Test bearing mount. The bearing mount is made with an outer race removal feature which permits the removal of the bearing outer race for cleaning and inspection without disturbing the aluminum oxide packing. Three spot-type thermocouples are located 120 degrees apart (radially around the 1.1). of the bearing mount and indicate the skin temperature on the periphery of the outer race , which is pressed into contact with these thermocouple junctions when it is installed in the bearing mount. One of these three thermocouple leads is connected to a differentiating type temperature controller (proportional controller) or to a suitable autotransformer. "ON-OFF'" type control is not recommended.

4.1.3.1 Three thermocouple junctions are silver-soldered to the outer-race housing. The soldering operation should leave enough excess metal to provide good contact with the outer race when it is pressed into the mount. Each of the three thermocouple leads are routed out directly through the bearing housing or end cover at 120 degree intervals.

4.1.3.2 Thermocouple packing. Teflon or an equivalent should be used for all thermocouple leads where they pass through the housing or end cover fitting. This also applies to the two Calrods where they pass out through the end cover.

4.1.4 Test oil system. A schematic of the test oil system is shown in Figure 2. The test oil cycle starts at the tank where three 1500-Watt, series connected heater elements (refer to 4.1.7) maintain the desired temperature by means of a differentiating type temperature controller or a suitable autotransformer. "ON-OFF" type control is not recommended. The test oil is then pumped from the tank to the bearing head where it passes through a No.60 drill size orifice and lubricates the test bearing. The test oil is drained from the bearing head at three locations. The front drain handles splash oil which does not pass through the test bearing, whereas the rear drain collects only oil that has gone through the bearing. The middle drain is looped into a 360 degree configuration to slow oil flow and lessen air entrainment in the oil. The three drains go into a sump from which the test oil is pumped back into the top of the tank.

4.1.4.1 The test oil system provides for the installation of a fine 100-mesh filter screen (stainless steel, Erdco P/N lRB 2006 S.S. for Type 1-1/2 test conditions) in the pressure line only just ahead of the jet to collect the

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sludge particles circulated in the test oil system. Pressure taps are located before and after the fine strainer in order to monitor the degree of screen plugging.

4.1.4.2 Heat loss from the test oil system has been minimized by placing a 0.6 cm (1/4-inch) insulating box around the test oil tank. For screening tests at 149° C (300° F) oil-in temperature, no other insulation is usually used. However, at 176° C (350° F) and 204° C (400° F) oil in temperature, the test oil lines are wrapped, if necessary, with 2.5 cm (l-inch) wide insulating tape. In addition, insulating covers are placed over the test oil pressure pump housing. The amount of insulation required is fixed for any individual system by the oil-in temperature requirements for each test. For all types of operation the test oil tank is vented to atmosphere, although plant exhaust suction systems are permissible as long as suction pressures do not exceed 12.7 cm (5.0 inches) of water. Normally, the test tank vapor space is slightly pressurized (O to 0.76 cm [0 to 0.3 inch] Hg) due to back pressure from vapor condensers in the vent line.

4.1.4.2.1 Only stainless steel tubing or pipe lines and fittings (including sump below head) should be used in the test oil system. No insulation is required on scavenge lines but is required on pressure lines and pump housings, as necessary to maintain the test oil temperature conditions; however, the test oil in the thermocouple tee should be well insulated at all times. The tee should be located not more than 7.6 cm (3 inches) from end cover and should be large enough to provide an oil annulus around the thermocouple. The tip of the thermocouple should be located in the center of the tee. A 40-mesh filter screen (stainless steel, Erdco P/N lRB 2007 S.S. for type 1-1/2 test conditions) should be used in the test oil scavenge filter housing which should be located between the bearing head and scavenge pump.

4.1.4.3 Test oil tank.

4.1.4.3.1 Overall configuration. The overall configuration and general construction details of the test oil tank should ccnform to the detailed Erdco Part No. 01RB2160. The tank and baffle is constructed from AMS 5504C material; (AISI 410) 12.5 percent chromium steel sheet and welding rod. Baffle plate height should be checked and adjusted if necessary to insure that the top of the plate is 12.1 cm (4-3/4 inches) from the bottom of the tank. The top of the stirrer propeller is to be even with the top of the baffle plate as determined by a straight edge.

4.1.4.3.2 Cover gasket material. A Teflon sheet gasket or equivalent cut to match the outside flange dimensions should be used between the cover and mounting flange around the top of the tank.

4.1.4.3.3 Stirrer and stirrer mounting. A Lightning Model L 1/30 horsepower motor having a no–load (in air) shaft speed of 1800 rpm should be used in conjunction with a 5.1 cm (2.0-inch) diameter, three-blade propeller.

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4.1.5 Air system. Saturated air is metered to the test oil compartment in the bearing head. The air supply for the test bearing compartment should be shop air connected in the following sequence; air supply to pressure regulator to flow control valve to rotameter to water saturator to water separator tank to end cover fitting on bearing head. The air directed through the end cover (at about 11 o'clock or 1 o'clock on the same diameter as the test oil jet) into the bearing compartmentis used primarily to control the pressure drop across the seal so as to insure against oil transfer from the support section into the test oil section. A l/4-inch by l/8-inch tubing to pipe fitting should be used for the metered air supply to the rig.

4.1.5.1 Air to the test head is metered through a rotameter. Prior to each run the rotameter is calibrated against a wet test gas meter for a flow of 9.90 L/rein. (0.35 CFM). The procedure is to disconnect the air supply line at thc fitting where the air enters the head and then connect tile supply line to a wet test gas meter which in turn discharges to atmosphere. A mercury manometer is located immediately upstream from the rotameter. The settings of the manometer and rotameter are observed and recorded for a wet test gas meter reading of 9.90 L/rein. (0.35 CFM). The air line is then reconnected to the bearing head and the previously observed manometer and rotameter settings are maintained throughout the test.

4.1.5.2 Seal (test support). The screw–type seal (P/N lRBB-6204) should be vented to the test cell at both top and the bottom of the seal housing connections.

4.1.5.3 Connections for seal differential pressure measurement. The lines to the manometer used to measure the differential pressure across the seal should be connected to top, front of the bearing head, and the rear vertical surface of the bearing housing between 11 and 1 o’clock 2.5 cm (one inch) above the junction of the rear case with the main housing. After startup there should be no venting of the manometer lines. In this connection, the pipe plug in the top of the gear box, if used, should be removed and replaced with a small valve to insure atmospheric pressure in the gear box and hence in the support system.

4.1.6 Fenwall thermostatic control switch (Cat. No. 17802-510 or equivalent) (-18° C to 315° C [0° F to 600° F] normally closed). This switch should have a stainless steel sheath and be located in end of tank opposite stirrer motor 10.8 cm (4-1/4 inches) from bottom and on the center line of the tank.

4.1.7 Heater unit. A Chromalox tubular heater unit (MT0345) having a rating of 4500 Watts, rated at 115-120 volts should be series connected to a 220 volt supply and controlled by means of a differentiating type temperature controller or a suitable auto-transformer. Three thermocouples installed 31.8 cm (12-1/2 inches) from terminal end of tank should be used. A11 thermocouple lead wire should be of the Ceramo, a metal-sheathed type. Test oil heater thermocouples are to be attached to the tubular neater by clamps, welded shoes, or spot weld.

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4.2 Graduated cylinder, borosilicate, 1000-ml.

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Lubricating oil, qualified under MIL-L-23699.

5.3 Dry cleaning solvent, (ASTM D484, Type I) [0,2,0].

5.4 No. 400 emery paper.

5.5 No. 30 grit aluminum oxide.

5.6 Bisolven; Isopropyl alcohol: Acetone - 1:1 [1,3,0].

6. PROCEDURE

6.1 Cleaning procedure.

6.1.1 Test oil tank. The test oil tank should be removed from the stand at the end of each test. After the deposits have been rated and photographed the tank assembly should be completely disassembled. The interior of the tank and the immersed part of the heater should each be thoroughly cleaned by solvents, hand scrubbing, and or mild abrasive blast to remove all traces of deposits from previous test. An electrical continuity check should be made on the immersion heaters before the tank is reinstalled on the stand. Instances of apparent electrical “shorts" in the immersion heater circuit can often be cured by additional air or oven drying.

6.1.2 Test oil pressure and scavenge pumps. The test oil pressure and scavenge pumps are to be completely disassembled and cleaned to remove all deposits from the previous test.

6.1.3 Oil-out sump. The oil sump located directly below the bearing head should be disassembled and cleaned with bisolvent followed by ultrasonic cleaning in an oakite/water mixture, if necessary. Rinse in bisolvent and air dry.

6.1.4 Test oil lines. All of the straight run test oil lines and fittings (elbows, tees) should be removed from the test oil system and hand reamed with wire brushes having bristles of steel or other metal except copper in a bath of cleaning solvent. Oil lines with bends greater than 10 degrees should be new at the start of each test.

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6.1.5 Oil filter assemblies. All oil filter housings in the test and support oil systems should be removed and wire brushed in cleaning solvent. A soft fiber brush is usually adequate in scrubbing the filter elements after a short soaking in a solvent bath.

6.1.6 Gage lines. The oil lines connected to gages on the instrument console require cleaning with air after each test.

6.1.7 Bearing head. The bearing head should be disassembled as far back as the seal and all of the removable parts, except the test bearing, are to be thoroughly cleaned by scouring with No. 400 emery paper, or glass beads (vacu-blasting), and solvent to remove all traces of deposits from the previous test. In cases of extreme dirtiness, the entire seal assembly should be removed and the parts solvent cleaned using No. 400 emery paper if necessary.

6.1.8 Test bearing. For qualification tests a new 10.0-cm test bearing should be used for each 100–hour endurance run. The new bearing should be cleaned in solvent and dipped in test oil prior to installing.

6.2 Bearing head assembly.

6.2.1 Screw thread seal. In installing the seal (P/N IRBB 6204) the right hand threads on the O.D. of the seal must be toward the front (test compartment) end of the rig. Reversing the seal position will cause the test and support oil to be whirled toward the center of the seal by the rotating action of the shaft and enhance the possibility of mixing the two oils.

6.2.2 Test bearing heater mount. The bearing outer race should be lightly pressed into the bearing heater mount with the serial number facing the front of the rig. The recommended fit on the bearing outer race is -0.(100508 to ±0.00178 cm (-0.0002 to +0.0007 inch). On repeated usage, the I.D. of the bearing mount may become -worn and result in a loose fit which might tend to cock the outer race. It may also result in erroneous temperature readings of the bearing outer race. When this happens, the I.D. of the mount should be chrome plated and brought back to proper dimension or that section of the mount replaced.

NOTE: The heater mount must be disassembled and repacked with No. 30 grit aluminum oxide after each test.

6.2.2.1 Reassembly of heater mount. Prior to assembly of the heater mount, the heater coils should be centered and checked to insure that no point of the coils comes within 0.318 cm (1/8 inch) of the inside surfaces of the front and rear mount plates. A method of accomplishing this is to assemble the unit without retainer ring; this allows visual inspection of the location of the heater-coils within the assembly. Areas where the coils come within 0.318 cm (1/8 inch) of either front or rear inner faces are marked. During final assembly, transite spacers 0.32 x 0.64 x 1.3 cm (1/8″ x 1/4″ x 1/2″) are placed at *these* marked points. In reassembling the heater mount, care should be

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exercised to insure that the front and rear vertical faces are parallel to each other and square with the I.D. of the mount. If these conditions are not maintained, the concentricity of the bearing outer race in relation to the axis of the shaft may be affected. Before installing the heater mount in the rig, the bearing outer race thermocouples should be checked for continuity.

6.2.3 Test bearing. Before installing the test bearing on the hub, it should be examined visually for any obvious mechanical defects. If the bearing appears satisfactory, the inner race and cage assembly should be pressed onto the hub with the serial number facing the front of the rig. The recommended fit of the bearing inner race on the hub is 0.0020 to 0.0036 cm (0.0008 to 0.0014 inches) tight. After repeated usage the O.D. of the bearing hub may become worn and result in a loose bearing fit. When this happens, the hub should be chrome plated back to proper dimension or replaced. After the bearing has been installed in the bearing head, turn the shaft by hand to make sure it turns freely. Bearing roughness can usually be detected in this manner. When properly installed the rollers should be evenly centered in the outer race. If the rollers are more than 0.32 cm (1/8 inch) off center on the outer race, check for missing shaft assembly parts or an improperly installed bearing outer race. It is important that the lock nut on the test bearing retainer be tight since it imparts the axial pinch on all of the shaft assembly parts back to the load bearing and in addition helps to prevent the bearing inner race from turning on the hub during operation.

6.2.4 End cover. Before installing the end cover on the rig, check the test oil jet tube alignment to make sure it is aimed midway between the test bearing outer race and the cage. A gasket, made from material to withstand high temperatures, should be installed under the end cover.

6.2.5 Bench check of seal operation. After assembly of the bearing head, the screw thread seal operation should be checked under a 2240 N (500-pound) radial load to the test bearing by applying 352 gage kPa (51 psig) shop air pressure to the loading cylinder and hand rotating the shaft to detect rubbing. If any rubbing occurs, the bearing head should be disassemled and a slight amount of material removed from either the screw threads or the seal plate, depending on the location and severity of the rubbing. The material is removed from the seal plate if the rubbing is localized, and the screw shread is ground if the rubbing is severe and occurs over a considerable area. On a new build, the seal plate may be coated with Prussian blue to determine the area of contact. On later rebuilds, the rubbing can usually be detected without the use of the dye. The seal should be checked for rubbing after every build.

6.2.6 Miscellaneous joint compounds. No pipe dopes, thread compounds, or gasket sealants should be used in the assembly of the rig or test oil system. Teflon tape (no adhesive) is an effective sealant when applied to pipe threads.

6.3 Rig installation and stand checks. After assembly, the bearing head is installed on the stand. The test oil tank is filled with 7.6 L (two gallons) of the oil to be tested. This oil is heated to 121° C (250° F) in the tank and

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then circulated for 20 minutes through the test oil system, including the bearing head. The oil is then drained from the tank and the bottom sections of the two oil filter housings. Fresh test oil is then added to the tank until the fluid level is 1.3 cm (1/2 inch) above the baffle plate with the test oil pressure and scavenge lines filled in preparation for the test.

6.3.1 A qualified MIL-L-23699 or MIL-L-7808 lubricating oil is used in the support system and is not normally changed after each run. Drain periods on the support oil are governed by the amount of deterioration as determined by laboratory tests and the degree of the filter plugging in the support oil system.

6.4 Critical test items. Before starting a test, care should be taken that critical items such as dimensional tolerances and heater electrical connections conform to those listed in Table II.

TABLE I. operating conditions for different severity levels of Erdco high temperature bearing test.

Condition	Type		
	1	1-1/2	2
Test oil-in temp., °C	149 ±2.5	177 +2.5	204 ±2.5
Test tank bulk oil temp., °C	171 ±2.5	199 +2.5	227 ±2.5
Test bearing temp.-max. , °C	260 ±2.5	260±2.5	260 ±2.5
Air flow to end cover, L per min.	9.9 ±1.4	9.9±1.4	9.9 ±1.4
Test oil-in temp., °F	300 ±5	350 +5	400 ±5
Test tank bulk oil temp., °F	340 ±5	390 ±5	440 ±5
Test bearing temp.-max., °F	500 ±5	500 ±5	500 ±5
Air flow to end cover, CFM	0.35±0.05	0.35±0.05	0.35 ±0.05

TABLE II. Critical test items.

	Minimum centimeter	Maximum centimeter	Minimum inch	Maximum inch
1. Dimensional tolerances:				
a. Test bearing outer race fit in heater mount	-0.00051	+0.0018	-0.0002	+.0007
b. Test bearing inner race fit on hub	-0.0020	-0.0036	-0.0008	-0.0014
c. Axial run-out of front vertical face of test bearing outer race assembled in rig	0.000	0.013	0.000	0.005
d. Screw type seal	0.046	0.056	0.018	0.022
2. Electrical connections				

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a. Test bearing heater. This is a single wrapped 4700 Watt unit which should be connected to 220–volt power source.

b. Test oil tank immersion heater. This unit is made up of three 1,500 Watt heaters which should be series–connected to a 220-volt power source.

6.5 Operating conditions.

6.5.1 Throughout the entire test the variables for different test severities (types 1, 1-1/2, and 2) as shown in Table I should be controlled within the limits specified.

6.5.2 Initial test oil jet calibration. To calibrate the test oil jet, the test tank should be heated until bulk oil temperature is about 149° C (300° F). Turn on air to the end cover. Then the test oil and support oil pumps are turned on, and the rig speed increased to 10,000 rpm. The rig speed should be brought up immediately after oil circulation is started as the screw thread seal depends on relative motion for its sealing action. The previous setting on the test oil pressure pump or a minimum of 69 gage kPa (10 psig) oil pressure at the jet should be used to insure against possible oil starvation during this initial startup. The pressure drop across the seal is maintained at 0.8 to 1.5 cm (0.3 to 0.6 inch) of test oil by making fine adjustments to the gear box vent valve. Under these conditions of air flow, the pressure in the test compartment should be 0.25–0.51 cm (0.1-0.2 inch) of test oil above rig room pressure conditions. As soon as a 121° C (250° F) oil temperature at the jet has stabilized, a minimum of two separate flow checks of one-minute duration each should be made at the three-way valve position on the pressure side of the scavenge pump. The oil pressure at” the jet should be adjusted using the variable speed drive unit on the test oil pump until the jet oil flow is 600 mL/min. Once the flow rate of 600 mL/min is established for an oil, the flow at this condition is maintained constant during the test.

6.5.3 After the oil jet calibration step, the following conditions are allowed to stabilize:

Oil-in temperature	121° c	250° F
Oil flow rate	600 +30 mL/min	600 ±30 mL/min
Bearing speed	10,000 rpm +100 rpm	10,000 rpm +100 rpm
Radial load	352 gage kPa (2220 N)	51 psig (500 lb)
Support oil-in temperature	71°-820 C	160°-1800 F
Support oil pressure	552-689 gage kPa	80-100 psig
Gear box oil pressure	172-207 gage kPa	25-30 psig
Air flow to end cover	9.9 ±1.4 L per min.	0.35 ±0.05 cfm
Pressure drop across seal	0.8-1.5 cm of test oil (test compartment higher)	0.3-0.6 inch of test oil (test compartment higher)

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6.5.3.1 After the foregoing conditions stabilize, the run is continued until the test bearing temperature from the highest reading thermocouple levels off (about one hour). This temperature is then noted and used as an indication of the mechanical condition of the bearing. Previous tests on bearing stabilization at a 121° C (250° F) oil-in temperature to the jet indicate that a temperature range of 149° C to 177° C (300° F to 350° F) is normal for a properly functioning 100-mm Erdco test bearing. Higher stabilization temperatures indicate the test bearing condition is questionable and the bearing should probably be replaced before continuing with the test.

6.5.4 Once the test bearing has reached a satisfactory stabilized temperature, the temperature setting on the temperature controller on the test tank should be increased to raise bulk oil temperatures to about 28° C (50° F) higher than the desired temperature of the oil at the jet (149° C [300° F] for- the test of type 1 lubricants, 177° C [350° F] for the type 1-1/2 lubricants, and 204° C [400° F] for the test of type 2 lubricants). In order to reduce the length of warmup time required to reach the desired test oil jet temperature, the Calrod heater should be turned on simultaneously with the change in test tank setting to bring the bearing outer race temperature (max) to 260° C (500° F). At this point, the three thermocouples attached to the bearing outer race should be checked to make sure that the thermocouple indicating the second highest temperature is attached to the Temperature Controller. Improper hookup of the bearing thermocouples will result in poor control of test bearing temperatures.

6.5.5 When the desired test conditions shown in Table I are reached, the test oil flow rate is again checked twice and adjusted if necessary to obtain 600 mL/min flow at the three-way valve position in the scavenge line. Then the 100-hour endurance test is begun. These data are recorded on a multi-channel strip chart continuously during the course of the test.

6.5.6 Test cycle. The 100-hour endurance test is run so that there is at least a seven-hour shutdown period out of every 24 hours of operation. Except for emergency stops, all shutdowns should be made in accordance with the detailed procedure as outlined in 6.6.4. Warmup time following shutdown periods is considered part of the 100-hour endurance test time.

6.5.7 Used oil analysis. The following laboratory tests are run on the new and used oil samples:

Test	ASTM method	50 mL samples
Viscosity at:		
37.8° C (100° F), cs	D 445	X
98.9° C (210° F), cs	D 445	X
Neutralization No.	D 664	X

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6.5.8 Test oil flow rate checks. During operation the test oil flow rate should be checked at the three-way valve in the scavenge line twice every startup. For convenience, a 1000-mL, borosilicate glass graduated cylinder should be used to collect the test oil during the flow check. The volume of oil collected in a one- or two-minute period should check the original volume flow in mL/min within +5.0 percent. In order to prevent too large a drop in test oil level in the tank–during flow checks, a maximum continous flow period should be two minutes. The hot test oil collected in the glass graduate should be dumped back into the test tank after each flow check. With the friction type variable speed drive unit on the test oil pressure pump, it is not possible to obtain a nonslip drive on the pump after oil pressures reach about 276 gage kPa (40 psig). At this point the test oil will usually have become so viscous it can no longer be effectively pumped and the test should be considered ended.

6.5.9 At the completion of the 100-hour endurance test, the test bearing is restabilized at 121° C (250° F) oil-in temperature to determine the relative change in stabilized temperatures compared to the results obtained at the start of the test. These data can be used to determine the change in frictional characteristics of the bearing resulting from metal wear or excessive oil deposits.

6.5.10 The rig is then shut down in accordance with the shutdown procedure described in 6.6.4.

6.5.11 When the system cools to room temperature, the tank and test oil system should be drained into a suitable container so that the volume of test oil remaining can be determined. After the volume of test oil has been measured and recorded, 3.8 L (one gallon) of the test oil should be poured into a clean container and saved for laboratory analyses.

6.5.12 Rig photographs. As soon as possible, the rig should be disassembled. Although color is preferred, black-and-white photographs, measuring at least 7.6 by 10.2 cm (3 by 4 inches) or slides should then be taken of the following parts:

a. Bearing compartment with cover removed - front view.
b. Heater mount - rear side.
c. Cover plate - rear side.
d. Seal plate in housing - heater and bearing removed.
e. Test bearing - inner race, rollers and cage assembly.
f. Test bearing - outer race, inside diameter.
g. Test oil tank - baffle plate.
h. Test oil tank - baffle removed.

6.5.13 After the photographs are completed, a more detailed visual inspection is made of these parts to determine the average depth, coverage, consistency, and type of oil deposits, plus the extent of abnormal metal wear on the test bearing cage, rollers, roller pockets, and outer race. Rate deposits according to 6.7.

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6.6 PROCEDURES

6.6.1 Flushing procedure.

1. Install a fine mesh (100 mesh) filter at the inlet of the spray nozzle and a coarse mesh (40 mesh) filter at the inlet of the scavenge pump. It is not necessary to preweigh the filters.
2. The same type of oil is used to flush the system as used in the test. Service the test oil tank with 7570 mLs (two gallons) of test oil.
3. Insure that the tank is vented by means of an exhauster/blower arrangement and that the vent is open.
4. Insure that the test oil supply valve at the inlet side of the pressure pump is closed.
5. The watt-hour meter reading for the test oil heater should be recorded before the flush is begun.
6. At the control panel turn on the following switches in the order shown:

   a. Control panel power.
   b. Support test oil cart power.
   c. Stirrer.
   d. Timer.
   e. Test oil heater.
   f. Strip chart recorder.
   g. Flowmeter timer.
   h. Doric.

7. Provide full power (220 volts) to the test oil heater.
8. When the temperature of the test oil in the tank exceeds 121 °C (250 °F) turn on the pressure and scavenge pumps. Immediately open the test oil supply valve (on the inlet side of the pressure pump) to allow oil to draw to the pressure pump. The pump speed should be maintained such that the pressure is a minimum of 138 gage kPa (20 psig) and the flow is 600 + 30 mL min.
9. Adjust the test oil heater as needed to–maintain a temperature of 121 °c (250 °F) in the test oil tank.
10. While the oil is circulating draw two samples of approximately 700 mL each and check for debris. If the samples are clean, return them to the system. If the samples contain debris, drain the oil and begin the flush again.

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11. Circulate the oil for at least 20 minutes and then turn off the tank heater.
12. When the test oil tank temperature has cooled to 38 “C (100 “F), close the oil supply valve on the inlet side of the pressure pump.
13. Turn off the following switches:

    a. Pumps
    b. Timer.
    c. Stirrer.
    d. Recorder.
    e. Flowmeter.
    f. Doric.
    g. Support test oil cart power.
    h. Control panel power.

14. Drain the test oil tank. Take two samples of the oil (20 mL and 60 mL). Mark the samples and the remaining oil:

    Flush oil
    B.R. Test
    Test #
    Oil Code (PE number)
    Date

15. After removing the two flush filters, clean and store them.

6.6.2 Preparation for test.

1. Update the strip chart recorder with the date, test number and oil code.
2. Install two preweighed filters. A fine mesh (100 mesh) filter is installed on the spray nozzle inlet and a coarse mesh (40 mesh) filter is installed on the inlet line of the scavenge pump.
3. Close the oil supply valve. Check the oil level in the test oil and support oil tanks. The test oil tank should be charged with test oil at room temperature until the fluid level is 1.3 cm (1/2 inch) above the baffle plate with the pressure and scavenge lines filled. This level should be marked and will establish the “FILL” mark or the minimum operating level during test operation. The expansion of the test oil upon heating to test conditions will establish the “FULL” mark. The support oil tank should contain approximately 23 to 30 L (6 to 8) gallons of a MIL-L-23699 or MIL-L-7808 lubricating oil.

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4. Insure that the test oil tank vent is open and that any vent line drain is closed.
5. Check the main air supply pressure, adjusting it if necessary to maintain a minimum of 207 gage kPa (30 psig).
6. Open water valves to dynamic and support oil cooler.
7. Check dynamic water pressure: it should be 310 gage kPa (45 psig).
8. Adjust the air pressure for the load cylinder to 207 gage kPa (30 psig).
9. Set the load valve to the zero load position (clockwise direction).
10. Add distilled water to the vapor bottle until the desired level is reached.
11. Open air bleeds on both sides of the differential manometer for the screw thread oil seals which should be filled with test oil.
12. Record the watt-hour meter readings from the test oil tank heater and bearing heater meters. Turn on the electric power (breaker boxes) to the test oil tank heater, support oil tank heater, test bearing heater, and the bearing drive motor.
13. Turn off automatic mode switch.
14. Turn on the following switches on the control panel:

    a. Control panel power.
    b. Strip chart recorder.
    c. Support test oil cart power.
    d. Stirrer motor.
    e. Timer (adjust as necessary).
    f. Test oil heater.
    g. Doric.
    h. Water heater.
    i. Load by-pass.

15. When the test oil temperature reaches 121 °C (250 °F) turn on the support oil heater. The temperature controllers should be adjusted to obtain 138 °C (280 °F) and 82 °C (175 °F) in the test oil and support oil tanks, respectively. In the test oil tank, the maximum heater skin temperature should not exceed 29 °C (85 °F) above the test oil tank target temperature during warmup. Higher temperatures indicate improper electrical hookup of excessively high supply voltage which should be corrected before continuing the test program.
16. When the bulk oil temperature in the test tank reaches 138 °C (280 “F) turn on the air supply to the end cover and adjust to approximately 9.9 L/rein (0.35 cubic feet per minute). Air pressure should be held at 34.4 gage kPa (5.0 psig).
17. Start the test oil pressure and scavenge pumps. Insure that the flow is 69 gage kPa (10 psig) minimum at the test oil jet. The test oil flowrate is 600 ±30 mL/min.

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18. Check the oil supply valve between the test oil tank and the variable speed pressure pump; it should be wide open.
19. Start the support oil pumps; there should be at least 414 gage kPa (60 psig) manifold pressure. At the screw thread seal there should be at least 0.8 cm (0.3 inches) of oil positive pressure relative to the support oil side (manometer leg to test compartment lower).
20. Set and maintain the support oil pressure at 552 to 689 gage kPa (80 to 100 psig) by means of a regulating valve.
21. Allow oil temperature at the support scavenge line to reach at 38.8 °C least (100 °F).
22. Start the bearing drive motor; the bearing speed is preset at 10,000 rpm. (If bearing drive is not constant speed, follow motor operating instructions to bring it up to the necessary speed.)
23. Turn off the load by-pass switch.
24. Apply, a load to the test bearing. Increase the load on the bearing gradually with the load controls. The load cylinder pressure should be held at 352 gage kPa (51 psig).
25. Continue running until the following conditions have been stabilized:

Test oil–in temp.	121 °C ±2.5 °C (250 °F ±5 °F)	
Test tank bulk oil temp.	138 °C ±2.5 °C (280 °F ±5 °F)	
Air flow, end cover	9.9 ±1.4 L/rein (corrected)	(0.35 ±0.05 ft^3 per minute) (corrected)

26. Make at least two separate flow checks of one-minute duration each at the three-way valve position on the pressure side of the scavenge pump. The measured volume flow rate should be 600 +30 mL/min. The hot test oil collected during the flow check should be poured immediately back into the test oil tank through the fill port and the port recapped.
27. Continue running for one hour at these conditions with the bearing heater off. If during or at the end of this period, the maximum bearing temperature has exceeded 177 °C (350 °F), shut down the rig, install a new test bearing, and repeat items 1 through 26. If the maximum bearing temperature has not exceeded 177 °C (350 °F) during this period, proceed with the next step.
28. Turn on the test bearing heater and adjust indicator flag to the target temperature on the temperature controller.
29. Check the three test bearing outer-race thermocouples to make sure that the second highest indicating thermocouple is connected to the temperature controller. Maintain 260 °C (500 °F) on the highest indicating thermocouple.

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30. Adjust the test oil tank thermal switch so that the target temperature for the type of test being run is met within 30 minutes (minimum) and 60 minutes(maximum). Maximum heater skin temperature should not exceed 29 °C (85 °F) above test oil target temperature during the warmup period. The nozzle temperature should be maintained at 177 ±25 °C (350 ±5 °F).

Test type	1	1 -1/2	2
Target Temp.	171 °C +2.5 °C (340 °F ±5 °F)	199 °C +2.5 °C (390 °F ±5 °F)	227 °C +2.5 °C (440 °F ±5 °F)
Oil-in Temp.	149 °C +2.5 °C (300 °F ±5 °F)	177 °C +2.5 °C (350 °F ±5 °F)	204 °C +2.5 °C (400 °F ±5 °F)

31. Continue running until the conditions of Table I for the type of test requested have stabilized.
32. Take at least two separate flow checks of one-minute duration at each of the three-way valve position on the pressure side of the scavenge pump. Flow rate should be 600 ±30 mL/min. The hot test oil collected during the flow check should be poured immediately back into the test oil tank through the fill port and the port recapped.
33. Continue endurance testing. At the completion of the 100-hour endurance test, the test bearing is to be restabilized at 121 °C (250 °F) oil-in temperature to determine the relative change ill stabilized temperatures compared to the results obtained at the start of the test.

6.6.3 Daily startup sequence.

1. Update strip chart recorder.
2. Check oil level through visual sight gauge. Add enough oil so that the bottom of the test oil meniscus is even with the mark that was made in step 3 of procedure 6.6.2. Open vent drain valve and remove all oil from tile vent line.
3. Repeat steps 4 to 23 for startup procedure.
4. Turn on test bearing heater and adjust as necessary to reach 260 +2.5 °C (500 +5 °F) on the highest reading thermocouple.
5. Continue running until the conditions have stabilized for the type of test being run *as* shown in Table I.
6. Make at least two separate flow checks of one-minute duration each at the three-way valve position on the pressure side of the scavange pump. The measured volume flow rate should be 600 +30 mL/min.

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6.6.4 Daily running procedure.

1. Monitor the strip chart recorder for maintenance of test temperatures within correct operating ranges. Monitor gauges and flowmeters as well.
2. Take two samples of test oil (20 mL and 60 mL) from the three-way valve in the scavenge line or with an automated system every ten hours (including warmup time along with endurance time). The first test sample should be fresh test oil before the oil is introduced into the system. If the ten-hour sampling period happens to fall during a shutdown period, take the samples just before shutdown or after first reaching type 1, 1-1/2, or 2 test conditions from next startup of rig. Mark each sample:

   B.R Test
   Test #
   Oil Code
   Date
   Hour of Sample

3. Makeup oil should be added immediately after each 80 mL sample is taken by adding sufficient quantity of unused test oil to the tank to bring the oil level in the visual sight gage to the full mark.
4. The test oil filter changes should be made after shutting down on the first day. If the pressure drop across the 100-mesh filter exceeds 21 gage kPa (3 psig) during operation, the rig should be shut down in accordance with the shutdown procedure under 6.6.5, and a new weighed filter reinstalled. The dirty 100-mesh filter element and the 40-mesh filter element are to be weighed and the amount of the weight gain recorded. prior to weighing, the 100-mesh and 40–mesh filter screens should be allowed to drain for, one hour at room temperature.
5. Actual running time should conform to the following conditions:

   a. Seventeen hours maximum test time between shutdowns.
   b. Minimum shutdown period of seven hours.
   c. Minimum daily running time of six hours.

6.6.5 Shutdown procedure.

1. Shut off bearing and tank heaters.
2. Open air regulated loading valve on console and reduce loading pressure to 172 gage kPa (25 psig).
3. Continue running at these conditions until test bearing temperature (maximum) drops to 204 °C (400 °F).
4. Reduce load completely and shut off drive motor.

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5. When the dynamatic output shaft stops turning, shut off test pumps, support pumps and heat, test tank stirrer, main electrical and water switches, and all air valves.

6.6.6 Post-stabilization run.

1. This procedure is done in place of the last shutdown.
2. Repeat steps 1 through 3 of the shutdown procedure.
3. Reduce load on bearing completely.
4. Allow the test oil tank temperature and the oil-in temperature to reach 138 °C (280 °F) and 121 °C (250 °F) respectively. Maintain these temperatures.
5. When the test temperatures stabilize, run for one hour and monitor the maximum temperature of the test bearing.
6. Record the highest bearing temperature.
7. Shut off bearing drive motor.
8. Repeat step 5 of the shutdown procedure.

6.7 Demerit system for rating deposits in Erdco bearing machine.

6.7.1 Outline of method.

6.7.1.1 Cleanliness demerits. Bearing head cleanliness shall be reported in this demerit system by the assignment of values of 0 to 20 to the inspection results, as follows:

0 shall designate a new or thoroughly clean condition.
20 shall represent the worst condition that could be expected.

6.7.1.2 Table III shows the numerical demerits to be assigned to different types and degrees of deposits.

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TABLE III. Deposit rating demerit scale.

Type of deposit	Degree	Demerit values
Flaked carbon	Heavy	20
	Moderate	19
	Light	18
Blistered carbon	Heavy	17
	Moderate	16
	Light	15
Crinkled	Heavy	14
	Moderate	13
	Light	12
Smooth carbon	Heavy	11
	Moderate	10
	Light	9
Sludge	Heavy	8
	Moderate	7
	Light	6
Varnish	Heavy	5
	Moderate	3
	Light	1
Clean		0

All demerits shall be reported to the nearest whole number.

6.7.1.3 Table IV defines deposit types and degrees.

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TABLE IV. Description of bearing deposit rating terms.

Type of deposit	Degree	Description
Flaked carbon		Carbonaceous coating that cannot be removed by wiping with a rag. Broken blisters, peeling.
	Heavy	Over 0.12 cm (3/64-inch) in thickness.
	Moderate	Ranges from 0.04 cm (1/64-inch) to less than 0.12 cm (3/64-inch) in thickness.
	Light	Ranges from just covering to less than 0.04 cm (1/64-inch) in thickness.
Blistered carbon		Same as for flaked carbon, blistered, bubbled.
	Heavy	Same as for flaked carbon.
	Moderate	Same as for flaked carbon.
	Light	Same as for flaked carbon.
Crinkled carbon		Same as for flaked carbon, ridged, not smooth.
	Heavy	Same as for flaked carbon.
	Moderate	Same as for flaked carbon.
	Light	Same as for flaked carbon.
Smooth carbon		Same as for flaked carbon, smooth coating.
	Heavy	Same as for flaked carbon.
	Moderate	Same as for flaked carbon.
	Light	Same as for flaked carbon.
Sludge		Shiny, oily emulsion of carbon and oil. Can be wiped off with a rag.
	Heavy	Approximately 0.42 cm (1/16-inch) thick.
	Moderate	Approximately 0.08 cm (1/32-inch) thick.
	Light	Just covering.
Varnish		Varnish or lacquer-like coating shiny.
Clean		Clean - no deposit.

6.7.2 Computation of overall rating of the Erdco high temperature bearing head.

6.7.2.1 An area demerit shall be determined in accordance with the area covered by the deposits as follows:

$$\frac{\text{Percent area covered}}{10} = \text{Area demerit}$$

6.7.2.2 A rating shall be obtained by multiplying the area demerit by the demerit value assigned in Table III. The rating for each item shall be modified by multiplying by the weight factor assigned by Table V which will yield a demerit rating.

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6.7.2.2.1 Bearing rating and demerits are determined from the following categories:

Rollers 1. face
2. rear
3. front
Cage 4. between rollers
5. rear
6. front
Outer ring 7. path
8. rear
9. front

$$\frac{\text{Sum of Ratings}}{11} \times 5 \text{ (Weight Factor)}$$

Demerit for Bearing

Inner ring 10. rear
11. front

6.7.2.3 The total bearing head deposit rating shall be the sum of the demerits for each item of Table V.

TABLE V. Bearing head deposit weight factor rating.

No.	Item		Weight factor		Demerit
1.	End cover	Multiply rating by	1	=	
2.	Spacer and nut	Multiply rating by	2	=	
3.	Heater-front	Multiply rating by	3	=	
4.	Heater-rear	Multiply rating by	3	=	
5.	Seal plate	Multiply rating by	3	=	
6.	Bearing	Multiply rating by	5	=	

6.7.2.4 The overall rating of the Erdco high temperature bearing head shall be the total bearing head deposit rating divided by 6.

6.7.2.5 An example of the calculations described is shown in Table VI.

TABLE VI. Example of detailed rating.

Item	Description	Area demerit 6.7.2.1	Demerit scale 6.7.1.2	Rating 6.7.2.2	Factor 6.7.2.2, Table III	Demerit
1. End cover	Clean	1	0	0	1	0
2. Spacer and nut	10 percent L. sludge	1	6	6		
	90 percent M. varnish	9	3	27	2	66
				33		
3. Heater-front	25 percent clean	2.5	0	0		
	25 percent L. varnish	2.5	1	2.5		
	25 percent L. crinkled carbon	2.5	12	30		
	25 percent M. crinkled carbon	2.5	13	32.5	3	195
				65		
4. Heater-rear	10 percent L. varnish	1	1	1		
	10 percent M. varnish	1	3	3		
	10 percent H. varnish	1	5	5		
	20 percent M. sludge	2	7	14		
	50 percent L. smooth carbon	5	9	45	3	195
				68		
5. Seal plate	5 percent M. varnish	0.5	3	1.5		
	95 percent clean	9.5	0	0	1	1.5
				1.5		
6. Bearing:						
a. Rollers:						
(1) Face	100 percent M. varnish	10	3	30		
(2) Rear	50 percent L. varnish	5	1	5		
(3) Front	50 percent M. varnish	5	3	15		
				50		

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TABLE VI. Example of detailed rating. (Continued)

Item	Description	Area demerit 6.7.2.1	Demerit scale 6.7.1.2	Rating 6.7.2.2	Factor 6.7.2.2, Table III	Demerit
b. Cage:						
(4) Between rollers	100 percent clean	10	0	0		
(5) Rear	50 percent clean	5	0	0		
	50 percent L. sludge	5	6	30		
(6) Front	50 percent clean	5	0	0		
	50 percent L. sludge	5	6	30		
				60		
c. Outer ring:						
(7) Path	75 percent clean	7.5	0	0		
	25 percent M. varnish	2.5	3	7.5		
(8) Rear	30 percent M. varnish	3	3	9		
	40 percent H. varnish	4	5	20		
	30 percent L. smooth carbon	3	9	27		
(9) Front	20 percent clean	2	0	0		
	40 percent M. varnish	4	3	12		
	40 percent H. varnish	4	5	20		
				95.5		
d. Inner ring:						
(10) Rear	50 percent L. varnish	5	1	5		
	50 percent M. sludge	5	7	35		
(11) Front	50 percent L. varnish	5	1	5		
	50 percent L. crinkled carbon	5	12	60		
				105		

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TABLE VI. Example of detailed rating. (Continued)

Item	Description	Area demerit 6.7.2.1	Demerit scale 6.7.1.2	Rating 6.7.2.2	Factor 6.7.2.2, Table III	Demerit
Bearing (total)				$\frac{310.5}{11} = 28.25$		141
Total						607.5
Overall rating (Av. of items 1, 2, 3, 4, 5, and 6)		$\frac{607.6}{6} = 101.2$				

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7. CALCULATION

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 As required by the specification.

9. PRECISION

9.1 Precision data have not been developed for this method.

Method prepared by:
Navy - NAPC - 1986

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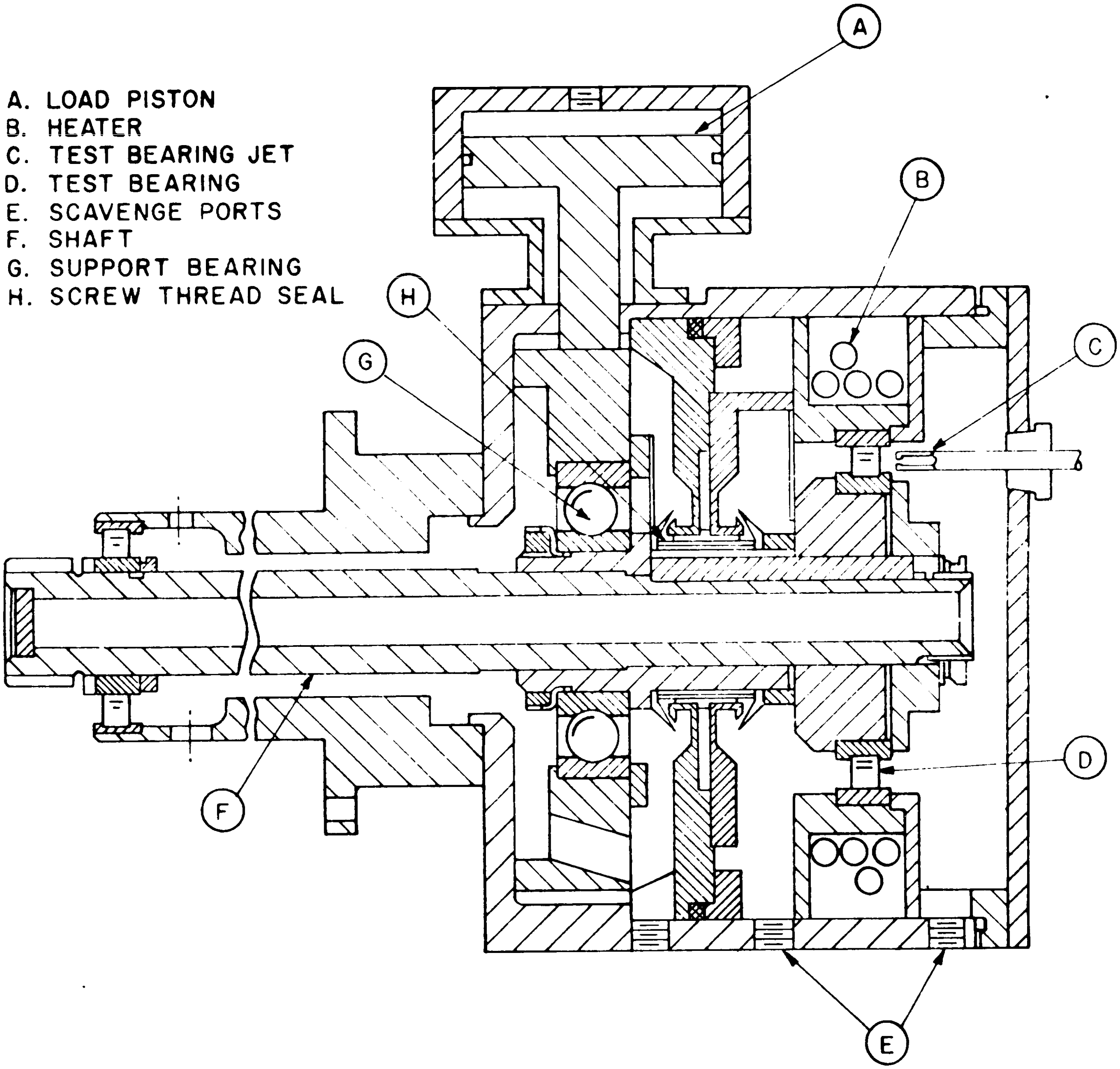

FIGURE 1. Standard ERDCO 100 mm roller bearing head (cross section).

X-4378

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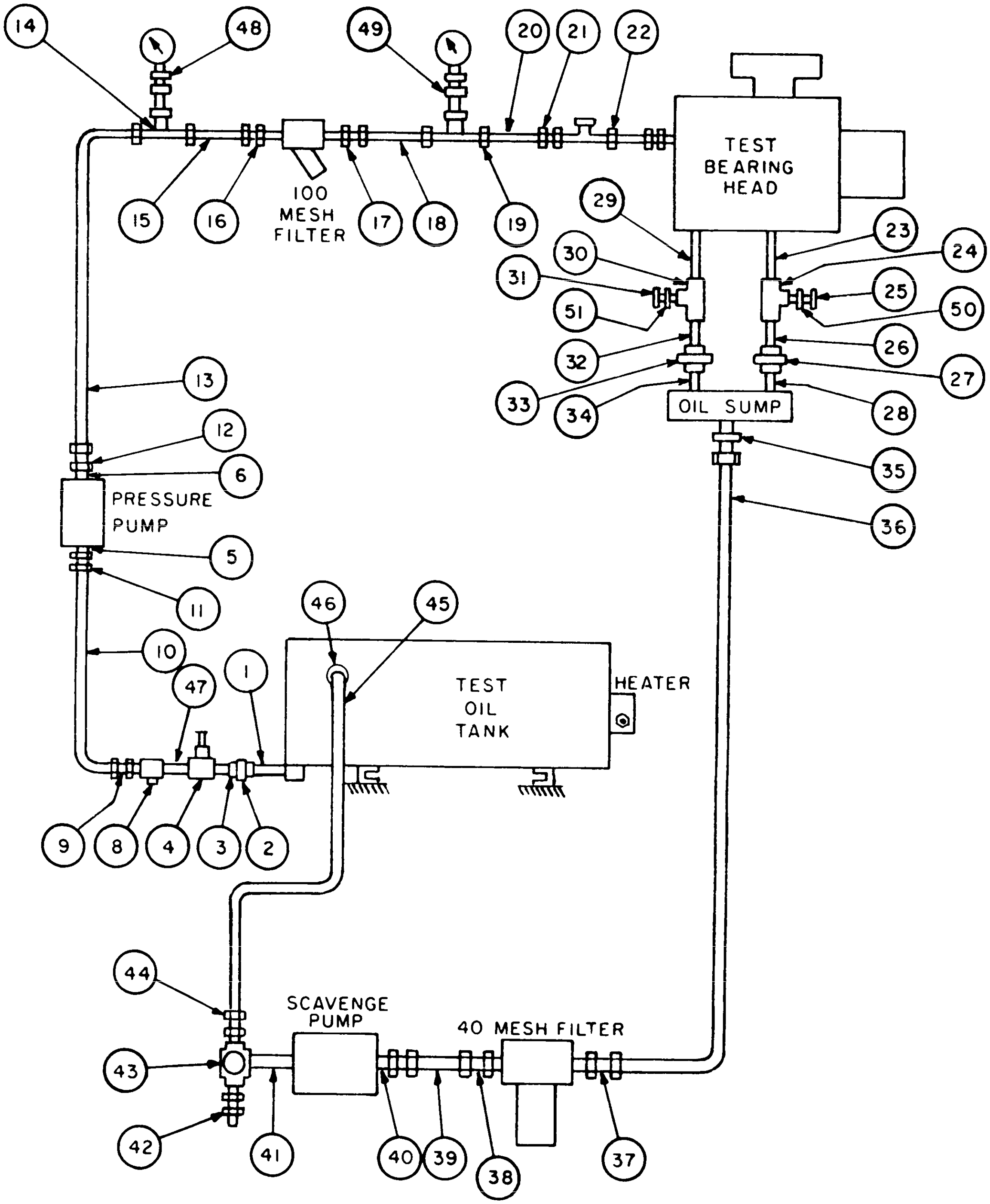

NOTE:
(SEE NOTES ON NEXT PAGE).

FIGURE 2. Schematic of test oil system.

X-4379

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Notes on figure 2.

1. 3/8 pipe nipple - 1-1/2 long
2. 3/8 pipe union
3. 3/8 pipe nipple - 1-1/2 long
4. 3/8 valve (iron)
5. 3/4 by 3/8 reducer
6. 3/4 by 3/8 reducer
7. omitted
8. 3/8 pipe tee
9. 3/8 tube x 3/8 npt-male
10. 3/8 tubing
11. 3/8 tube x 3/8 npt-male
12. 3/8 tube x 3/8
13. 1/2 tube
14. 1/4 tube tee
15. 1/4 tube
16. 1/4 tube x 3/8 npt-male
17. 1/4 tube x 3/8 npt-male
18. 1/4 tube
19. 1/4 tube tee
20. 1/4 tube
21. 1/4 tube x 1/8 npt-female
22. 3/16 tube x 1/8 npt-male tee (branch T/C modified)
23. 3/8 pipe nipple - 1-1/2 long
24. 3/8 pipe tee
25. 3/16 tube x 1/8 npt-male (T/C modified)
26. 3/8 pipe nipple - 1-1/2 long
27. 3/8 pipe union
28. 3/8 pipe nipple - 1-1/2 long
29. 3/8 pipe nipple - 1-1/2 long
30. 3/8 pipe tee
31. 3/16 tube x 1/8 npt-male (T/C modified)
32. 3/8 pipe nipple - 1-1/2 long
33. 3/8 pipe union
34• 3/8 pipe union - 1-1/2 long
35* 1/2 tube x 1/2 npt-male
36. 1/2 tubing
37. 1/2 tube x 3/8 npt-male
38. 1/2 tube x 3/8 npt-male
39. 1/2 tube
40. 1/2 tube x 1/2 npt-male
41. 1/2 pipe npl x 3 long
42. 1/2 tube x 1/2 npt-male
43. 1/2 three way valve (iron)
44. 1/2 tube x 1/2 npt-male
45. 1/2 tube
46. 1/2 tube x 3/8 npt-male
47. 3/8 pipe npt - 1-1/2 long
48. 1/4 tube bulkhead connector (steel)
49. 1/4 tube bulkhead connector
50. 3/8 by 1/8 reducing bushing
51. 3/8 by 1/8 reducing bushing

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THERMAL STABILITY AND CORROSIVITY OF AIRCRAFT TURBINE ENGINE LUBRICANTS

1. SCOPE

1.1 This method describes a procedure for determining the thermal stability and corrosiveness of aircraft turbine lubricants in an environment free of air and moisture. The catalytic effects of mild steel on the decomposition of the fluids and the corrosion of the steel by the thermal degradation products of the lubricant are measured.

2. SUMMARY

2.1 A weighed mild steel specimen is placed in a glass thermal stability test cell with a measured amount of test lubricant. Air and moisture are removed from the test cell by heating and shaking under vacuum prior to sealing the tube. The sealed test cell is then heated at a given temperature for a specified period of time. The stability of the lubricant is assessed by determining the change in viscosity, total acid number and by the appearance of the residual lubricant at the end of the heating period. The steel specimen is weighed and examined under a microscope to determine changes due to corrosion.

3. SAMPLE SIZE

3.1 Approximately 10 mL for each steel corrosion test.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Test cell - A borosilicate glass test cell having the dimensions given in Figure 1 is recommended as the sample container.

4.2 Heating bath, 9.5 L (ten quart) capacity, (manufactured by Sta-Warm Electric, Ravena, Ohio or equivalent). An aluminum block may be used in place of the heating bath if so desired. The resistance wire-heated aluminum block must have a suitable number of openings of the proper diameter (approximately 2.0 cm) and depth (approximately 21 cm) so that the sealed test cell is completely immersed in the heater. The temperature of the aluminum block or heating bath shall be capable of being controlled within ±1° C (+2° F) at the test temperature. The temperature gradient between oil sample and the aluminum block or bath shall be kept within 1° C (2° F).

4.3 Test cell holder - When a heating bath is used, a heavy-wall steel sample tube holder of the proper size to contain the test cell shall be provided for safety reasons.

4.4 Becton, Dickinson and Company Yale Luer-Lock (20YL), or equal 20 mL hypodermic syringe with a No. 14 square-tip needle approximately 20 cm (8 inches) long.

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4.5. Vacuum pump, capable of reducing the pressure to at least 10 micrometers of mercury or less.

4.6 McLeod gauge or other suitable pressure measuring device.

4.7 Water bath, capable of maintaining a temperature of 80° C ±3° C (175° F ±5° F) and sufficient size to contain the test cell.

4.8 Laboratory safety shield, constructed of either safety glass or wire reinforced plastic.

4.9 Balance, sensitivity 0.1 mg.

4.10 Microscope, 20 power magnification.

4.11 Forceps, stainless steel.

5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Toluene, reagent-grade [2,3,0].

5.3 Acetone, reagent-grade [1,3,0].

5.4 Nitric-sulfuric acid mixture, approximately 1:10 [3,0,2].

5.5 Abrasive paper, silicon carbide, 240 grit.

5.6 Steel specimens of approximately 0.15 X 0.7 X 7.5 cm made from QQ-S-698 mild steel shall be used.

6. PROCEDURE

6.1 Definitions

6.1.1 Thermal stability is the resistance to permanent changes in properties of the lubricant caused solely by heat.

6.1.2 Corrosion is any surface damage of the steel specimen resulting in a weight change.

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6.2 Preparation of apparatus.

6.2.1 Cutting test cells - The cells are cut in two, either on an emery cutoff wheel or by circumscribing the tube with a hot wire about 17 cm from the bottom.

NOTE 1: Circumscribing with a hot wire is preferred because it is cleaner and safer.

6.2.2 Cleaning test cell - Clean the divided test cell by scrubbing with a suitable detergent, rinsing in tap water, heating in hot nitric-sulfuric acid mixture, rinsing with distilled water and drying in an oven at 105° C (225° F) for 1 hour. The cells can be stored in a desiccator until used.

6.2.3 Preheat and adjust aluminum block or heating bath temperature to 274° C ±1° C (525° F ±2° F).

6.2.4 Preparation of steel specimens.

6.2.4.1 Cut samples approximately 0.15 X 0.7 X 7.5 cm.

6.2.4.2 Remove pits and other imperfections on a fine grinding wheel.

6.2.4.3 Polish with 240 grit silicon carbide paper to remove all surface blemishes from both sides and all four edges.

NOTE 2: In all succeeding steps, handle the steel specimens with filter paper or forceps.

6.2.4.4 Clean all metal dust from the samples by rubbing vigorously with lint-free tissue.

6.2.4.5 Wash sample strips in warm toluene, then in warm acetone and allow to air dry.

6.2.4.6 Weigh each specimen to within 0.1 mg.

6.3 Test procedure.

6.3.1 Duplicate tests are conducted.

6.3.2 A freshly prepared steel specimen is placed in the lower half of the cleaned cell, which is then fused to the top half.

NOTE 3: Proper annealing of the fused glass cell will prevent rupture and leaks during testing.

6.3.3 Introduce 6 mL of the oil samples below the capillary end of the test cell with the aid of the hypodermic syringe. With this sample volume the metal

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strip is only partially immersed in the oil leaving approximately 1.3 cm (1/2 inch) exposed.

6.3.4 Connect the fused test cell containing the oil sample and metal specimen to the vacuum pump. This can be done with vacuum tubing connected through a Kjeldahl connecting bulb, $\overset{T}{S}$ joint 24/40, and a No. 1 rubber stopper drilled to hold the thermal stability' tube.

6.3.5 Mount the test cell, while still connected to the operating vacuum pump, in a water bath maintained at. 80° C +3° C (175° F +5° F). Degas the cell and its contents while shaking gently for 20 minutes. A Thomas-Boerner oscillating platform shaking apparatus may be used. Mounting the tubes about l6 cm above the platform. A manifold can be used to evacuate more than one cell at a time. If frothing persists, continue the heating and snaking for another 10 minutes.

NOTE 4: certain ester based as well as other type synthetic libricants are hydrolytically unstable at the test temperature of 274° C 525° F). Therefore. the procedure described in 6.3.5 to remove all water before sealing the cell is necessary. The pressure in the cell, as measured with a McLeod gauge, or other suitable measuring device, shall be no more than 10 micrometers before sealing.

6.3.6 While the test cell is still under vacuum it is sealed and drawn off at the capillary approximately 3 cm above where it joins the cell body. (See Note 3).

6 .3.7 Weigh the test cell to the nearest mg.

6 .3.8 Insert the glass test cell in the heater [preheated to 274° F +1° c (525° F +2° F)] for period of 96 hours. If a heating bath is used, insert the test cell in the steel holder and place the assembly in the bath.

NOTE 5: Safety shields must always be used as a precaution when placing the test cells in the heater, removing the cells from the heater, and opening; the cells. Tremendous pressures are generated during the test period.

6 .3.9 At the conclusion of the heating period, remove the test cell and allow to cool to ambient temperature. Wipe down the outside of the cell with suitable solvent.

6.3.10 Visually observe the samples for evidence of insolubles, phase separation, interactions between metal and oil, or changes in color of the oil. A significant difference in final color between duplicate tests will necessitate retesting since color differences indicate improper preparation of one or both of the test cells.

6.3.11 Reweigh the test cell. Any significant loss in weight indicates leakage of the test cell and the test must be repeated.

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6.3.12 As a safety measure the cells must be cooled before cutting them open because of the pressure which develops in testing. Any convenient cooling method may be used such as dry ice - acetone, liquid nitrogen, cooling chambers, etc.

6.3.13 Remove the oil sample and steel specimen by carefully breaking the test cell. This may be accomplished by scribing a mark around the test cell near the top and applying a hot wire to the scratch mark. (See Note 5).

6.3.14 Remove the steel specimen with forceps, wash with a stream of toluene from a wash bottle to remove oil then dip in two successive warm toluene washes and a final dip in warm acetone. Wipe with lint-free tissue and air dry. Weigh to the nearest 0.1 mg. Using a 20 power microscope, carefully examine each steel specimen and note any evidence of pitting or etching either above or below the liquid level.

6.3.15 Inspect the tube for insoluble and gum deposits.

6.3.16 Determine the viscosity at 37.8° C (100° F) of both the original lubricant and the lubricant after exposure to heat in accordance with ASTM D 445.

6.3.17 Determine the neutralization number on both the original and heated lubricant in accordance with ASTM D 664.

7. CALCULATIONS

7.1 V1 - Viscosity, Initial
V2 - Viscosity after test

$$\text{Percent viscosity change} = \frac{V2 - V1}{V1} \times 100$$

7.2 N1 - Total Acid Number, Initial
N2 - Total Acid Number after test

$$\text{Total Acid Number change} = N2 - N1$$

7:3 B - Metal weight before test in mg
A - Metal weight after test in mg

$$\text{Change in weight of the steel specimen in mg/cm}^2 = \frac{B - A}{12.96}$$

8. REPORTING

8.1 The report shall include the following:

8.1.1 Visual appearance of test cell, insolubles and gum deposits.

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8.1.2 Visual appearance of lubricant after test.

8.1.3 Visual appearance of steel specimen above and below the liquid level.

8.1.4 Change in the neutralization number of the lubricant sample.

8.1.5 Percentage change in viscosity at 37.8° C (100° F).

8.1.6 Change in weight of the steel specimen in mg/cm^2.

9. PRECISION

9.1 Precision data have not been developed for this method.

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Navy - NAPC-1986

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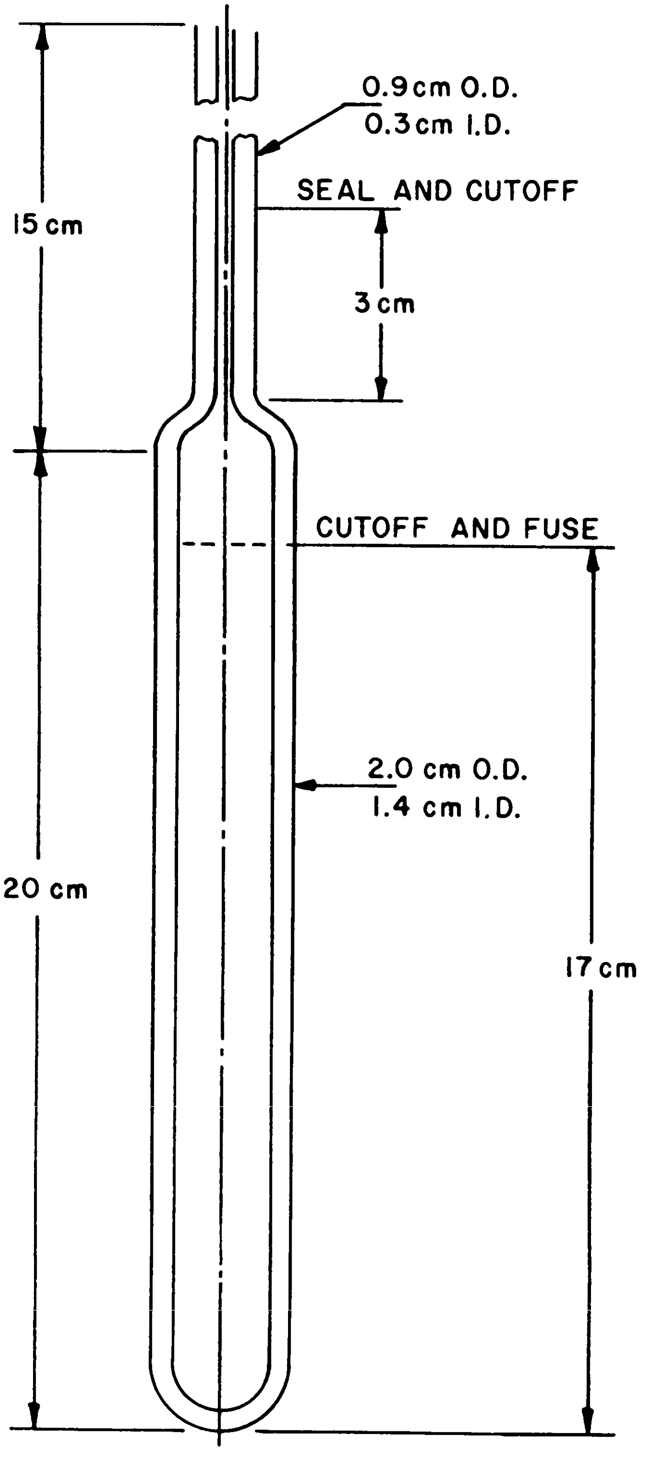

FIGURE 1. Thermal stability-corrosion test cell.

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METHOD 3430.2
September 30, 1986

COMPATIBILITY CHARACTERISTICS OF UNIVERSAL GEAR LUBRICANTS

1. SCOPE

1.1 This method is used for determining the compatibility of a universal gear lubricant when blended with a reference gear lubricant by observing for precipitation of additive material after storage.

2. SUMMARY

2.1 The test consists of mixing the reference gear and test gear lubricants, storing the mixture for 30 days, and centrifuging the mixture to determine the percentage of sludge present.

3. SAMPLE SIZE

3.1 Approximately 4 L (one gallon) of the gear oil to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 100 mL cone-shaped centrifuge tubes as in ASTM D 96.

4.2 Centrifuge with a diameter of swing (tip-to-tip of whirling tubes) 38.1 to 43.2 cm (15 to 17 inches) and shall be capable of being controlled at a speed of 1500 ±25 rpm.

NOTE 1: If the available centrifuge does not conform dimensionally to the preferred form, the speed of rotation of the available centrifuge must be adjusted to give the same centrifugal force at the tips of the tubes as that obtained with the prescribed instrument when operated at 1500 +25 rpm. The speed to operate the available centrifuge shall be calculated from the formula.

$$\text{rpm} = \sqrt{y} \times 1500$$

where:

y = The 40.7 divided by the diameter in cm of the swing (tip-to-tip of the whirling tubes) of the available centrifuge. Use 16 as the dividend when the diameter is measured in inches.

4.3 Balance capable of weighing to one mg.

4.4 Stirring apparatus capable of stirring the contents of a 400-mL tall-form beaker at approximately 200 rpm.

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4.5 Beakers, 400-mL capacity, tall form, heat resistant glass.

4.6 Forced circulation oven capable of being controlled at 104 °C ±2.5 °C (220 °F 35 °F) and 121 °C 21 °C (250 °F32 °F).

4.7 Desiccator capable of holding several centrifuge tubes.

4.8 Graduated cylinders, 25O-mL capacity,

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Naphtha, in accordance with TT-N-95B, type II [1,4,0]. Caution, Naptha is flammable.

5.3 Cleaning solution, consisting of concentrated sulfuric acid saturated with potassium bichromate.

5.4 Distilled water.

5.5 Denatured ethyl alcohol.

5.6 Reference oils. Information concerning reference oils can be obtained from:

SAE
400 Commonwealth Drive
Warrendale, PA 15096-0001

6. PROCEDURE

6.1 Make two compatibility tests with each reference oil,

6.2 Determine the residue in each of the reference oils and the sample oil by subjecting each of the oils alone (not mixed with any other oil) to the procedures described in 6.7 through 6.15. This data will be used in 7.1.

6.3 Preparation of centrifuge tubes. Clean one centrifuge tube for each compatibility test to be made in the following manner:

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a. Rinse tubes with naphtha.
b. Clean tubes with cleaning solution.
c. Rinse tubes with distilled water.
d. Rinse tubes with denatured ethyl alcohol.

6.4 Support the centrifuge tubes in an inverted position in an oven maintained at 121° C ±1° C (250° F ±2° F) for at least one-half hour.

6.5 Remove the tubes from the oven, place them in a desiccator, and permit them to cool to room temperature.

6.6 Number each tube, weigh to the nearest mg, and replace tubes in the desiccator until they are to be used.

6.7 Thoroughly ’shake sample and reference oils prior to sampling.

6.8 Place 110 ±1 mL of a reference oil and sample oil in a 400-mL beaker using the same graduated cylinder each time the sample is measured, but a clean graduated cylinder for each of the reference oils.

6.9 Heat the beaker containing the reference oils and test oil mixture in an oven at 121 °C +1 °C (250 °F +2 °F) for 20 +1 minute. Remove the beaker from the oven and stir (with a mechanical stirrer) the contents while still hot for 5 minutes.

6.10 Transfer 100 mL of the contents to the weighed centrifuge tubes.

6.11 Cork the centrifuge tubes and store them in an upright position in a darkened area such as a drawer or cupboard at room temperature for a period of 30 ±1 days.

6.12 At the conclusion of the storage period, remove the centrifuge tubes from the storage area, place it in the centrifuge, and operate the centrifuge at 1500 ±25 rpm for a period of 30 ±1 minute.

NOTE 2: In transferring the centrifuge tubes from the storage area to the centrifuge, care must be taken not to disturb any material which may have separated from the oil.

6.13 Remove the centrifuge tubes from the centrifuge and decant and discard the supernatant oil. Permit the centrifuge tubes to drain in an inverted position at room temperature for a period of two hours. Discard the drainings. If the residue is a solid, wash it with naphtha a sufficient number of times to insure that it is free of oil.

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NOTE 3: If the separated material is not sufficiently compacted by the centrifuging to permit decanting the supernatant oil, continue the centrifuging for 15 minute intervals until decanting is possible. If the material is a liquid at the conclusion of the 30 minute centrifuging period, or if it cannot be compacted, stopper the centrifuge tube and replace it in storage for an additional 30 days. At the end of the second storage period, proceed as directed in 6.12.

6.14 Place the centrifuge tube in an upright position in an oven controlled at 104 ±2.5° C (220° F +5° F) for approximately 2 hours.

6.15 Remove the centrifuge tube from the oven and place it in a desiccator to cool to room temperature. Weigh the tube and contents to the nearest mg. Subtract the weight of the empty centrifuge tube to determine the weight of the separated material.

NOTE 4: If the residue remains a liquid at the end of the second 30 day storage period, centrifuge the tube as specified in 6.12. Remove the tube from the centrifuge and note the volume of the separated liquids to the nearest 0.05 mL.

7. CALCULATIONS

7.1 Calculate the percent incompatibility for each test, using the following formulas:

$$\text{Theoretical zero incompatibility} = R + T$$

$$\text{Evidence of incompatibility} = X - (R + T)$$

$$\text{Percent incompatibility} = \frac{X - (R + T)}{0.9\ (50r + 50\ t)} \times 100$$

where:

R = Weight of separated material in reference oil (g/50 mL of oil). See 6.2.
T = Weight of separated material in sample oil (g/50 mL) of oil). See 6.2
x = Weight of separated material found in compatibility test. See 6.15.
r = Weight percent of additive in reference oil. This information is supplied by the Test Monitoring Center. See 5.6
t = Weight percent additive in sample oil. This information is supplied by the manufacturer of the sample oil.
0.9 = Assumed specific gravity of both reference oil and sample.

7.2 Calculate and report incompatibility for each reference oil as an average of the two test values obtained for the reference oil.

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NOTE 5: It may be of interest to make a chemical analysis of the residue found in the incompatible oil mixture.

8. REPORTING

8.1 Report the percent incompatibility of the test gear lubricants.

9. PRECISION

9.1 Precision data have not been developed for this method.

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Army - ME - 1986

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METHOD 3432.1
September 30, 1986

COMPATIBILITY OF ELASTOMERS WITH AIRCRAFT TURBINE LUBRICANTS

1. SCOPE

1.1 This method is used for determining effects of aircraft turbine lubricants on elastomers.

2. SUMMARY

2.1 It consists of determining the swelling effect, change in elongation, change in tensile strength and change in hardness of standard fluorocarbon and fluorosilicone elastomer specimens after being immersed in the sample for 72 hours, at temperatures of 175° C (347° F) for fluorocarbon specimens and 150° C (302° F) for fluorosilicone specimens.

3. SAMPLE SIZE

3.1 Approximately 1000 mL of the lubricant to be tested.

4. APPARATUS

4.1 Bath; aluminum block or oil bath capable of maintaining sample temperature within 1° C (1.8° F) of required test temperature. Aluminum block baths will have 5.0 mm +1 cm in thickness of insulation. Oil baths will have a cover with openings for—immersion of test tubes.

4.2 Test tubes, heat-resistant, 30 cm length and 3.9 cm outside diameter.

4.3 Hanger, specimen, made of stainless steel or nichrome wire.

4.4 Corks, standard size number 19.

4.5 ASTM Die C as described in ASTM D 412.

4.6 Bench Marker as described in ASTM, D 412.

4.7 Micrometer as described in ASTM D 412.

4.8 Testing Machine for elongation and tensile strength measurements as described in ASTM, D 412.

4.9 Grips as described in ASTM D 412.

4.10 Durometer, Type A Shore as described in ASTM D 2240.

4.11 Stamp Pad and Ink as described in ASTM D 412.

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4.12 Punch, Leather, 0.159 cm (1/16-inch) diameter.

4.13 Balance, sensitivity 0.1 mg, suitable for weighing in both air and water.

4.14 Tubing, Pyrex, 0.8 cm O.D.

4.15 Beaker, 400-mL.

5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Standard test rubber sheets, type F-A, conforming to U.S. Air Force Specification Bulletin 539.

5.3 Standard test rubber sheets, type FS, conforming to U.S. Air Force Specification Bulletin 539.

5.4 Cleaning solution, Turco Alkaline Rust Remover or equivalent.

5.5 Dry cleaning solvent (ASTM D 484, type II) [0,2,0].

5.6 Alcohol, ethyl, ACS grade [0,3,0].

5.7 Acetone, ACS grade [1,3,0].

5.8 Distilled water.

5.9 Filter paper.

6. PROCEDURE

6.1 Clean all glassware as follows:

a. Rinse in dry cleaning solvent, and allow to air dry (see note 1).

NOTE 1: Caution. Dry cleaning solvent is both toxic and flammable. Do not breathe its fumes nor allow it to come in contact with the skin. Keep flames away from the dry cleaning solvent.

b. Soak in glass cleaning solution at a temperature of 71° C (160° F) for one hour (minimum time), if glassware contains oil deposits from a previous test.

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c. Wash glassware with laboratory detergent. Rinse thoroughly with tap water and then with distilled water.
d. Dry in an oven at 100° C to 105° C (212° F to 221° F) and store in dust free location.

6.2 Clean suspension device and hooks throughly with dry cleaning solvent, wipe with a clean dry cloth, air dry and store in a dust free location.

6.3 Inspect the sheets of standard stock elastomer for flaws. Sections of an elastomeric sheet having a flaw will not be used for specimens. Cut four specimens from sheets of standard elastomer stock, with all sheets being from a single production batch, for each lubricant to be tested. Cut the specimens using ASTM Die C as described in method ASTM D 412. Punch a 0.159 cm (1/16-inch) hole in each end of the cut elastomer specimens using a leather punch. The hole shall be centered and 0.64 cm (1/4-inch) from the end of the specimen. Weigh each test specimen in air and in water in accordance with method ASTM D 471 (and record weights). Using a type A Shore Durometer obtain four Durometer readings (two on each large end) in accordance with method ASTM D 2240. Determine the initial hardness of each specimen by averaging the four readings.

6.4 Preheat and adjust immersion bath to maintain lubricant sample test temperature of 175° C (347° F) +1° C for F-A elastomers specimens and 150° C (302° F) ±1° C for FS elastomer–specimens. A suggested method of controlling these temperatures is to place a similar test tube containing 140 mL of lubricant in the bath at the same depth as the test lubricant. A thermocouple is then placed in this tube at a depth equal to the depth of the small section of the elastomeric specimens when suspended in the test lubricant tubes. The test tube containing the elastomeric specimens and test lubricant is placed into the bath to a depth which places the level of the test lubricant 4.1 cm (1-5/8-inches) above the top of the heating medium and not from the top of the insulation of bath covering.

6.5 Immerse the elastomeric specimens in the heated test lubricant by means of a specimen hanger made from stainless steel or nichrome wire. The hanger shall have two hooks at one end permitting one elastomeric specimen to be hung from each hook. The two specimens shall hang parallel and 1.3 cm (l/2-inch) apart. Attach the wire specimen hanger to a standard size number 19 cork and fit with two lengths of 0.8 cm pyrex glass tubing (chimneys). Insert one chimney, 7.6 cm (3-inches) in length, through the cork such that the chimney extends 1.3 cm (1/2-inch) above the top of the cork. Insert the second chimney 12.7 cm (5-inches) in length, through the cork such that the chimney extends 8.9 cm (3-1/2-inches) above the top of the cork. Place the cork fitted with the chimneys, specimen hanger and specimens into the pre-heated test tube containing the test oil. Adjust the length of the specimen hanger so that when the cork is placed tightly into the test tube, the specimens will hang with equal distance of test lubricant above and below the specimens using 140 mL of test lubricant. Hang only two elastomeric specimens in one tube and ad-just cork such that specimens do not contact the side of the test tube.

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6.6 Remove the elastomeric specimens from the test tube after 72 hours with the time starting when tubes are first inserted into the bath. Place the elastomeric specimens in a beaker of fresh test lubricant which is at room temperature and allow to cool for a minimum of 3(.) minutes. Remove the specimens from the cooling oil and place them into a beaker of acetone for a minimum of 14 and a maximum of 20 seconds. Dry the specimens with filter paper by blotting. Determine volume swell, hardness, elongation and tensile strength of the elastomeric specimens.

6.7 Determine a base line for elongation and tensile strength measurements for each batch of standard elastomer stock. Cut eight specimens in accordance with 6.3 with no more than two specimens being cut from any one sheet. Determine the elongation and tensile strength of each untreated specimen in accordance with method ASTM D 412 using a 2.5 cm (l-inch) bench marker. Use the average of these values in determining elongation change and tensile strength change of the oil treated specimens.

6.8 Weigh each oil treated specimen in air and in water in accordance with method ASTM D 472 and calculate percent volume swell for each specimen. Calculate the percent volume swell of the test lubricant as the average of four individual volume swell determinations.

6.9 Determine hardness readings on the specimens as described in 6.3. Calculate hardness change for the test lubricant as the difference between the initial hardness and the final hardness.

6.10 Determine elongation and tensile strength of the four specimens in accordance with method ASTM D 412 using a 2.54 cm (1 inch) bencil marker. Averge the four elongations measurements. Calculate the percent change in elongation, see 7.1.

6.11 Determine the tensile strength of the four specimens in accordance with method ASTM D 412 and average the four readings. Calculate the percentage change in tensile strength, see 7.2.

7. CALCULATIONS

7.1 Calculate the percent change in elongation as follows:

$$\text{Elongation, \% Change} = \frac{\text{Final Elongation}\sim - \text{Initial Elongation}}{\text{Initial Elongation}} \times 100$$

7.2 Calculate the percent change in tensile strength as follows:

Tensile Strength, % Change

$$= \frac{\text{Final Tensile Strength} - \text{Initial Tensile Strength}}{\text{Initial Tensile Strength}} \text{ X } 100$$

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8. REPORTING

8.1 Report the percentage change in the elongation and tensile strength.

9. PRECISION

9.1 Precision data have not been developed for this method.

Method prepared by:
Air Force - AFWAL/POSL - 1986

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COMPATIBILITY OF SYNTHETIC AIRCRAFT
TURBINE LUBRICANTS WITH SILICONE RUBBER

1. SCOPE

1.1 This method is used for determining the compatibility of synthetic aircraft turbine lubricants with a standard silicone rubber composition representative of commercial seal materials. It determines the extent of deterioration of a silicone rubber standard by the lubricating fluids.

1.2 Advanced synthetic lubricant fluids for aircraft turbine engines with modified additive systems must be compatible with materials of construction used in aircraft engines particularly with silicone rubber seals. This test was devised to reveal rubber seal-lubricating fluid compatibility problem areas.

2. SUMMARY

2.1 This method provides a procedure for exposing silicone rubber test specimens to the influence of synthetic lubricants under definite conditions of temperature and time for purpose of measuring the resulting deterioration by noting the changes in physical properties before and after immersion in the test liquid.

3. SAMPLE SIZE

3.1 Approximately 500 mL of the lubricant to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 References.

4.1.1 U.S. Air Force Specification bulletin 539, Standard Elastomer Stocks.

4.2 Apparatus

4.2.1 Oven, gravity convection, 121° C ±l° C (250° F +2° F).

4.2.2 Beakers, tall-form heat resistant, 600-mL.

4.2.3 Suspension device, glass, for holding test rubber specimens.

4.2.4 Hook, stainless steel, for suspending test rubber sheets from balance.

4.2.5 Balance, sensitivity, 0.1 mg.

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4.2.6 Dies and cutters - ASTM die A or equivalent so that width of rubber specimen suspended between jaws of tensile tester is 1.27 cm (1/2 inch).

4.2.7 Durometer - Standard shore durometer or equivalent.

4.2.8 Micrometer - To measure thickness of rubber.

4.2.9 Tension testing machines - Scott tensile tester model L or equivalent for rubber testing.

4.2.10 Borosilicate tubing - thermocouple holder closed at one end 18 cm length X 0.3 cm inside diameter X 0.5 cm outside diameter.

4.2.11 Thermocouple and recorder - to record temperature of test oils.

5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Standard silicone test rubber sheets, may be obtained from Naval Air Propulsion Test Center, Trenton, New Jersey 08628. Test sheets should be 15 (six inches) by 15 cm (six inches) by 0.19 cm thick (0.075 inches) as per U.S. Air Force Specification bulletin 539, Standard Elastomer Stocks.

5.3 Cleaning solution, glass (concentrated sulfuric acid [3,0,2] saturated with potassium or sodium bichromate [1,0,1]).

5.4 Methyl alcohol, ACS, particle free [1,3,0].

5.5 Solvent - naphtha [1,4,0] or toluene [2,3,0] ACS.

5.6 Acetone, ACS, particle free [1,3,0].

6. PROCEDURE

6.1 Definitions

6.1.1 Tensile stress - the applied force per unit of original cross sectional area of specimen.

6.2 Test specimen preparation.

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6.2.1 Test specimens are to be cut using ASTM die A or equivalent.

6.2.2 Straight specimens may be prepared where it is not practical to cut ASTM dumbell specimens. The minimum length must be 10.2 cm (four inches). The width should be 1.27 cm (1/2 inch) between the jaws which are 2.54 cm (one inch) apart.

6.3 Test procedure

6.3.1 Volume swell, change in hardness and change in tensile strength are all determined relative to original properties, from the post-test condition of the same specimens. The original tensile strength and hardness shall be determined, using duplicate specimens cut from the same sheet from which the test specimens were obtained. The duplicate specimens should be cut from an area of the sheet which is immediately adjacent to the area from which the test specimens were cut . The original rubber specimen volume is determined from the test specimen prior to immersion in the oil sample.

6.4 preparation

6.4.1 Clean all glassware.

6.4.1.1 Rinse in solvent, rinse with acetone and air dry.

6.4.1.2 Soak in glass cleaning solution for two hours (minimum).

6.4.1.3 Rinse thoroughly with tap water, and then with distilled water.

6.4.1.4 Dry in oven at 100° C (212° F) and store in dust free location.

6.4.2 Preheat and adjust oven to maintain a temperature of 121° C ±1° C (250° F±2° F).

6.4.3 Prepare standard test silicone rubber specimens.

6.4.3.1 Do not buff.

6.4.3.2 Cut three pieces (per 6.2) from the sheet. Pieces must be cut with the grain of the rubber as indicated by two grain marks at the top of the slab.

6.4.3.3 Punch a 0.3175 cm (1/8 inch) diameter hole at the center of the 10.16 cm (four inch) side, about 1.905 cm (3/4 inch) from the top edge.

6.4.3.4 Mark each piece for identification by cutting small pieces from one or more corners.

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6.4.3.5 Attach the wire suspension device to each piece.

6.4.4 Determine original volume of silicone test specimens.

6.4.4.1 Weigh each rubber test specimen and its look in air to the nearest 0.1 mg by suspending it from the balance by its hook. Record the weights.

6.4.4.2 Reweigh (to the nearest 0.1 mg) each sheet while suspended in distilled water at room temperature, being careful to remove all air bubbles from the sheet and prevent the sheet from touching the water container. Record the weights.

6.4.4.3 Determine (and record) the displacement weight of each piece by subtracting the weight in water from the weight in air.

6.5 Testing.

6.5.1 Fill a 600-mL beaker with 500 mL of the oil sample.

6.5.2 Attach the rubber specimen to the suspension device, and submerge the sheets in the sample so that the top edges are no less than 0.635 cm (1/4 inch) below the surface. Make certain that the sheets do not touch each other or contact the sides or bottom of the beaker.

6.5.3 Place the beaker in the oven at 121° C ±1° C (250° F ±2° F) for 96 hours.

6.5.4 Insert a thermocouple in a glass thermocouple holder and place assembly into oil. The temperature of each oil should be recorded during the test.

NOTE

Test liquids must not be reused.

6.5.5. At the end of 96 hours, remove the beaker from the oven and allow it to cool at room temperature for 30 +5 minutes.

6.6 Post test determination of physical properties.

6.6.1 Remove the rubber test specimens from the sample and wash in a fresh beaker of methyl alcohol, then rub gently with the fingers to remove all oil from the surface and rinse with a jet spray of methyl alcohol. Caution: Wear protective gloves.

6.6.2 Allow the rubber pieces to air dry for several minutes.

6.6.3 Volume swell.

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6.6.3.1 Measure the displacement weight of the rubber test specimens per 6.4.4.

6.6.4 Hardness.

6.6.4.1 The hardness of the rubber specimen shall be determined in accordance with ASTM Method D 2240, Type A durometer.

6.6.4.2 The thickness of the rubber specimen for the hardness test should be at least 0.3 cm. Therefore, a single-ply thickness of silicone rubber may be used as a cushion.

6.6.4.3 After swell testing, hardness readings shall be conducted on the end of each test specimen outside of the area to be used for tensile testing.

6.6.4.4 Apply the pressure foot to the specimen. Read the scale 15 seconds after the pressure foot is in firm contact with the specimen.

6.6.4.5 The hardness value of the test specimen shall be the average value obtained for the three test specimens.

6.6.5 Tensile strength.

6.6.5.1 Determine the loss in tensile strength by use of Method D 412, Standard Method of Tensile Testing of Vulcanized Rubber.

6.6.5.2 Three measurements shall be made for thickness; one at the center and one at each end of the specimen. The median of the three measurements shall be used as the thickness in caluclating the cross sectional area.

6.6.5.3 When rubber specimens of standard thickness are used as per section 5.2 of this test method and the difference between the maximum and minimum thickness does not exceed 0.0762 cm (0.003 inch), it is not necessary to calculate the cross-sectional area for each piece.

6.6.5.4 Place a specimen in the grips of the testing machine, using care to adjust it symmetrically in order that the tension will be distributed uniformly over the cross section. If tension is greater on one side of the specimen than the other, maximum strength of the rubber will not be developed. Start the machine and record the stress at the time of the rupture.

7 CALCULATIONS

7.1 Calculate the percentage change in volume (V) of each rubber sample as follows:

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$$V = \frac{(A-B)\,100}{B}$$

v = Change in volume, percent.
A = Displacement weight at conclusion of test, mg.
B = Displacement weight before immersion in sample, mg.

7.2 Calculate the percentage change in hardness (H) of each rubber sample as follows:

$$H = \frac{(C-D)\,100}{C}$$

H = Change in hardness, percent.
C = Hardness before test.
D = Hardness after test.

7.3 Calculate the change in tensile strength.

7.3.1 Observed tensile strength.

F/E = Tensile Strength in mPa (psi).
F = Observed force at break in newtons (pounds).
E = Cross-sectional area of the unstretched specimen in square centimeters (inches).

7.3.2 Change in tensile strength, percent

$$T = \frac{(J-K)\,100}{J}$$

T = Change in tensile strength, percent.
J = Tensile strength before test.
K = Tensile strength after test.

NOTE

See section 6.6.5.3

8. REPORTING

8.1 The report shall include the following:

8.1.1 Results calculated in accordance with paragraph 7, Calculations.

8.1.2 All observed and recorded data on which the calculations are based.

8.1.3 Date of test.

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8.1.4 Temperature of test.

8.1.5 Type and dimensions of specimens used.

8.1.6 Immersion fluid used.

8.1.7 Exposure period.

8.1.8 Condition of exposed specimen from visual and manual examination.

8.1.9 Test apparatus used for hardness.

8.1.10 Type of tensile test apparatus.

9. PRECISION

9.1 Precision data have not been developed for this method.

Method Prepared By:

Navy - NAPC - 1986

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STORAGE VOLUBILITY CHARACTERISTICS OF UNIVERSAL GEAR LUBRICANTS

1. SCOPE

1.1 This method is used for determining the storage volubility characteristics of universal gear lubricants.

2. SUMMARY

2.1 Universal gear lubricant is heated at 120° C and observed for separation of additive material after storage at room temperature for a period of 30 days.

3. SAMPLE SIZE

3.1 400 mL (one pint) of the gear oil to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Apparatus.

4.1..1 100-mL cone-shaped centrifuge tubes as specified in ASTM D 96.

4.1.2 Centrifuge with a diameter of swing (tip-to-tip of whirling tubes) 38 to 43 cm (15 to 17 inches) and shall be capable of being controlled at a speed of 1500 ±25 rpm.

Note 1. If the available centrifuge does not conform dimensionally to the preferred form, the speed of rotation of the available centrifuge must be adjusted to give the same centrifugal force at the tips of the tubes as that obtained with the prescribed instrument when operated at 1500 +25 rpm. The speed to operate the available centrifuge shall be calculated from the formula:

$$\text{rpm} = \sqrt{\frac{40}{d}} \times 1500$$

where d = the diameter of the swing (tip-to-tip whirling tubes) of the available centrifuge in centimeters.

4.1.3 Balance capable of weighing to one mg.

4.1.4 Beakers, 400-mL capacity, heat resistant glass.

4.1.5 Desiccator capable of holding several centrifuge tubes.

4.1.6 Forced circulation oven capable of being controlled at 105 ±3° C

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4.1.7 Forced circulation oven capable of being controlled at 120 ±1° C.

4.1.8 Cylinder, graduated, 100-mL, 400-mL.

5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Naphtha (TT-N-95, type II) [1,4,0].

Note 2. Caution. Naphtha is flammable.

6. PROCEDURE

6.1 Perform three volubility tests (three centrifuge tubes) for each oil.

6.2 Clean centrifuge tubes and dry them in oven at 105 ±3° C (220° ±5° F) and permit them to cool to room temperature in a desiccator.

6.3 Number each tube and weigh it to the nearest mg.

6.4 Place 320 mL of the oil into a 400-mL beaker and heat in an oven at 120° ±l°c for 20 +1 minutes.

6.5 Remove the beaker from the oven, allow the beaker to cool to 25 °C ±3 °C. Transfer 100 mL ±1 mL of the oil from the beaker to each of the tarred centrifuge tubes. Cork the tubes.

6.6 Place the centrifuge tubes in an upright position in a darked area such as a drawer or cupboard. The temperature should be maintained at 25 °C +3 °C for the length of the storage period, 30 days ±1 day.

6.7 In transferring the centrifuge tubes from the storage area to the centrifuge , care must be taken not to disturb any material which may have separated from the oil. Remove the tubes from the storage area, place them in a centrifuge, and operate the centrifuge at 1500 rpm +25 rpm for 30 minutes +1 minute. If the residue is a solid, wash it several–times with naphtha, a sufficient number of times to assure that it is free of oil.

6.8 Remove the centrifuge tubes for the centrifuge and decant and discard the supernatant oil. Permit the centrifuge tubes to drain in an upside down position at 25 ±C +3 °C for a period of two hours.

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Note 3. If the separated material in not sufficiently compacted by the centrifuging to permit decanting the supernatant oil, continue the centrifuging for 15 minute intervals until decanting is possible. If the material is a liquid at the conclusion of the 30 minute centrifuging period, or if it cannot be compacted, cork the centrifuge tube and replace them in storage for an additional 30 days. At the end of the second storage period, proceed as directed in paragraph 6.7. If there is no visual liquid or solid residue after 30 days, stop the procedure and report zero residue.

6.9 Place the centrifuge tubes in an upright position in an oven controlled at 105 °C ±3 °C for approximately two hours.

6.10 Remove the centrifuge tubes from the oven and place them in a desiccator to Coo1 to 25 °C +3 °C. Weigh the tubes and contents to the nearest mg. Subtract the weight of the empty centrifuge tubes to determine the weight of the separated material.

6.11 If the residue remains a liquid at the end of the second 30 day storage period, centrifuge the tubes as specified in 6.7. Remove the tubes from the centrifuge and note the volume of the separated liquids to the nearest 0.05 mL.

7. CALCULATIONS

7.1 Calculate the percent insoluble residue in the sample from the formula:

Percent insoluble residue =

$$\frac{\text{Average amount of separated residue (grams) from the three centrifuge tubes}}{0.9 \text{ X weight percent of additive in sample}} \times 100$$

where:

0.9 = assumed specific gravity of the sample:

Note 4. The weight percent of additive in the sample can be obtained from the manufacturer of the sample.

7.2 Calculate the volume percent liquid separation after the second storage period from the formula:

Percent volume liquid separation =

$$\frac{\text{Average separated liquid (mL) from the three centrifuge tube}}{\text{Volume percent of additive in the sample}} \text{ X } 100$$

Note 5. The volume percent of additive in the sample can be obtained from the manufacturer of the gear lubricant.

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8. REPORTING

8.1 Report the average amount of separated residue found in the three test samples.

9. PRECISION

9.1 Precision data have not been developed for this method.

Method Prepared by:

Army - ME - 1986

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METHOD 3450
September 30, 1986

BEARING DEPOSITION OF AVIATION

TURBINE ENGINE LUBRICANTS

1. SCOPE

1.1 This method describes detailed procedures used to conduct the bearing deposition test for evaluating deposit and degradation characteristics of aircraft turbine engine lubricants at various severity levels of bulk-oil temperature and bearing temperature for 48 hours duration.

2. SUMMARY

2.1 A sample of the lubricant is subjected to the required temperature levels for a controlled number of hours. At periodic intervals during the test and at the end of test, samples of the oil are examined for both physical and chemical changes when compared to the sample of new oil. A visual inspection is made at the end of test of the accumulated deposits on the bearing and other machine components. A weighted numerical rating system is used for rating individual areas as well as for obtaining an overall rating. Additional data on relative sludge forming tendencies of oils are obtained by weighing a 100-mesh filter element and a 40-mesh filter element.

3. SAMPLE SIZE

3.1 Approximately 10 L of test oil.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 The following documents, of the issue in effect on date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein.

Military specifications:

MIL-S-5059	- Steel, Corrosion Resistant (18-8), Plate, Sheet and Strip.
MIL-L-6082	- Lubricating Oil; Aircraft Reciprocating Engine (Piston).

(Copies of specifications, standards, handbooks, drawings, publications, and other Government documents required by contractors in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting activity.)

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Drawings:

Air Force Aero Propulsion Laboratory

A-B-67043	Test-Oil Pickup Line, Bearing Test Rig.
A-B-67044	Thermocouple, Bearing Test Rig.
A-B-67045	Test-Oil Jet Plug, Bearing Test Rig.
A-B-67046	Test-Oil Jet Assembly, Bearing Test Rig.
A-B-67047	Test-Oil-Out Filter Housing Assembly, Bearing Test Rig.
A-B-67049	Metal Specimen Shaft, Bearing Test Rig.
A-B-67051	Oil Level Rod Guide, Bearing Test Rig.
A-B-67052	Test-Oil Pump Shaft Extension, Bearing Test Rig.
A-B-67053	Thermocouple Connector, Bearing Test Rig.
A-B-67054	Test-Oil Sump Thermocouple, Bearing Test Rig.
A-B-67055	Scavenge Pump Discharge Line, Bearing Test Rig.
A-B-67059	Metal Specimen Spacer, Bearing Test Rig.
A-B-67060	Sump Vent Port, Bearing Test Rig.
A-B-67061	Metal Specimens, Bearing Test Rig.
A-B-67062	Scavenge Pump Modification, Bearing Test Rig.
A-B-67063	Test-Oil Pump Modification, Bearing Test Rig.
A-B-68114	Oil Level Indicator Tube, Bearing Test Rig.
A-B-68115	Test-Oil-In-Line, Bearing Test Rig.
A-B-69002	Test–Oil Pump Standoff Gasket, Bearing Test Rig.
A-B-69008	Cup-Vent Pipe Blower Assembly, Bearing Test Rig.
B-B-67039	Test-Oil–Filter Housing Details, Bearing Test Rig.
B-B-67040	Test-Oil Accumulator Assembly, Bearing Test Rig.
B-B-67058	Test-Oil Accumulator Details, Bearing Test Rig.
B-B-68049	Top Plate, Stand, Bearing Test Rig.
B-B-68050	Door, Stand, Bearing Test Rig.
B-B-68051	Side Panel, Stand, Bearing Test Rig.
B-B-68052	Rear Panel, Stand, Bearing Test Rig.
B-B-68053	Air Cooler, Bearing Test Rig.
B-B-68055	Blower Modification, Bearing Test Rig.
B-B-68056	Vent-Pipe Blower, Bearing Test Rig.
B-B-68057	Flange-Blower Vent Pipe, Bearing Test Rig.
B-B-68058	Gasket-Blower Vent Pipe, Bearing Test Rig.
B-B-68060	Test-Oil-In Filter Housing Assembly, Bearing Test Rig.
B-B-68061	Test-Oil-In Filter Housing Details, Bearing Test Rig.
B-6-69001	Test-Oil Pump Standoff, Bearing Test Rig.
B-6-69009	Sump-Oil Fill Port Adapter, Vent Pipe Blower Assembly, Bearing Test Rig.
C-B-68047	Stand Assembly, Bearing Test Rig.
C-B-68048	Frame, Stand, Bearing Test Rig.
c-B-68054	Blower Assembly, Bearing Test Rig.
D-B-67016	Test-Oil Sump Components, Bearing Test Rig.

(Application for copies should be addressed to the Air Force Aero Propulsion Laboratory, Attn: AFWAL/POSL, Wright-Patterson Air Force Base, Ohio 45433.)

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4.1.1 Other publications. The following documents form a part of this method to the extent specified herein. Unless otherwise indicated the issue in effect on date of invitation for bids or request for proposal shall apply.

Society of Automotive Engineers

AMS 3651	Polytetrafluoroethylene.
AMS 5040	Carbon Steel Sheet and Strip, Deep Forming Grade.

(Application for copies should be addressed to the Society of Automotive Engineers, Incorporated, 400 Commonwealth Drive, Warrendale, PA. 15096.)

American Society for Testing and Materials

ASTM D 445	Viscosity of Transparent and Opaque Liquids (Kinematic and Dynamic Viscosities).
ASTM D 664	Neutralization Number of Potentiometer Titration.

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.)

4.2 The apparatus used in this method is the bearing deposition rig which consists of a 100-mm roller bearing machine, a suitable drive and support-oil system, and a specially designed test-oil system.

4.2.1 100-mm roller bearing head. The bearing head is divided internally into two main sections, as shown on Figure 1. The front, or test section with its separate test-oil system, houses the unshielded 100-mm straight-roller test bearing, A. Heating of the test bearing is achieved by supplying heat to the bearing outer race. The outer race is secured in a bearing mount assembly containing a circular-wound tubular heating element, B, packed in aluminum oxide. Heater control is provided by a West Instrument Corporation type JP controller, or equivalent, in conjunction with a manually variable voltage transforms. A watt-hour meter is also contained in the heater circuit and is connected between the heater and controller to monitor total power input. The rear or support section of the bearing head houses the externally loaded bearing. D, and main shaft support bearing, P, together with a separate oil system. The test and support sections of the bearing head are separated by a screw-thread seal, H, to prevent mixing of the test and support oil.

4.2.1.1 Test-oil jet. The test-oil jet, F, is a nominal 0.1 cm (0.040-inch) diameter jet located at the 12 o'clock position on a 6.668 cm (2.625-inch) radius' from the center of the bearing machine end cover. Prior to test, the size of the jet is checked with standard plug pin gages, 0.099 cm (0.039-inch) diameter gage go, and 0.104 cm (0.041-inch) diameter gage no-go. In addition, the condition of the jet is observed under flow condition by connection to a pressurized water-line. Water flow through the jet is maintained by a 103.4 kPa gage (15-psig)

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pressure. The jet should deliver an essentially solid stream in axial alignment with the jet orifice. Corrections for size and axial straigtness of jet flow are made by replacing the jet plug or the entire test-oil jet as required.

4.2.2 Test bearing. An unshielded 100-mm straight-roller bearing (Rollway P/N RCS 120-560, or equivalent) is mounted on the free end of the shaft in the test-oil compartment of the bearing head. Load is applied to the bearing shaft, C, and hence to the test bearing, by means of a hydraulically controlled load piston, E, acting through the load bearing, as shown in Figure 1. The test bearing is lubricated by a single jet, F, which supplies essentially a solid stream of oil midway between the ID of the outer race and the OD of the roller retainer at the top or unloaded position of the test bearing.

4.2.3 Test-bearing mount. The bearing is made with an outer race removal feature which permits the removal of the bearing outer race for cleaning and inspection. Three spot-type thermocouples are located 120 degrees apart (radially) around the ID of the bearing mount and indicate the skin temperature on the periphery of the outer race of the test bearing, which is pressed into contact with these thermocouple junctions when it is installed in the bearing mount. One of these three thermocouple leads is connected to the West bearing temperature controller, or equivalent.

4.2.3.1 Test bearing outer race thermocouples. Insert fiber glass sheath, 20-gage, iron-constantan thermocouple wire through the three drilled holes in the heater mount from outside to inside. Silver-solder each thermocouple junction leaving spherical bead on the junction about 0.32 cm (1/8-inch) in diameter. Peen each bead back into the hole. Remove excess silver solder leaving just enough material to insure contact between the heater mount and the bearing outer race. Each of the three thermocouple leads is brought out directly through the bearing housing at 120 degree intervals.

4.2.3.2 Thermocouple packing. polytetrafluoroethylene, or equivalent, is used to insulate all thermocouple leads where they pass through the housing or end cover fitting. This also applies to the two bearing heater terminals where they pass through the end cover.

4.2.4 Test-oil system. A schematic of the test-oil system is shown on Figure 2. The test–oil cycle starts at the sump where external heaters maintain the desired bulk-oil temperature. Sump heaters, except for the uppermost band heater which is controlled by a manual switch, are controlled by a West type JP controller, or equivalent, with a watt-hour meter connected between the heaters and the l controller to monitor total power input. The test oil is pumped from the sump by the variable-speed pressure pump to the 100-mesh filterhousing. The lubricant then flows to a tubing cross attached to the filter housing. One leg of the cross contains a bayonet thermocouple measuring the test-oil-in temperature. One leg transmits fluid pressure to an indicating gage and two pressure safety switch units connected in series. The latter units are set with one unit at a minimum pressure of 34.5 kPa gage (5 psig) and one at a maximum pressure cf 241.3 kPa gage (35 psig). In the event of a test-oil pressure excursion outside this range, the

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applicable safety switch deactivates the main drive motor. The system protects against rig tieup as a consequence of lubricant starvation in the event of test-oil pump failure, jet plugging, or other equipment malfunction. The third leg of the cross delivers test oil to the jet and then to the test bearing. The test oil is drained from the bearing head at two locations, G, as shown on Figure 1. The front drain collects splash oil which does not pass through the bearing, whereas the rear drain collects only oil that has gone through the bearing. Both drains feed into a fluid accumulator via a single line leading to a three-way valve used for in-line sampling. The test-oil line continues beyond this valve to a second three-way valve which permits routing of the oil to an incorporated test-oil flow measuring system. The test oil next passes through a 40-mesh filter and enters the scavenge pump prior to discharging into the sump.

4.2.4.1 Heat loss from the test-oil system is minimized by placing insulation on the sump sides, base, and cover as identified on Figure 2. The test-oil-in lines and filter housing are wrapped with a single thickness of Fiberfrax insulation, or equivalent, to reduce the differential between test-oil-in temperature and sump temperature. Insulating in this manner will normally result in a test-oil-in temperature slightly below the required bulk-oil (sump) temperature. If this differential exceeds the allowed maximum, additional insulation thicknesses are applied. In operation, the test-oil sump is vented to atmosphere.

4.2.4.2 The test-oil entering the sump is normally hotter than the bulk-oil in the sump. A forced-air cooler, shown on Figure 2, is placed around the test-oil line section preceding the test-oil-out filter to cool the lubricant as required. In some cases, it may be necessary to insulate a portion of the scavenge line with insulating tape to maintain the desired oil temperature entering the sump.

4.2.4.3 Only stainless steel tubing or pipelines and fittings are used in the test-oil system. The fluid accumulator, filter housings, and sump are similarly constructed, of stainless steel.

4.2.4.4 Test-oil sump. The overall configuration and construction details of the test-oil sump conform to the detailed drawings specified in 4.1.

4.2.4.4.1 Sump cover seal. A 0.16 cm (1/16-inch) thickness gasket of suitable dimensions is cut to seal between the sump flange and sump cover. Raybestos-Manhattan A-56 gasket material, or equivalent, is employed.

4.2.4.4.2 Metal specimens. Metal specimens are mounted within the test–oil sump in order to provide information concerning possible metal attack by the lubricant. The specimen holder is a 0.95 cm (3/8-inch) rod mounted on the sump lid and extending 20.32 cm (8 inches) into the sump (or approximately 5.08 cm (2 inches) below the cold oil level). The specimens are secured to the rod by a 10-32 size screw, 3.81 cm (l-l/2-inch) in length. The specimens are individually placed on the screw and separated by spacers of 0.32 cm (1/8-inch) thickness and 0.79 cm (5/16-inch) OD. The mounting rod is tapped at the lower end to accept the screw such that the specimens are mounted with their major axis in a vertical plane.

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The metal specimens are 0.081 cm (0.032-inch) thick, 1.905 cm (3/4-inch) diameter disks with 0.635 cm (1/4-inch) center holes. A five-specimen set is used consisting of the following materials:

Aluminum - QQ-A-250/4, temper T-3 or T-4
Titanium - AMS 4908
Silver - MIL-S-13282, grade A
Steel - AMS 5040
Stainless Steel - MIL-S-5059, type 301, half-hard

A sketch of the metal specimen assembly, indicating the metal specimen order, is shown on Figure 3.

4.2.5 Air system. Water saturated air is metered to the test-oil compartment in the bearing head. The air supply for the test-bearing compartment is filtered shop air connected in the following sequence: air supply to pressure regulator to flow control valve to rotameter to water saturator to water separator column to end cover fitting on bearing head. The air directed through the end cover (at 1 o'clock on the same diameter as the test-oil jet) into the bearing compartment is used primarily to control the pressure drop across the seal so as to insure against oil transfer from the support section into the test-oil section. A 0.64 to 0.32 cm (1/4 X l/8-inch) tubing to pipe fitting, J of Figure 1, should be used for the metered air supply fitting at the end cover. The water saturator consists of a l-inch-diameter spherical gas diffuser stone submerged in distilled water within a 2 L filtering flask. The flask is initially charged with 1200 mL of water and is refilled to this level at each shutdown period during the test. A water separator column is connected downstream of the saturator to remove entrained droplets. The column consists of a 61 cm (24-inch) length of 5.08 cm (2-inch) borosilicate or equivalent, glass pipe flanged at both ends. The flanges are constructed of suitable aluminum plate with a polytetrafluoroethylene gasket seal between the glass pipe and flange, (see AMS 3651). The column is loosely, but completely, packed with glass wool fiber, Corning Cat. No. 3950, or equivalent.

4.2.5.1 Air to the test head is metered through a rotameter. Prior to each run, the rotameter is calibrated against a wet-test gas meter for a flow of 9.91 ±0.57 L/see (0.35 ±0.02 cfm). The procedure is to disconnect the air supply line at the fitting where the air enters the head and then connect the supply line to a wet-test gas meter which in turn discharges to atmosphere. A mercury manometer is located immediately downstream from the rotameter. The settings of the manometer and rotameter are observed and recorded for a wet-test gas meter reading of 9.91 L/see (0.35 cfm). The air line is then reconnected to the bearing head and the previously observed manometer and rotameter settings are maintained throughout the test.

4.2.5.2 Screw seal. The screw type seal is vented to atmosphere at both the top and bottom seal housing connections.

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4.2.5.3 Connection for seal differential pressure measurement. The lines of the manometer used to measure the differential pressure across the seal should be connected to the top, front of the bearing head, and to the rear vertical surface of the bearing housing between 11 and 1 o'clock, 2.54 cm (l-inch) above the junction of the rear case with the main housing. After startup, there should be no venting of the manometer lines. In this connection, the pipe plug in the top of the gearbox should be removed and replaced with a small valve to allow adjustment of the pressure in the gearbox and, hence, in the support system. The adjustment of the pressure of the atmosphere of the support-oil system controls the pressure drop across the screw seal, which is used to insure against oil transfer from the support section to the test-oil section. The required differential is controlled by maintaining a slightly higher test–oil compartment pressure of 0.76 to 1.27 cm (0.3 to 0.5 inch) of test-oil column relative to the support–oil compartment pressure.

4.2.5.4 Sump air venting. The sump is vented to the atmosphere through a sump cover port as shown on Figure 2. A line connected to the port terminates at a valve which permits connection of the line to a gas-flow meter. When the required test conditions are attained after each startup, the flow rate of the gas discharging from the sump is measured at the valve employing a portable gas flow rate meter. The speed control of the scavenge pump motor is set to provide a sump gas discharge of 14.16 L/see (0.5 cfm). During a test, additional measurements of the sump vent gas flow rate should be made when excessive scavenge pump wear or test-oil system airleaks are suspected.

4.2.5.4.1 The procedure for the sump-air venting discussed above is modified for bearing tests employing sump bulk-oil temperature above 176.7° C (350° F). The valve is closed to the atmosphere and vent pipe-blower assembly is connected to the sump oil-fill port, as shown on Figure 4 to condense the increased oil vapor created in the sump by the elevated oil temperature. Oil vapor/mist condenses in the blower housing and is drained back into the sump. The measurement of the sump vent gas flow rate is made at the valve as previously discussed. However, the vent pipe-blower assembly is removed and the sump-oil port is capped each time the airflow rate is to be measured. After each measurement, the vent pipe blower assembly is replaced at the sump-oil fill port.

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Dry cleaning solvent (ASTM D 484, type I) [0,2,0].

5.3 Carbon remover (Penetone Corporation 74 Hudson Avenue, Tenafly, New Jersey, Penetone ECS or equilvent) [u,u,u].

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5.4 n-Heptane [1,3,0].

5.5 Acetone [1,3,0].

5.6 MIL-L-6082, grade 1100, lubricating oil [0,0,0].

5.7 Polytetrafluoroethylene tape and gasket material [0,0,0].

5.8 Fiberfrax insulation [0,0,0].

5.9 Raxbestos-manhattan A-56 gasket material [0,0,0].

5.10 Metal specimens [0,0,0].

Aluminum - QQ-A-250/4, temper T-3 or T-4.
Titanium - AMS 4908.
Silver - MIL-S-13282, grade A.
Steel - AMS 5040.
Stainless steel - MIL-S-5059, grade 301, half-hard.

5.11 Glass wool fiber, Corning Cat. No. 3950 [0,0,0].

5.12 400 grit silicon carbide paper [0,0,0].

5.13 30 grit aluminum oxide [0,0,0].

6. PROCEDURE

6.1 Cleaning procedure.

6.1.1 Test-oil sump. The test-oil sump assembly is completely dismantled for cleaning of all internal componets after each test. The sump interior is thoroughly cleaned with a suitable solvent, hand scrubbing, or mild abrasive blast to remove all traces of deposits from the previous test. A new test-oil pumpshaft seal is installed prior to each test

6.1.2 Test-oil pressure and scavenge pumps. The test-oil pressure and scavenge pumps are completely disassembled and then cleaned to remove all deposits from the previous test.

6.1.3 test-oil accumulator. The test-oil accumulator located directly below the bearing head is disassembled and then cleaned with a stainless steel brush in dry cleaning solvent, or equivalent.

6.1.4 Test-oil lines. All of the straight run test-oil lines and fittings (elbows, tees) are removed from the test-oil system and hand reamed with stainless steel wire brushes in a bath of dry cleaning solvent, or equivalent.

6.1.5 oil filter assemblies. All oil filter housings in the test-oil system are removed and cleaned with a stainless steel brush in dry cleaning solvent, or

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equivalent. A soft fiber brush is usually adequate in scrubbing the filter elements after a short soaking in a solvent bath.

6.1.6 Pressure gage line. The test-oil lines leading to the pressure gage and safety switch units are flushed with approximately 25 mL of test oil prior to each test. Prior to starting the drive motor and to insure correct pressure transmission, the drain valve at the end of the line is opened momentarily while the system is under pressure.

6.1.7 Bearing head. The bearing head should be disassembled as far back as the seal and all of the removable parts, except the test bearing, are cleaned with a suitable carbon remover followed by scouring with No. 400 emery paper and solvent to remove all traces of deposits from the previous test. The entire seal assembly should be removed and cleaned when the level of deposits on the rear seal plate exceeds a light varnish condition.

6.1.8 Test bearing. A new 100-mm bearing is used for each 48-hour test. The new bearing is cleaned in solvent to remove preservative oil. In order to facilitate deposit rating, the bearing cage is thoroughly cleaned at three points using a stainless steel wire brush. This procedure removes the brown coating applied to the cage and allows for a more accurate evaluation of cage deposits by initially exposing the bright base metal. The three positions on the cage are arbitrarily selected for brushing but are approximately equally spaced. All exposed sides of the cage are cleaned at each position, covering a circumferential distance equal to that between identical points on two successive rollers. The bearing is recleaned in solvent taking care to remove all adhering wire bristles. The bearing is dipped in test oil prior to installation in the machine.

6.1.9 Metal specimens. Clean and prepolish the specimens by appropriate means of choice. If the specimens are being reused from a previous test, no pits, etchings, or signs of corrosion should be visible at this point. Finish with No. 400 grit silicon carbide paper, removing all marks that may have been' left by previous polishing. The specimens should not be handled with bare fingers from this point; handle them only with a clean cloth or paper, or with tongs or forceps. Cotton swab wash the specimens with solvents, first with n-Heptane and then with acetone, final rinse in clean acetone, air dry and weigh to the nearest 0.1 mg. If there is to be any delay before weighing, store under n-Heptane until ready.

NOTE: As a practical polishing procedure, place a sheet of the abrasive paper on a flat surface and rub the specimen against the paper with longitudinal strokes, protecting the specimen from contact with the fingers with clean cloth or ashless filter paper. An individual abrasive paper should be employed for each metal. Several specimens of the same metal may be polished with one paper.

6.2 Bearing head assembly.

6.2.1 Main shaft. If the main shaft is not solid, its front end should be plugged with an aluminum plug.

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6.2.2 Screw-thread seal. In installing the seal, the right-hand threads on the OD of the seal must be toward the front (test compartment) end of the rig.

6.2.3 Test-bearing heater mount. The bearing outer race is lightly pressed into the bearing heater mount with the serial number facing the front of the rig. The recommended fit on the bearing outer race is -0.0005 +0.0018 cm (-0.0002 to ±0.0007 inch). On repeated usage, the ID of the bearing mount may become worn and result in a loose fit which might tend to cock the outer race. It may also result in erroneous temperature readings of the bearing outer race. When this happens, the ID of the mount may be chrome plated and reground to proper dimension, or that section of the mount replaced.

6.2.3.1 Test-bearing heater assembly. In reassembling the heater mount, care should be exercised to insure that the heater coil is centered and that at no point should the heater coils come within 0.32 cm (1/8 inch) of the inside surfaces of the assembly faces. A method of accomplishing this is to assemble the unit without retainer ring; this allows visual inspection of the location of the heater-coils within the assembly. Areas where the coils come within 0.32 cm (1/8 inch) of either front or rear inner faces are marked. During final assembly, Transite spacers, or equivalent, (0.32 x 0.64 x 1.27 cm [1/8 x 1/4 x 1/2 inch]) are placed at these marked points. The heater mount cavity is repacked with new No. 30 grit aluminum oxide after each test. Suitably small portions of the oxide are added in increments, followed by brisk tapping of the mount exterior to eliminate voids. After adding a portion of the oxide, the mount is raised to the vertical position and tapped with a composition head hammer over front and rear surfaces working from bottom to top. The procedure is repeated at frequent intervals until the cavity is filled.

NOTE: Prior to installation of the heater mount and test-bearing assembly, the oil-jet alignment procedure of 6.2.5 is accomplished.

6.2.3.2 Test-bearing heatermount positioning. Care is exercised to insure that the front and rear vertical faces are parallel to each other and square with the ID of the mount. If these conditions are not maintained, the concentricity of the bearing's outer race in relation to the shaft axis may be affected. Before installing the heater mount in the rig, the bearing's outer race thermocouples are checked for continuity.

6.2.4 Test bearing. Before installing the test bearing on the hub, it is examined visually for any obvious mechanical defects. If the bearing appears satisfactory, the inner race and cage assembly is pressed onto the hub with the serial number facing the front of the rig. The recommended fit of the bearing inner race on the hub is 0.002 to 0.0036 cm (0.0008 to 0.0014 inch) tight. After repeated usage, the OD of the bearing hub may become worn and result in a loose bearing fit. When this happens, the hub may be chrome plated and reground to proper dimension or replaced. After the bearing has been installed in the bearing head, the shaft is turned by hand to make sure it turns freely. Bearing roughness

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can usually be detected in this manner. When properly installed, the rollers should be evenly centered in the outer race. If the rollers are more than 0.32 cm (1/8 inch) off center on the outer race, check for missing shaft assembly parts or an improperly installed bearing outer race. It is important that the lock nut on the test-bearing retainer be tight since it imparts an axial pinch on all of the shaft assembly parts back to the load bearing and in addition helps to prevent the bearing inner race from turning on the hub during operation.

6.2.5 End cover. Before installing the end cover on the rig, the test-oil jet tube alignment is verified. The jet positions midway between the outer race ID and the cage OD. Alignment is verfied by assembling (outside the machine housing) the heater mount with the outer race installed, the pinch plate, and end cover. The heater mount is fixed by installing the heater terminal nuts and making certian that the mount OD coincides with the pinch plate diameter. The end cover mounting bolts are inserted through the cover and corresponding pinch plate holes. The test-oil jet is inserted through its holder and the jet position verified by visual observations from the rear of the heater mount. The test-bearing roller and cage assembly is installed in the outer race through the heater mount rear side and the jet position noted with respect to the cage OD. Upon subsequent assembly of the bearing machine for testing, a gasket of Raybestos-Manhattan A-56 material, or equivalent, is installed between the end cover and pinch plate.

6.2.6 Check of seal operation. After assembly of the bearing head, the screw-thread seal operation is checked under a 2224 N (500-pound) radial load to the load bearing by applying 351.6 kPa (51-psig) shop air pressure to the loading cylinder and hand rotating the shaft to detect rubbing. If any rubbing occurs, the bearing head is disassembled and a slight amount of material removed from either the screw threads or the seal plate, depending on the location and severity of the rubbing. The material is removed from the seal plate if the rubbing is localized, and the screw thread is ground if the rubbing is severe and occurs over a considerable area.

6.2.7 Miscellaneous joint compounds No pipe dopes, thread compounds, or gasket sealants are used in the assembly of the rig or test-oil system. Polytetrafluoroethylene tape, or equivalent (no adhesive) is an effective sealant when applied to pipe threads.

6.3 Support-oil system. MIL-L-6082, grade 1100, lubricating oil is used in the support-oil system and is not normally changed after each run. Drain periods on the support oil are governed by the amount of contamination with test oil, which can be determined from periodic laboratory tests on support-oil samples.

6.4 Critical test items. Before starting a test, care should be taken that critical test items conform to the tolerances listed in Table I.

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TABLE I. Critical test items.

Item	Dimensional tolerances cm (in)	
	Minimum	Maximum
Test-bearing outer race fit in heater mount.	-0.0005 (0.0002)	0.00018 (+0.0007)
Test-bearing inner race fit on hub.	-0.002 (-0.0008)	-0.0036 (-0.00014)
Screw seal diametral clearance.	0.046 (0.018)	0.056 (0.022)
Test-oil jet.	0.099 (0.039)	0.104 (0.041)

6.5 Operating conditions.

6.5.1 Throughout the entire test, the test-oil-in temperature, bulk oil temperature, test-bearing temperature, and airflow to the end cover are controlled at the values required by the applicable lubricant specification.

6.5.2 Initial test-oil flow setting. The test-oil sump is charged with 7.75 L (2 gallons) of the test lubricant at room temperature and heated to a temperature of 126.7° C (260° F). Air to the end cover is set at 0.165 L/see (0.35 cfm). The test- and support-oil pumps are turned on and the main drive motor actuated to a speed of 10,000 rpm. The rig speed should be brought up immediately after oil circulation is started as the screw-thread seal depends on relative motion for its sealing action. The previous setting on the test-oil pressure pump or a minimum of 68.9 kPa gage (10-psig) oil pressure at the jet is used to insure against possible oil starvation during this initial startup. The pressure drop across the seal is maintained at 0.76 to 1.27 cm (0.3 to 0.5 inch) of test oil by making fine adjustments to the gearbox vent valve. As soon as a 121.1° C (250° F) oil temperature at the jet has stabilized, a minimum of two separate flow checks of l-minute duration each should be made at the incorporated test oil flow measuring system. The oil pressure at the jet should be adjusted using the variable speed drive unit on the test-oil pump until the jet oil flow is 600 mL/min. Once the flow rate of 600 mL/min is established for an oil, the flow at this condition is maintained constant during the test. The observed test-oil flow rate is checked and recorded once every 3 hours, or when indicated by any irregularities in test operation.

6.5.3 After the oil flow is set, the following conditions are allowed to stabilize:

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Oil-in temperature	121.1 ±1.4° C (250 ±2° F)
Oil flow rate	600 ±26 mL/min
Bearing speed	10,000 rpm ±200
Radial load	351.6kPa (2724 N) [51 psig (500 lb)]
Support-oil-in-temperature	71.1° to 82.2° C (160° to 180° F)
Support-oil pressure	551.6 to 689.5 kPa gage (80 to 100 psig)
Gearbox-oil pressure	172.4 to 206.8 kPa gage (25 to 30 psig)
Airflow to end cover	0.165 +0.01 L/see (0.35 +0.02 cfm)
Pressure drop across seal	0.76 to 1.27 cm (0.3 to 0.5 inch) of test oil (test compartment higher)

After the foregoing conditions stabilize, the run is continued until the test-bearing temperature from the highest reading thermocouple stabilizes (about 1 hour). This temperature is then noted and used as an indication of the mechanical condition of the bearing. Previous tests on bearing stabilization at a 121.1° C (250° F) oil-in temperature to the jet indicate that a temperature range of 148.9° C (300° F) is normal for a properly functioning 100-mm test bearing. Higher stabilization temperatures indicate the test-bearing condition is questionable, and the bearing should probably be replaced before continuing with the test.

6.5.3.1 Once the test bearing has reached a satisfactory stabilization temperature, the setting on the West controller for the test-oil heaters is increased to raise the bulk-oil temperature to required value. The uppermost sump band heater is controlled by a manual on-off switch, not the West controller. This heater is used only to accelerate the heating rate when a sump temperature of 232.2° C (450° F), or above, is employed. The heater is not actuated until a sump temperature of 204.4° C (400° F) is reached, and is deactivated when the desired sump temperature is achieved. The bearing heater should be turned on simultaneously with the change in sump heater setting to bring the bearing outer race temperature (max) to the required temperature. At this point, the three thermocouples attached to the bearing outer race should be checked to make sure that the thermocouple indicating the second highest temperature is attached to the West temperature controller.

6.5.3.2 When the required bearing and sump oil temperatures are reached, the test-oil flow rate is again checked and adjusted as necessary to maintain 600 mL/min. The sump vent-gas flow is also measured at this time. The scavenge pump motor speed is adjusted to obtain a flow of 0.24 ±0.01 L/see (0.5 ±0.02 cfm).

6.5.4 Test cycle. The 48-hour test is conducted in three 16-hour operating periods. A fixed shutdown period consisting of a minimum of 4 hours and a maximum of 8 hours is observed between each 16-hour operating period. Run time begins counting when the test-oil heaters are turned on, including bearing stabilization time. Test time stops when the test-oil heaters are deactivated. Except for emergency stops, all shutdowns are made in accordance with the detailed procedure subsequently outlined.

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6.5.5 Used oil analysis. The following laboratory tests are run on the new and used oil samples:

Test	ASTM method
Viscosity at 37.8° C (100° F), cSt	D 445
98.9° C (210° F), cSt	D 445
Neutralization No., mg KOH/g	D 466, using a pH llendpoint

6.5.6 Test-oil flow rate check. During operation, the test-oil flow rate is checked at the incorporated test-oil flow rate measuring system once every 3 hours. The system is located in the scavenge line as shown on Figure 2. It consists of a three-way valve located in the scavenge line which permits routing of the oil into an open 1000-mL separatory funnel. The funnel stopcock tube leads to a two-way valve which connects to the scavenge line.

6.5.6.1 The test-oil flow measuring procedure is carried out by setting the three-way valve to route the oil into the funnel for a period of 1 minute, at which time the valve is reset to its normal position. After the oil volume is measured, the two-way valve and stopcock are opened to drain the oil in the funnel back into the scavenge line. The two-way valve and stopcock are closed after the oil is drained in preparation for succeeding test-oil flow rate determinations. Care is taken to prevent air entering the scavenge line upon draining the separator funnel.

6.5.6.2 At the completion of the test, while the test oil is still hot, the sump and test-oil system is drained into a suitable container so that the volume of test oil remaining can be determined. After the volume of test oil has been measured (room temperature) and recorded, one L (one quart) of the test oil should be poured into a clean container and saved for laboratory analyses.

6.5.7 Rig photographs. As soon as practical, the rig is disassembled and 10 X 12.7 cm (4 X 5-inch) color photographs are taken of the following components:

a. Bearing compartment with cover removed - front view.
b. Heater mount - rear side.
c. End cover - rear side.
d. Seal plate in housing - heater and bearing removed.
e. Test bearing - inner race, rollers, and cage assembly close-up, 45-degree angle, 0-degree position.
f. Test bearing - inner race, rollers and cage assembly close-up, 45-degree angle, 180-degree position.
g. Test bearing - outer race close-up, inside diameter, 0-degree position (adjacent to test-oil jet).
h. Test bearing - outer race close-up, inside diameter, 180-degree position

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A typical set of photographs, reduced and in black and white, is shown on Figure 5.

6.5.7 After the photographs are completed, a detailed visual inspection is made of these parts to determine the average depth, coverage, and consistency and type of oil deposits, plus the extent of abnormal metal wear on the test-bearing cage, rollers, roller pockets, and outer race.

6.6 Test Procedure.

6.6.1 Preparation for test.

1. Turn on rig power switches.
2. Turn on support-oil tank heaters and set at 82.2° C (180° F).
3. Turn on multipoint temperature recorder.
4. Charge the test-oil sump with 7.57 L (2 gallons) measured at room temperature. The test-oil expansion upon heating to the required sump bulk-oil temperature will establish the "full" mark which should be noted on the level indicator tube.
5. Turn on test-oil heaters and adjust controller to obtain 126.7° C (260° F).
6. Open air bleeds on both sides of the differential manometer which is filled with test oil.
7. Checkloading valve on console. It should be in the open or zero-load position.
8. When the bulk-oil temperature in the test tank reaches 126.7° C (2600 F), turn on the air supply to end cover and adjust to 0.165 L/see (0.35 cfm).
9. Start the test-oil pressure and scavenge pumps. Test-oil pressure should be at least 68.95 kPa gage (10 psig) at test-oil jet.
10. Start the support-oil pumps.
11. Set and maintain support-oil pressure at 551.6 to 689.5 kPa gage (80 to 100 psig).
12. Adjust the load pressure to 68.95 kPa gage (10 psig) and start the drive motor.

13. Increase rig speed immediately to 10,000 rpm.
14. Close loading valve on console until 351.6 kPa gage (51 psig) is obtained on gage.
15. Close air bleeds on both legs of manometer used for pressure differential checks across the screw-thread seal. The required differential is controlled by maintaining a slightly higher test-oil compartment pressure of 0.76 to 1.27 cm (0.3 to 0.5 inch) of test-oil column relative to the support-oil compartment pressure.
16. Continue running until the following conditions are stabilized:

Test-oil-in temp	121.1 ±1.4° C (250° ±2° F)
Test-tank bulk-oil temp	126.7 ±2.8° C (260° ±5° F)
Airflow to end cover	0.165 ±0.01 L/see (0.35 ±0.02 Cfm)

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17. Make at least two separate flow checks of l-minute duration each at the test oil flow measuring system. The measured volume flow rate should be 600 +20 mL/min.
18. Continue running for 1 hour at these conditions with the bearing heater off. If during, or at the end of this period, the maximum bearing temperature has exceeded 176.7 ±C (350° F), shut down the rig, install a new test bearing, and repeat steps 1 through 17. If the maximum bearing temperature has not exceeded 176.7° C (350° F) during this period, preceed with the next step.
19. Turn on test bearing heater and adjust controller to obtain the required bearing operating temperature. Adjust bearing heater voltage to achieve consistent, but not accelerated, temperature rise. Upon reaching the required bearing operating temperature, the heater voltage is again adjusted to minimize the bearing temperature variation above and below the control point.
20. Check the three test bearing outer-race thermocouples to make sure the second highest indicating thermocouple is connected to the West temperature controller. However, maintain the required bearing operating temperature on the highest indicating thermocouple connected to a temperature recorder.
21. Adjust the test-oil heater controller to obtain the required bulk-oil temperature.
22. Continue running until the test-oil-in temperature, bulk-oil temperature, test-bearing temperature, and airflow to end cover are stabilized to the applicable specification values.
23. Mark the level indicator tube to show the full position. All subsequent oil level checks are made in reference to this point.
24. Take at least two separate flow checks of l-minute duration, each at the test-oil flow measuring system. Flow rate should be 600 ±20 mL/min.
25. Measure the sump vent-gas flow at the exhaust valve and adjust the scavenge pump motor speed to obtain 0.24 ±0.01 L/see (0.5 ±0.2 cfm) vent-gas flow.
26. Adjust airflow to air cooler to maintain specified test-oil return temperature.
27. Continue running to complete the 16-hour operating period, shut down the rig in accordance with 6.6.3 and observe a shutdown period.

6.6.2 Operating Procedure.

6.6.2.1 Record the following operational data at 30-minute intervals:

a. Test hours (count from the time when the test-oil heaters are turned on until turned off).
b. Time and date.
c. Load-oil pressure.
d. Test-oil pressure.
e. Ratiotrol setting - test-oil pump.

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f. Ratiotrol setting - scavenge pump.
g. Seal differential pressure - test versus support section.
h. Airflow to end cover - rotameter scale.
i. Test-bearing temperature (3 thermocouples).
j. Test-oil sump temperature.
k. Test-oil-in temperature.
l. Test-oil-out temperature - end cover side.
m. Test-oil-out temperature - seal side.
n. Test-oil return temperature.
o. Support-oil-in temperature.
p. Support-oil-out temperature.
q. Watt-hour meter, test-oil sump heater.
r. Watt-hour meter, test-bearing heater.

6.6.2.2 Take 40-mL samples of test oil from three-way valve in scavenge line every 4 hours (including warm-up time along with endurance time).

6.6.2.3 Makeup oil should be added immediately after each 40-mL sample is taken by adding sufficient quantity of unused test oil to bring the oil level to the full mark. Makeup oil is not added after the sample withdrawal at 16 and 32 hours. The rig is shut down at these times, and makeup oil is added after stabilization of test conditions for the subsequent 16-hour running period.

6.6.2.4 Test-oil-in and test-oil-out filters are replaced with clean, preweighed elements during each 4-hour down period. The used filter elements are allowed to drain for 1 hour at 85° C (185° F), weighed, and the weight gain recorded.

6.6.3 Shutdown sequence.

a. Shut off test-bearing and sump heaters.
b. Adjust loading valve on console and reduce load pressure to 172.4 kPa gage (25 psig).
c. Continue running at these conditions until test-bearing temperature (maximum) drops to 204.4° C (400° F).
d. Reduce load to 68.95 kPa gage (10 psig) and shut off drive motor.
e. When drive shaft stops, shut off test-oil pumps, support-oil pumps, and heater, main electrical and water switches, and all air valves.

6.6.4 Startup sequence.

a. Turn on rig power switches and support-oil heaters in sufficient time to attain the 82.2° C (180° F) temperature prior to startup.
b. Turn on multipoint temperature recorder.
c. Follow step Nos. 5 through 17 of 6.6.1.
d. Continue running until the maximum bearing temperature stabilizes within 2.8° C (5° F) between successive readings taken at 2-minute intervals. This stabilization normally occurs within 20 to 30 minutes after starting the drive motor.

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e. Follow step Nos. 19 through 22 of 6.6.1.
f. Add sufficient new oil to bring the sump level indicator to the full mark.
g. Follow step Nos. 24 through 27 of 6.6.1.

6.7 Deposit rating system.

6.7.1 Outline of method.

6.7.1.1 Deposit demerits. Bearing machine cleanliness is reported in this deposit demerit system by the assignment of values of 0 to 20. Identify the different types and thicknesses of deposits as follows: O shall designate a new or clean condition; 20 shall represent the worst condition that could be expected.

6.7.1.2 Table II shows the numerical demerits to be assigned to different types and degrees of deposits.

TABLE 11. Demerit rating numbers used for numerically describing deposits.

Deposit type	Demeric rating number		
	Light	Medium	Heavy
Varnish	1	3	5
Sludge	6	7	8
Smooth Carbon	9	10	11
Crinkled carbon	12	13	14
Blistered carbon	15	16	17
Flaked carbon	18	19	20

6.7.1.3 Table 111 defines deposit types and severities.

6.7.1.4 The following six major items in the test bearing section of the bearing machine are visually inspected and rated to obtain the overall deposit demerit rating:

a. End cover.
b. Spacer and nut (considered to be one piece).

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Table III. Description of deposit types and degrees.

Deposit type	Degree	Description
Varnish	•••••••	Varnish or lacquer-like coating, shiny.
	Light	Light gold or yellow in color, translucent.
	Medium	Brown or dark brown in color, translucent.
	Heavy*	Black in color, opque.
Sludge	......	Shiny, oily emulsion of carbon and oil usually light brown in color. Removable by wiping with a rag.
	Light	Less than 1/64 in. thickness.
	Medium	1/64 to 3/64 in. thickness.
	Heavy	3/64 in. thickness or more.
Smooth Carbon	......	Carbonaceous coating not removable by wiping with a rag.
	Light*	Less than 1/64 in. thickness.
	Medium	1/64 to 3/64 in. thickness.
	Heavy	3/64 in. thickness or more.
Crinkled carbon	.....	Same as for smooth carbon, ridged or uneven surface, not smooth.

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Table III. Description of deposit types and degrees. (Continued)

Deposit type	Degree	Description
	Light	Less than 1/64 in. thickness.
	Medium	1/64 to 3/64 in. thickness.
	Heavy	3/64 in. thickness or more.
Blistered carbon	.....	Same as for smooth carbon, blistered, bubbled.
	Light	Less than 1/64 in. thickness.
	Medium	1/64 to 3/64 in. thickness.
	Heavy	3/64 in. thickness or more.
Flaked carbon	.....	Same as for smooth carbon, flaked or broken blisters, peeling.
	Light	Less than 1/64 in. thickness.
	Medium	1/64 to 3/64 in. thickness.
	Heavy	3/64 in. thickness or more.

* Some difficulty may be encountered in distinguishing between light smooth carbon deposit and heavy varnish. The varnish deposit appears shiny and glossy and upon scraping indicates a tacky consistency or thin, brittle flaking. The smooth carbon deposit appears dull and lusterless and upon scraping reveals a grainy consistency.

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c. Heater-mount front.
d. Heater-mount rear.
e. Seal plate.
f. Test bearing.

6.7.1.5 The specific areas rated on each of the six major items are as follows:

a. End cover: The surface of the end cover normally exposed to test oil.
b. Spacer and nut: The entire surface of the spacer, nut, lock-washer, and flat washer (all considered to be one piece) normally exposed to test oil.
c. Heater-mount front: The surface of the heater-mount front which is parallel to the plane of the end cover and normally exposed to test oil. The portion of the heater-mount front which contacts the heater-mount retainer is not included in the area rated.
d. Heater-mount rear: The surface of the heater-mount rear which is parallel to the plane of the end cover and normally exposed to test oil.
e. Seal plate: The visible surface of the seal plate, with the slinger in place, normally exposed to test oil.
f. Test bearing: The test bearing is divided into four section for rating purposes. These four sections are in turn broken down into eleven specific areas as follows:

Rollers	1.	Front
	2.	Rear
	3.	Contact surface
Cage	4.	Front
	5.	Rear
	6.	Outside diameter surface
Outer race	7.	Front
	8.	Rear
	9.	Contact surface
Inner race	10.	Front
	11.	Rear

6.7.2 Computation of overall deposit rating.

6.7.2.1 An area demerit rating is determined according to the area covered by the deposit as follows:

$$\frac{\text{percent area covered}}{10} = \text{area demerit rating}$$

Surface deposits are not normally subdivided into areas smaller than 5 percent.

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6.7.2.2 A rating for each inspected item is obtained by multiplying the area demerit rating by the demerit value assigned in Table II and summing all such results to account for 100 percent of the item being inspected. In the event that more than one type of deposit is present on the area being inspected, the rating for that area item is the total of the individual rating values. The deposit rated is that which is visible without the removal of another deposit. Double ratings, such as sludge over varnish, are not used. The rating for the test bearing is obtained by taking a sum of the 11 rated areas and dividing by 11. The rating for each item is then modified by multiplying by the assigned weight factor which will yield a demerit rating as follows:

Major item	Rating	Factor	Demerits
End	X_1	1	X_1
Spacer and nut	X_2	2	$2X_2$
Heater mount front	X_3	3	$3X_3$
Heater mount rear	X_4	3	$3X_4$
Seal plate	X_5	1	X_5
Test bearing	X_6	5	$5X_6$

6.7.2.3 The overall deposit rating is the sum of the major item demerits divided by six.

6.7.2.4 After test, a rating of the interior test-oil sump wall and bottom is made. This rating, which is not included in the calculation of the overall test rating, is reported in terms of the type of surface deposits present and the area covered by each deposit rather than numerical demerits.

6.8 Metal Specimen Preparation.

6.8.1 After test, the metal corrosion specimens are disassembled from the holder and solvent-rinsed to remove residual test oil. (The specimens are stored in n-Heptane if final processing is delayed). The individual specimens are n-Heptane swabbed using a series of cotton swabs or pads until clean pads are noted. The coupons are then rinsed in clean n-Heptane and acetone, air-dried, and weighed to the nearest 0.1 mg.

6.8.2 Significant specimen weight change is reported in mg/cm^2 ignoring edge areas in the calculation of exposed surface area. A significant weight change is defined as a weight variation of ± 0.20 mg/cm^2 or more.

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7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 As required by the specification.

9. PRECISION

9.1 Precision data for this test is reported in AFAPL-TR-70-8, Volume I, Deposition and Degradation Characteristics of Aircraft Turbine Engine Lubricants.

Copies are available through DDC (No. AD-871991).

Method prepared by:
Air Force-AFWAL/POSL - 1986

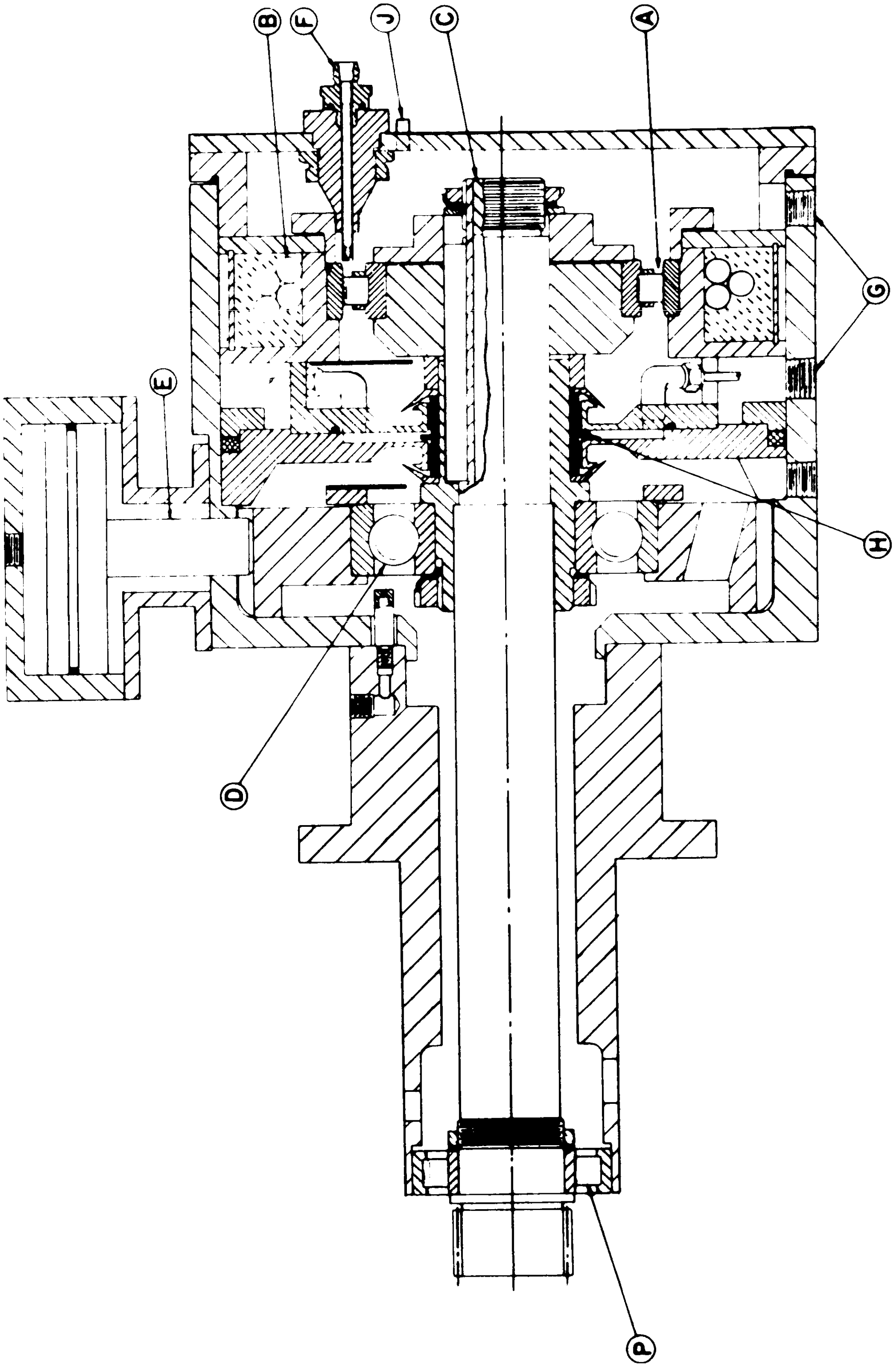

FIGURE 1. Cross section of 100-mm roller bearing machine.

X-4449

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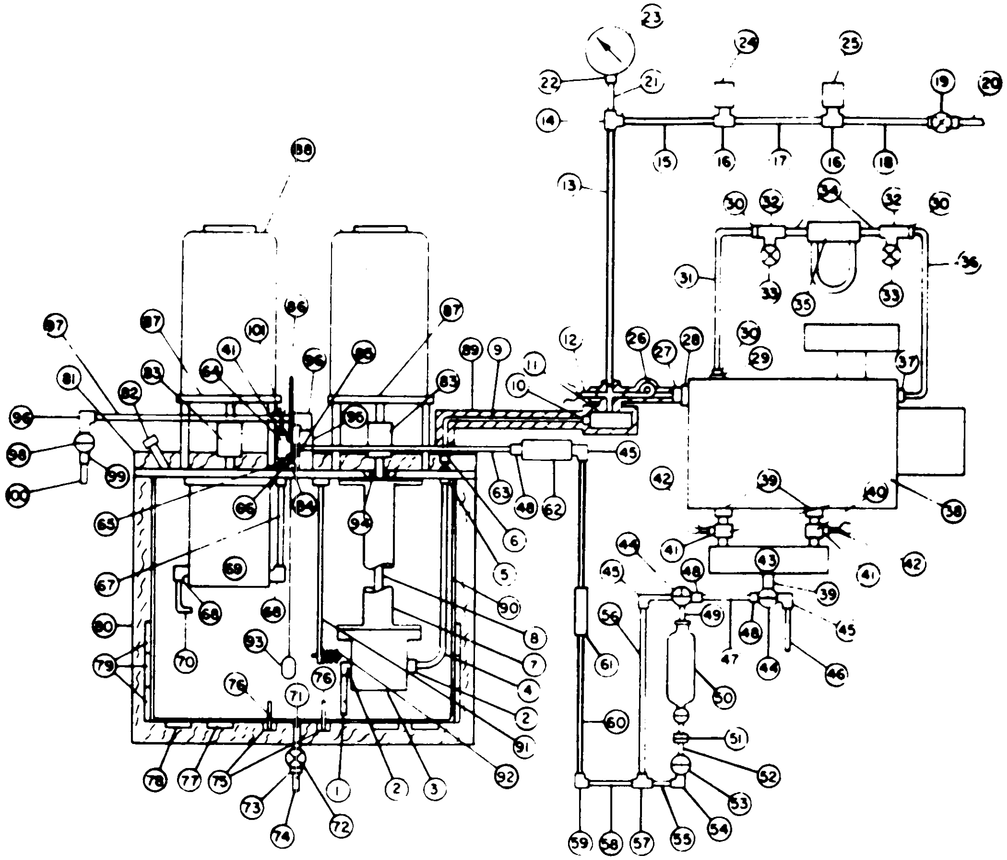

FIGURE 2. Schematic of test-oil system.

X-4450

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Identification of test-oil system parts.

Item No.	Description	No. required
1	3/8-in. tube, (A-B-67043)*.	1
2	3/8-in. tube, X 3/8-in NPT male elbow.	2
3	Test-oil pump, Brown & Sharp, Model 00, ** modified (A-B-67063).	1
4	3/8-in. tube, approximately 6-1/2 in. long.	1
5	3/8-in. tube bulkhead union.	1
6	3/8-in. tube X 1/4-in. tube reducer.	1
7	Standoff, test-oil pump (B-6-69001) & (A-6-69002).	1
8	Shaft extension (A-B-67052).	1
9	1/4-in. tube, approximately 8 in. long.	1
10	1/4-in. tube X 1/4-in. NPT male connector.	1
11	Test-oil-in filter (B-B-68060).	1
12	Thermocouple (A-B-67044).	1
13	1/4-in. tube, as required for installation.	1
14	1/4-in. tube tee.	1
15	1/4-in. tube, as required for installation.	1
16	1/4-in. tube X 1/4-in. tube X 1/8-in NPT male branch tee.	2
17	1/4-in. tube, as required for installation”	1
18	1/4-in. tube, as required for installation.	1
19	Valve, 43S4-316 ball valve, Whitey Research Tool Co. **.	1
20	1/4-in. tube, as required for installation.	1
21	1/4-in. tube, as required for installation.	1
22	1/4-in. tube X 1/4-in. NPT female connector.	1
23	O to 60-psi pressure gage.	1
24.	Pressuretrol , L404A, 5- to 150-psi range, Minneapolis-Honeywell Co. **.	1
25	Pressuretrol , L404B, 5- to 150-psi range, Minneapolis-Honeywell Co. **	1
26	1/4-in. tube (A-B-68115).	1
27	Test-oil jet (A-B-67046).	1
28	Test-oilJet guide, IRBB-6214 Erdco Engineering Co. **	1
29	Vent plug, IRBB-6067, Erdco Engineering Co. **	1
30	1/4-in. tube, X 1/8-in. NPT male connector.	3
31	1/4-in. tube, as required for installation.	1
32	1/8-in. NPT branch tee.	2
33	Valve, 43F2-316 ball valve, Whitey Research Tool Co. **	2
34	1/4-in. X 1/8-in. NPT hex reducing nipple.	2

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Identification of test-oil systems parts. (Continued)

Item No.	Description	No. required
35	Manometer, 6 in. Meriam Model 10AA25WM **	1
36	1/4-in. tube, as required for installation.	1
37	1/4-in. tube X 1/8-in. NPT 45” male elbow.	1
38	100-mm bearing machine IRBB-6200, Erdco Engineering Co. **	1
39	3/8-in. NPT hex close nipple.	3
40	3/8-in. NPT tee, modified (B-B-67040).	2
41	1/4-in. tube X 3/8-in. NPT male connector, modified (A-B-67053).	3
42	Thermocouple (A-B-67044).	2
43	Accumulator (B-C-67040).	1
44	3-way valve, 3229T, stainless steel, 3/8-in. NPT, Quality Controls, Inc. **	2
45	1/2-in. tube X 3/8-in. NPT male elbow.	3
46	1/2-in. tube (as required for sampling).	1
47	1/2-in. tube, 8 in. long.	1
48	1/2-in. tube X 3/8-in. NPT male connector.	3
49	3/8-in. nipple, 4 in. long.	1
50	Funnel, 7253-20, Ace Glass Co. **	1
51	Clamp, 7666-15, Ace Glass Co. **	1
52	Stainless steel socket, 7658-40, Ace Glass Co. **	1
53	2-way valve, 2229S, stainless steel, 1/2-in. NPT, Quality Controls, Inc., **	1
54	1/2-in. tube x 1/2-in. NPT male elbow.	1
55	1/2-in. tube, approximately 2-1/2 in. long.	1
56	1/2-in. tube, approximately 23 in. long.	1
57	1/2-in. tube union tee.	1
58	1/2-in. tube, approximately 2-1/2 in. long.	1
59	1/2-in. tube union elbow.	1
60	1/2-in. tube, approximately 42 in. long.	1
61	Air cooler (B-B-68053).	1
62	Test-oil-out filter (A-B-67047).	1
63	1/2-in. tube, approximately 2-1/2 in. long.	1
64	1/2-in. tube X 3/8-in NPT female X 1/2-in. long tee.	1
65	1/2-in. tube, approximately 2-in. long.	1
66	1/2-in. tube bulkhead union.	1
67	1/2-in. tube, approximately 7-1/2 in. long.	1
68	1/2-in. tube X 1/2-in. NPT male elbow	2
69	Scavenge pump, Brown & Sharpe, Model 2S** equipped with Viton O-ring in mechanical seal and special Graphalloy carbon bearings, modified (A-B-67062).	1

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Identification of test-oil system parts. (continued)

Item No.	Description	No. required
70	1/2-in. tube (A-B-67055).	1
71	1/4-in. NPT hex nipple, 2 in. long.	1
72	2-way valve, 2229S, stainless steel, 1/4-in. NPT, Quality Controls, Inc. **	1
73	3/8-in. tube X 1/4-in. NPT male connector.	1
74	3/8-in. tube, as required for installation.	1
75	1/8-in. tube X 1/8-in. NPT thermocouple connector, 2-2 FH4BZ-SS Parker CPI.	2
76	Thermocouple (A-B-67054).	2
77	Ring heater, Edwin L. Wiegand Co., Chromalox** No. .4-70-660 watts, 240 volts.	1
78	Ring heater, Edwin L. Wiegand Co., Chromalox** No. .4-90, 1000 watts, 240 volts.	1
79	Band heater, Edwin L. Wiegand Co., Chromalox** No. SE-3801, 1000 watts, 240 volts, bent lengthwise to clamp on 12-in.-diameter cylinder with mounting tabs bent out to allow securing element to cylinder with one bolt.	3
80	Insulation, Johns-Manville Co., Spinglas Type ** 102, 1-1/2-in. thick.	
81	Insulation, Johns-Manville Co., Marinite 23A, ** 2-in. thick.	
82	1-1/2-in. NPT pipe cap.	1
83	Coupling, Lovejoy, Model L070, 5/8-in. bore **	2
84	Oil level rod guide (A-B-67051).	1
85	5/16-in. tube X 1/4-in. NPT male connector with Teflon ferrule.	1
86	Oil level indicator tube (A-B-68114).	1
87	Motor stand (D-B-67016).	2
88	Variable speed motor, Boston Gear Works, ** V-33B Ratiotrol motor Speed Control, 1/3-hp, 115-volt and No. V-93300, face mounted, shunt-wound DC drip-proof motor.	2
89	Insulation, Carborundum Co., Fiberfrax Lo-Con, ** 6-lb/cu ft density, 1/4-in. thick.	
90	Test-oil sump (D-B-67016).	1
91	Metal specimen shaft (A-B-67049).	1
92	Metal specimens (see Fig. 16).	

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Identification of test-oil system parts. (continued)

Item No.	Description	No. required
93	Oil level float and rod, Chicago Float Works. ** Type L, 2-in X 3-in., 302 stainless steel with 1/8-in. tube rod, 14 in. long.	1
94	Pump shaft seal, Torostel 50009 or equivalent.	1
95	Sump vent port (A-B-67060).	1
96	3/8-in. tube X 1/4-in. NPT male elbow.	2
97	3/8-in. tube approximately 8-in. long.	1
98	2-way valve, K-702-GG6D aluminum 1/4-in. NPT, Kohler Co. **	1
99	3/8-in. tube X 1/4-in. NPT male connector.	1
100	3/8-in. tube, as required for installation.	1
101	Thermocouple (A-B-67044).	1

* All tubing, tubing fittings, and pipe fittings listed are AISI type 304 or 316 stainless steel.

** Or approved equivalent.

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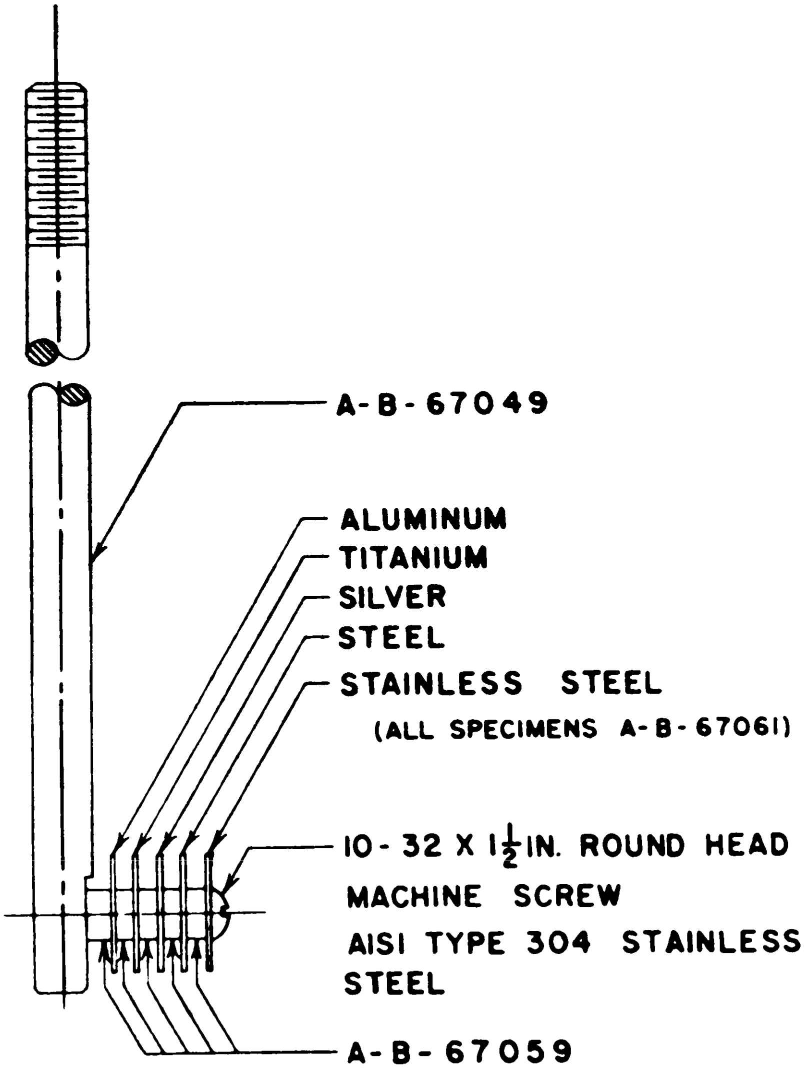

FIGURE 3. Metal specimen assembly.

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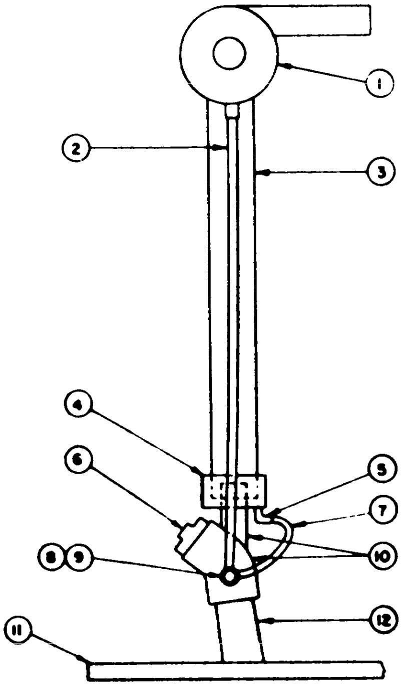

IDENTIFICATION OF VENT PIPE BLOWER ASSEMBLY PARTS

Item No.	Description	No. Required
1	Blower (B-B-68055)	1
2	3/8-in. tube, approximately 28-in. long	1
3	Vent pipe (B-B-68056)	1
4	Vent pipe cup (A-6-69008)	1
5	1/4-in. tube X 1/8-in. male elbow	1
6	1-1/2-in. NPT pipe cap	1
7	1/4-in. tube, approximately 6 in. long	1
8	3/8-in. male run tee	1
9	3/8-in. X 1/2-in. tube end reducer	1
10	Sump-oil fill port adapter (B-6-69009)	1
11	Sump cover	1
12	Sump-oil fill port	1

All tubing, tubing fittings, and pipe fittings listed are AISI Type 304 or 316 stainless steel.

FIGURE 4. Schematic of vent pipe blower assembly.

X-4452

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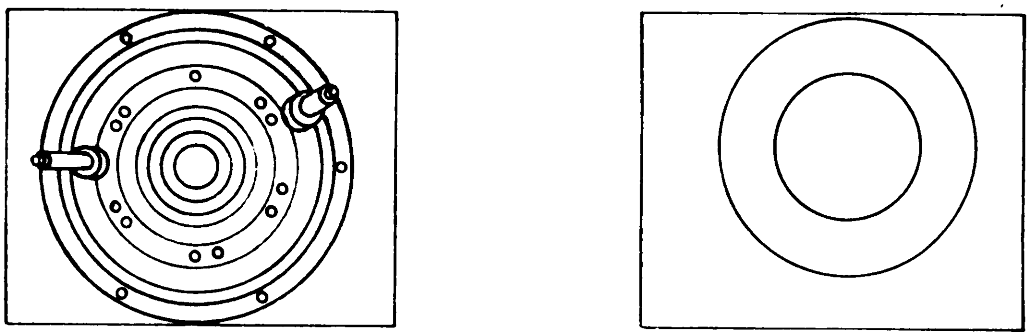
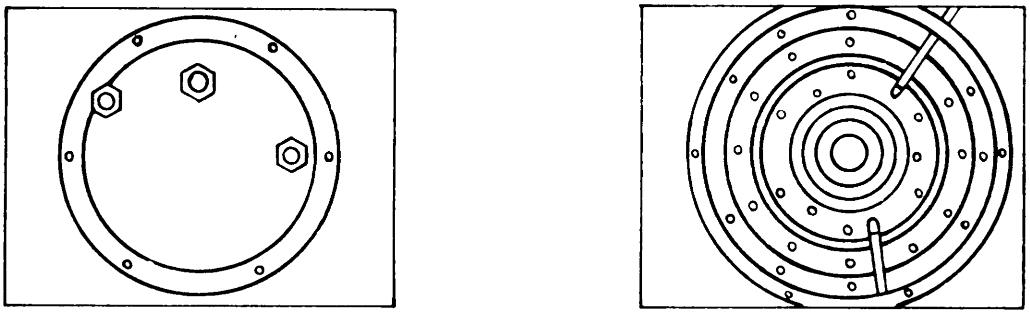


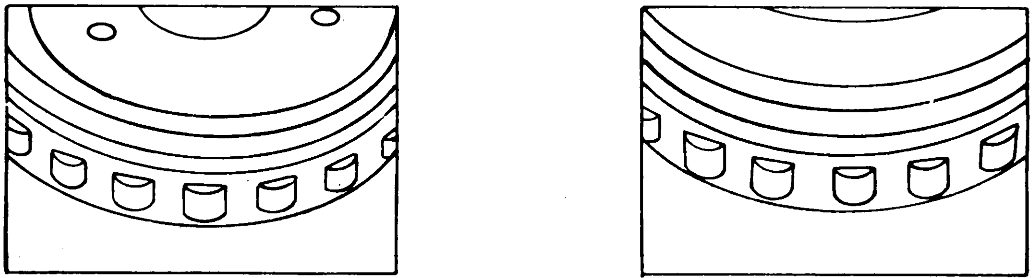
BEARING COMPARTMENT

HEATER MOUNT



END COVER

SEAL PLATE



TEST BEARING-0° POSITION

TEST BEARING-180° POSITION

TEST BEARING-OUTER RACE, 0° POSITION

TEST BEARING-OUTER RACE, 180° POSITION

FIGURE 5. Typical diagrams of disassembled rig after test.

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METHOD 3451.4
September 30, 1986

STABILITY OF LUBRICATING OILS WORK FACTOR)

1. SCOPE

1.1 This method is used for determining the stability of a lubricating oil when subjected to an endurance test in the Navy work factor machine.

2. SUMMARY

2.1 It consists of operating a journal (at 2000 or 3000 rpm) in a Bronze-metal bearing lubricated with the oil for 100 hours; checking the oil for changes in viscosity, neutralization number, and carbon residue; and computing the work factor from the changes noted.

3. SAMPLE SIZE

3.1 Approximately 8.0 L (8.5 quarts) of the oil to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Test stand (such as that shown in Figure 1), consisting of:

a. Block and Cap made of nickel-chromium case iron (Nickel 0.75-2.5 percent, Chromium 0.40-1.00 percent) and heat treated.

b. Bearing made of Johnson Alloy CC-17-27.

c. Journal made of SAE 52100 steel hardened to 65 Rockwell C (700 Brinell), ground to a tolerance of 9.6543 - 9.6548 cm (3.8009 - 3.8011 inches). Journals are discarded when they are smaller than 9.6543 cm (3.8009 inches).

d. Springs, crucible steel, tempered, of the following dimensions:

Maximum diameter of coil	4.7625 cm	(1-7/8")
Minimum inner diameter of coil	2.54 cm	(l”)
Maximum free height	13.35 cm	(5-1/4”)
Maximum load each	544.31 kg	(1200 lbs)
Compression under maximum load	3.048 cm	(1.2”)

e. Loading device, to apply a load of 1034 ±34 gage kPa (150 ±5.0 psig) to bearing.

f. Drive unit, to drive journal at 2000 ±200 rpm or 3000 ±300 rpm (depending on the type of oil).

g. Oil system, recirculating, 5.7 ±0.5 L (5 ±0.5 quart) capacity, to pump oil sample at 69 or 103 +3 gage kPa (10 or 15 ±0.5 psig) depending on the type of oil. ,

h. An oil pressure safety switch (not shown on drawings) is installed on the oil inlet line, pressure side of the pump, as a protective measure in case of failure of the lubricating system.

i. Film Pressure Gauge, (15.2 cm face; 0-3450 gage kpa [6” face; 0-500 psig]) range.

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j. Oil Inlet Pressure Gauge, (10.2 cm 0-414 gage kPa [4" face; O-60 psig]) range.
k. Thermocouples, IC, range 66° C - 232° C (150° F - 450° F).

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Naptha, precipitation, ASTM D 91 [1,4,0].

6. PROCEDURE

6.1 Determine and record the following properties of the oil sample:

a. Viscosity, in Saybolt Universal Seconds (SUS) at 37.8° C, 54.4° C, and 98.9° C (100° F, 130° F, and 210° F), by ASTM D 88 (directly) or by ASTM D 445 (converting results from centistokes to SUS).

NOTE 1: 'For samples of oils designated by Military symbols 5150 or 5190, the viscosity at 100° F need not be determined.

b. Carbon residue, percent, by ASTM D 189. (The carbon residue must not exceed that shown as "Maximum Initially Acceptable"' in Table 1.)
c. Neutralization number, by ASTM D 974. (The neutralization number for oils designated by Military symbol 5150 or 5190 must not exceed 0.15. the number for all other Military symbol oils must not exceed 0.10.)
d. Precipitation number, by ASTM D 91. (It must not exceed 0.05;)

TABLE I. carbon residue.

Specimen (Military symbol No.)	Carbon residue, percent	
	Maximum initially acceptable	Final rejection point
1065	0.60	1.20
1100	1.20	2.40
5150	3.00	4.00
5190	3.25	5.00

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6.2 Bearing preparation.

a. Insert bearing manufactured of Johnson Bronze.
b. Load bearing to prescribed load and check pressure and temperature. If pressure and temperature are not correct, reshim bearing accordingly. If reshiming does not correct situation, install new bearing.

6.3 Conduct test as follows:

a. Drain all oil remaining in the system immediately after concluding a test. Flush system with 3000 mL of precipitation naphtha for 1 hour. Drain and air blow system for 1/2 hour through oil filter vent with all drain valves open. Add 3000 mL of oil sample and run system at following conditions:

Head pressure	1200 kPa	(160 psig)
Speed	2000 rpm	
Oil in pressure	240 kPa	(20 psig)

When "oil in" temperature reaches 71.11° C (160° F), run for 15 minutes. Shut down and drain.

b. Charge oil system of test stand with 4.7 L (5 quarts) of oil sample, and operate system to supply oil to bearing at 103 gage kPa (15 psig).
c. Start drive unit, and gradually load bearing to 1034 gage kPa (150 psig). Note the time, and bring journal to the speed of 3000 rpm (except when testing Military symbol 5150 or 5190, maintain speed at 2000 rpm.)
d. Without adding any more oil to the oil system, allow test stand to operate for 100 ±1/2 hours.
e. Bearing temperatures shown in Table II to be held at point "F", Figure 1. Normally these limits are met by varying motor speed from the nominal by ±10 percent.

TABLE II

Military Symbol	Bearing Temperature °C	°F
1065	135-138	275-280
1100	138-149	280-300
5150	123-127	255-260
5190	132-135	270-275

6.4 At the end of the 100-hour endurance test, recheck the properties of the oil sample as given in 6.1.

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7. CALCULATIONS

7.1 Compute (from increases in viscosity, carbon residue, and neutralization number) the work factor as follows:

a. Determine the viscosities of the oil sample, before and after the endurance test at 37.8° C, 54.4° C, and 98.9° C (100° F, 130° F, and 210° F) and compute the viscosity work values for each temperature as follows:

$$\text{Viscosity work value} = 1.00 - \frac{C(A - B)}{B}$$

A = Viscosity after endurance test, SUS.
B = Viscosity before endurance test, SUS.
C = 5 (for Military Symbols 1065, 1100).
c = 4 (for Military Symbols 5150 and 5190).

The viscosity work value is determined by averaging the values obtained at 37.8° C, 54.4° C, and 98.9° C (100° F, 130° F, and 210° F).

b. Compute the carbon residue work value:

$$\text{Carbon residue work value} = \frac{D - F}{D - E}$$

D = Carbon residue ‘*Final Rejection Point” (Table I).
E = Carbon residue before endurance test, percent.
F = Carbon residue after endurance test, percent.

c. Compute the neutralization number work value:

$$\text{Neutralization number work value} = \frac{1.01 - l\text{-}i}{1.01 - G}$$

G = Neutralization number before endurance test.
H = Neutralization number after endurance test.

d. Average the work values obtained in a, b, and c above and record the result as the work factor.

8. REPORTING

8.1 Report the work factor.

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9. PRECISION

9.1 Repeatability. The repeatability of the method depends upon the level of the result. Duplicate values should not differ by more than the limits given below.

Level of result	Repeatability
>0.9	0.07
0.8 to 0.9	0.10
0.7 to 0.8	0.22
<0.7	Not established

9.2 Reproducibility. This has not been established.

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Navy - NAPC - 1986

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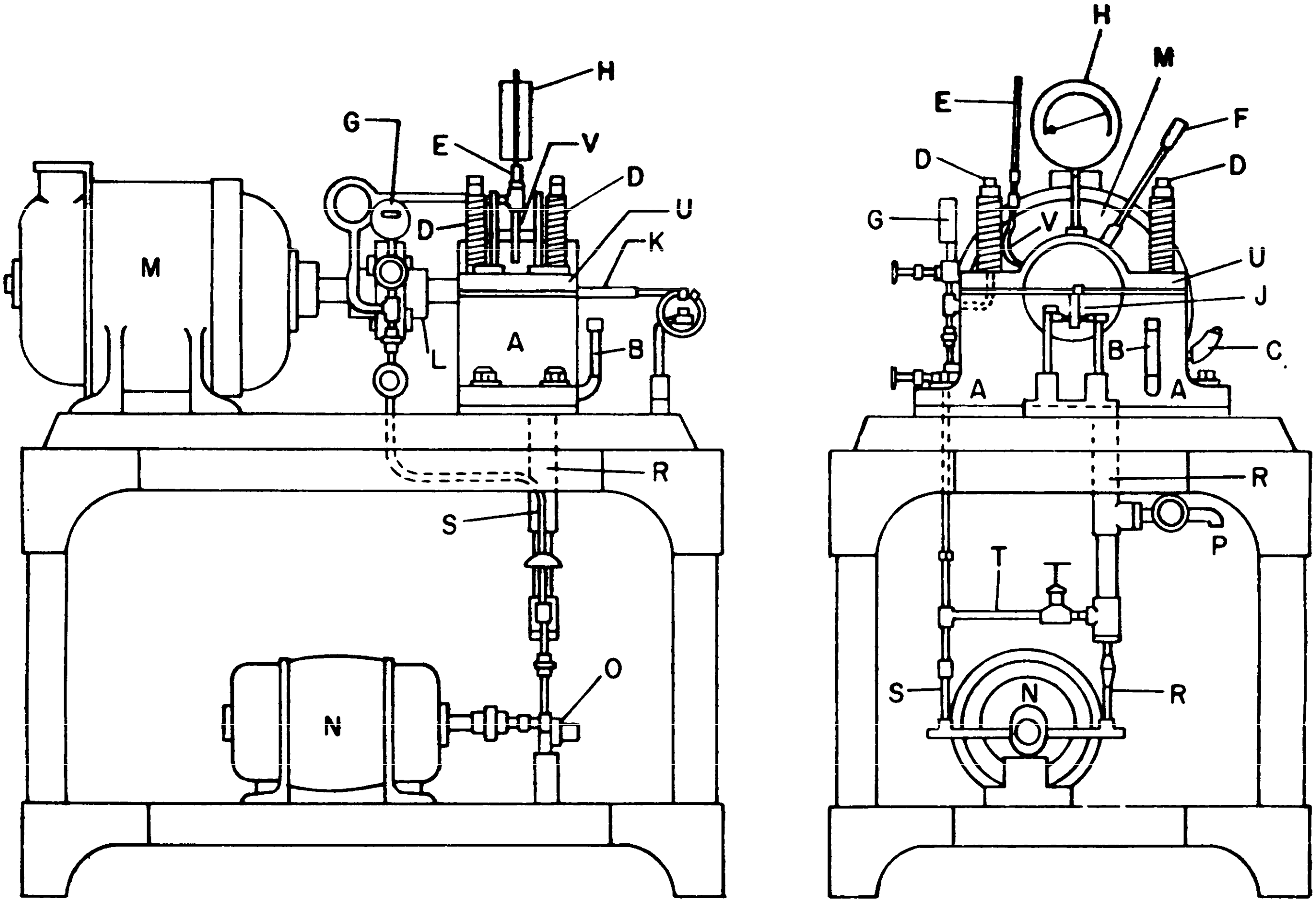

A. Bearing base and oil reservoir
B. Oil gage glass
C. Oil filling connection
D. Calibrated bearing pressure springs
E. Thermocouple, inlet oil temperature
F. Thermocouple, bearing temperature
G. Inlet oil pressure gage
H. Bearing pressure gage
J. Revolutions counter
K. Machine steel journal

M. Motor, journal drive, 5-hp
N. Motor, oil pump
O. Oil pump
P. Drain valve
R. Return oil line
S. Pressure oil line
T. Bypass oil line
U. Bearing cap
V. Oil inlet line

FIGURE I. Test stand.

X-4381

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BEARING COMPARABILITY OF TURBINE OILS

1. SCOPE

1.1 This method is used for determining the bearing comparability (lacquering, deposits, and corrosion) and stability of MIL-L-17331 turbine lubricating oils when subjected to an endurance test.

2. SUMMARY

2.1 A Journal is operated at specified speed in a babbitt metal bearing lubricated with the test lubricant for 200 hours; examining the test bearings and checking the lubricant for changes in viscosity, total acid number, and carbon residue; and computing the work factor from the changes noted.

3. SAMPLE SIZE

3.1 Four L (1 gallon) of the oil to be used in each test. (An additional 20 L (5 gallons) should be on hand for use in repeating the 3-L (3-quart) flushing procedure as required.)

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Test equipment illustrated schematically in Figure 1 consist of:

a. Journal (H), shaft material, 4340 steel, 2.750-inch diameter (at bearing surfaces) and hardened to a Rockwell "C" hardness of 40-45, finish ground not to exceed 0.041 micrometers (16 microinches) rms.

b. Bearings (I, J, and K) babbitt metal in split bearing housing (to accommodate journal), size 6.9886 - 6.9936 cm (2.7514 - 2.7534 inch) (vertical diameter when installed) by 4.60 cm (1-13/16 inches) long. (Bearings should be free of scratches or other blemishes). The bearing material over steel backing is 0.013 - 0.025 cm (0.005 to 0.010 inch) thick tin base babbitt (SAE 12 babbitt); composition as per SAE standard J460 is: Sn (minimum) 88.25 percent, Sb 7.0-8.0, Pb 0.50 (maximum), Cu 3.0-4.0 (maximum), Fe 0.08 (maximum), As 0.10 (maximum), Bi 0.08 (maximum), Zn 0.005 (maximum), Al 0.005 (maximum), and others 0.20 (maximum) total. Bearings of this size and composition may be obtained from Mogul-Bower Bearings, Incorporated, Detroit 13, Michigan under the following part numbers: Upper half B-10994, Lower half B-10995.

c. Loading Device (0), hydraulic cylinder or other suitable unit capable of maintaining a load of 1520 +20 gage kPa (220 +3 psig) of projected bearing area on the loading–bearing (j). (This loading equivalent to approximately 4,400 N [1000-lb force] on the loading yoke.)

d. Drive unit (f), to drive journal at a speed of either 1750 or 3500 rpm.

e. Oil system, recirculating, 4 L (l-gallon) capacity sump, equipped with 3.8 L/rein (1 gpm) pump and bypass line to sump, to circulate 1.9 - 2.3 L/rein (0.5-0.6 gpm) of test lubricant to support and test bearings.

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f. Oil temperature control. A thermistor (L) or other suitable' temperature sensing device mounted to contact steel shell of upper half of test bearing; this controls the sump heater. Bearing temperature is monitored by spring-loaded thermocouple (M) in contact with steel shell of upper half of test bearing. Temperature of oil supply to bearing is monitored from thermocouple (P). High-temperature cutoff switch (C) to sump is to insure against overheating of oil. Temperature of oil in sump is recorded from thermocouple (D). High temperature cutoff in the recorder is set for 150° C (300° F).

Note 1. A suitable cover for the machine is useful for controlling temperatures during winter months. A wooden box can be used. Thermocouples placed inside and outside the box serve for recording these ambient temperatures.

g. Oil flow rate and pressure control. Oil supply to bearings (sum of oil flow to three bearings) is observed at flowrater (T). Oil supply pressure to bearings is observed on gage (Q). A minimum oil pressure to bearings of 13.7 gage kPa (2 psig) pressure is insured by low-pressure cutoff switch (S).

Note 2. Detailed drawings of test equipment may be obtained from US Navy Marine Engineering Laboratory, Annapolis, MD.

4.2 The properties of the new lubricating oil will be determined as follows:

a. Viscosity in centistokes at 38° C (100° F), 54° C (130° F), and 99° C (210° F), by method D 445, ASTM Standards.
b. Carbon residue, percent, by method D 524, ASTM Standards.
c. Total acid number by method D 974, ASTM Standards.

5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Naphtha; aliphatic (TT-N-95), type II [1,4,0].

6. PROCEDURE

6.1 Determine and record the following properties of the new lubricating oil:

a. Viscosity
b. Carbon residue
c. Total acid

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6.2 Subject the oil to endurance test as follows:

a. Drain any old oil remaining in the system; remove sump and wipe clean with lintless wiping cloths and naphtha; remove bearing caps, bearings,. and shaft from machine; wipe shaft with lintless wiping cloths and naphtha to remove stains.

b. Spread film of test oil on journal and three sets of new bearings; install the shaft and bearings; use a torque of 115-129 N•m (85-95 lb-ft) on bearing cap bolts.

c. Flush run. Temporarily install a 10 micrometer filter between the oil sump and pump inlet. (Filter should be a clean or new filter.) Place approximately 3 L (3 quarts) of the test oil in sump. Start pump and turn on sump heater, and slowly adjust oil flow to 1.9 - 2.3 L/rein (0.5-0.6 gpm) (to avoid excess oil pressures). Start motor at 1750 rpm. Allow system to operate for 30 minutes. During the last 10 minutes apply a load (half that specified for test) to check out the system functioning. Shut down the machine by first unloading the bearing and then stopping the motor drive. Shut off the oil pump and heater. Drain all oil from the system and wipe sump clean with lintless wiping cloths. Remove the oil filter from the system and install direct connect from pump inlet to sump.

Note 3. A single flush run, following the above procedure, will usually provide sufficient system cleaning.

d. Test oil. Place 4 L (1 gallon) of test oil in clean sump and start heater. Start oil pump and adjust flow with bypass valve to give 1.9 - 2.3 L/rein (0.5-0.6 gpm). Start motor drive at speed of 3500 rpm and gradually load bearing (using 2 or 3 min.) with loading device to yield a load of 1517 gage kPa (220 psig) of projected bearing area. As the system temperature comes to equilibrium, adjust sump temperature controller to give a bearing temperature of 138 +0.5° C (280 ±1° F) which shall be maintained during the test. Operate the machine under these conditions for a period of 200 hr. During this time continuously record bearing temperature, temperature of oil supply to bearing, and ‘temperature of oil in sump. Observe and record (daily) oil flow rate and oil pressure to bearings. Oil flow rate to bearings shall be adjusted during test period to maintain 1.9 - 2.3 L/rein (0.5-0.6 gpm) to bearings.

6.3 Inspection of bearings at end of 200-hour endurance test. Dismantle all journal bearings and rinse in naphtha. Observe bearing surfaces for evidence of deposits, corrosion, wiping, or other changes. Particular reference is to be made to loaded (center) bearing. Report the observation for all bearings.

6.4 At the end of the 200 hour endurance test, determine the properties of the used lubricant, as given in paragraph 6.1.

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7. CALCULATIONS

7.1 Compute the viscosity, carbon residue, and neutralization number work values of the test oil. The values shall be computed and reported as follows:

a. Viscosity work value $= 1.00 - \frac{5(A - B)}{B}$

A = Viscosity after endurance test, SUS
B = Viscosity before endurance test, SUS

Viscosity work value is determined by averaging the three values obtained from individual calculations based on viscosity data at 38° C (100° F), 54° C (130° F), and 99° C (210° F).

b. Carbon residue work value $= \frac{0.80 - D}{0.80 - C}$

C = Carbon residue before endurance test.
D = Carbon residue after endurance test.

c. Total acid number work value = $\frac{1.01 - F}{1.01 - E}$

E = Neutralization number before endurance test.
F = Neutralization number after endurance test.

d. Average the work values obtained and this value is called the work factor.

8. REPORTING

8.1 Report the three work values and the work factor.

9. PRECISION

9.1 Repeatability. The appearance of the test bearing is of primary importance. A quantitative rating or comparison scale for this characteristic has not yet been established. There has, however, been no difficulty in reaching conclusions with respect to excellent, borderline or failing oils. Experience to date indicates that duplicate work factor values can be expected not to differ by more than ±0.02 units from the mean.

9.2 Reproducibility. This has not been established.

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Navy - SH - 1986

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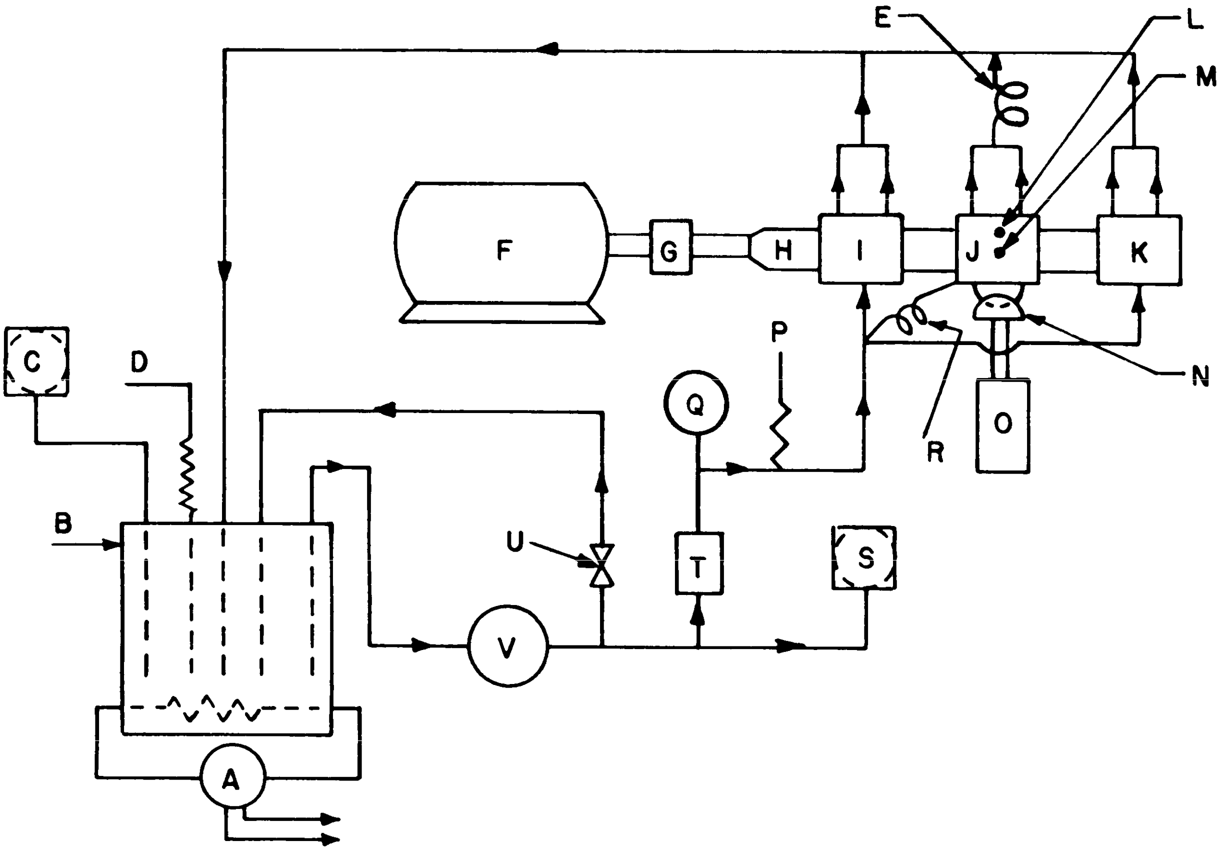

A	Variac , to temperature controller.
B	Electric glue pot, 110-V ac, 1000 watts (4 L capacity).
C	Temperature control, remote bulb mercury switch, high-temperature cutoff.
D	Thermocouple (sump oil temperature) to reorder.
E	Lube oil return from loading bearing (nonrestraining connection) .
F	Motor, 2.5-5.0 hp, 220/440-v ac, 1750 and 3500 rpm (comply NEMA standards) ,
G	Flexible coupling.
H	Shaft (journal).
I	Support bearing.
J	Loading bearing.
K	Support bearing.
L	Thermistor (bearing temperature) glue pot oil temperature control.
M	Thermocouple (bearing temperature) to recorder, high-temperature cutoff at 149° C (300° F).
N	Bearing loading yoke assembly.
O	Loading device for loading bearing.
P	Thermocouple (oil to bearings) to recorder.
Q	Oil pressure gage.
R	Lube oil to loading bearing (non-restraining connection).
S	Low-pressure cutoff switch.
T	Flowrator, gpm.
U	Bypass valve.
V	Pump-motor unit.

FIGURE 1. Oil stability tests arrangement.

X-4382

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CHANNELING CHARACTERISTICS OF LUBRICANTS

1. SCOPE

1.1 This method is used for determining the channeling characteristics of lubricants at low temperature.

2. SUMMARY

2.1 The test consists of storing the sample for 18 hours at the temperature required by the specification, cutting a channel in the lubricant with a metal strip, and determining whether the lubricant flows together to cover the bottom of the container within 10 seconds.

3. SAMPLE SIZE

3.1 Approximately 650 mL of lubricant to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Steel strip, square end (channeling tool), approximately 0.3 cm by 2 cm by 23 cm.

4.2 Thermometer, HB Instrument Co., No. 22360, or equivalent.

4.3 Container, flat bottom, approximately 9 cm ID by 11 cm high, with 2.5 cm (minimum) legs, and with cover to support thermometer in center and steel strip at side of container. (See Figure 1).

4.4 Heating bath, 46° to 48° C.

4.5 Cooling bath (nonliquid), capable of maintaining the specified temperature within 1° C, size sufficient to accommodate container within 3 cm (minimum) clearance on all sides.

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

6. PROCEDURE

6.1 Prepare test setup as follows:

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a. Fill container to within 1.3 cm of top with specimen, place in heating bath , and allow sample to reach 46° C (115° F). (If a liquid bath is used, adjust bath level to height of sample.)
b. When sample reaches 46° C, cover container and remove from bath; allow the samples to cool to 22 ±1 °C.
c. Position the thermometer sO that the bulb is just below the surface. Insert the steel strip into the slit in the cover so that it is in a vertical position in contact with the wall of the container, with the end resting on the bottom of the container. Immediately place the sample in the cooling bath.

6.2 Store container in cooling bath without interruption for 18 +2 hours. Begin timing the storage period immediately after placing the sample in the cooling bath.

6.3 At end of storage period, remove container from cooling bath, and within 30 seconds cut a channel in the sample as follows:

a. Check sample temperature and make sure that it is within ±l° C (±2° F) of specified storage temperature.
b. Without moving steel strip, remove cover and thermometer from container.
c. Note time to nearest second, and within 5 seconds scrape the vertically-held steel strip all the way across bottom of container.

6.4 Within 10 seconds after cutting the channel (see 6.3), check to determine whether sample has flowed back and completely covered bottom of container. If it has, note it as nonchanneling; if not, note it as channeling”

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Report the result as channeling or nonchanneling.

9. PRECISION

9.1 Precision data have not been developed for this method.

Method Prepared by:

Army - ME - 1986

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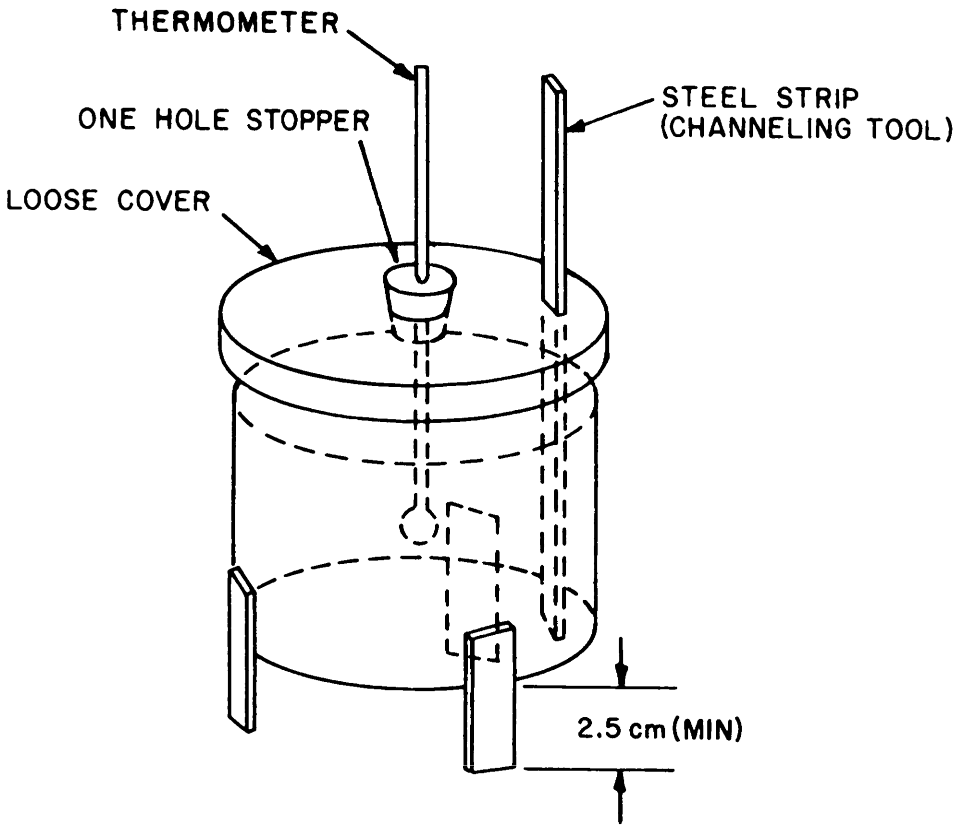

FIGURE 1. Test setup.

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METHOD 3457.2
September 30, 1986

HYDROLYTIC STABILITY

1. SCOPE

1.1 This method is used for determining the resistance of a finished oil to reaction when in contact with water.

2. SUMMARY

2.1 The test consists of tumbling under specified conditions, a mixture of the oil and water in a bottle containing a copper strip, and then testing for changes in the oil, water, and coppers

3. SAMPLE SIZE

3.1 Approximately 125 g of the oil to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Standards.

4.1.1 ASTM.D 445 Kinematic Viscosity of Transparent and Opaque Liquids.

4.1.2 ASTM D 974 Neutralization Number by Color - Indicator Titration.

4.1.3 ASTM D 1500 ASTM Color of Petroleum Products.

4.2 Oven, convection, air; controllable to +0.5° C (±1° F) in temperature range of 66° C and 93° C (150° F and 200° F).

4.3 Fluid container (carbonated beverage bottle), 210 mL (7 oz); capable of being sealed with a cork-lined steel cap.

4.4 Tumbling mechanism (for rotating the fluid container end-over-end at 5 rpm, inside the oven).

4.5 Brush, short-bristled, stiff (typewriter cleaning brush, or equal).

4.6 Gooch crucible.

4.7 Centrifuge, 1500 rpm.

4.8 Centrifuge tubes, cone-shaped, 100-mL.

4.9 Microscope, 20-diameter magnification.

4.10 Balance, sensitivity 0.2 mg.

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5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000; Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Emery paper, 00 or finer.

5.3 Litmus paper.

5.4 Petroleum ether (0-E-751) [1,4,0].

5.5 1,1, 1-trichlorothane (methyl chloroform), stabilized (MIL-T-81533) [2,1,0].

5.6 n-Hexane (technical grade) [1,3,0].

5.7 Sodium sulfate, anhydrous (ACS) [u,u,u].

5.8 Copper strip (QQ-C-502), 16 to 22 gage (B&s), 1.3 cm by 5.1 cm.

6. PROCEDURE

6.1 Determine the acid number of the oil by ASTM D 974.

6.2 Determine the kinematic viscosity of the oil by ASTM D 445.

6.3 Heat the oven to the temperature required by the specification.

6.4 Weight (to within 0.5 g) 75 g of the sample and 25 g of distilled water and place in the clean fluid container (see 4.3).

6.5 Using the filter paper to prevent fingerprints during handling, polish all surfaces of the copper strip with the fine emery paper.

6.6 Wash the copper strip in warm petroleum ether or n-hexane, dry, and weigh to within 0.2 mg, and immediately place the strip in the container.

Note 1. Caution. Petroleum ether and n-hexane are both flammable. Use these materials in a well ventilated area. Do not breathe their fumes nor permit them to come in contact with the skin. Keep all flames away from these materials.

6.7 Cap the bottle (with inert seal in place), and mount it in the tumbling mechanism in the oven.

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6.8 Allow the mechanism to rotate the container end-over-end at 5 rpm for the time required by the specification.

6.9 After the container has rotated for the required time, filter the liquid contents through a tared Gooch crucible lined with a thin layer of asbestos. Save the filtrate. (The operator should wear heavy asbestos gloves and a face shield while handling the hot beverage bottle) Rinse the copper strip and beverage bottle with 50 mL of distilled water and 50 mL of petroleum ether and filter through the Gooch crucible. Save only the water washings and add them to the filtrate.

6.10 Process any insoluble that remain in the crucible, as follows:

a. Wash the precipitate with 50 mL of distilled water, and add the washings to the filtrate.
b. Wash the precipitate with 50 mL of petroleum ether, and dry the crucible at 66° C to 93° C (150° F to 200° F).
c. Determine and record the increase in weight of the crucible to within 0.2 mg.

6.11 Process the filtrate as follows:

a. Weigh a clean centrifuge tube to within 0.2 mg.
b. Transfer the filtrate to the tube, and centrifuge the tube for 15 minutes at 1500 rpm (min.).
c. After centrifuging, decant the oil and water layers to suitable separate containers.

6.12 Process the oil layer from the centrifuge tube as follows:

a. Wash the oil with 25 mL portions of distilled water until the water is neutral to litmus. Save the water from this washing.
b. Examine the oil for insolubles, and remove any that still exist, using a combination of filtration, centrifuging, and solvent extraction as necessary.
c. When all insolubles have been removed, dry the oil with anhydrous sodium sulfate.
d. Determine the acid number of the oil by ASTM D 974, and calculate the change from the original acid number.
e. Determine the kinematic viscosity of the oil by ASTM D 445, and calculate the change from the original viscosity.
f. Determine the color of the oil by ASTM D 1500.

6.13 Process the water layer from the centrifuge tube and the washings as follows:

a. Combine the water from the centrifuge tube with the water from the washings.

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b. Determine the acid number of this water (based upon the original weight of the oil sample) by ASTM D 974.

6.14 Determine the weight of any insolubles remaining in the centrifuge tube as follows:

a. Add 50 mL of new test oil to the tube, and centrifuge until the oil is clear.
b. Carefully decant the oil, and dry the tube in the oven to remove all traces of water.
c. Again wash the contents of the tube with new test oil, centrifuge until clear, and decant the oil.
d. Wash the residue with petroleum ether (to remove the remaining oil); centrifuge, decant, and dry the tube in the oven.
e. Determine the increase in weight of the tube to within 0.2 mg.

6.15 Calculate the percentage (by weight) of the insoluble in the oil (see 7.1).

6.16 Remove the copper strip from the fluid container, and process it as follows:

a. Wash the strip with petroleum ether, warm n-Hexane, and warm 1,1, 1-trichloroethane and allow it to dry in air. See note 1 (see 6.6) and note 2.

Note 2. Caution. 1,1,1-trichloroethane is toxic. Do not permit it to come in contact with the skin or breathe its fumes. Use only in well-ventillated area.

b. Determine the weight change of the strip to within 0.2 mg. Calculate the change in weight per square centimeter of total surface.
c. Examine the strip under 20X magnification, and record any visible signs of corrosion.
d. Again wash the strip with petroleum ether, warm n-hexane, and warm 1,1,1-trichloroethane. While washing, scrub the strip with the short-bristled brush. Allow the strip to air dry, and reweigh to within 0.2 mg.
e. Repeat this washing until the strip reaches a constant weight.
f. Determine the weight loss of the strip (after brushing) from its originally polished condition.
g. Calculate the loss in weight per square centimeter of total surface.

7. CALCULATIONS

7.1 Calculate the percentage (by weight) of the insoluble in the oil as follows:

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$$\text{percent insolubles} = \underline{100(A + B)}$$

A = Increase in weight of Gooch crucible.
B = Increase in weight of centrifuge tube.
w = Original weight of oil sample.

8. REPORTING

8.1 Report the following:

a. Weight change of the metal strip before brushing.
b. Weight change of the metal strip after brushing.
c. Change in acid number of the sample.
d. Acid number of the water layer after hydrolysis.
e. Change in viscosity of the oil.
f. Weight of insoluble formed during hydrolysis.
g. Color of the oil after hydrolysis.
h. General appearance of the sample after hydrolysis.

9. PRECISION

9.1 Precision data have not been developed for this method.

Method Prepared By:

Army - AR - 1986

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METHOD 3458.1
September 30, 1986

LOW TEMPERATURE STABILITY TEST FOR OIL

1. SCOPE

1.1 This method is used for determining the tendency of components of finished oil blends to be incompatible or to form gels during low-temperature exposure.

2. SUMMARY

2.1 The test consist of refrigerating the sample for 72 hours at the temperature required by specification, and examining it visually for evidence of gelling, separation, crystallization, and clouding.

3. SAMPLE SIZE

3.1 Approximately 100 mL of oil to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Sample bottle, clear-glass 120 mL, with stoppers

4.2 Cold box, capable of maintaining the specified temperature within ±6° C.

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

6. PROCEDURE

6.1 pour sample into bottle, and store bottle for 72 hours at the temperature of (±6° C) required by the specification.

6.2 At the end of 72 hours, remove the container from the cold box, and immediately examine the sample visually for evidence of gelling, separation, or crystallization.

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

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8.1 Report the oil as unstable at the specified temperature, if there is any evidence of gelling, separation, or crystallization; if there is no such evidence, report the oil as stable. Also report the presence of dense cloud, if any, that does not settle out.

9. PRECISION

9.1 Precision data have not been developed for this method.

Method Prepared by:

Army - ME - 1986

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METHOD 3459.1
September 30, 1986

LOW TEMPERATURE STABILITY

1. SCOPE

1.1 This method is used for determining the stability (at low temperature) of finished fluid blends.

2. SUMMARY

2.1 The test consists of storing a sample for the time and at the temperature required by the specification, agitating it, comparing its turbidity with a standard, and checking it for evidence of gelling, crystallization, or solidification.

3. SAMPLE SIZE

3.1 Approximately 240 mL of test fluid.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Cooling apparatus, capable of maintaining the specified temperatures.

4.2 Sample bottle (2), clear-glass, 250-mL, with cork stoppers.

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Methyl-alcohol-glycerine (technical grade), 1:1 solution (by volume) [1,3,01.

5.3 Turbidity standard, prepared within 30 minutes of use, as follow:

a. Pour 25 mL of 0.00322 - molar barium chloride into a 250-mL volumetric flask [0,0,2].
b. Add 125 mL of 0.050N sulfuric acid, and shake well to insure complete precipitation [3,0,2].
c. Add approximately 25 mL of 1N sodium hydroxide to make solution alkaline [3,0,1].
d. Add distilled water to bring total volume to 250 mL.
e. Pour solution into a sample bottle, and seal it tightly with stopper.

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Note 1. For red hydraulic liquids, in place of plain distilled water, use distilled water containing 200 ppm red dye (National Erie Bordeaux B, manufactured by National Aniline Division of Allied Chemicals and Dye Corporation, or equivalent).

6. PROCEDURE

6.1 Clean sample bottles, and dry at approximately 100° C for 24 hours (min).

6.2 Pour sample into bottle, and seal bottle tightly with stopper.

6.3 Store sample at the specified temperature for the specified number of hours.

6.4 Before end of storage period, cool the methyl-alcohol-glycerine solution to -54° C (-65° F).

6.5 Within 5 minutes of making comparison, shake turbidity standard vigorously for 10 seconds, and pour into the other sample bottle.

6.6 At the end of the storage period, remove sample from cold storage and shake vigorously for approximately 10 seconds.

6.7 Dip specimen into methyl-alcohol-glycerine solution to eliminate frosting (if necessary), and within one minute of removal from cold storage, compare sample visually with turbidity standard.

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Report turbidity of sample as less than, more than, or equal to the standard. Also report any evidence of gelling, crystallization, or solidification of the sample.

9. PRECISION

9.1 Precision data have not been developed for this method.

Method Prepared by:

Army - NADC - 1986

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METHOD 3463.2
September 30, 1986

STABILITY OF GREASE IN HOT WATER (WATER IMMERSION)

1. SCOPE

1.1 This method is used for determining the stability of grease in the presence of hot water.

2. SUMMARY

2.1 The method consists of immersing the sample in boiling water for 10 minutes, and checking the water for cloudiness or other evidence of emulsification of the sample.

3. SAMPLE SIZE

3.1 Approximately 5 g of grease to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Beaker, 600-mL.

4.2 Stirring rod, glass.

5. MATERIAL

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Distilled water.

6. PROCEDURE

6.1 Place approximately 500 mL of distilled water in the beaker, and heat it to gentle but active boiling.

6.2 Apply a single lump or globule of the sample to one end of the stirring rod.

6.3 Immerse the sample in the boiling water for 10 minutes while visually examining the water, and note the presence of cloudiness, or other evidence of emulsification of the sample.

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

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8. REPORTING

8.1 Report the presence of cloudiness, or other evidence of emulsification of the sample.

9. PRECISION

9.1 Precision data have not been developed for this method.

Method Prepared by:

Navy - NADC - 1986

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METHOD 3465.1
September 30, 1986

STORAGE STABILITY TEST OF FLUIDS AND LUBRICANTS

1. SCOPE

1.1 This method is used for determining the storage stability of aircraft turbine lubricants and hydraulic fluids. It consists of storing the lubricant in darkness for 12 months at 23.8 +3° C (75° +5° F), and then inspecting it for changes in homogeneity.

2. SUMMARY

2.1 This method duplicates a typical warehouse environment, and it determines if twelve months of static storage at moderate temperatures can affect product homogeneity by producing cloudiness, sediment, suspended matter, discoloration, etc. The presence or absence of observed visual changes in homogeneity is a reliable and economical indicator of extended storage stability.

3. SAMPLE SIZE

3.1 Approximately 4 L (one gallon) of the lubricant or fluid to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Chamber, constant-temperature 24 +3° C (75° ±5° F), free of vibration (such as caused by heavy traffic).

4.2 Jar, clear-glass, 3.8 L (1 gallon), wide-mouth with cap.

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment measures, and spill practices of each chemical are explained.

5.2 Aluminum foil, commercial grade.

5.3 Scouring powder, commercial grade.

5.4 Distilled water.

6. PROCEDURE

6.1 Clean the jar and cap by scrubbing with scouring powder and rinsing with tap water.

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Complete the rinsing with distilled water, and air dry the jar and cap (using an oven at 104° C if desired).

6.2 Line the cap with aluminum foil.

6.3 Pour approximately 3.8 L of the sample into the jar, and replace and tighten the cap.

6.4 Wrap aluminum foil around the jar to exclude all light from the sample.

6.5 Identify the contents of the glass jar (including type of sample, date stored, and any other useful information).

6.6 Store the sample for one year in the storage chamber 24 ±3° C (75° ±5° F).

6.7 At the end of the 12-month period, remove the jar from the chamber and take off the aluminum wrapper, being careful not to shake or agitate the contents.

6.8 Visually examine the sample, and note the presence of cloudiness, sediment, suspended matter, discoloration, or other changes in homogeneity.

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Report the presence of cloudiness, sediment, suspended matter, discoloration, or other changes in homogeneity.

9. PRECISION

9.1 Precision data have not been developed for this method.

Method Prepared by:

Air Force - SFTL - 1986

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METHOD 3467.1
September 30, 1986

STORAGE STABILITY OF LUBRICATING GREASE

1. SCOPE

1.1 This method covers a technique used for measuring the stability of a lubricating grease after a definite storage period at an elevated temperature.

Note 1. The storage period and temperature at which the grease is to be stored must be given in the specification referencing this test method.

2. SUMMARY

2.1 A determination for consistency (unworked and work penetration) is made after the storage interval and the results compared with data established prior to the storage interval.

3. SAMPLE SIZE

3.1 Approximately 1 kg of grease, sufficient to fill two standard grease cups (ASTM D 217) with test sample.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 TWO standard grease worker CUPS, grease worker, penetrometer, etc. (ASTM D 217).

4.2 Oven, gravity - convection.

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

6. PROCEDURE

6.1 Fill one standard grease worker CUP with the test sample and remove excess grease to insure that the surface of grease is flush with the top of the cup. (Sample for unworked penetration, see 6.6.)

6.2 Fill another cup with sufficient quantity of grease to insure over filling of the cup. (Sample for worked penetration, see 6.6.)

6.3 Cover the samples with aluminum foil.

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6.4 Place the grease filled cups in an oven at the designated test temperature for the required storage interval.

6.5 After completion of storage interval, remove the cups from the oven and allow to cool to 25° C (77° F).

6.6 Conduct unworked and worked penetration measurements on the grease samples in accordance with ASTM D 217.

7. CALCULATIONS

7.1 Calculate the change in worked penetration after storage as follows:

$C = A-B$
c = Change in worked penetration
A = Penetration before storage
B = Penetration after storage

8. REPORTING

8.1 Report the unworked and worked penetration after storage. Report the difference in worked penetration before and after storage as the change in worked penetration.

9. PRECISION

9.1 Precision data have not been developed for this method.

Method Prepared by:

Navy - NADC - 1986

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HOMOGENEITY AND MISCIBILITY OF OILS

1. SCOPE

1.1 This test determines if an oil is and will remain homogeneous, and if it is miscible with certain standard reference oils after being submitted to a prescribed cycle of temperature changes.

2. SUMMARY

2.1 Using standard reference oils, an oil sample is tested to determine if it is and will remain homogeneous and if it is miscible with the reference oils. A sample oil is mixed thoroughly with a reference oil and heated. When the oils reach room temperature, they are observed for color and evidence of separation. The pour point is determined for each oil. A series of tests are made in cooling baths at 12° C above the expected pour point. The temperature is read at a multiple of 3° C. The test jar is removed and it is tilted to determine if there is movement of the oil. The test jar is placed in successively lower cooling baths until the oil has ceased to flow. When the oil does not flow when the jar is tilted, hold the jar in a horizontal position for 5 seconds and observe the oil. If the oil shows any movement under these conditions, place the jar in the cooling bath at the next lower temperature. The test is continued under these conditions until there is no movement when the jar is tilted in a horizontal position. The thermometer reading is recorded at this temperature. The samples are thawed. When the cloudiness has barely disappeared, the color and evidence of separation is recorded. After the samples reach room temperature, the thermometers are removed and the samples are heated to 232° C in an oil bath. The sample jars are corked and stored at their pour points for 18 to 24 hours. When the cloudiness has barely disappeared, after heating, the color and evidence of separation is recorded. The last procedure is repeated. The data is recorded on the Homogeneity and Miscibility Test forms.

3. SAMPLE SIZE

3.1 Approximately 300 mL of oil to be tested.

4. REFERENCE, STANDARDS, AND APPARATUS

4.1 Test jar. A test jar of clear glass, cylindrical form, flat bottom, approximately 3.0 to 3.5 cm I.D. and 12 to 13 cm in height.

4.2 Thermometers. -80° C to ±21° C range, conforming to ASTM El.

4.3 Cork. To fit the test jar, bored centrally to take the test thermometer.

4.4 Jacket. Glass or metal, water tight, of cylindrical form, flat bottom, about 12 cm in depth, with inside diameter 0.9 to 1.2 cm greater than the outside diameter of the test jar.

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4.5 Disk. Cork of felt, 0.6 cm in thickness of the same diameter as the inside of the jacket.

4.6 Gasket. A ring gasket, about 0.5 cm in thickness, to fit snugly around the outside of the test jar and loosely inside the jacket. The purpose of the ring gasket is to prevent the test jar from touching the jacket.

4.7 Bath. A cooling bath of a type suitable for obtaining the required temperatures.

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Six reference oils. Information concerning the availability of the reference oil may be obtained from USA Belvoir Research, Development, and Engineering Center, ATTN: STRBE-VF, Ft. Belvoir, VA 22060-5606.

6. PROCEDURE

6.1 Shake oil sample well and pour into six sample jars to 3.2 cm mark and one sample jar to the 7.5 cm mark. Add a reference oil to each of the six sample jars to the 7.5 cm mark.

6.2 Mix the oil thoroughly and heat to 46° C in a water bath.

6.3 After the oils reach room temperature, observe and record the color and evidence of separation.

6.4 Determine and record the pour point of each oil.

a. Maintain the temperature of the cooling bath at -1° C to 2° C. Support the jacket, containing the test jar, firmly in a vertical position in the cooling bath so that not more than 2.5 cm of the jacket projects out of the cooling medium.
b. Starting at a temperature 12° C above the expected pour point remove the test jar from the jacket carefully and tilt it just enough to ascertain whether there is a movement of the oil in the test jar. Take a test thermometer reading when the temperature is 3° C lower then the previous reading. The complete operation of removal and replacement shall require not more than 3 seconds. If the oil has not ceased to flow when its temperature has reached 10° C, place the test jar in the jacket in a second bath maintained at a temperature of -18° C to -15° C. If the

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oil has not ceased to flow when its temperature has reached -7° C, place the test jar in the jacket in a third bath maintained at a temperature of -35° C to -32° C. For determinations of very low pour points, additional baths should be maintained with successively lower temperature differentials of about 17° C. In each case transfer the test jar when the temperature of the oil reaches a point of 28° C above the temperature of the new bath. At no time place the cold test jar directly in the cooling medium. As soon as the oil in the test jar does not flow when the jar is tilted, hold the test jar in a horizontal position for exactly 5 seconds, as noted by a stop watch or other accurate timing device, and observe carefully. If the oil shows any movement under these conditions, place the test jar immediately in the jacket and repeat a test for flow at the next temperature 3° C lower.

c. Continue the test in this manner until a point is reached at which the oil in the test jar shows no movement when the test jar is held in a horizontal position for exactly 5 seconds. Certain lubricating oils tend to move as a whole and should be very closely observed. Record the reading of the test thermometer at this temperature, corrected for error if necessary.

6.5 Allow the samples to thaw; and when the cloudiness has barely disappeared observe and record the color and any evidence of separation.

6.6 When the samples reach room temperature, place them in an oil bath after removing the thermometers. Heat the bath to 232° C and immediately remove the samples.

6.7 Cork the samples and store them at their respective pour points for 18 to 24 hours.

6.8 Remove the samples and allow them to thaw. When cloudiness has barely disappeared, observe and record the color and any evidence of separation.

6.9 Repeat the last operation when the samples reach room temperature.

6.10 Note the homogeneity and miscibility of the samples.

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Report the data on the homogeneity and miscibility test forms.

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9. PRECISION

9.1 Precision data have not been developed for this method.

Method Prepared by:

Army - ME - 1986

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ENGINE OIL HOMOGENEITY AND MISCIBILITY TEST

COMPANY ____________________ SAMPLE NO. ____________________
VISCOSITY GRADE ____________________ TEST NO. ____________________
DATE ____________________

QUALIFIED OIL ADDED TO SAMPLE	NONE	1-30	2-30	3-30	4-30	5-30	6-30
BEFORE TREATMENT							
EVIDENCE OF SEPARATION							
LOCATION							
COLOR							
PARTICLE SIZE							
COLOR OF OIL							
COOLED TO POUR POINT, “C							
WARMED JUST ABOVE CLOUD POINT							
EVIDENCE OF SEPARATION							
LOCATION							
COLOR							
PARTICLE SIZE							
COLOR OF OIL							
HEAT TO 232” C COOL TO POUR POINT STORE 24 HOURS WARM ABOVE POUR POINT							
EVIDENCE OF SEPARATION							
LOCATION							
COLOR							
PARTICLE SIZE							
COLOR OF OIL							
WARM TO ROOM TEMPERATURE							
EVIDENCE OF SEPARATION							
LOCATION							
COLOR							
PARTICLE SIZE							
COLOR OF OIL							

ABBREVIATIONS

EVIDENCE OF SEPARATION

D	DEFINITE
N	NONE OR DOUBTFUL

LOCATION

T	NEAR TOP
B	NEAR BOTTOM
F	FILAMENT
u	UNIFORMLY DISTRUSTED

COLOR

w	WHITE OR VERY LIGHT
Y	YELLOW
B	BLACK

PARTICLE SIZE

s - SMALL, AS IN CLOUD OR HAZE
s_P - SPECKS OR LARGER PARTICLES

OIL PHASE COLOR

d - TOO DARK TO SEE THROUGH
m - TRANSPARENT BUT DARK
1 - LIGHT

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METHOD 3472
September 30, 1986

SONIC SHEAR STABILITY OF POLYMER-CONTAINING OILS

1. SCOPE

1.1 This method covers the evaluation of the shear stability of an oil containing polymer in terms of the permanent loss in viscosity that results from irradiating a sample of the oil in a sonic oscillator. This method may be useful in predicting the continuity of this property in an oil where no change is made in the base stock or the polymer. It is not intended that this method serve to predict the performance of polymer-containing oils in service.

2. SUMMARY

2.1 A convenient volume of polymer-containing oil is irradiated in a sonic oscillator for a period of time and the changes in viscosity are determined by ASTM method D 445 - IP 71, Test for Determination of Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity). A standard polymer-containing oil (ASTM Reference Fluid A)1/ is run frequently to assure repeatable performance of the equipment.

2.2 This method permits the evaluation of shear stability with minimum interference from thermal and oxidative factors present in some applications.

3. SAMPLE SIZE

3.1 25 to 50 mL of test oil.

4. REFERENCES, STANDARDS AND APPARATUS.

4.1 Oscillator - A 10-kHz oscillator as described in Appendix Al.

4.2 Auxiliary Equipment - To facilitate uniform performance, the following auxiliary equipment is recommended.

4.2.1 Voltage Regulator,2/ 1000-V•A capacity, capable of controlling the output voltage within 2 percent.

4.2.2 Automatic Timer, such that irradiation times can be preset in the range from 2 to 120 minutes.

4.2.3 Water-circulating system, with provision to measure water flow rate and to maintain cooling water at some predetermined temperature, for example, 38 +3° C (100 +5° F)

1/ This fluid may be obtained from Rohm and Haas Co., Research Laboratories, Spring House, PA 19477.

2/ Some of the parts for existing equipment are obtainable from the Raytheon co., Richards Ave., South Norwalk, Corm 06856, or Sola Electric Co., Chicago, ILL 60656.

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4.2.4 Sonic-Insulated Box, with opening at top, to enclose the treatment unit and reduce the noise level in the laboratory.

4.2.5 Cooling Fan, mounted in the insulated box, to maintain a satisfactory temperature.

4.3 Viscometer - Any viscometer and bath meeting the requirements of method D 445.

5. Materials

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references, and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures , and spill practices of each chemical are explained.

5.2 The primary reference fluid is ASTM Reference Fluid A,1/ a petroleum oil containing a polymer capable of being broken down by turbulence at high rates of shear. This oil has the following typical properties:

	Petroleum Base	Reference Fluid A
Viscosity at 210 F. cSt	5.2	11.0
Viscosity at 100 F, cSt	31	62.0
Polymer concentrate, weight percent	l..	7.8

6. PROCEDURE.

6.1 Calibration of Apparatus

6.1.1 The reference fluid provides a practical way to define the performance (severity level) of a sonic oscillator unit so that satisfactory comparison can be made between tests run on different days in the same unit and between tests run with different units.

6.1.2 The loss in viscosity observed for a given polymer-containing oil on irradiation in an oscillator unit depends on a number of factors. Decreasing the sample volume, increasing the irradiation time, and increasing the power setting are effective ways of increasing the severity of the test. The choice of gasket material and tightness of fit are also important3/ Tuning to

1/ See footnote 1 on p. 1.

3/ Use of 3/64-inch TFE-fluorocarbon gasket tightened to a torque of 60 lbžft (81 Nom) or more has been found satisfactory Good success has also been reported with gaskets made of copper-tin or copper-lead.

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resonance is also critical with maximum cavitation, sound, and RF amperage usually occuring at nearly the same setting of the "tune" control (frequency). The procedure described in 6.1.3 and 6.1.4 is recommended for establishing a reproducible performance level for a given unit.

6.1.3 With the “tune” control set to give maximum current reading, make four successive 10-minute runs on 30 mL samples of the reference fluid using power settings to give output currents between 0.7 and 1.2 A. For each run, calculate the percentage loss in viscosity at 38° C (100° F). From a plot of the percentage loss in viscosity versus power setting, find the setting corresponding to a stated loss in viscosity; for example, 15 percent. Use this setting for subsequent tests run that day. Future calibration work may be lightened by adjusting the power setting up or down as indicated from an initial run at this same level. While the power setting required to produce a stated viscosity loss may vary from day to day, this method of standardizing the operating severity level of the unit makes it possible to compare results obtained on different days.

6.1.4 This procedure may be used to establish severity levels appropriate for the requirements of a number of specific applications. Sample size from 25 to 50 mL have been used successfully at various power settings. Once the conditions for a given severity level have been established, it is possible to compare the shear stability of fluids at one or many irradiation times.

NOTE 1 - For interlaboratory comparisons, the laboratories should define a common severity level in terms of a specified viscosity loss of the reference fluid occurring in a given irradiation time with a given volume of sample. For example, "the reference fluid should undergo a viscosity loss of 15 percent when a 30 mL sample is treated for 10 minutes."

Alternatively, two or more laboratories may define equivalent operating conditions by a curve of percent viscosity loss of the reference fluid versus irradiation time. Power setting and sample size are varied until each laboratory finds a combination that satisfies two or more points on the reference curve. This procedure provides a comparison of the shear stability of an unknown fluid with that of the reference fluid over a range of irradiation times.

6.2 Test procedure.

6.2.1 Connect and turn on the cooling water adjusting the temperature to the desired value. Turn on the filament switch. If the oscillator has not been in use, add 30 mL of light oil to the cup and start the oscillator by turning on the plate switch. Adjust the power setting to the desired level (see 6.1) and adjust the "tune” control to that peak in the output current where maximum frying noise occurs accompanied by cavitation of the liquid in the cup (Note 2). Allow 30 minutes for warm-up, then shut off the plate switch and disconnect the cooling water (Note[3]). Remove the warm-up oil, rinse the cup several times with light petroleum naphtha or other suitable hydrocarbon solvent, and dry the cup with clean air or vacuum.

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NOTE 2 - It is recommended that the controls not be changed once the optimum levels have been established. Slight changes in power setting do not affect the tunning appreciably.

NOTE 3 - Care should be taken to avoid damage to the rod by bumping against any hard object. The cup may be cleaned without removing from the stand by the use of an aspirator and a wash bottle containing solvent.

6.2.2 Add the desired amount of sample to the cup with a graduated cylinder or volumetric pipet with enlarged tip or syringe. Readjust the circulating water temperature to 38 +3° C (100 ±5° F) and allow 10 to 15 minutes for the sample to reach equilibrium temperature. Set the timer and turn on the plate switch. At the close of the preselected irradiation time, turn off the plate switch, and remove the sample for viscosity determinations (Note 4). Rinse out the cup with solvent, dry with clean air or vacuum, and replace in unit. Connect the cooling water and the unit is ready for the next run. If there are no more runs to be made, shut down the unit by turning off the filament switch and the water supply.

NOTE 4 - The sample may be taken without removing the cup from the stand by using a volumetric pipet.

6.2.3 Determine the viscosity of the oil by Method D 445 before and after irradiation.

7. CALCULATIONS.

7.1 Calculate the percentage loss of viscosity as follows:

Viscosity loss, percent $= [(V_o - V_1)/V_o] \times 100$ where:

V_o = viscosity of oil before irradiation, cSt, and

V_1 = viscosity of oil after irradiation, cSt.

8. REPORTING.

8.1 Report the average of two runs as the percentage loss of viscosity at 38° C (100° F) in the specified irradiation time.

NOTE 5 - It may be convenient to record the percentage loss in viscosity of the reference fluid under the same conditions of power setting and irradiation time.

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9. PRECISION.

9.1 The following criteria should be used for judging the acceptability of results (95 percent confidence):

9.1.1 Repeatability - Duplicate results by the same operator using the same unit should be considered suspect if the ratio of the larger to the smaller result ecceeds 1.26.

9.1.2 Reproducibility - Results submitted by two laboratories should be considered suspect if the ratio of the larger to the smaller result exceeds 1.41.

Method prepared by:
NAVY - NAPC -1986

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APPENDIX

Al. RAYTHEON MAGNETOSTRICTIVE OSCILLATOR - MODEL DF-101

All Model DF-101 is a 250-W, 10-kHz magnetostrictive oscillator. Its operation is based on the fact that a magnetic material changes its dimensions when placed in a changing magnetic field. This so-called magnetostrictive effect is utilized by attaching a diaphragm to a magnetic rod. The diaphragm forms the bottom of the test cup and the rod is placed within a coil of wire connected to an electronic oscillator.

A1.2 The apparatus Note Al consists of two parts, a treatment unit and a driver unit. The treatment unit consists of the sample cup with a vibrating diaphragm for a bottom, a laminated nickel rod, a field coil encased in a stand for holding the rod ‘and cup, and a built-in system for water cooling. An acoustic transformer linkage magnifies the small vibrations of the magnetostrictive rod into relatively large vibrations of the diaphragm. The driver comprises a power supply and an electronic oscillator which can be tuned to the resonant frequency of the cup and rod assembly and the sample under test.

NOTE Al - This apparatus is shown in ASTM Standards on Petroleum Products and Lubricants, Vol 1, Oct. 1961, P. 1160.

NOTE AZ - The cup and rod assembly must be handled with great care as its magnetostrictive property can be ruined by careless handling.

NOTE A3 - Caution - The driver cabinet contains circuits operating at 2000 V and a filter condenser capable of holding under abnormal conditions, a dangerous charge for a long time after the whole circuit has been disconnected from a power source.

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METHOD 3480.1
September 30, 1986

VOLATILITY OF BLENDED OILS

1. SCOPE

1.1 This method is used for determining the volatility characteristics of a blended oil.

2. SUMMARY

2.1 The test consists of heating the sample for 24 hours at 105° C (221° F), and determining its percentage of weight lost as result of evaporation.

3. SAMPLE SIZE

3.1 Approximately 10 grams of test oil.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Oven, gravity-convection, 105° ±0.5° C (221 ±1° F).

4.2 Evaporating disk, aluminum foil, 5.7 cm (2-1/4-in) ID, 1.6 cm (5/8-in) deep.

4.3 Balance, sensitivity 0.1 mg.

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Test oil.

6. PROCEDURE

6.1 Heat oven 105° +0.5° C (221° ±l° F).

6.2 Weigh evaporating dish to within 0.2 mg.

6.3 Pour sample into evaporating dish, and weigh dish and contents to within 0.2 mg. Then place dish into heated oven for 24 hours.

6.4 At the end of 24 hours, remove dish, and allow sample to cool to room temperature.

6.5 Determine the evaporation loss of sample within 0.2 mg (see 7.1).

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7. CALCULATIONS

7.1 Calculate the evaporation loss of the sample as follows:

$$\text{Evaporation loss, percent by weight} = \frac{S-W}{S} \times 100$$

where:

S = initial weight of sample, in g.
W = weight of sample, in g after the test.

8. REPORTING

8.1 Report the evaporation loss to the nearest 0.2 mg.

9. PRECISION

9.1 Precision data have not been developed for this method.

Method Prepared By:

Air Force - AFWAL/POSL - 1986

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METHOD 3500.1
September 30, 1986

MONOBASIC ACID COMPONENTS OF SYNTHETIC ESTER LUBRICANTS BY GAS CHROMATOGRAPHY

1. SCOPE

1.1 This method covers the determination of monobasic acid components of ester lubricants by gas chromatography. The method is intended for use on any neopentyl polyol ester lubricants where the acid components contain from 4 to 10 carbon atoms.

2. SUMMARY OF METHOD

2.1 The lubricant to be analyzed is hydrolyzed with potassium hydroxide, followed by hydrochloric acid treatment to evolve the acids. After ether extraction of the acids, the acids are physically separated by gas chromatography and are identified by comparing them to corresponding acids separated under identical operating conditions from a reference standard acid mixture of known composition. The acids are determined quantitatively by also using the chromatogram of the sample which is interpreted by comparing peak heights with those obtained on the reference standard mixture of pure acids of known concentration.

3. SAMPLE SIZE

3.1 Approximately 20 g of sample are required for duplicate determination.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Chromatograph and recorder - A chromatography with a thermal conductivity detector and a strip-type recorder may be used provided that the butyric and isovaleric acid components in the standard acid mixture (see 5.21) can be satisfactorily resolved when the column of 6.1.1 is used and the conditions of 6.1.2 are met. In addition, the equipment shall have sufficient sensitivity to meet the precision requirements of section 9.

4.2 Two columns 183 cm (6 feet) stainless steel 0.635 cm (0.25 inches) O.D. packed with the mixture and in the manner described in section 6.1.1.

4.3 Erlenmeyer flask, wide mouth 3.7 cm (l-46 inches) I.D., 250-mL.

4.4 Reflux condenser, spiral, block tin.

4.5 Electric hotplate.

4.6 Steam bath or flash evaporator.

4.7 Crystallizing dish, 9.0 cm diameter x 5.0 cm deep.

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4.8 Graduated cylinders, 50- and 100-mL.

4.9 Separator funnel, pear-shaped, 250-mL.

4.10 Erlenmeyer flask, narrow mouth, glass stoppered, 300-mL.

4.11 Erlenmeyer flask, narrow mouth, standard taper joint, 300-mL.

4.12 Vigreux fractionating column, standard taper joint at lower end complementary to joint of flask described in 4.11.

4.13 Syringe, 10 microliter capacity, graduated in 0.2 microliters.

4.14 Analytical balance, 200 g capacity.

4.15 Vacuum oven.

4.16 Vacuum pump.

4.17 Electric stirrer.

4.18 Electric vibrator.

4.19 Filter, size 4.7 cm diameter, pore size 10 micrometers.

4.20 Stainless filter holder and funnel.

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Potassium hydroxide, reagent grade [3,0,1].

5.3 Ethyl alcohol, 95% [0,3,0].

5.4 Distilled water.

5.5 Hydrochloric acid, dilute, made by diluting one volume of reagent grade acid, sp. grav. 1.18, with an equal volume of water [3,0,0].

5.6 Ethyl ether, reagent grade [2,4,1].

5.7 Sodium sulfate, anhydrous, reagent grade [u,u,u].

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5.8 Diethyleneglycol adipate polyester [u,u,u].

5.9 Gas Chrom P, 60 to 80 mesh, acid-based washed, or equivalent.

5.10 Chloroform, reagent grade [2,2,0].

5.11 Phosphoric acid, reagent grade, 85% [2,0,0].

5.12 Helium, oil free.

5.13 Butyric acid, reagent grade [2,2,0].

5.14 Isovaleric acid, reagent grade [u,u,u].

5.15 Valerie acid, reagent grade [u,u,u].

5.16 Caproic acid, reagent grade [2,1,0].

5.17 Heptylic acid, reagent grade [u,u,u].

5.18 Caprylic acid, reagent grade [u,u,u].

5.19 Pelargonic acid, reagent grade [u,u,u].

5.20 Capric acid, reagent grade [u,u,u].

5.21 Standard acid mixture prepared as follows:

5.22 By means of an analytical balance successively weigh into a 125 mL glass stoppered bottle all the acids listed in 5.13 through 5.20 in the amounts indicated in the table below. These listed weights give concentrations of the mixed acids in terms of the indicated individual mole-percent.

Acid	Number of carbon1/ atoms in acid	Weight in grams2/	Mole percent
Butyric	4	4.41	10
Isovaleric	5	5.11	10
Valerie	5	5.11	10
Caproic	6	5.81	10
Heptylic	7	6.51	10
Caprylic	8	10.82	15
Pelargonic	9	11.87	15
Capric	10	17.23	20

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1/ For convenience, these acids hereafter in this method will be referred to by the number of their carbon atoms; e.g., butyric as C_4, isovaleric as iso C_5.

2/ These weights, or some multiple of them are recommended as giving a satisfactory chromatogram of the acids relative to peak heights.

6. PROCEDURE

6.1 Preparation of apparatus.

6.1.1 Column preparation.

6.1.1.1 Packing for chromatographic column prepared as follows:

6.1.1.1.1 Dissolve 6.0 g of diethyleneglycol adipate polyester in 150 mL of chloroform with rapid stirring.

6.1.1.1.2 Add 1.06 g of phosphoric acid to the mix and continue stirring until the acid is completely dispersed.

6.1.1.1.3 Add 23.1 g of Gas Chrom P to the mix and continue stirring for 10 minutes.

6.1.1.1.4 Remove bulk of chloroform from mix by flash evaporator or on steam bath.

6.1.1.1.5 Remove remaining chloroform by heating in a vacuum oven for 2 hours at 200° C and 0.1 cm pressure.

6.1.1.1.6 Cool and load into chromatographic column using vibrator on column to ensure uniform and complete packing.

6.1.2 Chromatograph - Mount the columns in the chromatography and use the programmed temperature operation. For this operation, set the controls of the chromatography for an initial column temperature of 140° C (284° F), a final column temperature of 210° C (410° F), a temperature rate of 8° C (46° F)/min., a hold time of 20 minutes at the final temperature, an injection port temperature of 220° C (428° F), a detector temperature of 220° C (428° F), a bridge current of 150 mA, and the helium flow at 30 ±5 ml per minute. The temperature programming must start immediately after injection.

6.2 Test procedure.

6.2.1 Hydrolysis of lubricant to be analyzed - Weigh 10 g of the lubricant into a 250-mL wide-mouth Erlenmeyer flask, add a solution consisting of 8 g of potassium hydroxide and 15 mL water, followed by 60 mL ethyl alcohol. Swirl to mix contents. Insert spiral reflux condenser in mouth of flask, connect condenser to cold water line, place flask on hot plate, adjust heat so that contents boil gently and continue refluxing for 16 hours.

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6.2.2 Recovery of acids - Transfer contents of flask to crystallizing dish, rinse flask 3 or 4 times with 15 mL water and add washings to dish. Take to complete dryness on steam bath, 1/ add 15 mL water to dish and warm to dissolve salts. Transfer solution to separator funnel, rinse dish 3 or 4 times with 15 mL water, and add washings to funnel. Place funnel in ice bath, add 50 mL of cold dilute hydrochloric acid (1:1), cool for 10 minutes and swirl to complete mixing of contents. Add 50 mL of ethyl ether, shake vigorously for 2 minutes, venting frequently to relieve pressure. Let phases separate completely and run the lower (water) phase into a second separator funnel. Run the upper (ether) layer into a 300-mL glass-stoppered Erlenmeyer flask. Add 50 mL of ethyl ether to the second funnel and re-extract the water layer as above, adding the ether layer to the 300-mL flask. Repeat the ether extraction of the water layer twice more in individual funnels, collecting the ether layers in the 300-mL flask. Discard the water layer. Add 35-40 g of sodium sulfate to the ether extract, shake and let stand a few hours or preferably overnight. Filter the ether solution through 10 micrometer filter membrane (using stainless filter and funnel) into a 300-mL Erlenmeyer flask with tapered joint. Rinse filter and funnel a few times with ethyl ether to ensure complete removal of acids from sodium sulfate. Add 6-10 granules of silicon carbide into the flask to avoid superheating, connect to Vigreux column and distill off the ether in a hot-water bath until the remaining solution is 20-25 mL stopper flask and retain for assay. Conduct recovery of acids under hood.

6.2.3 Preparation of chromatograms - Using standard acid mixture and the recovered acids, prepare chromatograms in the following manner: Inject 1 microliter of the standard acid mixture into the chromatography, mark for reference on recorder chart paper where recorder pen was located at the time of injection, and complete chromatogram. Examine chromatogram for peak heights of the acids. If the greatest peak height is approximately three quarters of the chart width, the dosage and attenuator settings are satisfactory. If not, adjust dosage and attenuator until the desired peak height is attained. In a similar manner inject one microliter of the recovered acids, obtain chromatogram and proceed as above until the peak height of the scan is satisfactory.

6.3 Identification and quantitative determination of recovered acids.

6.3.1 Identification of the acids recovered from the sample - On the chromatogram of the standard acid mixture, assign C_4 acid to first peak from reference mark on chart, designate next peak as iso-C_5 acid, then the successive peaks to C_5 through C_{10} acids in numerical order. Measure in mm the distances from reference mark to each peak and record each distance against the corresponding acid. These values are designated as the retention times of the acids. On the chromatogram of the recovered acids, measure distances from reference mark to each peak, compare with those obtained from the standard acid scan and identify each recovered acid accordingly.

1/ A flash evaporator may be used as an alternate for removal of the water and alcohol.

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6.3.2 Quantitative determination of the recovered acids - On the chromatogram of the standard acid mixture, draw a base line from the reference mark to that point on the scan which indicates the C_{10} acid has been eluted completely. From the base line measure each peak height in mm and sum all peak heights. Normalize each peak height by dividing each by the sum of the heights. Establish a correction factor for each acid by dividing the normalized peak height per mole of C_5 acid by the normalized peak height per mole of each component acid. On the chromatogram of the recovered acids, proceed as above up to and including the normalization of each peak height. Multiply the normalized peak height of each acid component by its appropriate correction factor to obtain a “corrected” height for each. To obtain the mole-percent of each acid, divide the “corrected” peak height of each by the sum of all the “corrected” heights times 100. Record each component to the nearest integral value. Examples of the foregoing calculations are illustrated in Tables 1 and 2.

TABLE 1. Standard acid mixture.

Chromatographic retention times and correction factors				
Acid	Retention time	Peak height	Normalized peak height	Correction factor
	(see 6.3.1) in mm (measured)	in mm (measured)	$\frac{\text{peak height of one component}}{\text{sum of peak heights of all components}}$	$\frac{\text{normalized peak height of } C_5 \text{ acid per mole}}{\text{normalized peak height of component acid per mole}}$
C4	70	168	11.6	1.14
iso C_5	74	187	12.9	1.02
C_5	84	192	13.2	1.00
C_6	98	182	12.6	1.05
C_7	115	155	10.7	1.23
C_8	136	212	14.6	1.36
C_9	162	169	11.7	1.69
C_{10}	196	184	12.7	2.08

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TABLE 2. Unknown acid mixture.

Chromatographic identification and mole-percent determination						
Identified acid	Retention time, mm (see 6.3.1)	Peak height, (measured)	Normalized peak height 1/	Correction factor (see Table 1)	"Corrected" height 2/	Mole-percent (rounded) 3/
C_4	71	5	1.2	1.14	1.4	1.2 = 1
iso C_5	0	0	0	0	0	0 = 0
C_5	84	165	40.0	1.00	40.0	34.4 = 34
C_6	99	84	20.4	1.05	21.4	18.4 = 18
C_7	115	87	21.1	1.23	26.0	22.4 = 22
C_8	136	21	5.1	1.36	6.9	5.9 = 6
C_9	162	50	12.1	1.69	20.4	17.6 = 18

1/ $\frac{\text{Peak height of one component}}{\text{sum of peak heights of all components}}$

2/ Peak height times correction factor.

3/ $\frac{\text{100 times “corrected” height of component}}{\text{sum of all “corrected heights}}$

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Report each component to the nearest integral value.

9. PRECISION

9.1 Repeatability - Replicate determinations shall not differ from one another by more than ±1 mole-percent.

9.2 Reproducibility has not been established.

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SWELLING OF SYNTHETIC RUBBERS

1. SCOPE

1.1 This method is used for determining the effect of petroleum products on synthetic rubber.

2. SUMMARY

2.1 The test consists of determining the volume of three standardized test rubber sheets by water displacement, storing them immersed in the sample for 168 hours at 70° C, then determining the average change in volume of the sheets.

3. SAMPLE SIZE

3.1 For liquid products: Approximately 300 mL of the liquid to be tested.

3.2 For greases: Approximately 400 g of grease to be tested.

4. REFERENCE, STANDARDS, AND APPARATUS

4.1 Container, heat-resistant, consisting of:

a. For liquid sample: Test Tube, 5 cm OD by 40 cm long. A graduated cylinder with these dimensions may be used provided it doesn't have a pouring spout.
b. For grease sample: Petri dish, 10 cm OD by 5 cm deep with cover (watch glass).

4.2 Balance, sensitivity 1 mg, suitable for weighing in both air and water.

4.3 Oven, gravity-convention, 70° C ±l° C (158° +2° F).

4.4 Spatula (for grease sample).

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Test sheets (3), rubber standard, type as required by the specification, approximately 2.5 by 5.1 by 0.19 cm. Samples of synthetic rubber stock should not be older than 6 months.

5.3 Alcohol, ethyl or methyl, anhydrous [1,3,0].

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5.4 Filter paper.

5.5 Distilled water.

6. PROCEDURE

6.1 Determine the water displacement of each test sheet to the nearest 1 mg by weighing each sheet in air, then in distilled water at 24 +3° C, recording the weights, and computing the difference between the weight in air and the weight in water for each sheet (see 7.1).

6.2 Fill container with sample, using the following:

a. For liquid sample: Approximately 20 mL of sample for each gram of total weight of test sheets.
b. For grease sample: Sufficient sample to fill container completely.

6.3 Blot dry each test sheet with filter paper, then immerse sheets completely in sample in container. For grease samples, immerse test sheets vertically, with 5 cm edge uppermost, and cover the container.

6.4 Store container in oven at 70° C +1° C (158° +2° F) for 168 hours +0.5 hours (approximately one week). For liquid samples, maintain a ratio of 20 mL of oil to each gram of test sheet. Make up oil must be the same temperature as the test fluid when added. For grease samples, check daily (except weekends), that the samples are in complete contact with test sheets and close any voids by using a spatula.

6.5 At the end of the storage period, cool the sample to 24° ±3° C. Then clean test sheets as follows:

a. Remove test sheets from sample and wipe them to remove most of the adhering sample.
b. Dip sheets in alcohol and wipe or blot them dry, using filter paper (or soft cloths). NOTE THE TIME.

6.6 Within 5 minutes of drying test sheets, redetermine the water displacement of each sheet as specified in 6.1.

7. CALCULATIONS

7.1 Compute the percentage change in volume of each rubber sheet as follows:

$$V = \frac{(A-B)\ 100}{B}$$

V = Change in volume, percent.
A = Displacement weight at conclusion of test, mg.
B = Displacement weight before immersion in sample, mg.

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8. REPORTING

8.1 Report the average percent volume change of the three rubber sheets.

9. PRECISION

9.1 Repeatability. Test results, obtained by one operator at one laboratory, for each test sheet must not vary from the average by more than the following:

a. If average is 0 to 5 percent units: 0.5 percent unit.
b. If average is above 5 percent units: 1 percent unit.

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Navy - NADC - 1986

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METHOD 3604.2
September 30, 1986

SWELLING OF SYNTHETIC RUBBER BY AIRCRAFT TURBINE LUBRICANTS

1. SCOPE

1.1 This method is used for determining the swelling effect of aircraft turbine lubricants on synthetic rubber. Synthetic lubricating fluids for aircraft turbine engines must be compatible with materials-of-construction, such as elastomers used in the engines. Elastomers are used in seals, o-rings, and related areas. This method is designed to reveal lubricating fluid-elastomer compatibility problems relative to volume swell.

2. SUMMARY

2.1 The volume of three standard test rubber samples is determined by water displacement. The rubber samples are immersed in the test lubricant for a specified time (such as 72, 96 or 168 hours) at a given temperature. After storage, the average change in volume is determined.

3. SAMPLE

3.1 Approximately 350 mL of the lubricant to be tested.

4. REFERENCES, STANDARDS AND APPARATUS

4.1 Oven, gravity-convection, 70° C ±l° C (158° F +2° F).

4.2 Beakers (2), Borosilicate, 400-mL.

4.3 Suspension device, glass or stainless-steel (for holding test rubber-sheets completely immersed in specimen in 400-mL beaker so that they do not touch each other or the beaker).

4.4 Hooks, stainless-steel wire (for suspending test rubber sheets from suspension device and from balance).

4.5 Balance, sensitivity, 0.1 mg.

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

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5.2 Standard test rubber sheets, type H or FA, fabricated less than one year prior to use. Test sheets should conform to the properties listed in U.S. Air Force specification bulletin 539, Standard Elastomer stocks. If stored for more than one year, the elastomer should be retested before use. Storage should be in a dark place at a temperature of less than 25° C (77° F) away from electrical apparatus.

5.3 Cleaning solution, glass (concentrated sulfuric acid [3,0,2] saturated with potassium or sodium bichromate [1,0,1], technical grade).

5.4 Solvent naphtha, technical grade [1,4,0].

5.5 Toluene, technical grade [2,3,0].

5.6 Alcohol, ethyl [0,3,0].

5.7 Emery cloth No. 60.

6. PROCEDURE

6.1 Clean all glassware as follows:

a. Rinse in toluene, followed by naphtha, and allow to air dry. An alternative procedure is to wash in a commercial type dish washer.
b. Soak in glass cleaning solution for two hours (minimum).
c. Rinse thoroughly with tap water, and then with distilled water.
d. Dry in an oven at 100° C (212° F), and store in dust free location.

6.2 Clean suspension device and hooks throughly with (toluene and ndphtha) solvents, air dry, and store in a dust free location.

6.3 Preheat, and adjust the oven to maintain the required temperature.

6.4 prepare standard test rubber sheets as follows:

a. Using No. 60 emery cloth, buff both sides of the rubber sheet, using strokes first in one direction and then at 90 degrees to that direction. Buff just enough so that no gloss can be seen on the sheet when viewed by reflected light.
b. Cut three pieces (3.5 by 5 cm) from the sheet.
c. punch a 0.3 cm (1/8-inch) (approximate) hole at the center of the 5 cm side, about 0.6 cm (1/4 inch) from the edge.
d. Mark each piece for future identification by cutting small pieces from one or more corners.
e. Attach wire hooks to each piece.

6.5 Weigh each rubber test sheet (and its hook) in air to the nearest 0.1 mg by suspending it from the balance by its hook. Record the weights.

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6.6 Reweigh (to the nearest 0.1 mg) each sheet while suspended in distilled water at room temperature, being careful to remove all air bubbles from the sheet and to prevent the sheet from touching the water container. Record the weights.

6.7 Determine (and record) the displacement weight of each piece by subtracting the weight in water from the weight in air.

6.8 Fill a 400-mL beaker with 350 mL of the sample.

6.9 Attach the rubber sheets to the suspension device, and submerge the sheets in the sample so that the top edges are no less than 1.3 cm (1/2 inch) below the surface. Make certain that the sheets do not touch each other or contact the sides or bottom of the beaker.

6.10 place the beaker in oven at the required temperature for the specified time.

6.11 At the end of 72 hours, remove the beaker from the oven and allow it to cool at room temperature for 30 ±5 minutes.

6.12 Remove the rubber test sheets from the sample and wash them in ethyl alcohol, rubbing them gently with the fingers to remove all oil from the surfaces. Caution - wear protective gloves.

6.13 Wipe the rubber pieces dry with soft lint-free cloth, and allow them to air dry for several minutes.

6.14 Repeat 6.5 to 6.7 to determine the displacement weight of the rubber sheets after immersion in oil.

7. CALCULATION

7.1 Displacement weight

  Weight of test sheet in air
- Weight of test sheet in water
  Displacement weight

7.2 Calculate the percentage change in volume of each rubber sheet as follows:

$$V = \frac{(A-B)100}{B}$$

V = Change in volume, percent.
A = Displacement weight at conclusion of test, mg.
B = Displacement weight before immersion in sample, mg.

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8. REPORTING

8.1 Report the averge percent volume change of the three rubber sheets.

9. PRECISION

9.1 Repeatability. Results by one operator using one apparatus must not differ by more than 1 percent.

9.2 Reproducibility. Results from different operators or different apparatus must not differ by more than 2 percent.

Method prepared by:
Navy - NAPC - 1986

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METHOD 3710.1
September 30, 1986

MOLYBDENUM DISULFIDE PURITY

1. SCOPE

1.1 This method is used for determining the purity of molybdenum disulfide powder.

2. SUMMARY

2.1 This method consists of dissolving the MoS_2 in nitric acid and perchloric acid, removing iron with ammonium hydroxide and precipitating solution with lead acetate. The purity of MoS_2 is determined from the weight of lead molybdate precipitate.

3. SAMPLE SIZE

3.1 Ten g of molybdenum disulfide (MoS_2) powder.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Hot plate.

4.2 Beakers, borosilicate, 400-mL and 600-mL.

4.3 Pipet, 50-mL.

4.4 Volumetric flask, 500-mL.

4.5 Buret, 50-mL.

4.6 Mechanical stirrer.

4.7 Porcelain crucible.

4.8 Muffle furnace capable of maintaining 550° to 600° C (1,020° to 1,110° F).

4.9 Desiccator.

4.10 Analytical balance.

5. MATERIALS

(Unless otherwise indicated, it is intended that all chemicals shall be of reagent grade and shall conform to the specifications established by the Committee of Analytical Reagents of the American Chemical Society, where such specifications are available.)

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501 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Potassium chlorate (reagent grade) [1,0,2].

5.3 Nitric acid, concentrated (reagent grade) [2,0,0].

5.4 Hydrochloric acid, concentrated (reagent grade) [3,0,0].

5.5 Ammonium hydroxide, concentrated (reagent grade) [u,0,U].

5.6 Methyl orange indicator solution. Dissolve 0.1 g methyl orange crystals (reagent grade) in 100 mL of distilled water [u,u,u].

5.7 Annnonium acetate solution. Dissolve 605 g of ammonium acetate (reagent grade) in distilled water and dilute with distilled water to 2 L [u,O,U].

5.8 Glacial acetic acid (reagent grade) [2,2,1].

5.9 Lead acetate solution. Dissolve 20 g of lead acetate, $Pb(CH_3COO)_2 3H2@$ (reagent grade) in distilled water, add 20 mL of glacial acetic acid (reagent grade) and dilute with distilled water to 1 L [u,u,u].

5.10 Tannic acid [0,1,0].

5.11 Tannic acid indicator. Dissolve 0.05 g tannic acid (reagent grade) [0,1,0] in 48 mL of distilled water and add 2 mL of glacial acetic acid (reagent grade) [2,2,1].

5.12 Ammonium nitrate solution. Dissolve 30 g of ammonium nitrate (reagent grade) in distilled water and dilute with additional distilled water to 1 L [0,1,3].

6. PROCEDURE

6.1 Weigh a moisture- and oil-free sample (See Note 1) of powder, 2.6 to 2.8 g, on an analytical balance to the nearest 0.1 mg and transfer the sample to a 400-mL beaker.

Note 1. Moisture may be removed by heating MoS_2 Powder in a drying oven at 105° C for 1 hour. Oil may be removed by extraction with acetone and petroleum ether.

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6.2 Add 1 mL of distilled water to the sample and moisten particles of MoS_2. Add with caution 30 mL of a saturated solution of potassium chlorate in nitric acid.

6.3 After vigorous action ceases, place the beaker on a hot plate and digest the sample slowly until the solution becomes pale yellow or almost white. Add 0.5 g of potassium chlorate to the solution and evaporate it to dryness.

6.4 Add 15 mL of cone. HC1, and boil solution until all brown fumes are expelled. Allow solution to cool and while stirring dilute with distilled water to 50 mL ±5 mL.

6.5 To this solution add 40 mL of concentrated ammonium hydroxide (this will precipitate iron). Heat to boiling and while hot filter through Whatman No. 40 (or equivalent) paper. Paper pulp may be added to aid filtration. Collect filtrate in 600-mL beaker and retain.

6.6 Wash residue on filter paper 5 times with 10 mL portions of hot distilled water, collecting the filtrate in the 600-mL beaker containing first filtrate. Retain combined filtrate.

6.7 Transfer filter paper with residue to clean 400-mL beaker, add 10 mL of hydrochloric acid. Stir until filter paper is pulped.

6.8 To this solution add 40 mL of distilled water and while stirring add 40 mL of concentrated ammonium hydroxide. Bring solution to a boil. While the solution is hot, filter through Whatman No. 40 (or equivalent) paper, and collect the filtrate in the 600-mL beaker containing the previous filtrate. Wash residue on filter paper with 25 mL portions of hot distilled water 8 times, collecting filtrate in the 600-mL beaker with the combined filtrate.

6.9 Discard filter paper and residue (see note 2) and retain combined filtrate.

Note 2. The filter paper and residue can be used to determine percent total insoluble matter. Place filter paper and residue in a previously ignited and weighed porcelain crucible, carefully burn off filter paper and then place in muffle furnace at 600° C for 1 hour. Remove crucible and place in desiccator for 1 hour, when cooled remove and weigh. Repeat ignition to constant weight. Calculate percent total insoluble matter (see 7.1).

6.10 Transfer the combined filtrate from the 600-mL beaker to a 500-mL volumetric flask, dilute with distilled water to 500 mL.

6.11 Using a 50-mL pipet, pipet a 50 mL aliquot into a 400-mL beaker, add 2 drops of methyl orange indicator and neutralize the excess ammonium hydroxide in the filtrate aliquot with drops of concentrated hydrochloric acid. Neutralization will be complete at the first sign of pink or red color in the solution.

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6.12 Add 30 mL of ammonium acetate to the solution and 10 mL of glacial acetic acid. Heat solution to near boiling.

6.13 Add a previously calculated amount of lead acetate solution (31 to 33 mL/0.26 to 0.28 g of sample) in aliquot respectively, (see note 3), to the sample solution from a buret, dropwise at the rate of 30 mL in 2 minutes. While stirring the solution mechanically add an excess of 3 mL of lead acetate and stir for 5 minutes after complete addition.

Note 3. For an accurate check on the quantity of lead acetate solution required, the tannic acid solution can be used as an outside indicator. The end point is reached when a drop of the neutralized aliquot solution added to 0.1 mL of the tannic acid indicator solution on a spotplate fails to give a brown coloration.

6.14 Place sample solution on a hot plate and heat until near boiling and hold at this point for at least 1 hour and allow the precipitated lead molybdate to settle completely.

6.15 Decant the bulk of the solution through a Whatman No. 42 (or equivalent) paper containing a small amount of paper pulp. Transfer the precipitate to the filter paper and wash 4 times with 50 mL portions of hot ammonium nitrate solution. The filtrate can be discarded.

6.16 Place filter paper with residue in a previously cleaned, ignited, cooled and weighed porcelain crucible. Ignite carefully in a muffle furnace at 550° to 600° C (1,020° to 1,110° F) for 1 hour.

6.17 Remove crucible and place in desiccator for 30 to 60 minutes and allow to cool to room temperature. Weigh crucible. Repeat ignitions to constant weight. Calculate the weight percent MoS_2 (see 7.2).

7. CALCULATIONS

7.1 The percent total insoluble matter may be calculated as follows:

$$\text{Percent total insoluble matter} = \frac{c}{w} * 100$$

Where:

c = weight of residue in crucible
w = weight of moisture- and oil-free sample

7.2 The percent MoS_2 is calculated using the following equation:

$$\text{Percent } MoS_2 = \frac{c}{w} * 435.9$$

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Where:

C = increase in weight of crucible
w = weight of moisture- and oil-free sample

8. REPORTING

8.1 Report the percent total insoluble matter and percent MoS_2.

9. PRECISION

9.1 Precision data have not been developed for this method.

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MOLYBDENUM DISULFIDE CONTENT OF LUBRICATING GREASE

1. SCOPE

1.1 This method is used to determine the molybdenum disulfide content of lubricating greases. This method does not apply to lubricating greases that contain non-soap thickeners.

2. SUMMARY

2.1 This method consists of dissolving the base oil and soap thickener in a mixture of oleic acid and benzene. The MoS_2 is removed by filtration and MoS_2 content determined by weighing the MoS_2.

3. SAMPLE SIZE

3.1 5 g of lubricating grease to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Desiccator.

4.2 Erlenmeyer flask, 125-mL.

4.3 Filter pump (aspirator).

4.4 Flask, filtering heavy wall.

4.5 Gooch crucible and suitable holder.

4.6 Oven capable of 100° C.

4.7 Steam bath.

5* MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 n-Hexane, ACS grade [1,3,0].

5.3 Oleic acid, USP grade [0,1,0].

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5.4 Petroleum ether (O-E-751) [1,4,0].

6. PROCEDURE

6.1 Perform the test as follows:

a. Weigh 3 to 5 g of the grease to be tested to the nearest mg and distribute as a thin layer in a 125-mL Erlenmeyer flask prior to adding 90 mL of a 50-50 mixture by volume of n-hexane and oleic acid. (See Note 1).
b. Warm the flask for approximately 1/2 hour on a steam bath with occasional agitation until all lumps have disappeared and the molybdenum disulfide is dispersed.
c. Filter the contents of the flask through a previously prepared and weighed (to the nearest mg) Gooch crucible. Wash the flask and crucible with approximately 10 mL of a 50-50 mixture by volume of oleic acid and n-hexane, followed by three washings with petroleum ether. (See Note 1.)

Note 1. Caution. n-hexane and petroleum ether are both toxic and flammable. Do not breath their fumes nor allow them to come in contact with the skin. Keep flames away from the n-hexane and petroleum ether.

d. Dry the crucible and contents at 100° C for 1/2 hour, cool in a desiccator to room temperature and weigh. (See Note 2).

Note 2. The purity of MoS_2 powder may be determined in accordance with test method No. 3710 or by means of spectrochemical analysis.

7. CALCULATIONS

7.1 Calculate the percentage of molybdenum disulfide as follows:

Percent molybdenum disulfide (as insoluble matter) =

$$\frac{\text{Increase in weight of crucible}}{\text{Weight of sample}} \times 100$$

8. REPORTING

8.1 Report the percent molybdenum disulfide as insoluble matter.

9. PRECISION

9.1 Precision data have not been developed for this method.

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METHOD 3722.2
September 30, 1986

MOLYBDENUM DISULFIDE CONTENT OF NON-SOAP THICKENED LUBRICATING GREASES

1. SCOPE

1.1 This method is used to determine the MoS_2 content of non-soap thickened greases.

2. SUMMARY

2.1 The test consists essentially of extracting the base oil from the grease with n-hexane and determining the molybdenum disulfide content of the remaining solids by precipitation to sulfate with barium chloride.

3. SAMPLE SIZE

3.1 Approximately 5 g of grease to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Desiccator.

4.2 Oven capable of 100° C.

4.3 Muffle furnace capable of 760 °C.

4.4 Hotplate.

4.5 Steam bath.

4.6 Soxhlet extraction apparatus with 250-mL flask.

4.7 Beakers, 600-mL (2).

4.8 Crucibles, 50-mL (2).

4.9 Funnels (2).

4.10 Burner, Meker (or equivalent).

4.11 Policeman, rubber.

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic

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and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Hexane, normal, ACS [1,3,0].

5.3 Extraction thimble (double thickness 3.3 x 8.0 cm).

5.4 Filter paper (Whatman No. 1 or equivalent).

5.5 Filter paper (Whatman No. 40 or equivalent).

5.6 Eschka's mixture - 2 parts of calcined ("light") magnesia thoroughly mixed with one part of sodium carbonate [u,u,u].

5.7 Bromine water, saturated [4,0,0].

5.8 Barium chloride, 10 percent [0,0,2].

5.9 Sodium carbonate, CP [u,u,u].

5.10 Potassium carbonate, CP [u,u,u].

6. PROCEDURE

6.1 Determine the solids content of the grease as follows:

a. Dry an extraction thimble (3.3 x 8.0 cm) at 100° C, cool in a desiccator and weigh to the 100° C nearest tenth of a mg. Dry thimble to constant weight. Weigh approximately 5 g of the grease to be tested into the extraction thimble.

b. Place 200 mL of n-hexane in the flask, place the thimble containing the grease sample in the Soxhlet extraction tube, and assemble the apparatus as shown in Figure 1.

c. By means of a hotplate bring the hexane to boiling and reflux until the base oil has been completely extracted from the grease (see Note 1). Complete removal of the oil may be determined by sampling small (2 mL) quantities of hexane from the extraction tube and evaporating on a clean evaporating dish. An oily film will remain if oil is contained in the sample.

Note 1. Caution. Hexane is both toxic and extremely flammable. Use only in a well ventilated area. Do not breathe its fumes nor allow it to come in contact with the skin. Keep all flames away from the Hexane.

de Remove the thimble from the extraction tube and dry in an oven at 100° C. Allow to cool in a desiccator. After cooling, remove and weigh to

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constant weight. Subtract the weight of the thimble from the latter weight to determine the weight of the solids in the grease. Calculate the percent solids (see 7.1).

6.2 Determine percent molybdenum disulfide in the grease as follows:

a. Ignite a clean crucible (50-mL) in the blue oxidizing flame of a Meker burner. Cool in a desiccator. Remove and add approximately 2 g of Eschka's mixture and weigh to the nearest 0.1 mg.
b. Add approximately 0.1 g of the grease solids (6.1 d) and reweigh to the nearest 0.1 mg (throughly mix by stirring sample using a wire rod).
c. Place a layer 0.6 cm (0.25 in) of Eschka's mixture on the sample from 6.2 b. Do not mix.
d. A blank determination using 4 g of Eschka's mixture is conducted in a separate crucible.
e. Place both crucibles in a cold muffle furnace and slowly raise the temperature to 760° C. Maintain a temperature of 760° C for two hours. Remove the crucibles from the muffle furnace and allow to cool.
f. Remove the contents of each crucible into separate 600-mL beakers and place the crucibles in a horizontal position in the beakers. Cover the crucibles with distilled water.
g. Place on heated steam bath for 30 minutes. Remove and rinse each crucible so that the rinse water is deposited in the beakers.
h. Pass the contents of beaker through filter paper (Whatman No. 1 or equal) and rinse the residue 2 or 3 times with distilled water. Discard residue and paper.
i. Add 10 mL of saturated bromine water to the filtrates. Heat gradually to boiling. Continue to boil until the volume is reduced to 200 mL.
j. Cool the solution and add 5 mL of concentrated hydrochloric acid to each beaker and boil until colorless.
k. While boiling, add at a very slow rate 10 mL of 10 percent solution of barium chloride. Heat on a steam bath for at least 3 hours, and allow to stand for 24 hours.
1. Pass the solutions through filter paper (Whatman No. 40 or equal). Remove all barium sulfate adhering to the surfaces of the beakers by means of a rubber policeman. Wash the precipitates and discard the filtrates.
m. Clean the crucibles by fusing 50-50 mixture of sodium and potassium carbonates. Do not use potassium bisulfate. Dry and cool the crucibles and weigh to the nearest 0.1 mg.
n. Fold the filter paper and precipitates, and place in the clean weighed crucibles.
o. Place the crucibles in a cold muffle furnace and heat gradually to a temperature of 400° C. Hold at 400° C until the filter papers are thoroughly charred. Slowly raise the temperature to 760° C and maintain at this temperature until there is no longer any carbon present. This will require approximately 1 hour at 760° C. The barium sulfate should be pure white.

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p. Allow the crucibles to cool and determine the weight of barium sulfate in each one. Subtract the weight of barium sulfate in the blank from that of the sample and record the difference as the weight of barium sulfate. (See note 2).

q. Calculate the percent MoS_2 in the grease solids (see 7.2).

r. Calculate the percent MoS_2 in the grease (see 7.3).

Note 2. A spectrochemical analysis may be conducted to determine purity of MoS_2.

7. CALCULATIONS

7.1 Calculate the percent solids as follows:

$$\text{Percent solids} = \frac{W_2}{W_1} * 100$$

W_1 = Weight of Solids in sample
W_2 = Weight of sample

7.2 Calculate the percent MoS_2 in the grease solids as follows:

$$\text{Percent } MoS_2 \text{ in grease solids} = \frac{M_2 * 0.343 * 100}{M}$$

M = Weight of solids from grease sample
M_2 = Weight of barium sulfate

7.3 Calculate the percent MoS_2 in the grease as follows:

Percent MoS_2 = Percent Solid (see 7.1) * Percent MoS_2 in grease solids (see 7.2).

8. REPORTING

8.1 Report the percent solids, percent MoS_2 in grease solids, and percent MoS_2.

9. PRECISION

9.1 Precision data have not been developed for this method.

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METHOD 3816.1
September 30, 1986

FILM THICKNESS OF DRY SOLID FILM LUBRICANTS

1. SCOPE

1.1 This method provides a means for measuring the film thickness of dry film lubricants.

2. SUMMARY

2.1 The thickness of a coated and uncoated aluminum panel is measured in four specified areas using a template and precision micrometer. The difference in readings represents the film thickness of the lubricant.

3. SAMPLE SIZE

3.1 240 mL (8 ounces) of solid-film lubricant in a mixture of sprayable consistency.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Binks Spray Gun, Model 18, with a 66 SD Head attachment (Binks Manufacturing Company, Chicago, Illinois or equal).

4.2 Vernier micrometer capable of measuring to the nearest 0.0025 mm (0.0001 in), or an equivalent measuring device.

4.3 Template - 7.6 cm x 15.2 cm (3 in x 6 in) with four 0.95 cm (3/8 in) holes centered 3.8 cm (1-1/2 in) in from the 7.6 cm side and 1.6 cm (5/8 in) in from the 15.2 cm side (see Figure 1).

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Aluminum alloy test panel conforming to QQ-A-250/5, 7.6 cm x 15.2 cm x 0.051 cm (3 x 6 x 0.020 in) thick, anodized in accordance with MIL-A-8625, Type 1.

5.3 1,1,1-trichloroethane (MIL-T-81533) [2,1,0].

6. PROCEDURE

6.1 Prepare test panel as follows:

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a. Degrease the test panels in 1,1,l-trichloroethane.
b. place template in position on the uncoated panel, trace the circumferences of the openings in the template on to the test panel.
c. Measure the thickness of the test panels at the circled areas with a micrometer having 0.0025 mm (0.0001 in) graduations. Note the thickness measurement for each circled area.

6.2 Perform the test as follows:

a. Apply two coats of dry solid film lubricant by spraying the solid lubricant to the unmarked side of the test panel. Application shall be conducted in a well ventilated area or hood, where no flames or ignition sources are present. Care should be taken to insure that the panel has a uniform coating of solid lubricant.
b. Air dry, temperature 25 ±2° C (77° +3° F) test panel for ten minutes between coats. After the final application, allow coated test panel to air dry for fifteen minutes, then cure the film in accordance with specification requirements.
c. Maintain a distance of approximately 30 cm (12 in) between spray gun and test panel while spraying.
d. Use an air pressure of 275 ±35 gage kpa (40 ±5 psig)
e. Allow test panel to reach room temperature after curing.
f. Remeasure the thickness of the test panel at the same positions.
g. Duplicate tests shall be conducted.

7. CALCULATIONS

7.1 Calculate the firm thickness as follows:

$F = A-B$
F = Film thickness
A = Thickness of the coated panel
B = Thickness of the uncoated panel

8. REPORTING

8.1 The average of four readings shall be reported as the film thichess of the dry solid film lubricant.

9. PRECISION

9.1 precision data have not been developed for this method.

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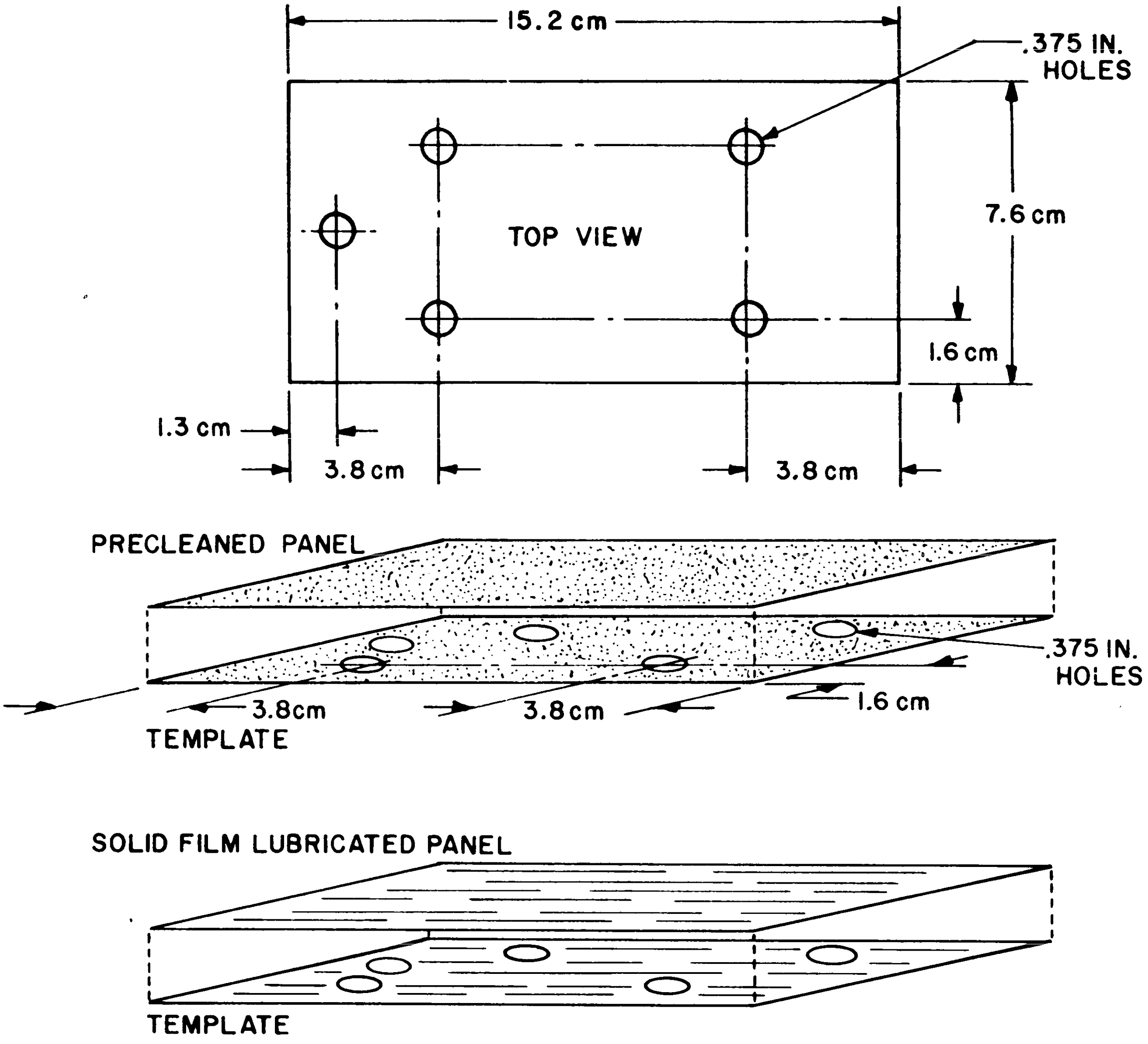

FIGURE I. Template for measuring thickness.

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METHOD 4001.3
September 30, 1986

CORROSION PROTECTION BY COATING: SALT-SPRAY (FOG) TEST

1. SCOPE

1.1 This method is intended for the determination of the corrosion protection provided by fluid, semi-solid, and solid coatings.

2. SUMMARY

2.1 The test consists of exposing test panels to either 5 or 20 percent salt (NaCl) spray as stated in the product specification. When the salt concentration is not stated in the product specification, the 5 percent salt solution shall be used.

3. SAMPLE SIZE

3.1 Approximately 500 mL of the material to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Exposure chamber, with racks for supporting test panels, and with suitable heaters and controls.

Note 1. The chamber and all accessories shall be made of material which will not affect the corrosiveness of the fog (such as glass, hard rubber, plastic, or wood other than plywood.) In addition, all parts which come in contact with the test panels shall be of materials that will not result in accelerated local attack associated with dissimilar metal crevices. The chamber and accessories shall be so constructed and arranged that there is no direct impinging of the spray or dripping of the condensate on the test panels, so that the spray circulates freely about all panels to the same degree and so that no liquid which has come in contact with the panels returns to the salt solution reservoir. The chamber shall be properly vented. Satisfactory cabinets may be obtained from the Industrial Filter and Pump Mfg. Co., Chicago, Illinois.

4.2 Atomizers, including suitable nozzles and compressed air supply (for producing a finely divided, wet, dense fog).

4.3 Humidifier, atomizer-air (for warming and humidifying the air to produce a relative humidity at the nozzle of at least 85 percent).

Note 2. A high humidity insures against clogging the atomizers by salt deposition. A satisfactory method of humidifying the air is to pass it in very fine bubbles through a tower containing heated water. The temperature of the water should be 35° C (95° F) or higher. The permissible temperature increases with increasing volume of air and with decreasing heat insulation of the chamber and temperature of its surroundings. It should not exceed a value above which an

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excess of moisture is introduced into the chamber (for example, 43° C [110° F] at an air pressure of 82 gage kPa [12 psig]), or a value which makes it impossible to meet the required operating temperature.

4.4 Air supply, compressed, free from impurities such as oil and dirt.

4.5 Reservoir (for salt solution).

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Sodium chloride (0-C-265) [0,0,2].

5.3 Hydrochloric acid (0-C-265)[3,0,0].

5.4 Sodium hydroxide (O-C-265) [3,0,1].

5.5 Bromthymol blue (MIL-B-11845), solution, indicator, 6.0 to 7.6 pH range [u,u,u].

5.6 Distilled water ACS.

5.7 1,1,1-trichloroethane (0-T-620) [2,1,0].

5.8 Cleaning tissue, facial (UU-T-450).

5.9 Three test panels made of low-carbon, open-hearth, cold-finished 1010 steel, 7.5 x 5.0 by 0.32 cm thick (3 inch x 2 inch by 1/8 inch thick).

6. PROCEDURE

6.1 Preparation of salt solutions.

6.1.1 Five percent solution. Dissolve 5 +0.5 parts by weight of sodium chloride in 95 ±0.5 parts by weight distilled water. Filter the solution if there is any suspended matter. The specific gravity of this solution shall be between 1.027 and 1.041 when measured at 35 ±1° C (95 +2° F). Maintain the pH of the solution between 6.5 and 7.2 by the addition of either hydrochloric acid or sodium hydroxide as necessary. Determine the pH of the salt solution electrometrically or calorimetrically using bromthymol blue as an indicator.

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6.1.2 Twenty percent solution. Dissolve 20 +2 parts by weight of sodium chloride in 80 + 2 parts by weight distilled water. Filter the solution if there is any suspended matter. The specific gravity of this solution shall be between 1.1267 and 1.157 when measured at 35 ±1° (95 ±2°F). Maintain the pH of the, solution between 6.5 and 7.2 by the addition of either hydrochloric acid or sodium hydroxide as necessary. Determine the pH of the salt solution electrometrically or calorimetrically using bromthymol blue as an indicator.

6.2 Preparation of panels for testing.

6.2.1 Cleaning of panels. Handle all panels as little as possible, particularly on the significant surfaces. Clean uncoated metal panels with warm 38 to 54° C (100 to 130° F) 1,1,1-trichorethane and cleaning tissue. Clean all significant surfaces until they are free from water-break. If a panel has an organic coating, do not clean it with an organic solvent. Dry all panels thoroughly. Coat the edges of panels which may come in contact with supports with wax or with some material which is impervious to moisture.

6.2.2 Application of coatings to panels. Fluid, semi-solid, or solid coatings (see 1.1) shall be applied to test panels in accordance with product specification.

6.3 Location of panels in the exposure chamber. Test panels shall be supported in such a manner that the significant surfaces are approximately 15 degrees from the vertical position and are parallel to the principal direction of horizontal flow of fog through the chamber. Whenever practicable, the panels shall be supported from the bottom or from the side. When panels are suspended from the top, suspension shall be accomplished with glass hooks or waxed string. The use of metal hooks is not permitted. The panels shall be positioned so that they do not shield each other from the freely settling fog, and so that corrosion products and condensate from one panel do not fall upon another.

6.4 Operating conditions.

6.4.1 Temperature. The test shall be conducted with a temperature in the exposure zone maintained at 35° ±1°, -1.5° C (95° +2°, -3° F). Satisfactory methods for controlling the temperature accurately are by housing the apparatus in a properly controlled constant temperature room, by thoroughly insulating the apparatus and preheating the air to the proper temperature prior to atomization, and by jacketing the apparatus and controlling the temperature of the water or of the air used. The use of immersion heaters for the purpose of maintaining the temperature within the chamber is prohibited.

6.4.2 Atomization. The conditions maintained in all parts of the exposure zone shall be such that a suitable receptacle placed at any point in the exposure zone will collect from 0:5 to 3 mL of solution per hour for each 80 square cm of horizontal collecting area (l0-cm diameter) based on an average run of at least

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16 hours. The solution thus collected shall have a sodium chloride content of 4.5 to 5.5 percent for the 5 percent solution (specific gravity 1.027 to 1.041 when measured at 35° ±1° C [95° +2° F]) or a sodium chloride content of 18 to 22 percent for the 20 percent solution (specific gravity 1.126 to 1.157 when measured at [35° ±1° C]). At least two clean fog-collecting receptacles shall be used, one placed nearest to any nozzle and one farthest from all nozzles. Receptacles shall be fastened so that they are not shielded by specimens and so that no drops of solution from specimens or other sources will be collected.

NOTE 3. When using nozzles made of material nonreactive to the salt solution, suitable atomization has been obtained in boxes having a volume less than 0.34 m^3 (12 cubic ft) with the nozzle pressure 82 to 124 gage kpa (12 to 18 psig) with the orifices of 0.05 to 0.08 cm, and with the atomization of approximately 3 L (3 qts) of salt solution per 0.28 m3 (10 cubic ft of box volume per 24 hours). When using large size boxes having a volume considerably in excess of 0.34 m^3 (12 cubic ft), the above conditions may have to be modified to meet the requirements for the operating conditions.

6.4.3 Length of test. The length of the salt spray test shall be as required by the product specification. The test shall be run continuously for the specified test period, or until a definite indication of failure is observed, with interruption only for adjustment of the apparatus and for inspection of the test panels.

6.5 At the end of the test, the test panels shall be examined immediately to determine compliance with the standards of acceptability given in the product specification. If necessary for examination purposes, the test panels may be washed gently or dipped in running water not warmer than 38° C (100° F) and brushed lightly.

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Report the number of specimans tested and the number of passing or failing results.

9. PRECISION

9.1 Precision data have not been developed for this method.

Method Prepared by:

Army - ME - 1986

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DEPOSIT-FORMING TENDENCIES OF AIRCRAFT TURBINE LUBRICANTS

1. SCOPE

1.1 This test method describes a procedure for determining the deposit and sludge forming tendencies of aircraft gas turbine lubricants.

2. SUMMARY

2.1 A sample of the lubricant is circulated under controlled conditions for a prescribed period of time through an aerated test chamber containing an aluminum tube held at constant temperature. From the chamber the oil passes through a cooler, a line filter, a circulating pump and back into the chamber. The weight of solid decomposition products on the heated tube and on the line filter are determined. Changes in the viscosity and neutralization number of the oil can be determined if desired.

3. SAMPLE SIZE

3.1 As needed.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Deposition tester, Wright Air Development Center (Erdco Engineering Corp., Adison, IL) consisting of an oil circulation pump, coking head with tube, oil feeder, oil cooler, line filter, and the necessary instrumentation and supporting structure (see Figure 1 through 5).

NOTE 1: Model 1 is equipped with a pyrometer, Model 2 with a temperature recorder, and Model 3 with a pyrometer, a selector switch, and a differential pressure recorder. A "W" following the model number indicates the inclusion of a watt-hour meter.

a. Cabinet. The test cabinet consists of a test section and an instrument section. Ventilation and heat are provided to maintain the test section at 48.9° C ±3° C (120° F ±5° F) and the instrument section at not more than 6° C (10° F) above room temperature. The sections are separated by a partition.

b. Instrument section. The instruments and their locations are shown in Figure 1. Optional items (differential-pressure recorder, watt-hour meter, pyrometer, and selector switch) are included in this Figure.

c. Thermocouples. All thermocouples and leads are made from precision calibrated iron constantan wire. Two bayonet thermocouples are provided for the coking tube, one of which is connected to the stepless temperature control, the other to the pyrometer or temperature recorder. Two bare-wire thermocouples are provided for

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measuring “oil-in” temperature. One is connected to the off-on temperature controller, the other to the pyrometer or temperature recorder. One bare-wire thermocouple, connected to pyrometer or temperature recorder, is provided for measuring “oil-out*’ temperature. A thermocouple, design optional, is used to measure the test section air temperature and is connected to the pyrometer or temperature recorder.

d. Test section. The test section components and their approximate location are shown in Figure 2. A schematic drawing of the entire rig is shown in Figure 3. The test section components are mounted on a rack that can be removed from the cabinet to permit easy disassembly for cleaning. A spare test section can be advantageously utilized to keep down-time on the rig to a minimum

e. Coking tube. The coking tube consists of an aluminum tube with a shrunk-in 1500-watt cartridge heater. Two thermocouple holes are provided. The configuration and dimensions of the coking tube are shown in Figure 4.

f. Line filter. The filter consists of a two-piece body, a 100-mesh stainless-steel screen, and a screen support. These components are shown assembled in Figure 5.

g. Oil cooler. The oil cooler is designed for oil downflow through annular space and water upflow through the inner tube. A continuous water bleed to waste is taken through an orifice just ahead of the inlet to the cooler (see Figure 2, item 32). This acts as a drain for the cooler when the water flow is shut off by the control, air being bled back into the cooler through a check valve (see Figure 2, item 30).

4.2 Balance, capacity 500-gm, sensitivity 10 mg.

4.3 Stop watch, accuracy 0.1 second.

4.4 Wet test gas meter.

4.5 Brushes, metal, special; 0.195-inch diameter, 1/2 inch B.P., 10 inch; P.A. No. 22 single stem 0.0025 fill (Mill-Rose Co., 1985 East 59th Street, Cleveland, OH).

4.6 Holding fixture, coking-tube (for supporting coking tube by top end without marring or distorting the tube).

4.7 Oven 99° C to 104.4° C (210° F to 220° F).

4.8 Thermometer, platinum-resistance or a thermometer certified by the Bureau of Standards (for weekly check of thermocouples at normal operating temperature).

4.9 Compressed-air source.

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4.10 Millivoltmeter (precision potentiometer).

4.11 Gooch crucible with asbestos mat.

5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Silicon-carbide paper, No. 400.

5.3 Solvent, dry-cleaning (ASTM D 484, type 11) [0,2,0].

5.4 Cleaning solution, glass (concentrated sulfuric acid [3,0,2] saturated with potassium or sodium bichromate [1,0,1], technical grade).

5.5 n-Hexane, thiophene-free (ACS) [1,3,0].

5.6 Isopropyl alcohol (ACS), [1,3,0].

5.7 Petroleum ether (ACS) [1,4,0].

5.8 Acetic acid, 25-percent solution [2,2,1].

5.9 Distilled water.

5.10 Scouring powder, commerical grade.

5.11 Steel wool.

5.12 Pipe cleaners.

5.13 Cleaning compound, special (Penetone ECS; Penetone Corporation, 74 Hudson Avenue, Tenafly, New Jersey 07670; [201] 567-3000 or equivalent) [u,u,u].

5.14 New parts to be installed before each test (available form Erdco Engineering Corp.):

a. Pump shaft seal.
b. O-rings for sealing the filter, cooler, and oil-bypass relief valve.
c. Air-diffuser stone for coking head. (The stone in the humidifier is not replaced except as needed).

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6. PROCEDURE

6.1 Ascertain (at least once a week) that all thermocouples are operating properly, using a platinum-resistance thermometer (or a thermometer certified by the Bureau of Standards) and immersing only the tip of the thermometer in the bath. Discard any thermocouple that is off by 3° C (6° F) or more; apply a correction factor to the reading if the thermocouple error is 1° C (2° F) or more.

NOTE 2: When the rig is in operation, a continuous check is available on the “oil-in” and coking-tube temperature since two independent thermocouples and instruments are used on each. The two readings on each of the above thermocouples should agree within 2.5° C (5° F). Disagreement in excess of 2.5° C (5° F) should be resolved immediately by a thorough check on instruments, leads, and thermocouples. The "oil-out” and test-section thermocouples should be checked daily with a precision millivoltmeter. This is primarily a check on the leads and measuring instrument which can be eliminated on Models 2 and 2W as the recording millivoltmeter on these models is not affected by variations in lead or contact resistance.

6.2 Clean bayonet thermocouples by swabbing and rinsing in isopropyl alcohol and then air dry. Clean bare-wire thermocouples by rinsing in isopropyl alcohol and using brushes, steel wool or No. 400 silicon carbide paper as necessary for deposit removal. After final rinsing, air dry.

6.3 Prepare the oil system of the tester as follows:

a. Disassemble all components of the test oil system completely (except for pipe-threaded aluminum joints which cannot be removed without damage).
b. Disassemble pump, relief valve, and all valves completely. Disconnect all lines including those from the pressure gage and from the humidifier to the coking tube.
c. Discard used O-rings, pump shaft seal, and air dispersion stone in the coking head.
d. Soak all reusable components of the test oil system, except the coking tube, in dry-cleaning solvent for 20 minutes.
e. Drain excess solvent, and soak for 4 hours in special cleaning compound. Cleaner at 43° C to 49° C (110° F to 120° F).
f. Remove from cleaner, and rinse thoroughly with running water to remove all cleaner, brushing all parts thoroughly with the special metal brushes to remove all deposits.
g. Rinse all components thoroughly with clean isopropyl alcohol, then with clean petroleum ether, and blow dry with clean, dry air.
h. Inspect the parts for deposits, and repeat the cleaning if necessary (starting with the soak in special cleaning compound), until they all are completely clean.

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NOTE 3: It is advisable to cut open lines and critical fittings periodically to check on the efficiency of cleaning. The most critical section is between the coking head and the cooler.

i. Clean glass coker-assembly body and glass oil-filler tube with scouring powder, rinsing afterwards with water then with isopropyl alcohol. Air dry and immerse both in glass-cleaning solution for at least one hour. Rinse thoroughly using distilled water for the final rinse, then oven dry at 99° C to 104.4° C (210° F to 220° F).
j. Clean glass feeder flask and its connection by rinsing thoroughly with isopropyl alcohol and air dry.
k. Store all parts in a clean, dust-free location until ready for reassembly.

6.4 Check the water side of the oil cooler for cleanliness, and clean as necessary. (The frequency of the cleaning depends on the hardness of the water used.) With very hard water it may be necessary to de-lime the inside of the cooling-water tube after each test. Cleaning is best accomplished by corking the bottom end of the tube and filling it with dilute acetic acid (25 percent), allowing it to stand for 15 to 30 minutes as needed, and then flushing thoroughly with water. This cleaning is in addition to the regular cleaning procedure for the removal of deposits from the oil side.

6.5 Prepare the coking tube as follows:

a. Clean the coking tube by hand abrasion with No. 400 silicon carbide paper holding the tube by the top end in a jig or fixture designed to avoid marring or distorting the tube. (To avoid getting dust in the thermocouple wells it is best to plug them with paper during this operation.)
b. Inspect the surface of the tube for pits. If the tube is pitted, turn it down in a lathe. (However, when the diameter has been reduced from its original 2.984 to 2.883 cm [1.175 inches to 1.135 inches] or less, replace the tube.) Then repolish it by hand.
c. After the final polishing with silicon carbide paper, wipe free of dust with clean rags. Then rinse thoroughly with n-hexane (including thermocouple wells). Blow dry with clean, dry air. (Thermocouple wells should also be swabbed out with clean pipe cleaners.)

CAUTION

After final cleaning, the coking tube must be handled only by the top end to avoid contamination of the coking surface.

d. Inspect the thermocouple wells for residual oil. If there is any evidence of oil, repeat the n-hexane rinse and swab with pipe cleaners until all oil is removed.

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e. Install a clean coking-tube thermocouple in one of the wells, and heat the tube to 204° C (400° F) by plugging in the power rig.
f. Allow the tube to cool, and store it in a dust-free location.

6.6 Weigh a clean coking tube (within 10 mg), and record the weight. Handle by the top to avoid contaminating coking surface.

6.7 Weigh a clean filter screen to the nearest 10 mg, and record the weight.

6.8 Clean a new coking-head diffuser stone, a new pump-shaft seal, and a complete set of new O-rings by rinsing in isopropyl alcohol, and then in petroleum ether, and allow them to air-dry.

6.9 Assemble clean components of the test section, installing the previously cleaned new parts (see 6.8)

CAUTION

> Do not use compound of any type on threaded fittings, stopcocks, or elsewhere in the system.

6.10 After assembly, check to see that all fittings are tight, all valves are in proper position, bayonet thermocouples are ‘*bottomed” in the coking tube, all thermocouples are registering, and the temperature indicates on all controllers and recorders read correct ambient temperature. (Adjust if necessary.)

6.11 Level coking head by means of adjusting screws.

6.1.2 Ascertain (at least once a month) that the air flowmeter is calibrated to deliver 300 mL per minute of saturated air at atmospheric pressure and 25° C (8° - F). In calibrating (to detect leaks in the flowmeter or line), use a (definite flowmeter pressure (preferably 69 gage kPa [10 psig]) and a wet test meter, connecting from the discharge line of the humidifier to the inlet of the meter.

6.13 Flush the oil system as follows:

a. Charge the circulating system with unused isopropyl alcohol, and circulate for five minutes, alternating the flow several times between the filter (36, Figures 2 and 3), and the pressure-relief bypass valve (34). This is accomplished by use of valves (35) and (37). Drain thoroughly opening valve (37), and tubing connections as necessary for complete venting and draining. Discard the used isopropyl alcohol.
b. Repeat step (a) using unused petroleum ether. Drain thoroughly, and discard used petroleum ether.
c. If the first flush of petroleum ether comes out dirty or discolored, repeat until petroleum ether remains colorless. Drain thoroughly, and discard all used solvents.

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6.14 Check the adjustment of the system as follows:

a. open valve (29), and charge the system with test oil through oil filler system.

b. Turn on pump, and continue to add oil until level in coking head glass is at or slightly above the mark 3.8 cm ([1-1/2 inches] below top of glass) .

c. Fill humidifier half full of distilled water, and adjust air flow control valve to give an air flow of approximately 150 mL per minute.

d. Turn on the coking tube heater, and set controller for 274° C (525° F). (It is imperative that this temperature is not exceeded during flow check since higher temperatures would cause coke formation). As the test oil heats and expands, drain as necessary to maintain a visible level in the coking head. It is desirable to have the oil level close to the top of the coking head glass. Valve (29) must be kept open.

e. Turn on the cooling water, and check the operation of the water solenoid valve by adjusting "oil-in" temperature controller to open and close solenoid, keeping water by-pass valve (17) closed and water trim valve (16) wide open. (When water flow is shut off, the cooler should drain in ten seconds or less.)

f. Set "Oil-in" temperature control to 149° C (300° F), keeping water-bypass valve (17) closed and water-trim valve (16) wide open.

g. As soon as "oil-in" temperature is above 121° C (250° F), check the setting of bypass relief valve (34) by cutting off filter flow at valve (35). Adjust the relief valve to give a pressure of 34.5 kPa gage (5 psig) higher than obtained when flowing through the filter.

h. Open valve (35) to direct flow through the filter.

i. Shut off coking-tube heater as soon as the "oil-in" temperature reached 138° C (280° F). Check hot flow rate by measuring the time required for a discharge of 100 mL of oil through three-way valve (28). Pour the 100 mL of oil back into the filler tube immediately, keeping valve (29) open. Calculate the flow rate in mL per minute.

j. Turn on the coking tube heater.

k. If first hot flow check shows a rate of 300 +5 mL per minute, record the actual flow rate and proceed to step (l). If the flow rate is outside this limit, readjust the variable-speed-transmission speed control (14) to correct for the difference, and repeat steps (i) and (j) until a flow rate of 300 +5 mL per minute is obtained.

1. Direct oil flow through the bypass valve (34) by blocking the flow through the filter, and again check the hot oil flow as in step (i). If the flow rate is above 255 mL per minute, record this value and preceed to 6.15. If the flow rate is below 225 mL per minute, the pump is worn or defective and must be replaced or rebuilt before proceeding further. In this event, after replacing or rebuilding the pump, repeat 6.13 and 6.14.

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NOTE 4: The entire sequence of flow check procedure (steps j though 1) must be completed within 30 minutes to avoid excessive oil deterioration.

TABLE I. Standard operating conditions.

Condition	Value	
Coking-tube temperature, C° (°F)	310 +2.5	(590 +5)
“Oil-in” temperature, C° (°F)	149 ±2.5	(300 ±5)
Air temperature (test section), C° (°F)	48.9 °2.5	(120 ±5)
Oil flow, mL per minute		300 ±5
Air flow, mL per minute		300 ±5
Oil level (aerated), below top of coking-head glass, cm (inches)	3.81 ±0.32	(1-1/2 ±1/8)

6.15 Using the standard operating condition listed in Table I, conduct a 12-hour (±10 minutes) run on the test oil used in adjusting the system (see 6.14). Perform the test as follows:

a. While the system is hot, adjust the oil level in the oil filter tube to about 3.8 cm (1-1/2 inches) below the oil level mark on the tube (to allow for an increase in volume as a result of aeration).
b. Start the oil flow at 300 mL per minute.
c. Adjust the air flow to 300 mL per minute.
d. Fill the oil feeder flask completely with test oil, stopper tightly, and install in oil filler tube.

NOTE 5: The feeder flask must be full at the start of the test run (to minimize oil ejection due to air expansion). It is helpful to heat flask and oil to 54.4° C (130° F) prior to its installation. The stopper on the flask must be tight to avoid air leakage after installation.

e. Set coking tube temperature control to 310° C (590° F).
f. Check setting of "oil-in” temperature control for 149° C (300° F).
g. As soon as **oil-in*’ temperature reaches 138° C (280° F) start timing the test period by setting the timer (4, see Figure 1) on 12 hours. If apparatus is so equipped, set watt-hour meter (5) to zero. Read and record all temperatures and pressures.
h. Adjust height of oil-filler assembly to maintain the aerated oil level in the coking head at the mark on the coking-head glass to within +0.32 cm (+1/8 inch). Maintain this level for duration of test. Keep valve (29)—open for duration of test.
i. Check the operation of the coking-tube temperature control, and adjust to hold 310° C +2.5° C (590° F +5° F) coking-tube temperature. If the control does not hold within these limits, adjustment of the band width is required. (See instruction manual for the control).

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j. Check "oil-in" temperature control, and adjust to hold 149° C +2.5° C (390° F +5° F) '*oil-in" temperature. If the *'oil-in" control does not hold within prescribed limits, it can usually be corrected by adjusting the water supply to the cooler by means of trim valve (16).

k. Keep cabinet door closed throughout the test, opening only when necessary and for as short periods as possible. Check and adjust operation of ventilating and heating equipment to hold test-section air temperature at 48.9° C (120° F ±5° F).

(1) Record the following data every 30 minutes for the duration of the test:

Oil-in temperature, °C (°F)
Oil-out temperature, °C (°F)
Coking-tube temperature, °C (°F)
Cabinet-air temperature, °C (°F)
Heater voltage
Watt-hour meter (total)
Air flow (rotameter setting and pressure), mL/min
Aerated-oil level (above or below mark), cm
Pump pressure, kPa (psig)

6.16 At the end of the 12-hour test run, shut off the coking-tube heater, and immediately shut filler valve (29). Remove feeder flask, and empty all fresh oil from the filler tube.

6.17 Shut off air flow.

6.18 With pump running, drain the used oil into a clean, dry container through drain valve (37). Save used oil if optional analysis is desired.

6.19 Turn off all switches on control panel.

6.20 While the test rig is still hot and as soon after the completion of the test run, check for sludge deposits in the filter as follows:

a. Remove the filter (see Figure 5) as a unit, and allow it to drain for 5 minutes with the inlet at the top and the filter housing tilted approximately 30 degrees from the vertical.
b. Being careful not to dislodge sludge particles, disassemble the filter housing, and place the screen (deposit side up) on a clean, absorbent paper towel or on a piece of qualitative-grade filter paper.
c. After 10 minutes replace paper with a new one and allow screen to drain an additional 50 minutes.
d. Weigh the screen and deposits to the nearest 10 mg, and record.
e. Oils with very high sludge values may leave deposits on the upstream half of the filter housing. These deposits should be removed with petroleum ether and a policeman, and filtered through a tared Gooch crucible. The crucible and contents should be washed thoroughly with

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petroleum ether until the washings are completely free from discoloration. The crucible and contents are than dried in an oven at 96° C (205° F) for one hour, cooled at least one hour in a desicator, and reweighed. The resulting deposit weight should be added to that obtained from the filter screen, and the total obtained reported as sludge.

6.21 Check the coking tendency of the oil as follows:

a. Being extremely careful not to dislodge any deposits, remove the coking tube from the coking head.
b. Allow the tube to cool for at least one hour.
c. Immerse the tube up to its flange in n-hexane, and allow it to soak for 10 minutes.

CAUTION

Handle carefully to avoid dislodging deposit.

d. Repeat the soaking for 10 minutes in clean n-hexane.
e. Swab out the thermocouple wells with pipe cleaners to remove any oil. Then install a clean thermocouple in one of the wells.
f. Connect the heater to the rig power source, and heat tube to 204° C (400° F) maximum.
g. Remove the thermocouple, allow the tube to cool in air at room temperature for at least one hour, weigh to nearest 10 mg, and record.

6.22 Disassemble and clean the deposition test rig. (Refer to 6.3, 6.4, and 6.5.)

7. CALCULATIONS

7.1 Calculate the following:

a. Sludge is expressed as the difference between the final and initial weights of the filter screen.
b. Coke is expressed as the difference between the final and initial weights of the coking tube.
c. Deposit rating is calculated as follows:

$$\text{Deposit rating} = \text{Sludge} + 10 \times \text{Coke}$$

8. REPORTING

8.1 Report the weight, in g, of the sludge and the coke separately, and the deposit rating of the oil.

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8.2 Report the following operating data:

a. Elapsed time (to within 1./2 hour) to pump-pressure increase of 34.5 gage kPa (5 psig).
b. Oil consumption (differnce between initial and final oil volumes in feeder flask).
c. Unusual operational condition (such as foaming of oil in coking head).
d. Elapsed time (and reasons for termination) if test run must be stopped before 12 hours.

9. PRECISION

9.1 Repeatability. TWO or more runs on the same oil in the same apparatus and by the same operator should differ from their mean by no more than 0.75 deposit rating.

9.2 Reproducibility. The average values for the same oil obtained on different apparatus or by different operators (or both) should not differ by more than 0.75 Deposit Rating.

Method prepared by:
Air Force-AFWAL/POSL-1986

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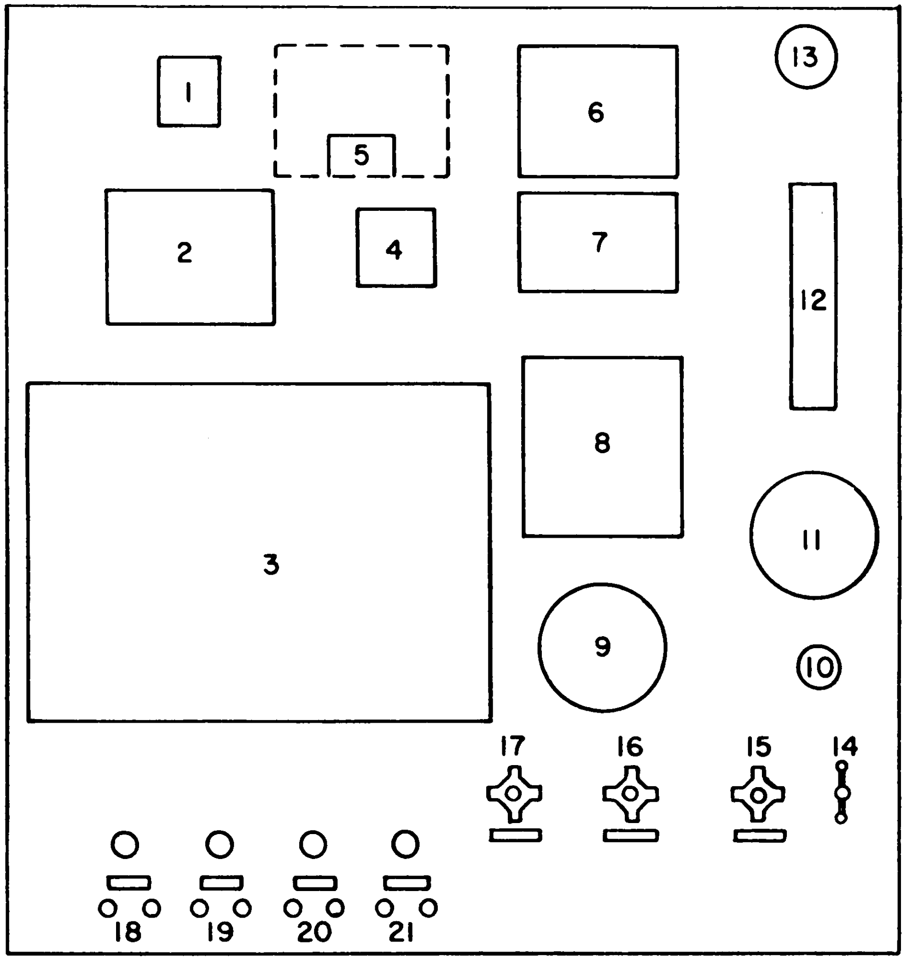

1. Voltmeter, 0 to 300 volts
2. Controller (stepless), coking-tube temperature, -18° to 430° C (0° to 800° F)
*3. Strip chart recorder (potentiometer), 6-channel; or differential pressure recorder, 0 to 25 cm (0 to 10) inches of mercury
4. Timer, 24-hour
*5. Watt-hour meter
6. "OFF-ON" controller, oil-temperature, -18° to 320° C (0° to 600° F)
*7. Pyrometer
*8. Selector switch
9. Filter pressure gage, 0 to 69 gage kPa (0 to 10 psig)
10. Pressure regulator, air-flow
11. Air-pressure gage, 69 gage kPa (10 psig) (working)
12. Air flowmeter, 0 to 500 mL/min
13. Air throttle valve
14. Speed control, variable-speed pump-drive
15. Humidifier-water valve
16. Water trim valve (flow regulation through solenoid valve)
17. Solenoid-bypass water valve
18. Pump switch and indicating light
19. Coking-tube heater switch and indicating light
20. Air solenoid-valve switch and indicating light
21. Ambient-air heater switch and indicating light (off-on by thermoswitch)

* Optional.

FIGURE 1. Deposition tester instrument and control section.

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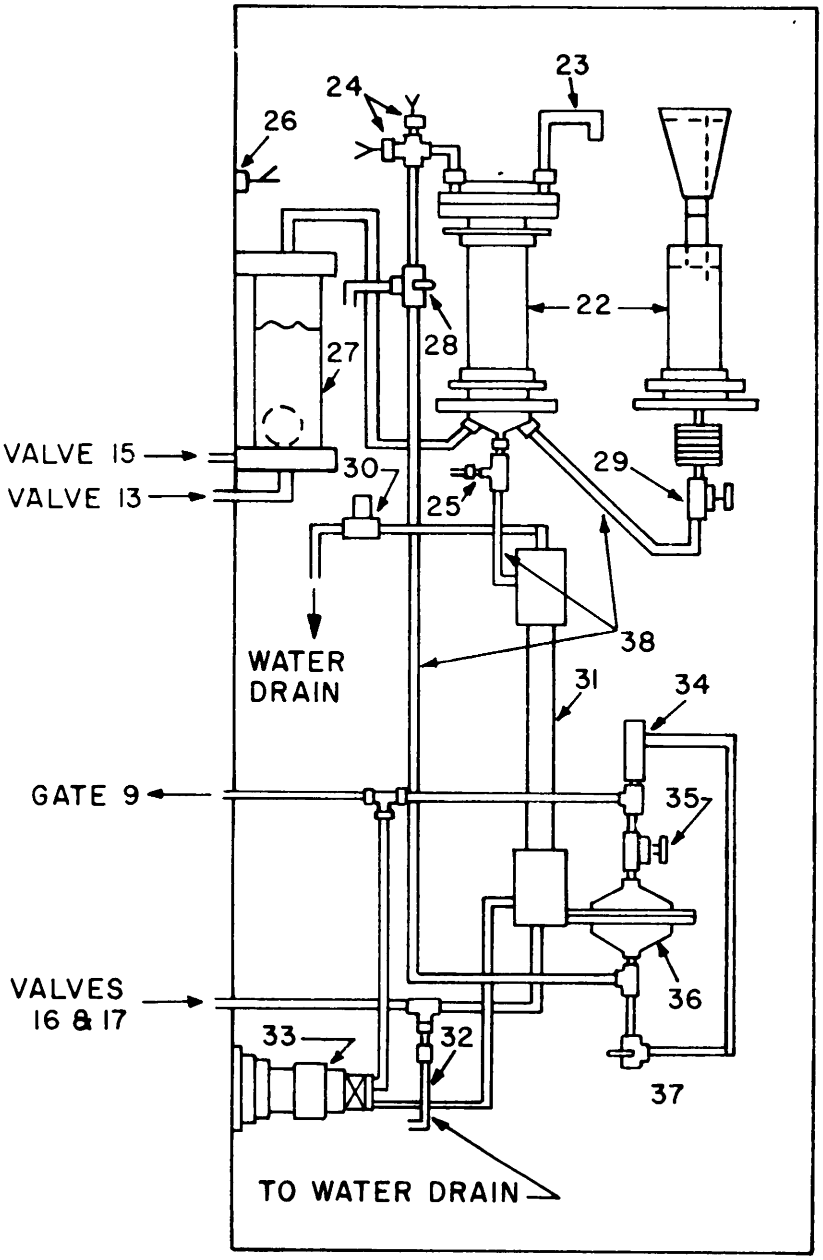

22. Coking head and oil reservoir
23. Vent line
24. Oil-in thermocouples
25. Oil-out thermocouple
26. Test-cabinet ambient-temperature thermocouple
27. Humidifier
28. Bypass valve to coking head
29. Shut-off valve, oil reservoir
30. Check valve (air bleed)
31. Oil cooler
32. Orifice (water-drain)
33. Oil pump and variable-speed transmission
34. Pressure-relief bypass valve
35. Shut-off valve, test-filter
36. Test filter
37. Drain valve, test-oil system
38. All test-oil tubing shall be 1/4 inch aluminum tubing

FIGURE 2. Test section components.

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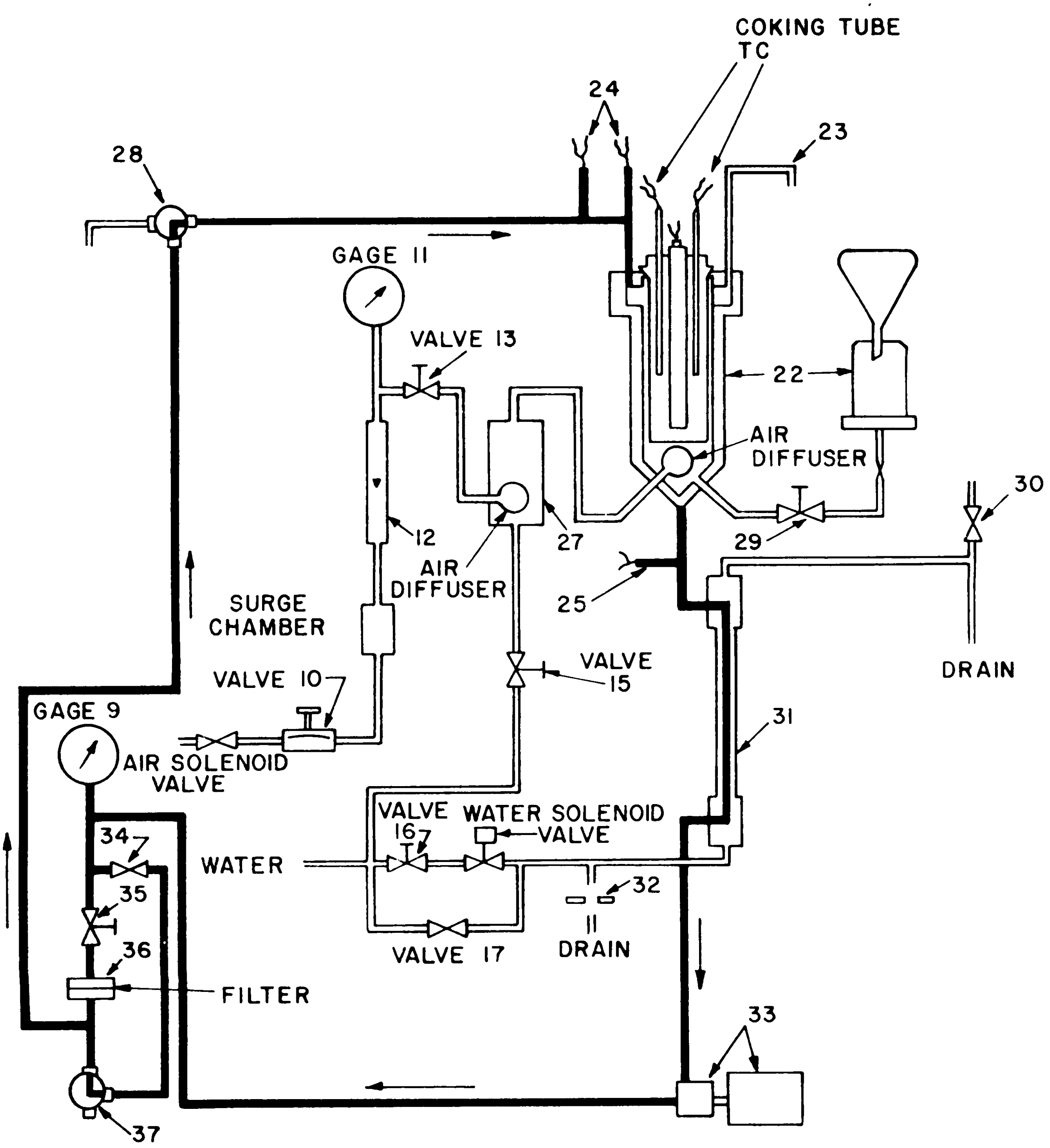

FIGURE 3. WADC deposition tester (schematic).

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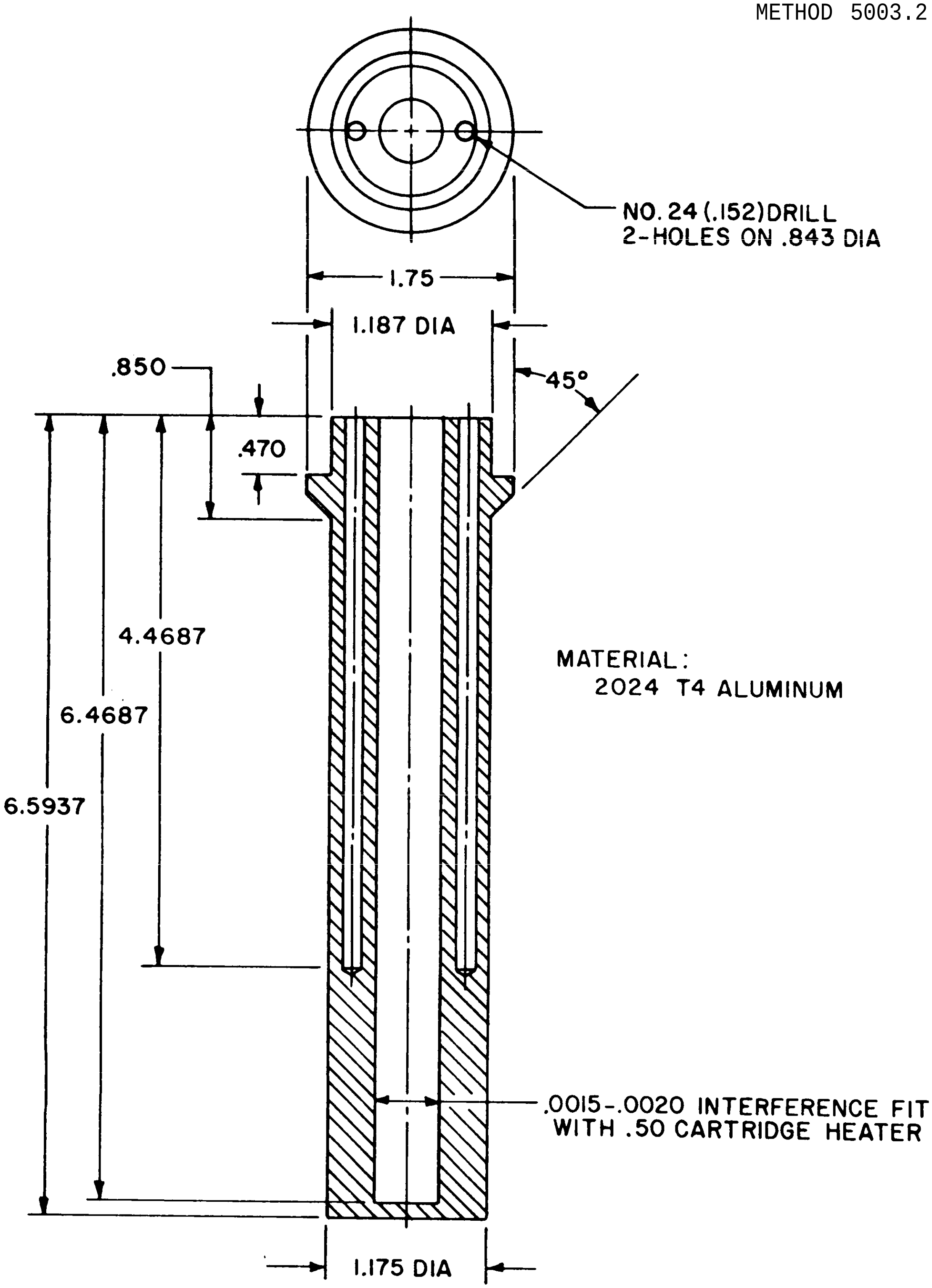

NOTE: DIMENSIONS IN INCHES.

FIGURE 4. Coking tube.

X-4388

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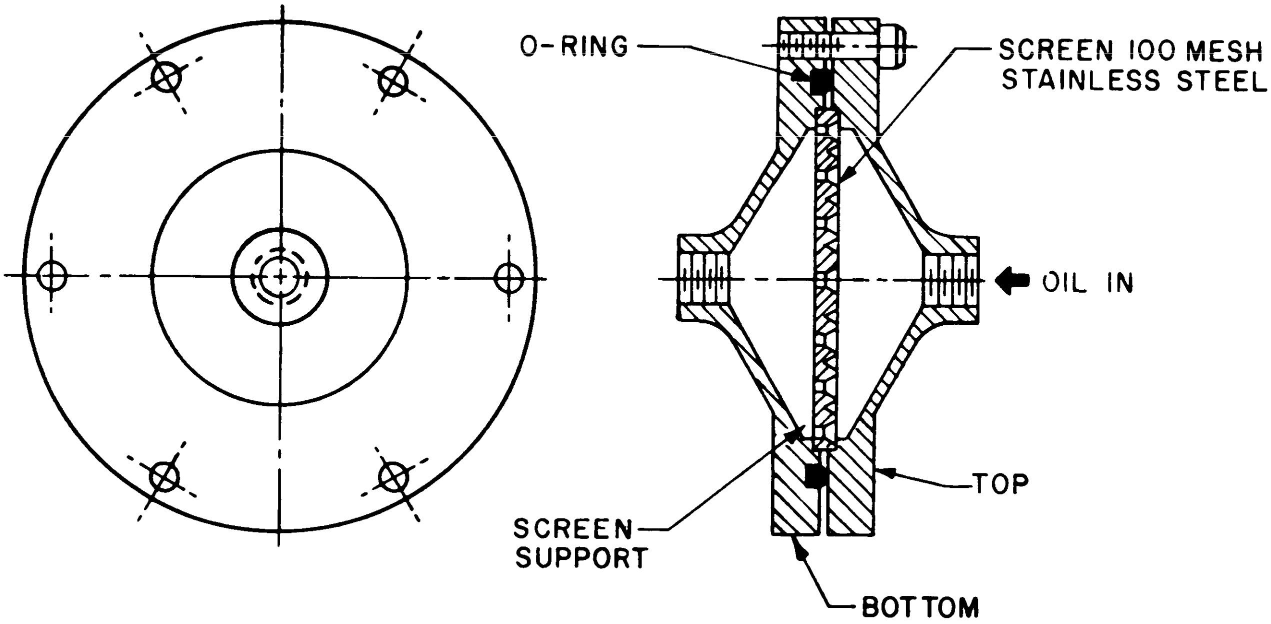

FIGURE 5. Line filter.

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NEUTRALITY (QUALITATIVE)

1. SCOPE

1.1 This method describes a qualitative procedure for determining the acidity of a hydrocarbon liquid (see Note 1) or distillation residue from gasoline or petroleum solvent. An acid reaction indicates the presence of acids which are corrosive to metals.

Note 1. If desired to determine alkalinity of hydrocarbon liquid, follow procedure described in 6.1.1 but substitute 8 drops of phenophthalein indicator solution for the methyl orange indicator solution. A pink or red color in aqueous layer when phenophthalein is used, indicates alkalinity (i.e., pH of 8.2 to 10.0). A pink or red color in aqueous layer when methyl orange indicator is used, indicates acidity.

2. SUMMARY

2.1 The method consists of extracting the acid components from the sample with distilled water and determining the acidic or basic nature of the sample, after centrifuging, by using liquid indicators.

3. SAMPLE SIZE

3.1 50 mL of the hydrocarbon to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Centrifuge.

4.2 Centrifuge tube, cone shaped or other type as shown in ASTM D 96.

4.3 Cork stoppers to fit centrifuge tube and test tube.

4.4 Test tube, to fit in centrifuge.

4.5 Pipette, approximately 10-mL capacity.

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Methyl orange indicator solution, 0.1 percent [u,u,u].

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5.3 Distilled water.

5.4 phenophthalein indicator solution [u,u,u].

6. PROCEDURE

6.1 Liquid (other than distillation residue) extraction determination.

6.1.1 Place 50 mL of the sample, 15 mL of distilled water, and 3 drops of the methyl orange solution in a centrifuge tube (see note 1).

6.1.2 Stopper the tube and shake vigorously 30 seconds.

6.1.3 Remove the stopper and place the tube in the centrifuge.

6.1.4 Spin the tube at 1500 rpm for 10 minutes.

6.1.5 Remove the tube from the centrifuge and observe the color in the lower aqueous layer (see 8.1).

6.2 Residue (from gasoline or petroleum solvents distillation) determination.

6.2.1 Cool the residue from the distillation to room temperature.

6.2.2 Transfer the residue to the test tube and add 3 volumes of distilled water.

6.2.3 Stopper the tube and shake vigorously for 30 seconds.

6.2.4 permit the layers to separate and remove most of the aqueous layer to a clean test tube by means of a pipette.

6.2.5 Add 1 drop of the methyl orange solution and note the color (see 8.2).

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 For liquid other than distillation residue, report the result as acid if the lower layer is pink or red. Report the results as neutral if the lower layer is yellow, when using the methyl orange indicator. If the phenophthalein indicator is used, report the results as neutral if color is unchanged, or as basic in pink.

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8.2 For a residue from gasoline or petroleum solvents distillation, report the result as passing unless a yellow color is formed, when using the methyl orange indicator solution. Report result as failing if the color is pink or red (i.e., a pH of 3.2 - 4.4).

9. PRECISION

9.1 Precision data have not been developed for this method.

Method Prepared By:

NAVY - SH - 1986

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METHOD 5102.1
September 30, 1986

ACID AND BASE NUMBER BY EXTRACTION

(COLOR-INDICATOR TITRATION)

1. SCOPE

1.1 This method is used for determining the amount of acidic or basic material in petroleum and synthetic oils. It is a satisfactory method for both new and in-service oils.

2. SUMMARY

2.1 The method consists essentially of titrating an extract of the oil and computing the number of mg (per g of oil) of potassium hydroxide used (or required to neutralize the acid used) to reach the end-point. This method includes separate procedures; 6.1 for neutralization (total acid and strong base number), and 6.2 for strong acid number.

3. SAMPLE SIZE

3.1 The following approximate amount of test oil (weighed to within 0.1 g) are required:

a. For neutralization number: 10 g.
b. For strong acid number: 25 g.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Hotplate, electric.

4.2 Glassware (for neutralization number):

a. Buret (2), 10-mL (0.05 mL graduations).
b. Flask (2), Erlenmeyer, 250-mL.

4.3 Glassware (for strong acid number):

a. Buret, 50-mL (0.1 mL graduations).
b. Separator funnel, 250-mL.
c. Casserole, 500-mL.

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

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5.2 Potassium hydroxide [3,0,1], 0.1 N aqueous solution, standardized to within 0.005 N against potassium hydrogen phthalate (ACS) [u,u,u], or benzoic acid (ACS) [u,u,u], using phenolphthalein indicator [u,u,u]. Prepare solution as follows:

a. Dissolve approximately 6 g of reagent-grade potassium hydroxide [3,0,1] in 1 L of freshly boiled and cooled (carbon dioxide free) distilled water.
b. Add a small amount of barium hydroxide [u,u,u] slurry, sufficient to precipitate any carbonate ion present, and allow to stand until the supernatant liquid is clear.
c. Filter the solution through a fine paper, or carefully withdraw the clear liquid into another bottle. Store the solution in a chemically resistant bottle.
d. Dispense in such a manner that the solution is protected from atmospheric carbon dioxide by means of a guard tube containing soda lime [u,u,u] or soda asbestos (ascarite) and such that the solution does not come in contact with cork, rubber, or saponifiable stopcock grease.
e. standardize, frequently enough to detect normality changes of 0.005, against pure, potassium acid phthalate or benzoic acid [u,u,u], using phenolphthalein indicator [u,u,u].

5.3 Sulfuric acid [3,0,2], 0.1 N aqueous solution, standardized to within 0.01 N against the potassium hydroxide [3,0,1] solution, using phenolphthalein indicator [u,u,u].

5.4 Alcohol solution, consisting of 1 part (by volume) absolute methyl alcohol (ACS) [1,3,0], 10 parts 95-percent ethyl alcohol (ACS) [0,3,0], and 11 parts distilled water (for neutralization number).

5.5 Phenolphthalein, l-percent alcoholic solution [u,u,u].

5.6 Methyl orange, 0.1-percent aqueous solution [u,u,u].

5.7 Distilled water.

6. PROCEDURES

6.1 Neutralization number procedure.

6.1.1 Prepare for titration as follows:

a. Fill two 10 mL burets, one with 0.1 N potassium hydroxide and the other with 0.1 N sulfuric acid, and note buret readings.
b. Heat 50 ±1 mL of distilled water to 85° +5° C.
c. Mix specImen with 100 ±1 mL of alcohol sOlution in a 250-mL Erlenmeyer flask, and heat mixture to boiling within 5 minutes.
d. Remove flask from hotplate, add 1 mL of phenolphthalein solution, and swirl for 5 seconds (max).

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6.1.2 Immediately titrate mixture, completing all operations in 120 ±15 seconds, as follows:

a. Commence titration, using 0.1 N potassium hydroxide to a pink end point, if mixture is colorless (acid); or using 0.1 N sulfuric acid to disappearance of color, if mixture is pink (base).
b. When end point indication persists more than momentarily, add the 50 ±1 mL of hot distilled water, and check end point indication by shaking for 3 to 5 seconds and observing color of alcohol layer.
c. Continue titration until end point indication persists on checking. Note final buret reading, and determine amount of reagent used.
d. Confirm end point by adding 2 drops of either 0.1 N sulfuric acid or 0.1 N potassium hydroxide (whichever was not used in titration). If the end point indication persists, repeat the test (6.1.1 and 6.1.2).

6.1.3 Perform blank determination as follows:

a. Fill 10-mL buret with 0.1 N potassium hydroxide, and note buret reading.
b. Heat 50 +1 mL of distilled water to 85° +5” C.
c. Heat 100 +1 mL of alcohol solution to boiling in a 250-mL Erlenmeyer flask.
d. Remove flask from hotplate, add 1 mL of phenolphthalein solution, and add the 50 +1 mL of hot distilled water.
e. Titrate, using 0.1 N potassium hydroxide, to a pink end point. Note final buret reading, and determine amount of reagent used.

6.1.4 Compute the neutralization (total acid or strong base) number, see 7.1.

6.2 Strong acid number procedure.

6.2.1 Prepare for titration as follows:

a. Fill 50-mL buret with 0.1 N potassium hydroxide and note buret reading.
b. Heat approximately 200 mL of distilled water to boiling.
c. Place specimen in a 250-mL separatory funnel.
d. Extract specimen first with 100 mL and then with two 50 mL. portions of the hot distilled water, draining the water into a 500-mL casserole. Discard original specimen.
e. Add 0.1 mL of methyl orange solution to the water extract. (If the solution does not become pink or red, it is basic, and this test is not applicable.)

6.2.2 Titrate the water extract, using 0.1 N potassium hydroxide to a golden-brown end point. Note the final buret reading, and determine the amount of reagent used.

6.2.3 Perform blank determination as follows:

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a. Fill 50 mL-buret with 0.1. N potassium hydroxide, and note buret reading.
b. Heat approximately 200 mL of distilled water to boiling.
c. Remove water from hotplate, and add 0.1 mL of methyl orange solution.
d. Titrate, using 0.1 N potassium hydroxide, to the same depth and shade of color obtained in the water extract titration (6.2.2). Note final buret reading and determine amount of reagent used.

6.2.4 Compute strong acid number, see 7.2.

7. CALCULATIONS

7.1 Compute neutralization (total acid or strong base) number as follows:

$$\text{Total acid number} = \frac{56.1\, N\, (A - B)}{W}$$

$$\text{Strong base number} = \frac{56.1\, (Cn + BN)}{W}$$

A = Potassium hydroxide used in specimen titration, mL.
B = Potassium hydroxide used in blank titration, mL.
C = Sulfuric acid used in specimen titration, mL.
W = Weight of specimen, g.
n = Normality of sulfuric acid solution.
N = Normality of potassium hydroxide solution.

7.2 Compute strong acid number as follows:

$$\text{Strong acid number} = \frac{56.1\, N\, (D - E)}{W}$$

D = Potassium hydroxide used in water extract titration, mL.
E = Potassium hydroxide used in blank titration, mL
N = Normality of potassium hydroxide solution.
W = Weight of specimen, g.

8. REPORTING

8.1 Report - total acid number, strong acid number, or strong base number.

9. PRECISION

9.1 Results should not differ from the mean by more than the amounts specified in Table 1.

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TABLE 1. Precision.

Material	Acid or Base Number	Repeatability (one operator)	Reproducibility (different operators)
New Oils	0.5 and under Over 0.5	0.05 10 percent of mean	0.05 20 percent of mean
Used oils	0.05 and under Over 0.5	0.10 10 percent of mean	0.10 30 percent of mean

Method prepared by:
Navy - NAPC - 1986

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CORROSIVENESS OF GREASES OR SEMI-SOLID PRODUCTS AT 25° C

1. SCOPE

1.1 This method is used for determining the presence of corrosive compounds in grease or other semi-solid products at room temperature (25° C; 77° F).

2.1 The method consists of half covering two copper strips with the product under test and examining for corrosion after 24 hours.

3. SAMPLE

3.1 Approximately 5 g of material to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Watch glass for covering sheets.

5. MATERAILS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measure, and spill practices of each chemical are explained.

5.2 Copper strips (2), (QQ-C-576), 2.5 x 2.5 x 0.3 cm (1 x 1 x 1/8 inch).

5.3 n-Hexane (ACS) [1,3,0].

5.4 Acetone (O-A-51), technical grade, [1,3,0].

5.5 Abrasive paper (silicon-carbide or alumina), various grade of grit.

5.6 Abrasive paper, silicon-carbide, 240 grit.

5.7 Silicon-carbide, 150 mesh.

5.8 Cotton, absorbent (JJJ-C-561).

6. PROCEDURES

6.1 Prepare the copper strip as follows:

6.1.1 Using progressively finer grades of abrasive paper, remove all surface blemishes from one side of strip.

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6. 1.2 Polish strips with the 240 grit paper to remove any marks produced by the coarser abrasive. Do not touch the strips with the fingers. Handle strips only with lint-free paper or tongs. Store strips immersed in acetone until ready for final polishing.

6.1.3 Remove strips from the acetone, and final polish one sise to a mirror finish, using 150-mesh silicon-carbide grit (held on an acetone-moistened cotton pad).

6.1.4 Clean all metal dust from the strip by rubbing vigorously with clean pads of absorbent cotton until a fresh pad remains unsoiled.

6.1.5 Wash strips in fresh warm n-Hexane, then in fresh warm acetone, and allow to air-dry,

NOTE 1. Caution. n-Hexane and acetone are toxic. Use only in a well ventilated area. Do not breathe its fumes nor allow it to come in contact with the skin. Keep all frames away from these materials.

6.2 place approximately one-half of the sample on each strip, taking care to leave approximately half of the polished surface exposed.

6.3 Cover the strips with inverted watch glasses, and let stand at room temperature for 24 hours.

6.4 Remove the watch glasses, and visually examine the sample for a green color.

6.5 Wash the copper strips in non-corrosive n-hexane and inspect them for brown stains.

7. CALCULATION

7.1 This section is not applicable to the test procedure.

8. REPORT

8.1 Report the lack or the presence of any evidence of corrosion (green color in sample or stain on copper sheets).

9. PRECISION

9.1 precision data have not been developed for this method.

Method Prepared by:

Army - ME - 1986

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CORROSIVENESS OF LUBRICANTS AT 232° C (450° F)

1. SCOPE

1.1 This method is used for determining the corrosive tendencies of lubricants at high temperatures. It consists of immersing copper and silver strips in the sample at 232° C (450°) for 50 hours, and then examining them for weight change.

2. SUMMARY

2.1 This method duplicates an extended, high-temperature engine or gear box environment. Copper and silver strips are exposed to the heated lubricant for 50 hours and carefully cleaned and weighed for loss of weight due to corrosive action resulting from corrosive decomposition products being formed in lubricant.

3. SAMPLE SIZE

3.1 Approximately 400 mL of lubricant to be tested.

4. REFERENCES, STANDARDS AND APPARATUS

4.1 Oven, explosion-proof, 232° ± 3° C (450° ± 5° F).

4.2 Copper strip (QQ-C-576), 3.8 cm by 3.8 cm by 0.16 cm (1-1/2 x 1-1/2 x 1/16 in).

4.3 Silver strip, pure electrolytic (MIL-S-13282, grade A), 3.8 cm by 3.8 cm by 0.32 cm (1-1/2 x 1-1/2 x 1/8 in).

4.4 Beakers (2), Borosilicate glass, Griffin low-form, 400-mL.

4.5 Supports (2), glass (for holding copper or silver strip vertically in beaker with point contact, so that strip does not touch the sides or bottom of the beaker).

4.6 Balance, sensitivity 0.1 mg.

4.7 Electrolytic bath, carbon-rod anode, 0.5 amp (rein), containing sulfuric acid solution (5 percent by weight in distilled water) as the electrolyte.

4.8 Tongs, stainless steel.

4.9 Watch glass (2), 10 cm or larger.

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000,

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Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Solvent, dry-cleaning (ASTM D 484, type 1) [0,2,0].

5.3 1,1,1-trichloroethane (reagent grade) 12,1,0].

5.4 Acetone (ACS) [1,3,0].

5.5 Nitric acid solution (3 parts concentrated nitric acid and 7 parts distilled water) [2,0,0].

5.6 Pumice, FFF grade.

5.7 Eraser (Eperhard Faber "pink Pearl” No. 100, or equivalent).

5.8 Cleaning solution, glass (concentrated sulfuric acid [3,0,2] saturated with potassium or sodium bichromatell,O,lj, technical grade).

Note 1. If the glass-cleaning solution cannot remove all deposits (see 6.1) use a special cleaner, such as Turco Transpo cleaner (Turco products Co., Chicago, IL).

5.9 Distilled water.

6. PROCEDURE

6.1 Clean two glass supports and two 400-mL beakers as follows:

a. Rinse with dry-cleaning solvent to remove excess oil.
b. place each support in its beaker, and fill each beaker with glass-cleaning solution. Let them stand for at least eight hours or until all traces of deposits are removed.
c. Remove from the glass-cleaning solution, and rinse the glassware with running tap water followed by distilled water.

6.2 Handling only with tongs, clean the copper and silver strips ill separate bath solutions as follows:

a. Wash with dry-cleaning solvent.
b. Immerse in dilute nitric acid solution for 15 + 1 second.
c. Rinse the silver strip only in hot 82° to 100°C (180° to 212°F) tap water, and then wet polish with pumice. (No polishing of the copper strip is required.)
d. Rinse the strip in hot tap water, and then in not distilled Walter.
e. Dip in acetone, and allow to air dry.

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6.3 Handling the strips with tongs, weigh each strip to the nearest 0.1 mg.

CAUTION

> In succeeding steps the strips must be handled only with tongs until after they leave been weighed (see 6.9) at the end of the test.

6.4 Mount each strip in a glass support then place each support in a separate beaker so that the strip does not touch the sides of the beaker.

6.5 Add 200 mL of the sample to each beaker, and cover with watch glass to avoid evaporation losses.

6.6 Store both beakers in an oven for 50 hours at 232° ± 3° C (450° ± 5° F).

6.7 At the end of the heating period, remove both beakers from the oven and allow them to cool to room temperature.

6.8 Remove the copper and silver strips from the supports and clean them as follows:

a. Wash each strip with successive portions of fresh, [hot 60° c (approx. 140° F) 1,1,1-trichloroethane, to remove as much discoloration and deposit as practicable.
b. If carbonaceous deposits remain, place the strip (as a cathode) in the electrolytic bath for ten minutes at 0.5 amperes.
c. Wash each strip in hot, running water, while rubbing it with an eraser.
d. Rinse each strip with distilled water, then with acetone, and air dry both strips.

6.9 Weigh each strip to the nearest 0.1 mg, and compute the change in weignt of each strip (see 7.1).

6.10 Measure the surface area of each strip (both sides) (see 7.1).

7. CALCULATIONS

7.1 The calculations to determine mg/sq cm as follows:

$$CW = \frac{W_1 - W_2}{2*W*L}$$

CW = Change in mg/sq cm.
W_1 = original weight in mg.
W_2 = Final weight in mg.
w = Width of metal strip in cm.
L = Length of metal strip in cm.

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8. REPORTING

8.1 Report change in weight in mg/sq cm rounded off to the nearest mg.

9. PRECISION

9.1 Repeatability. Results of each test obtained by one operator using the same apparatus must not vary by more than that shown in Table 1.

9.2 Reproducibility. Results of each test obtained by different operators or different apparatus must not vary by more than that shown in Table 1.

TABLE 1 - precision.

Average weight change, mg/sq cm	permissible variation	
	Repeatability	Reproducibility
O to 0.46	0.046 mg/sq cm	0.09 mg/sq cm
Above 0.46	10 percent	20 percent

Method prepared by:

Air Force - SFTL - 1986

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METHOD 5306.5
September 30, 1986

CORROSIVENESS OF EMULSIFIABLE CUTTING FLUIDS

1. SCOPE

1.1 This method is used for determining the corrosiveness of soluble cutting oils and chemical type metal working fluids on brass, copper, cast iron, and steel.

2. SUMMARY

2.1 The test consists of placing a metal strip and the sample in a test tube. A bubble tower filled with sodium hydroxide is used to permit air into the test tube at a specifed rate and temperature. The strip is examined for conformance with specification requirement.

3. SAMPLE SIZE

3.1 Approximately 10 mL of the fluid to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 ASTM D 130 Detection of Copper Corrosion from Petroleum Products by the Copper Strip Tarnish Test.

4.2 Source of clean compressed air.

4.3 Air pressure regulator.

4.4 Approximately 7.3 m (24 feet) of 0.6 cm (1/4 inch) I.D. rubber tubing.

4.5 Four screw type pinch clamps.

4.6 One bubble tower, capacity 500-mL.

4.7 Four test tubes, approximately 3.2 cm O.D. by 20.0 cm long.

4.8 Four pieces of glass tubing, 0.6 ±0.1 cm I.D., by 23.0 ±1 cm long.

4.9 Forceps, stainless steel.

4.10 Graduated cylinder, capacity, 250-mL.

4.11 Magnifier, 5X.,

5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000,

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Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 500 mL of sodium hydroxide solution containing approximately 25 percent NaOH by weight [3,0,1].

5.3 Normal hexane, commercial [1,3,0].

5.4 1,1,1-trichloroethane (0-T-620) [2,1,0].

5.5 Distilled water.

5.6 Cleaning tissue (UU-T-450).

5.7 Two copper strips, approximately 76 x 13 cm by 0.32 cm (3 x 1/2 x 1/8 inch) (QQ-C-576, electrolytic tough pitch, cold-rolled, half-hard temper).

5.8 Two brass strips, approximately 76 x 13 x 0.32 cm (3 x 1/2 x 1/8 inch) (QQ-B-613, composition 2 [cartridge brass], half-hard temper).

5.9 Two cast iron strips, approximately 76 x 13 x 0.32 cm (3 x 1/2 x 1/8 inch) (QQ-I-652, class 20, strip only).

5.10 Two steel strips, approximately 76 x 13 x 0.32 cm (3 x 1/2 x 1/8 inch) (QQ-S-698, physical quality cold-rolled, half-hard temper - CR half-hard No. 2 temper).

6. PROCEDURE

6.1 Prepare two strips of each type of metal listed in section 4 in, accordance with ASTM D 130.

6.2 Using the forceps, place one strip of each type of metal in a separate test tube. Place the duplicate strips in a bottle filled with the normal hexane. Keep this bottle tightly stoppered until time to examine the strips.

Note. Caution. Normal hexane is flammable. Use only in a well ventilated area. Keep all flames away from the normal hexane.

6.3 Prepare a solution of the cutting fluid by placing 190 mL of distilled water and 10 mL of the cutting fluid in a 250-mL graduate. Stopper the graduate and invert it several times. Continue inverting the graduate until a uniform mixture is obtained.

6.4 Place 50 mL of the cutting fluid solution in each of the four test tubes. Mark the fluid level on the outside of each test tube and maintain this level by the addition of distilled water during the course of this test.

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6.5 Fill the bubble tower with the sodium hydroxide solution and connect the tower, through the air pressure regulator, to the source of compressed air by means of the rubber tubing.

6.6 Connect each length of glass tubing, by means of rubber tubing and an appropriate manifold or series of Y-tubes, to the discharge outlet of the bubble tower. Place a screw type pinch clamp on each piece of rubber tubing leading to the glass tubes.

6.7 Insert each glass tube to the bottom of a test tube and adjust the air flow into each tube to produce approximately one bubble per second by means of the air pressure regulator and pinch clamps.

6.8 Permit the air to bubble into the tubes at room temperature 24° C ±3° C (75° F ±5° F) for a period of 48 hours.

6.9 At the end of the test period, remove the metal strips from the test tubes. If the cutting fluid under test is a soluble oil type, wash the metal strips in 1,1,1-trichloroethane and permit them to air dry. If the cutting fluid under test is a chemical solution type, wash the metal strips in distilled water and blot them dry with facial tissue.

6.10 Remove the duplicate metal strips from the bottle of normal hexane and permit them to air dry. Exmaine the exposed and duplicate metal strips under 5X magnification for conformance with the specification requirement.

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Comply with specification requirement.

9. PRECISION

9.1 Precision data have not been developed for this method.

Method Prepared By:

Army - AR - 1986

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METHOD 5307.2
September 30, 1986

CORROSIVENESS AND OXIDATION STABILITY OF AIRCRAFT TURBINE ENGINE LUBRICANTS

1. SCOPE

1.1 This method is used to determine the oxidation and corrosion characteristics of aircraft turbine engine lubricants. Either petroleum or synthetic origin fluids may be evaluated using either moist or dry air with or without metal test specimens. The specific conditions selected including test temperature will depend upon the specification requirements established for the fluid subjected to the test.

2. SUMMARY

2.1 Basic method: A sample of the lubricant is subjected to a specified oxidative, thermal and catalytic environment for a specified controlled number of test hours. Specified test temperatures range from 120° C (248° F) to 360° C (680° F) depending on the type of lubricant being subjected to test. A test duration of 96 hours is considered the standard test time. At periodic intervals during the test and at the end of test, 10 mL samples of the lubricant are extracted and examined for both physical and chemical changes through viscosity and total acid number measurements. Corrosion of metal test specimens is determined by changes in specimen weight and by microscopic examination.

2.2 Alternate method: An alternate test procedure may be specified which deletes the necessity for intermediate oil sampling during the test period. This alternate test procedure may not be used interchangeably with the basic test procedure. This alternate test procedure may be used only when specifically required by the specification requirements established for the fluid subjected to the test.

3. SAMPLE SIZE

3.1 Approximately 250 mL of the lubricant to be tested (200 mL for test sample and 50 mL for viscosity and TAN).

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Sample tube, borosilicate glass, standard wall, 5.1 cm O.D., 45 ±1 cm overall length (see Figure 1).

4.2 Sample tube head borosilicate glass \$ 71/60 male ground glass joint with upper surface formed in a dome-shaped contour (see Figure 2).

4.3 Air tube, borosilicate glass (see Figure 3).

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4.4 Thermocouple tube, borosilicate glass (see Figure 4). A bare-wire thermocouple is inserted to the bottom of the glass tube and a small volume of high temperature fluid such as polyphenyl ether is injected to facilitate heat transfer.

4.5 Condenser, Allihn type, borosilicate glass, 30 cm water jacket length, with lower end formed as a male $\overset{T}{S}$ 24/40 joint.

NOTE 1: Above glassware is available from:

Houston Glass Fabricating Co.
5313 Harrisburg Blvd.
Houston, Texas 77011

Koehler Instrument Co.
1595 Sycamore Avenue
Bohemia, L.T., NY 11716

Scientific Glass Apparatus Co.
735 Broad Street
Bloomfield, New Jersey 07003

4.6 Spacer, Borosilicate glass, standard wall, 0.9 cm Oil., 0.6 cm length.

4.7 Adapter, Teflon $\overset{T}{S}$ 10/18 joint, used to position and seal air inlet tube.

NOTE 2: The air tube adapter (4.7) may be obtained as catalog No. K–17980 from:

Kontes Glass Company
Vineland, New Jersey 08360

4.8 Oil sampling device, consisting of a convenient length of 0.4 cm borosilicate glass tubing with one end fixed by means of one-hole stopper in a 25-mL filtering flask. The tubing is bent in a U-shape with one leg (sampling side) approximately 60 cm in length. The tube leg attached to the flask may be a much shorter, convenient length.

4.9 Heat medium, constant temperature, capable of maintaining the specified test temperature (sample temperature) within limits of +1° C (+2° F) and allowing for a sample tube immmersion depth of 25 +2 cm. For test temperature above 220° C (428° F) aluminum block heat medium or other non-oil type heat medium is required due to hazards and problems of using oil baths above this temperature. Adequate hood and ventilation facilities are required when operating either oil or block baths.

4.10 Flowmeter, capable of an airflow measurement of 10 ±1 L/hr, calibrated for conditions of 21° C (70° F) and 101 gage kPa (760 mm Hg).

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4.11 Air supply, tree of reactive contaminants. For lubricant specifications requiring "dry air", in conducting this test, the dew point of the air shall be -68° C (–90° F) or below. For lubricant specifications requiring "wet dir", the moisture content shall be 10 ±1 mg water per L of air standard conditions.

4.12 Air drier (if required). The precise method of air drying is optional. A satisfactory apparatus is a glass column containing 8 mesh anhydrous calcium sulfate. The column diameter is selected such that the face velocity of the airflow does not exceed 1.2 m/min. Commercial air dryers are also satisfactory for providing air with a dew point of-68° C.

4.13 Air humidifier (if required). The precise method of humidifying the test air is optional. A satisfactory device is shown in Figure 5. Air enters through a length of 0.95 cm (3/8-inch) tubing and discharges through a 2.5 cm (1-inch) diameter differuser stone. The controlled temperature is that indicated by the thermocouple near the air exit fitting. One heater is operated by an on-off switch and used only for inital preheating. A second heater is in circuit with a variable potential transformer. The transformer is adjusted to control the air exit temperature equired to give the proper moisture content. The stainless steel tank is in lated over the entire exterior surface and placed within a refrigerator. The air exit fitting and line are well insulated to avoid moisture condensation. The exit line length within the refrigerator is held to a minimum and the downstream portion of the line between the refrigerator and sample tube must not encounter a temperature region lower than the control temperature, or condensation will occur.

NOTE 3: The stainless steel tank may be obtained as type G–lW from:

A. C. Tank Company
P. O. Box 389
Burlington, Wisconsin 53105

4 .13.1 The apparatus described above will satisfactorily serve as an air humidifier for several sample tubes, up to a known total of 16 each. At this flow rate (160 L/hr), the following control parameters are typical for achieving a moisture of 10 mg water per L of air:

Exit air temp	15° C (59° F)
Water temp	15.6° C (60° F)
Refrigerator temp	12.2° c (54° F)
Control heater power	>10 watts

4 .13.2 The exit air temperature is monitored daily; however, with satisfactory insulation, the transformer setting should not require adjustment during a 96 hour test.

4. 13.3 The exit air temperature is selected to (obtain the desired moisture content. Moisture content may be determined gravimetrically using a U-shaped

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Schwartz tube with standard taper glass stoppers. The tube is filled with anhydrous calcium sulfate and weighed to the nearest 0.1 mg. The air moisturizer is allowed to temmerature equilibrate at the required total airflow. While maintaining the total flow through the moisturizer, the weighing tube is connected to any one of the sample tube air lines. After a 1 hour flow period, the tube weight gain should be 100 +10mg. Any change in the total airflow necessitates recalibration of moisture content since the air velocity through the moisturizer could affect the relative humidity of the air. In the event that a test is performed with a lesser number of sample tubes than that for which originally calibrated, unused flowmeters should be left on to maintain the normal total airflow.

4.14 Balance, analytical, sensitivity 0.1 mg.

4.15 Balance, laboratory, 2500-g capacity, 0.1 g sensitivity.

4.16 Centrifuge, capable of producing a relative centrifugal force of 840 ±40 (see ASTM D 91).

4.17 Tube, centrifuge, ASTM cone shaped, 100-mL (see ASTM D 91).

4.18 Microscope, 20X magnification.

4.19 Bath, elect recleaning, consisting of a 1–L glass beaker, hot plate, and variable D.C. voltage source capable of supplying a current of 1 ampere. A satisfactory voltage source is the model D–612T Filtered, D.C. Power Supply manufactured by Electro Products Laboratories, Inc. , 6125 W. Howard St. , Chicago IL 60648.

4.20 Oven, Drying, for glassware.

4.21 Cabinet, dust free for storing glassware after cleaning.

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled care fully. Federal Test Method 10000, Material handling satety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Metal specimens (one each), washer type, 1/4 inch (0.64 cm) I.D. by 3/4 inch (1.9 cm) O.D. by 0.032 inch (0.081 cm) thick, as follows:

5.2.1 Titanium (AMS 4908).

5.2.2 Magnesium (QQ-M-44, AZ31B, condition H24).

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5.2.3 Steel, M-50 (AMS6490).

5.2.4 Steel, carbon, mild (QQ-S-698, grade 1009, cold rolled, condition No. 4 or 5).

5.2.5 Bronze, silicon (AMS 4616).

5.2.6 Silver, (MIL-S-13282 [ord], Grade A).

5.2.7 Aluminum (QQ-A-250/4, T-3 or T-4).

NOTE 4: Above metal specimens may be obtained from:

Metaspec Co.
P. O. BOX 28125
San Antonio, Texas 78228

5.3 Abrasive paper, silicon carbide, 240 and 400 grit.

NOTE 5: *’Wet or dry” or “waterproof” cloths or papers, or iron containing abrasives such as natural emery, are not satisfactory.

5.4 Cotton, absorbent.

5.5 n-Heptane, reagent grade [1,3,0].

5.6 Acetone, reagent grade [1,3,0].

5.7 Cleaning solution, glassware, consisting of 1000 mL cone sulfuric acid [3,0,2] and 35 mL saturated sodium dichromate [1,0,1] solution (aqueous).

5.8 Nitric acid, cone, reagent grade [2,0,0].

5.9 Solvent, De-Greasing, Trichlorotrifluoroethane ("Freon"-TF, Freon –11, or Genesolve-D) [u,u,u].

5.10 Carbon remover, glassware, such as Calgon Carb–N-Kleen.

5.11 Solution, metal specimen electrocleaning, aqueous solution of 15 g/L sodium hydroxide and 15 g/L trisodium phosphate.

5.12 Detergent, Alconox or equivalent.

6. PROCEDURES

6.1 Operating conditions.

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6.1.1 Under normal operation conditions, the test is run continuously for a period of 96 hour at 10 L/hour airflow. During the 96 hour test period, intermediate 10 mL samples are taken at 16, 24, 40, 48, 64, 72, 88 and 96 hours. During the test period, the oil sample temperature is maintained with +1° C (+2° F) Of the specified test temperature. No specific requirements are made with regard to ambient conditions except that the condenser cooling water out temperature be below 27° c (81° F) and the water flow controlled to maintain this water out temperature.

NOTE 6: An alternate test procedure may be specified which deletes the necessity for intermediate oil sampling during the 96 hour test period. When intermediate sampling is emitted, the initial oil charge size is reduced from 200 mL to 165 ML in order to produce approximately comparable results. See 6.2.12.

6.2 Preparation for test.

6.2.1 perform all necessary calibrations of thermocouples, flowmeters, etc.

6.2.2 Turn on heat medium and bring to a temperature that will maintain the oil sample within ±1° C (±2° F) of the specified test temperature.

6.2.3 If the test glassware is to be cleaned from a previous run, proceed as follows:

6.2.3.1 Rinse all glassware items and the air tube adapter with de-greasing solvent to remove residual oil, and air dry.

6.2.3.2 Fill or immerse the sample tube, air tube, and 0.9 cm glass spacers in carbon remover at room temperature until carbonaceous deposits are removed. Water rinse after removal.

6.2.3.3 Wash all glassware items and the air tube adapter with detergent. Rinse with water, to remove detergent, and dry.

6.2.3.4 Fill or immerse all glassware items with glassware cleaning solution and soak for 3 to 16 hours (for cleaning solution see 5.7).

6.2.3.5 Remove glassware from cleaning solution and rinse several times with water, followed by distilled water, and oven dry.

6.2.3.6 Store all items in a dust free cabinet until required for test. If stored for more than 1 week, the glassware is again rinsed with distilled water and oven dried before use.

6.2.4 If new glassware is to be used, clean according to 6.2.3, omitting steps 6.2.3.1 and 6.2.3.2

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6.2.5 Assemble the appropriate number of clean sample tubes and accessory items and intermediate sampling containers. only test oil is used to lubricate ground glass joints during assembly.

6.2.6 Determine the neutralization number of the original oil sample by method ASTM D 664, using a titration endpoint of pH 11.

6.2.7 Determine the kinemetic viscosity of the original oil sample at 40° C (104° F) and 100° C (212° F) by method ASTM D 445.

6.2.8 Collect the required number and types of metal specimens to be used for test.

6.2.8.1 Clean and prepolish the metal specimen face surfaces and inner and outer edges using 240-grit abrasive paper. No pitting, etching, or other signs of corrosion should be visible when viewed through a 20x microscope. The specimens are handled only with forceps, ashless filter paper, or polyethylene gloves from this point.

6.2.8.2 Finish with 400-grit paper removing all marks that may have been left by the previous polishing.

NOTE 7: As a practical polishing procedure, place a sheet of the abrasive paper on a flat surface and rub the specimen against the paper with longitudinal strokes, holding the specimen with ashless paper. Do not use the same sheet of abrasive paper for polishing different metal types.

6.2.8.3 Cotton swab the specimens with n-Heptane, followed by acetone, using fresh cotton pads until a pad remains unsoiled.

6.2.8.4 If there is a short delay before weighing, store the specimens under n-Hexane.

6.2.9 As soon as the metal set is polished and cleaned, weigh each specimen to within 0.1 mg.

6.2.10 Slide the specimens onto the air tube. The first specimen rests directly on the air tube collar and succeeding specimens are each separated by a 0.9 cm glass spacer (see 4.6). Assemble the metals on the air tube in the following order: Aluminum (bottom position), silver, bronze, mild steel, M-50 steel, magnesium, titanium (top).

6.2.11 Place the air tube, with metals, into the sample tube. Position the head on the sample tube with the air tube extending through the center glass joint. Seat the teflon adapter on the air tube, with the air tube resting on the bottom of the sample tube, and tighten the gland. Insert the thermocouple tube, making sure the closed end of the tube is at least 1 cm from the sample tube wall, and weigh the entire assembly to the nearest 0.1 g.

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6.2.12 Add 200 ±2 mL of oil (165 +2 mL if alternate test Procedure is to be used, note 6) to the sample tube, reweigh the assembly, and determine weight Of sample added.

6.3 Start of test.

6.3.1 Position the sample tube in the heat medium, preadjusted to test temperature, to an immersion depth of 25 ±2 cm.

6.3.2 Insert the Allihn condenser and start the water flow.

6.3.3 After a 15-minute warmup period, connect the air supply anti adjust the flow rate to 10 ±1 L/nour. Begin counting test time from this point.

NOTE 3: When using aluminum heating blocks without heat transfer medium, start airflow and test time one hour after inserting tube in block.

6.3.4 perform adjustment of the heat medium temperature such that the oil sample temperature is held to within ±1° C (±2° F) of the required test value.

6.4 Test operation.

6.4.1 Verify sample temperature and airflow rate just prior to each intermediate sampling time.

6.4.2 Sample the test oil according to the following schedule:

10 mL Sample
16 hr
24 "
40 "
48 "
64 "
72 "
88 "
96 "

Omit samples 16 through 88 if alternate test procedure is used. Note 6

6.4.3 perform both intermediate and final sampling by witndrawing the thermocouple tube and inserting the 4 mm tube attached to a filtering flask. By means of a rubber bulb, exert a slight suction at the flask Lube. and draw the oil to a premarked level. perform the sampling without interrupting the airflow or removing the sample tube from the heat medium.

6.4.4 Record the total weight of all samples removed during test.

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6.4.5 Determine the neutralization number of all samples. Determine viscosity at 40° C (104° F) of all samples, and viscosity at 100° C (212° F) of original and final sample.

NOTE 9: Due to the reduced sample volume available, viscosity measurement is made using the semi-micro viscometers listed in ASTM D 445. In addition, it may be necessary to determine neutralization number using a titration sample size less than that required by ASTM D 664.

6.5 Termination and evaluation.

6.5.1 After withdrawing the final sample, shut off the airflow and condenser water and remove the condenser. If no further tests are required, turn off heat medium.

6.5.2 Immediately remove the sample tube assembly from the heat medium, wipe the tube exterior, cool and rinse tube exterior with solvent. Weigh the assembly to the nearest 0.1.g. Compute the percentage of oil weight loss, see 7.1.

6.5.3 Remove the thermocouple tube, air tube Teflon adapter, and sample tube head.

6.5.4 Remove the air tube with metal specimens. Rinse with n-Hexane and carefully slide the specimens off the tube onto a clean absorptive surface. Keep metal specimens in order for identification.

NOTE 10: If processing of the specimens is to be delayed more than 4 hours after end of test, store them under n-Hexane.

6.5.5 Drain the test oil from the tube into a clean glass container and hold for sludge determination.

6.5.6 Rinse the metal specimens, individually, in n-Hexane wetted cotton pads until clean pads are noted. Rinse with clean n-Hexane and acetone, air dry, and weigh to within 0.1 mg.

6.5.7 If, at this point, there are visible carbon deposits remaining oil the specimens, they are electrocleaned. The individual specimens except aluminum, are catholically cleaned in hot 75° C to 83° c (167° F to 185° F) electrocleaning solution for a period of 15 to 30 seconds to a current density of 0.08 amp/cm^2. Remove from the bath, rinse in tap water, and cotton swab to remove loose deposits. (Repeat the electrocleaning step, as necessary to remove all deposits.) Rinse the speimens in acetone, air dry, and reweign.

6.5.8 Soak the aluminum specimen in concentrated nitric acid for 15 minutes, then water rinse, and cotton swab to remove loose deposits. (Repeat the cleaning as necessary to remove all deposits.) Rinse the specimens in acetone, air dry, and reweigh.

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NOTE 11: If metal types other than those cited herein are used, the compatibility of the elect recleaning procedure with metal composition should be determined, and if applicable, other appropriate procedures used.

6.5.9 Examine the metal specimens by microscope at 20x magnification. Record evidence of pitting, etching, etc.

6.5.10 Using a representative portion of the bulk oil sample (6.5.5), centrifuge a 25 mL aliquot for 1 hour at a relative centrifugal force of 840 +40. Note the volume of solid or semisolid sludge obtained, estimating to 0.1 mL where possible. Record the percentage volume of sludge.

7. CALCULATIONS

7.1 Calculate the percentage of oil weight loss as follows:

$$\text{Percent weight loss} = \frac{W_2 - (W_3 + W_4}{W_2 - W_1}$$

Where: W_1 = Weight of tube assembly.
w_2 = Weight of tube assembly plus oil before test.
W_3 = Weight of tube assembly plus oil after test.
W_4 = Weight of accumulative sample removed.

8. REPORTING

8.1 Report kinematic viscosity, expressed in centistokes, for all samples at 40° C (104° F) and for original and final samples at 100° (212° F). Report percentage change from original viscosity for all intermediate and final samples at 40° c (104° F) and for final sample at 100° C (212° F).

8.2 Report the neutralization number for original, all intermediate and final oil samples, expressed in mg KOH/g. Report the change in neutralization number for all intermediate and final samples.

8.3 Report volume percent of sludge in oil obtained by centrifuging.

8.4 Report weight percent of oil loss during test.

8.5 Report the weight change before and after electrocleaning or nitric acid soak, of each metal specimen from the initial. Express the change in mg/cm2, calculated to the nearest 0.1 mg/cm^2. Specimen area is based on the top and bottom surfaces; edges are ignored.

8.6 Report the appearance of the metal specimens after cleaning with respect to any pitting, etching, or other corrosion observed either without magnification, or with 20x magnification.

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8.7 Report test conditions, and any irregularities or deviations from required test procedures and conditions.

9. PRECISION

9.1 precision data have not been developed for this method.

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Air Force - AFWAL/POSL - 1986

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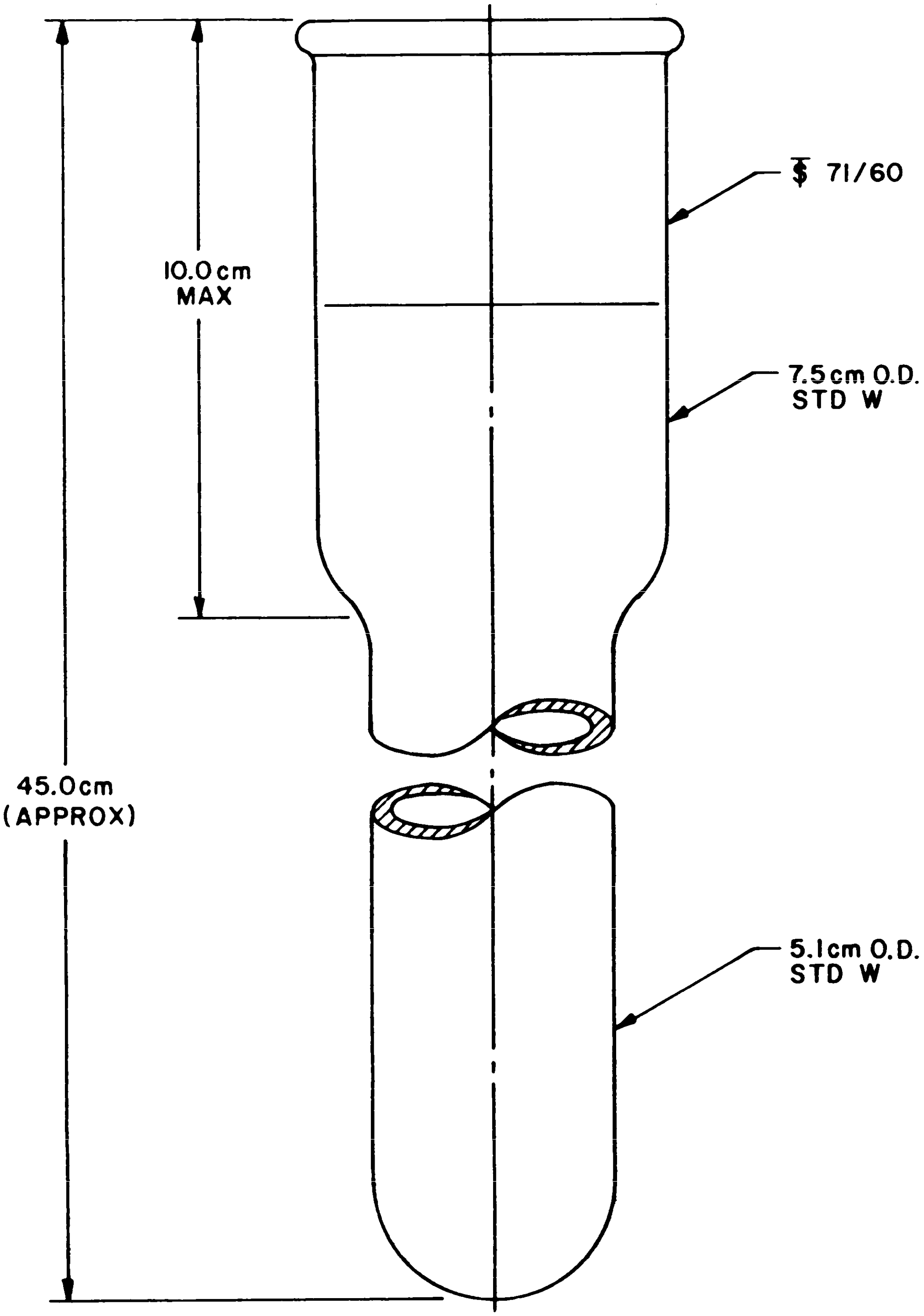

FIGURE 1. Sample tube.

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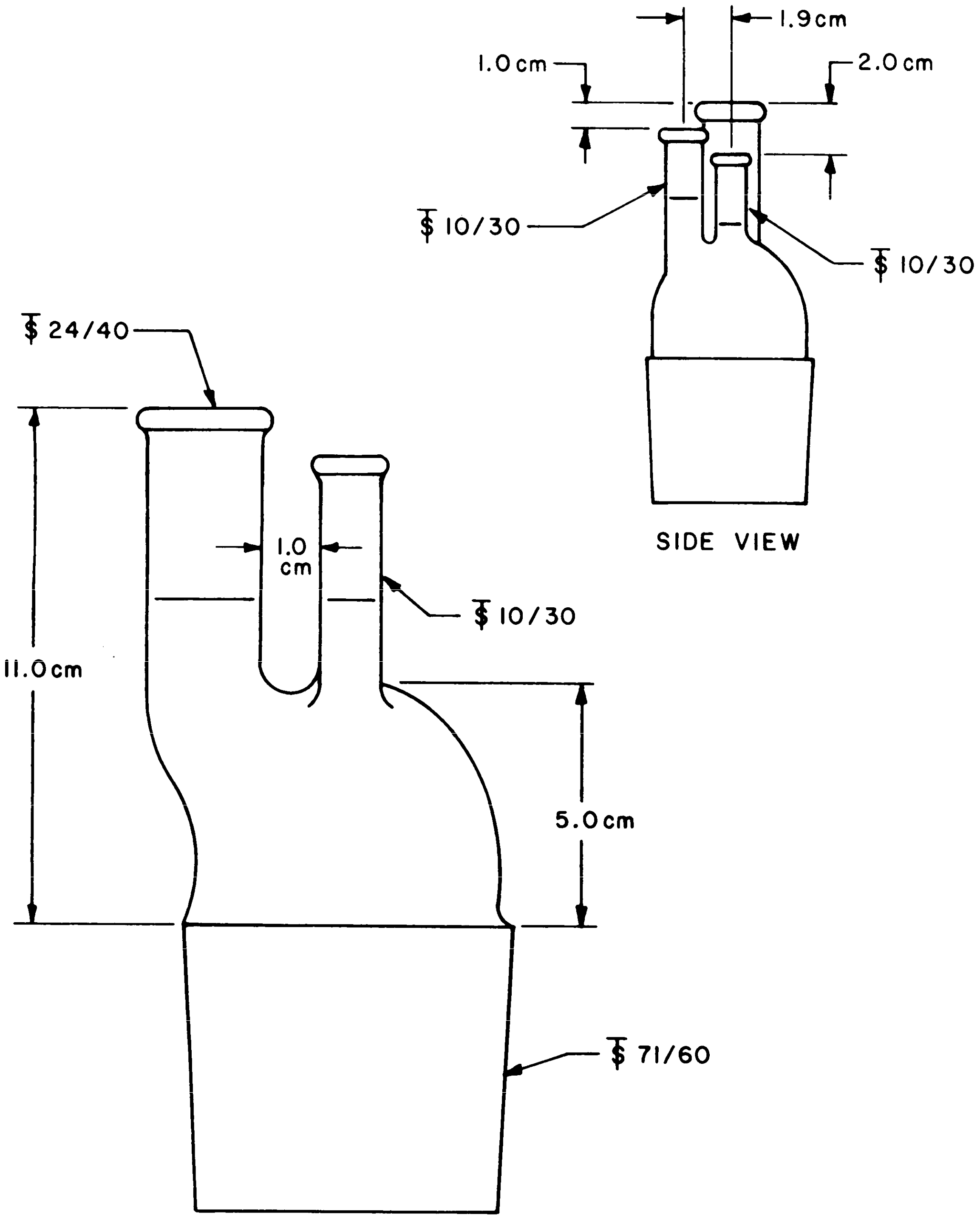

FIGURE 2. Sample tube head.

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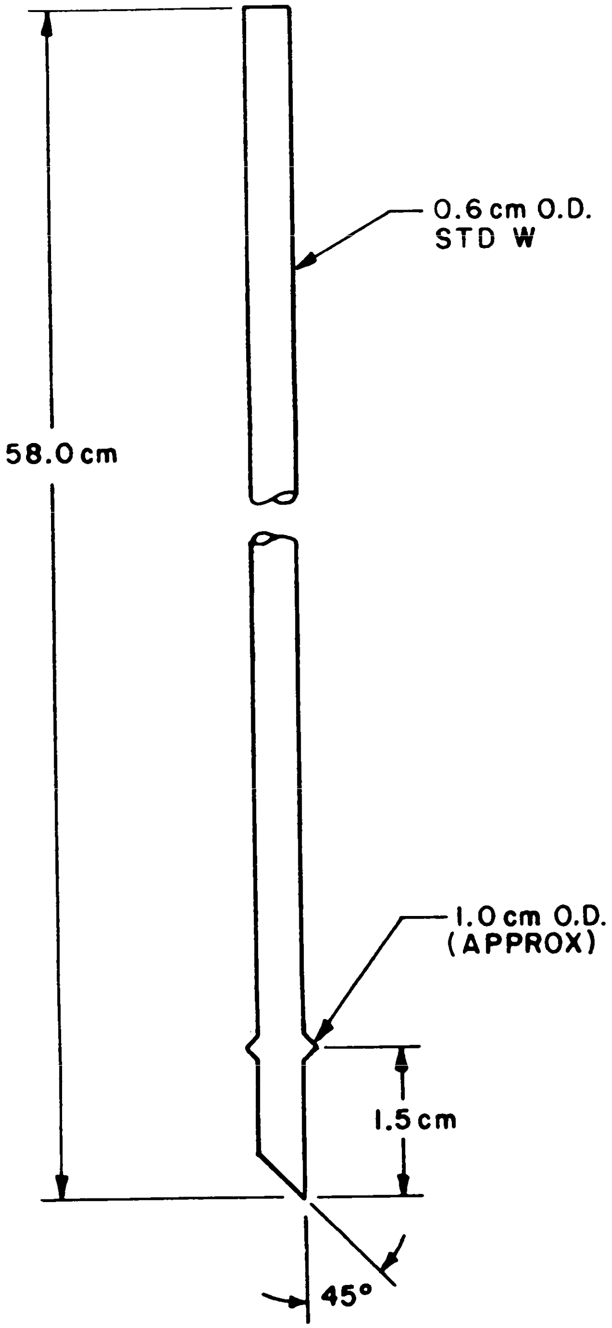

FIGURE 3. Air tube.

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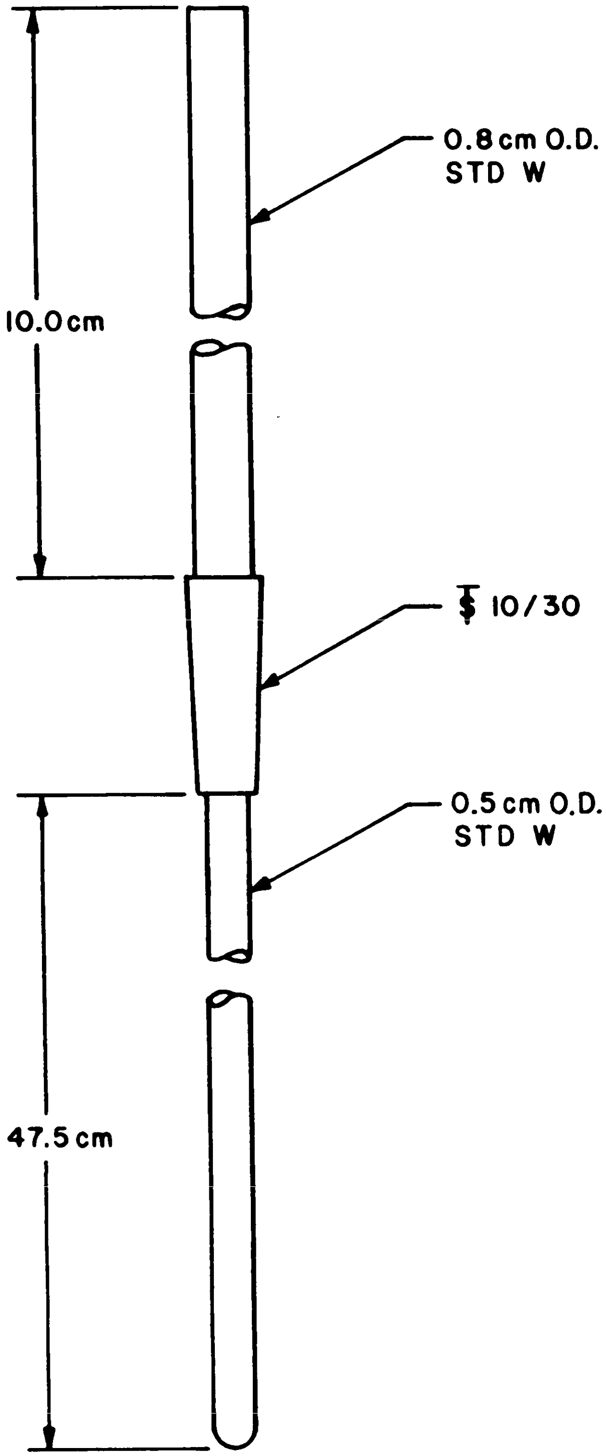

FIGURE 4. Thermocouple tube.

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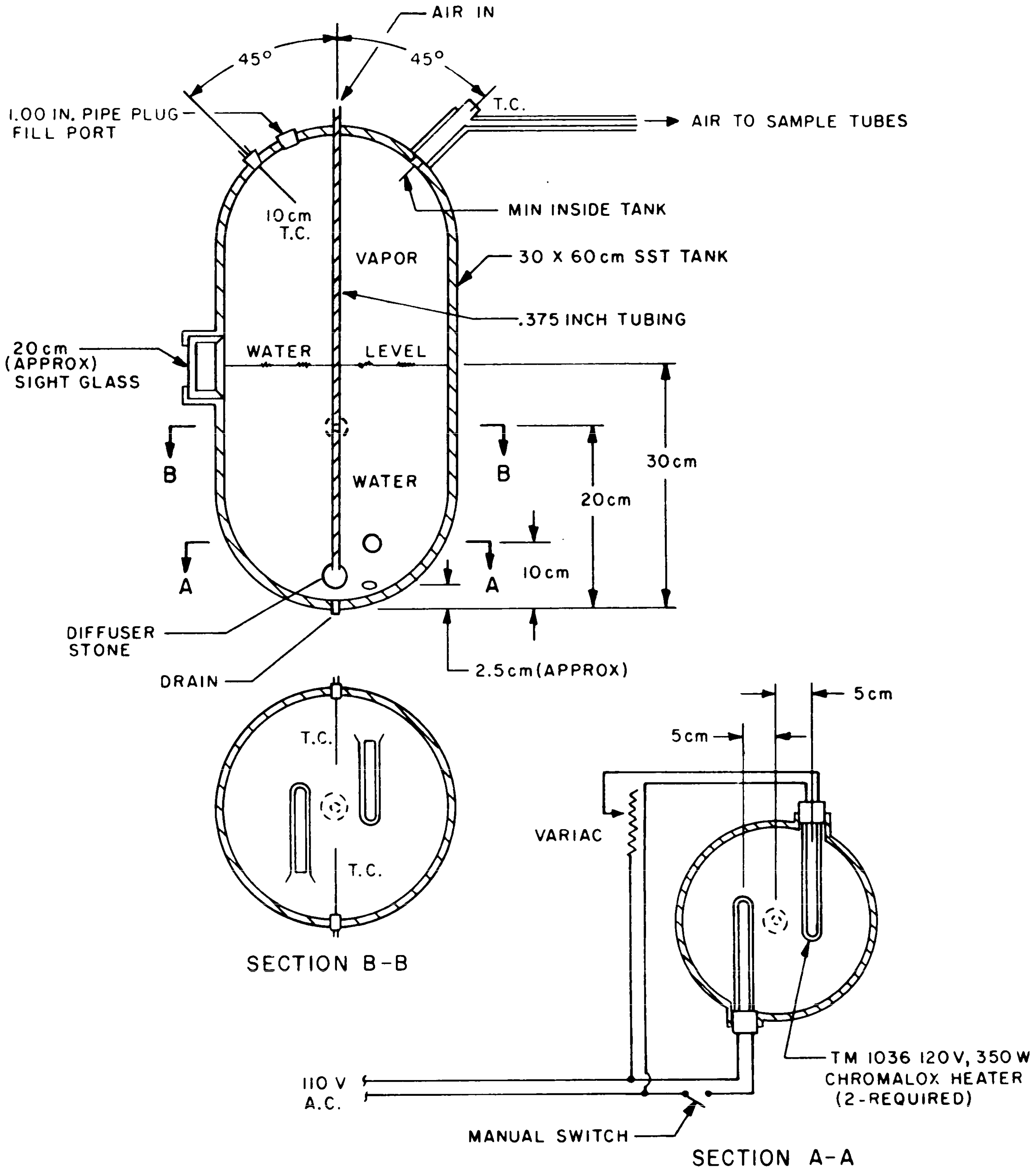

FIGURE 5. Air moisturizer.

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CORROSIVENESS AND OXIDATION STABILITY OF LIGHT OILS (METAL SQUARES)

1. SCOPE

1.1 This method is used for testing hydraulic oils (spindle oils), and similar, highly refined, light oils to determine their ability to resist oxidation and their tendency to corrode various metals.

2. SUMMARY

2.1 Metal specimens are suspended in a measured amount of lubricant. The oil, at an elevated temperature, is blown with air for a period of time. When the test is completed, the oil is tested to determine the extent of degradation. The metal specimens are examined for corrosion.

3. SAMPLE SIZE

3.1 Approximately 225 mL of oil to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Test tube, borosilicate, standard-wall; 5.0 +0.3 cm O.D., 50.0 +1 cm long; with open end formed as a male ground-glass joint, joint is ₷ 71/60.

4.2 Condenser, Allihn type. Borosilicate 3.5 cm O.D. (Min) by 300 +2.0 cm long jacket, with the lower end formed as a female ground-glass joint to mate with the test tube; joint is ₷ 71/60; drip tip in ₷ joint, 60 cm, min length; tabulations are parallel at opposite sides of the condenser, they are about 1.0 cm O.D.; open end has an ID of approximately 2.2 cm.

NOTE 1. The test tube (4.5.1) and condenser (4.5.2) may be obtained from:

John A. Glover
8225 Parkview Avenue
Munster, Indiana

4.3 Air tube, borosilicate, standard wall; 0.6 to 0.8 cm O.D. length 5.0 cm greater (rein) than combined length of assembled test tube and condenser, about 94.0 cm, with one end drawn to a 0.16 cm ±0.04 cm (1/16 ±1/64 inch) diameter orifice. A capillary tube with a 0.16 cm ±0.04 cm (1/16 ±1/64 inch) bore may be used.

4.4 Bath constant - temperature, capable of maintaining the sample ± 0.5° C (1° F) of the specified temperature.

Note 2. A liquid medium bath is not to be used over 135° C (275° F). Above 135° C (275° F) use an aluminium block. The heaters should be placed on the

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sides of the aluminum block. Base heaters are to be avoided. A satisfactory heater arrangement is described in method 350 of this standard. Unless otherwise specified the bath temperature is 121° C (250° F) for all oils except spindle oils where it is 100° C (212° F).

4.5 Assembly fixture, wood (slotted to hold metal squares for tying with cord, as shown in Figure 1).

4.6 Balance, sensitivity 0.1 mg.

4.7 Microscope, 20 diameter magnification.

4.8 Air-supply, clean, dry, low-pressure, 3-5 ± 0.5 L/hr.

4.9 Forceps, stainless-steel.

4.10 Brush, short-bristled, stiff (typewriter cleaning brush, *or* equal).

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Metal squares (1 each) 0.081 cm (0.032 in.) thick by 2.5 cm (1 inch) square, with and without two drilled holes (Figure 1), as follows:

5.2.1 Copper, electrolytic (QQ-C-576).

5.2.2 Steel, carbon, mild (ASTM A 366, class 1, commercial bright finish).

5.2.3 Aluminum alloy (QQ-A-250/4, temper T-3 or T-4).

5.2.4 Magnesium alloy (QQ-M-44, AZ31B), (condition H24 or H26).

5.2.5 Anodes, cadmium (QQ-A-671).

5.3 Cord (cotton, nylon, or linen), light-weight, clean (for tying metal squares together).

Note: A fine stainless steel wire may be used to tie the metal squares together when a test temperature of over ‘204° C (400° F).

5.4 Abrasive paper (silicon-carbide or alumina), various grades of grit.

5.5 Abrasive paper, silicon-carbide, 240 grit.

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5.6 Silicon-carbide grains, 150 mesh.

5.7 Cotton, absorbent (JJJ-C-561).

5.8 1,1,1-trichloroethane (0-T-620) 12,1,0].

5.9 Acetone (ACS), sulfur-free [l,3,0].

5.10 Filter paper (NNN-T-1475).

5.11 Naphtha, Aromatic (TT-N-97) [l,4,0].

6. PROCEDURE

6.1 Determine the acid number of the sample by method ASTM D 664 or D 974, whichever is applicable.

6.2 Determine the viscosity in centistokes of the sample by method ASTM D 445 at 40° C unless otherwise specified.

6.3 Wash a length of the cord by boiling it in distilled water for 10 minutes, and allow it to dry.

6.4 Prepare the solid cadmium squares by removing any burrs from the drilled holes.

6.5 Prepare the aluminum copper, magnesium, and steel squares. For testing spindle oil, use only metal squares of copper and steel. The squares are prepared as follows:

6.5.1 Using progressively finer grades of abrasive paper, remove all surface blemishes from both sides and all four edges of each square, and any burrs from the drilled holes.

NOTE 4. Caution. In all succeeding steps, handle the squares with tongs or filter paper only, until the final weighing (see 6.11).

6.5.2 Polish each square with the 240 grit paper to remove any marks produced by coarser abrasive. Store squares immersed in separate containers of acetone until ready for final polishing.

Note 5. Caution. Acetone is flammable. Use only in a well ventilate area. Keep all flames away from acetone.

6.5.3 Remove each square from the acetone, and final polish both sides to a mirror finish, using 150 mesh silicon-carbide grit (held on an acetone-uoiste[leu cotton pad).

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6.5.4 Clean all metal dust from the square by rubbing vigorously with clean pads of absorent cotton until a fresh pad remains unsoiled.

6.6 Continue preparation of all five squares as follows:

6 .6.1 Wash squares in warm 1,1,1-trichloroetl~ane (approximately 54° C [130° Fj], rinse with 1,1,l-trichloroethane, and allow them to air-dry.

Note 6. Caution. 1,1,1-tricilloroethane is toxic. Do not breathe its fumes nor allow it to come in contact with the skin.

6.6.2 Immediately weigh each square to within 0.1 mg.

6.6.3 Arrange squares in the wooden assembly fixture in the pattern shown in Figure 1, making certain that the magnesium and copper squares do not touch each other. (When testing spindle oil, the metal squares shall be placed in the test tube in such a manner as to form a “V”’ in the bottom of the test tube.)

6.6.4 Using only forceps to handle the clean cord, tie the squares together as shown in Figure 1.

6.7 prepare new test set up as follows:

6.7.1 Insert the tied metal squares in the test tube, positioning the squares vertically (so that the air tube can be inserted to touch the bottom of the test tube). Weigh the air tube, test tube, and contents together to within 0.1 g.

6.7.2 Add 100 + 1 mL of sample to the test tube, reweigh the air tube, test tube, and contents together to within 0.1 g, and determine weight of sample added.

6.7.3 Assemble the test tube and condenser and mount the assembly so that 30 + 5 cm of test tube is submerged in the bath operating at specified temperature.

6.7.4 Start the flow of cooling water through the condenser jacket.

6.7.5 Insert the air tube (orifice-end down) through the condenser and into the sample and support it so that its orifice is within 0.3 cm (1/8 inch) of the bottom of the tube. (When testing spindle oil, orifice should be within 0.6 cm (1/4 inch) of the junction of the metal square.)

6.8 Connect the source of clean, dry air (3 + 0.2 L/hr for spindle oils; 5 + 0.5 L/hr for other oils) to the air tube and allow the air to flow for 168 hours.

6.9 At the end of the specified period, shut off the air-flow, and disassemble, and check test setup as follows:

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6.9.1 Remove air tube and disconnect condenser.

6.9.2 Remove test tube from constant-temperature bath, and wipe off the outside of the tube with a naphtha-darnpened cloth.

Note 7. Caution. Naptha is flammable. Use only in a well ventilated area. Keep all flames away from naptha.

6.9.3 Reweigh the air tube, test tube, and contents to within 0.1 g, determine weight of sample remaining, and compute the percentage of weight loss resulting from evaporation of sample (see 7.1). (It the evaporation loss is greater than 8 percent, leakage is present. Correct the leak, and repeat the determination, using fresh sample and new metals squares.)

6.9.4 Using forceps, withdraw the metal squares from the test tube, and remove the cords holding them together. (Retain the test tube and sample for further examination.)

6.10 prepare squares for examination as follows:

6.10.1 Using forceps, wash each square individually in warm l,l,l-trichloroethane (approximately 54° [130° F]).

6.10.2 Repeat the washing, using fresh 1,1,1-trichloroethane and scrubbing the squares with the short-bristled brush, until the 1,l,l-trichloroethane shows no additional discoloration, and allow the squares to air-dry.

6.11 Examine each square as follows:

6.11.1 Reweigh each square to the nearest 0.1 mg and compute (in mg per sq cm of surface) the change in weight of each square (see 7.2).

6.11.2 Using the 20–power microscope, carefully examine each square, and note any evidence of pitting or etching.

6.11.3 Note the color of any stains present on the copper square.

6.12 Examine the sample in the test tube as follows:

6.12.1 Inspect for any evidence of insoluble or gummy material as required by the specification and record.

6.12.2 Determine the acid number by method ASTM D 664 or D 974, whichever is applicable, and calculate the change from the original acid number (see 0.1 and 7.3).

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6.12.3 Determine viscosity in centistokes by method ASTM D 445 at 40° c (104° F) (unless otherwise specified), and calculate the percentage change from the original centistoke viscosity (see 6.2 and 7.4).

7. CALCULATIONS

7.1 Evaporation loss:

$$L = \frac{W_1 - W_2}{W_1} * 100$$

L = Percentage evaporation loss
W_1 = Initial weight
W_2 = Final weight

7.2 Change in metal square weight:

$$M = \frac{(M_2 - M_1) * 1000}{2 * (W * L)^2}$$

M = Change in metal weight per surface area (mg/cm^2)
M_2 = Final weight in g
M_1 = Original weight in g
w = Width of metal square in cm
L = Length of metal square in cm

7.3 Change in acid number:

$$A = AN_2 - AN_1$$

A = Change in acid number
AN_2 = Final acid number
AN_1 = Original acid number

7.4 Change in viscosity:

C = Change in viscosity
V_2 = Final viscosity in centistokes
V_1 - original viscosity in centistokes

8. REPORTING

8.1 Report as corrosiveness stability the change in weight of each of the metal squares in mg/cm2 and the appearance of each of the metal squares.

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8.2 Report as oxidation stability of the fluid the result of the insoluble gummy material inspection, the change in acid number, and the change in viscosity.

9. PRECISION

9.1 Precision data have not been developed for this method.

Method Prepared by:

Army - ME - 1986

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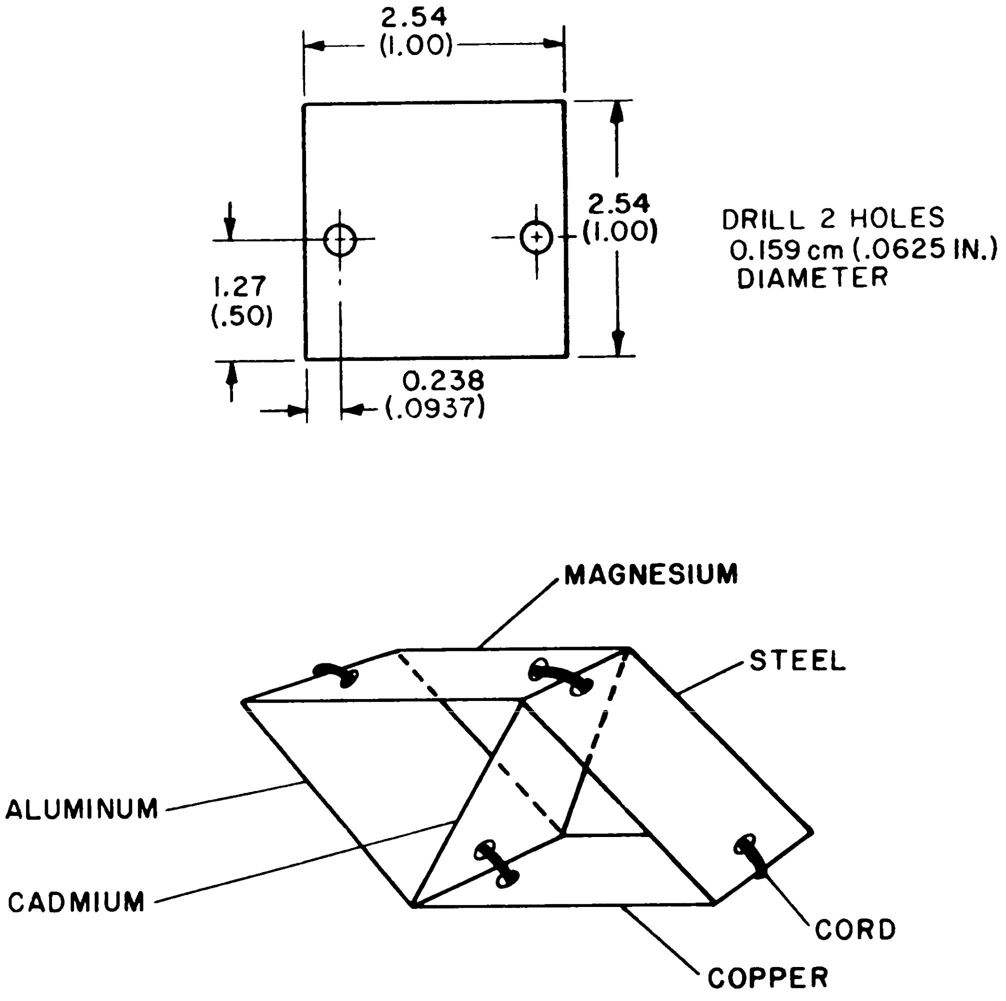

NOTE: DIMENSIONS IN cm (INCHES).

FIGURE 1. Metal square dimensions and arrangement.

X-4462

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METHOD 5309.5
September 30,1986

CORROSIVENESS OF GREASES

(Copper Strip, 100° C)

1. SCOPE

1.1 This method is used for determining the corrosive properties of grease at elevated temperatures.

2. SUMMARY

2.1 The test consists of partially immersing a copper strip in the sample at 100° C for 24 hours then visually examining both sample and strip for evidence of corrosion.

3. SAMPLE SIZE

3.1 Approximately 20 mL of grease to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Oven, 100° C.

4.2 Microscope, approximately 60x diameter magnification.

4.3 Test tube, clean, dry, approximately 2.5 cm diameter by 10 cm.

4.4 Support (beaker) for holding test tube approximately vertical.

4.5 Forceps, stainless steel.

5. MATERIALS

501 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Copper strip (Copper and Brass Research Association No. 110 Electrolytic Grade), soft tempered, annealed, approximately 1.3 cm by 7.6 cm by 0.15 cm or 0.3 cm.

5.3 n-Hexane (ACS Grade) noncorrosive (as determined by ASTM D 130) [1,3,0].

5.4 Acetone (ACS Grade) [1,3,0].

5.5 Polishing materials.

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5.5.1 Fine silicon-carbide or alumina grit paper.

5.5.2 240 grit silicon-carbide paper.

5.5.3 150 mesh silicon-carbide grains.

6. PROCEDURE

6.1 Prepare finish of copper strip as follows:

a. Surface preparation - Remove all blemishes from all six sides of the strip with silicon-carbide or alumina grit paper of such degree of fineness as is needed to accomplish the desired results effectively (see note 1). Finish with 240 grit silicon-carbide paper, removing all marks that have been made by other grades of paper used previously. Immerse the strip in acetone (see note 2) from which it may be withdrawn immediately for final polishing or in which it may be stored for future use.

Note 1. As a practical manual procedure for surface preparation moisten it with kerosene or acetone and rub the strip against the paper with a rotary motion protecting the strip from contact with the finger with an ashless filter paper. Alternatively the strip may be prepared by use of motor driven machines using appropriate grades of dry paper or cloth.

Note 2. Caution. Acetone is both toxic and flammable. Use only in a well ventilated area. Do not breathe its fumes nor allow it to come in contact with the skin. Keep all flames away from the acetone.

b. Final polishing – Remove a strip from the acetone. Holding it in the fingers protected with the ashless filter paper, polish first the ends and then the sides with 150-mesh silicon carbide grains picked up from a clean glass plate with a pad of absorbent cotton moistened with a drop of acetone. Wipe vigorously with fresh pads of absorbent cotton and subsequently handle only with stainless steel forceps; do not touch with fingers. Clamp in a vise and polish the main surfaces with silicon carbide grains on absorbent cotton. Rub in the direction of the long axis of the strip, carrying the stroke beyond the end of the strip before reversing the direction (see note 3). Clean all metal dust from the strip by rubbing vigorously with clean pads of absorbent cotton until a fresh pad remains unsoiled. When the strip is clean, immediately immerse it in the prepared sample.

Note 3. It is important to polish the whole strip uniformly to obtain a uniformly strained strip. If the ends show wear (surface eliptical) they will likely show more corrosion than the center. The use of a vise will facilitate uniform polishing.

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6.2 Fill test tube with sample to depth of 5 cm. Remove air pockets from the grease by tapping the tube on the bench or table as it is being filled.

6.3 Using stainless steel forceps, insert copper strip until it touches the bottom of the tube.

6.4 Place the test tube (supported approximately vertically in 100° C) oven for 24 hours (unless otherwise specified).

6.5 At the end of the specified time, remove test tube from oven and allow it to cool at room temperature.

6.6 Using forceps, remove copper strip, and wash in non-corrosive ACS grade n-hexane. (See Note 4.)

Note 4. Caution. n-Hexane is both toxic and flammable. Use only in a well ventilated area. Do not breath its fumes nor allow it to come in contact with the skin. Keep all flames away from the n-hexane.

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Report whether the section of the strip immersed in the sample is darker in color than the exposed section.

8.2 Report by describing any corrosion of the strip when examined under a microscope of approximately 60 diameters magnification.

8.3 Report development of any green color in the grease.

9. PRECISION

9.1 Precision data have not been developed for this method.

Method prepared by:

Navy - NADC - 1986

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CORROSION OF LEAD BY LUBRICATING OILS

1. SCOPE

1.1 This method is used for measuring the corrosiveness of lubricating oils on lead in the presence of a copper catalyst.

2. SUMMARY

2.1 It consists of rotating panels of lead and copper in the test lubricant under specific conditions, and determining the degree of corrosion from the change in weight of the lead panel.

3. SAMPLE SIZE

3.1 Approximately 500 mL of the oil to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Sample tube, SOD (Standard Oil Development), available from Koutes Co., Spruce St., Vineland, NJ 08360 or SGA Scientific, Inc., 735 Broad St., Bloomfield, NJ 07003 (see Figure 1).

4.2 Bath, constant-temperature, 163° C ±1° C (325° F ±2° F), minimum depth 31 cm (12 inches).

4.3 Motor, stirring, 600 ±50 rpm.

4.4 Shaft, stirring, with attaching hardware (see Figure 2).

4.5 Air supply, clean, dry, approximately 7 gage kpa (1 psig) to provide flow of 0.940 ±0.047 L per minute (2 ±0.1 cubic feet per hour).

4.6 Balance, sensivity 1 mg.

4.7 Forceps, stainless-steel.

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

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5.2 Test panel, chemical-lead grade (ASTM B29–55 or equal) 3.5 by 4.13 by 0.16 cm (1-3/8 by 1-5/8 by 1/16 inches), conforming to Table I.

TABLE I. Composition of lead test pane.

Element	Content Percent	
	Max .	Min.
Silver	0.020	0.002
Copper	0.080	0.040
Arsenic, antimony, and tin (total)	0.002	-----
Zinc	0.001	-----
Iron	0.002	-----
Bismuth	0.005	-----
Lead (by difference)	---- -	99.90

5.3 Test panel, copper, electrolytic (QQ-C-576, 3.5 by 4.13 by 0.130 cm [1-3/8 by 1-5/8 by 0.051 inch 1 [16 gage]).

5.4 Naphtha, petroleum (MIL-N-15178) [1,4,0].

5.5 Acetone (0-A-51) [1,3,0].

5.6 Steel wool, No. 00 (FF-W-556).

5.7 Pads, absorbent-cotton (JJJ-P-141).

6. PROCEDURE

6.1 Preheat and adjust bath to 163° C ±1° C (325° F ±2° F).

6.2 Pour 500 mL of the sample into a clean sample tube, and place tube into the bath so that the bath level is at least 2.5 cm (1 inch) above the sample level.

6.3 Connect air supply line to the aerator intake of the sample tube.

6.4 Allow approximately 30 minutes for the specimen to come to test temperature.

6.5 Drill a 3/16-inch hole in the center of each test panel (see 5.2 and 5.3).

6.6 Polish and clean the test panels (handling only with forceps) as follows:

a. Polish the faces and edges of the panels with steel wool until a uniform bright surface is produced.

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CAUTION

> When polishing the lead panel, avoid excessive pressure which may cause the steel wool to become embedded in the lead.

b. Remove all loose particles from the panels, using naphtha-soaked cotton pads.
c. Rinse with fresh naphtha, and allow to air dry.

6.7 Using forceps to handle the panel, record the weight of the lead panel to the nearest milligram.

6.8 Clean the stirrer shaft and panel attaching hardware by rinsing with naphtha, using naphtha-soaked cotton pads or steel wool as required. Rinse in clean naphtha, and allow to air dry.

6.9 Using forceps to handle the panels, mount both panels on the shaft as shown in Figure 2.

6.10 Attach stirrer motor to the shaft, and lower the shaft into the sample tube so the center of the lead panel is centered in the tube approximately 7.5 cm (3 inches) from the bottom.

6.11 Start the stirrer and immediately adjust the air flow 0.940 +0.047 L per minute (2 ±0.1 cubic feet per hour). Continue the operation for 60 ±1 minute.

6.12 Remove the stirrer assembly, and detach the lead panel from the shaft. Swab the lead panel lightly with naphtha-soaked cotton pads to remove any loose surface deposits. Rinse with fresh naphtha and then with acetone, and allow the panel to air dry.

6.13 Reweigh until there is no change in the weight.

7. CALCULATIONS

7.1 Calculate the change in weight in mg per square cm (mg per square inch) of the exposed surface area (including the faces and edges, but excluding the areas covered by the washers).

8. REPORTING

8.1 Report the change in weight to the nearest 1.5 mg per square cm (mg per square inch).

9. PRECISION

9.1 Repeatability. Results by one operator using the same apparatus must not differ:

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a. By more than 0.15 mg/cm^2 (1 mg per square inch) if the change in weight does not exceed 1.5 mg/cm2″ (10 mg per square inch);

or

b. By more than 10 percent of the average, if the change in weight exceeds 1.5 mg/cm^2 (10 mg per square inch).

9.2 Reproducibility. Results from different operators or different apparatus must not differ:

a. By more than (2 mg per square inch) if the change in weight does not exceed 1.5 mg/cm^2 (10 mg per square inch),

or

b. By more than 20 percent of the average, if the change in weight exceed 1.5 mg/cm2 (10 mg per square inch).

Method prepared by:
Air Force - SFTL - 1986

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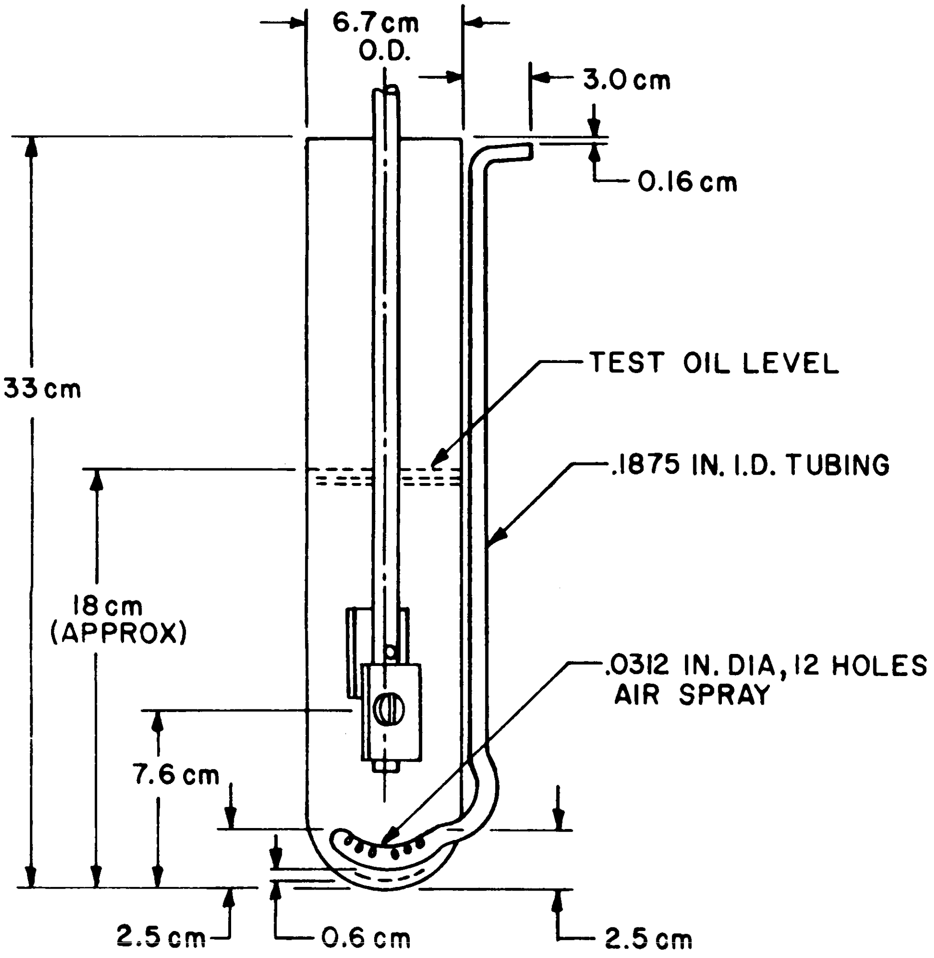

FIGURE I. SOD sample tube.

X-4395

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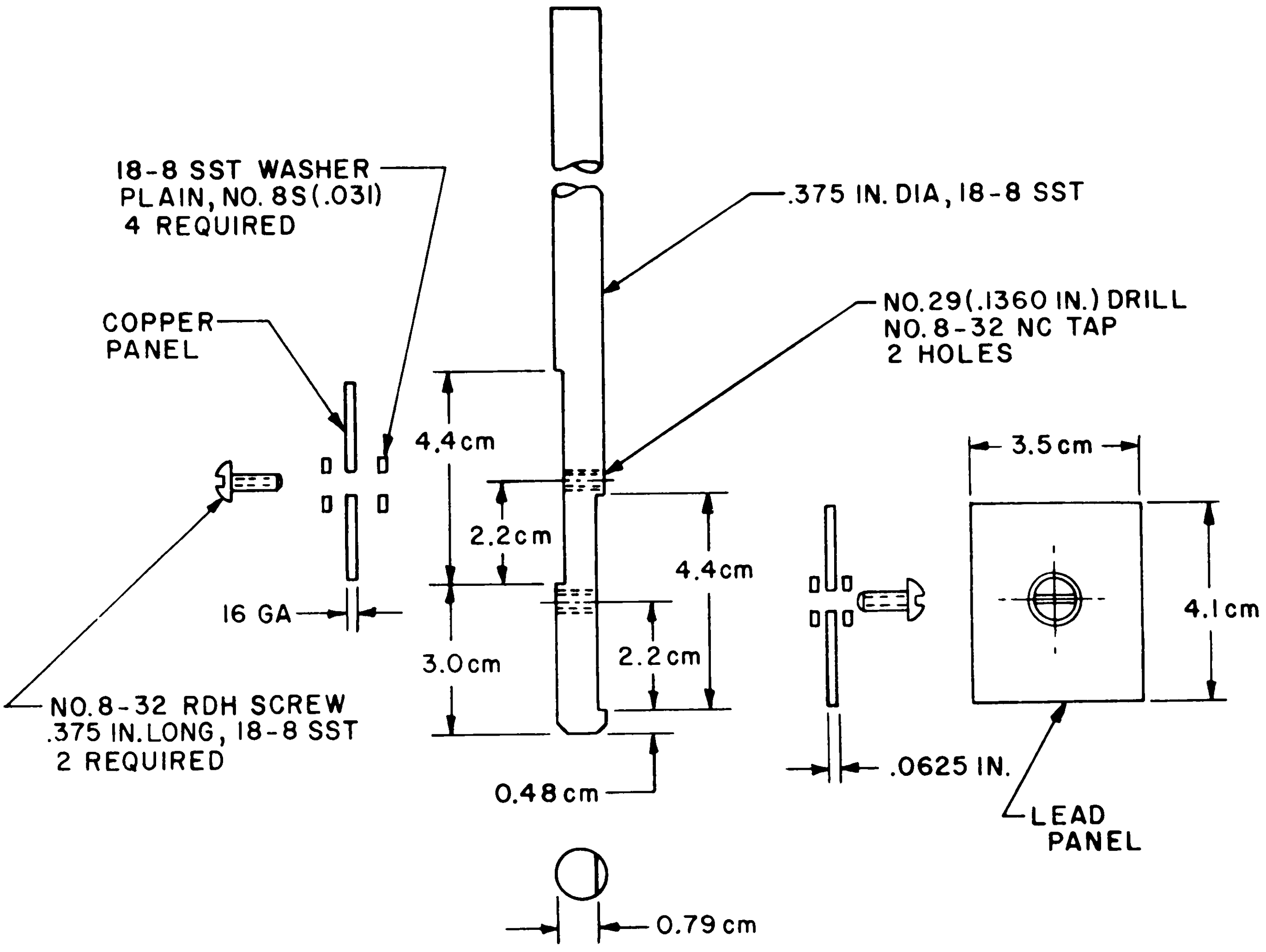

NOTES:
1. LENGTH AND TOP CONFIGURATION OF SPINNER SHAFT TO SUIT SHAFT ROTATOR.
2. ALUMINUM MAY BE SUBSTITUTED FOR 18-8 STAINLESS STEEL.

FIGURE 2. Stirring shaft and test panels.

X-4396

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CORROSIVENESS OF OIL ON A BIMETALLIC COUPLE

1. SCOPE

1.1 This method is used for determining the corrosive effect (chemical or electrochemical) of an oil on a bimetallic couple.

2. SUMMARY

2.1 The method consists of fitting a brass clip to the oil-coated surface of a steel disk, storing the assembly in a humidity cabinet for 10 days, and visually inspecting the assembly for evidence of corrosion.

3. SAMPLE SIZE

3.1 Approximately 2 g of the oil to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Humidity cabinet, approximately 50 percent relative humidity.

4.2 Magnifier, 10-power.

4.3 Desiccator, containing desiccant.

4.4 Stirring rod, glass.

5. MATERIAL

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Steel disks (3) (ASTM A 322, composition G52986), heat treated to Rockwell C-62, 2.54 cm (1 inch) diameter by 1.25 (1/2 inch) to 2.54 cm (1 inch) thick ground on one side to 0.508 micrometer (20 microinch) rms prior to hand-polishing (see 6.1.2). This treatment need not be repeated prior to each test unless the disks are badly corroded.

5.3 Clips (3), brass (QQ-B-613, composition 2), spring temper, fabricated to dimensions shown in Figure 1.

5.4 Abrasive papers, silicon–carbide or aluminum oxide, 150, 240, 400, and 600 grit.

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CAUTION

Do not use papers containing iron oxide.

5.5 Cloth, lint-free, clean, dry.

5.6 Acetone (0-A-51), technical [l,3,0].

5.7 Etching solution, consisting of:

5.7.1 Distilled water, 450 mL.

5.7.2 Nitric acid (ACS), concentrated, 225 mL [2,0,0].

5.7.3 Sulfuric acid (ACS), concentrated, 300 mL [3,0,2].

.5.7.4 Hydrochloric acid (ACS), concentrated, 8 mL [3,0,0].

5.8 Methyl alcohol (ACS), absolute [1,3,0].

5.9 Distilled water.

6. PROCEDURE

6.1 Prepare the three steel disks as follows:

6.1.1 Slush the disks in the methyl alcohol to remove traces of coolant used in grinding.

NOTE 1. Caution. Methyl alcohol is both toxic and flammable. Use it only in a well ventilated area. Do not permit it to come in contact with the skin or breathe its fumes. Keep all flames away from this material.

6.1.2 polish the surface-ground side using 150, 240, 400, and 600 grit silicon carbide or aluminum oxide paper in succession. perform each polishing operation at right angles to the previous one, and continue until all cross scratches from the previous operation are removed.

6.1.3 Clean the disks by wiping with the clean, dry, lint-free cloth, being careful not to touch the polished surface with bare hands.

6.1.4 Examine with the 10-power magnifier for discoloration, etching, pitting, or other signs of corrosion. Discard disks with any sign of corrosion.

6.1.5 Store the disks in the desiccator until use. Immerse the brass clips (see 5.3) in the etching solution for 20 seconds, and immediately wash successively in cold running water, distilled water, and acetone. Allow to air

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dry, and store in the desiccator until ready for use. Be careful not to touch (with bare hands) the surface that will be in contact with the steel disks (see Figure 1).

NOTE 2. Caution. Acetone is flammable. Use it only in a well ventilated area. Keep all flames away from this material.

6.3 Remove the disks from the desiccator (being careful not to touch the finished surface), and using the stirring rod, drip the test sample over the entire polished surface of each disk.

6.4 Remove the brass clips from the desiccator (being careful not to touch the area to be in contact with the polished surface of the disks), and place on the disks as indicated in Figure 1 so that the center of the clip is in full contact with the disk.

6.5 place the assemblies in the humidity cabinet for 10 days [reiative humidity, 50 percent; temperature 27°C (79° F)].

6.6 Remove the assemblies from the cabinet after 10 days, and using a sharp pencil, mark an outline of the clips where they were in contact with the polished surface of the disks. Remove the clips, and wipe the disks clean with lint free cloth.

6.7 Using the 10-power magnifier, examine the marked-off area of the disks for discoloration, etching, pitting, or other signs of corrosion.

6.8 Repeat the test (if the test results are questionable), using new disks and extending the exposure time in the humidity cabinet to 20 days. Examine the disks and report as before indicating that the test was repeated.

7. CALCULATION

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Report the oil as failing the test if the test areas of more than one disk show signs of corrosion, pitting, or other attack. Also report the oil as failing

Report the oil as passing if the condition of the disk is other than these.

9. PRECISION

9.1 precision data have not been developed for this method.

Method Prepared by:

Army - ME - 1986

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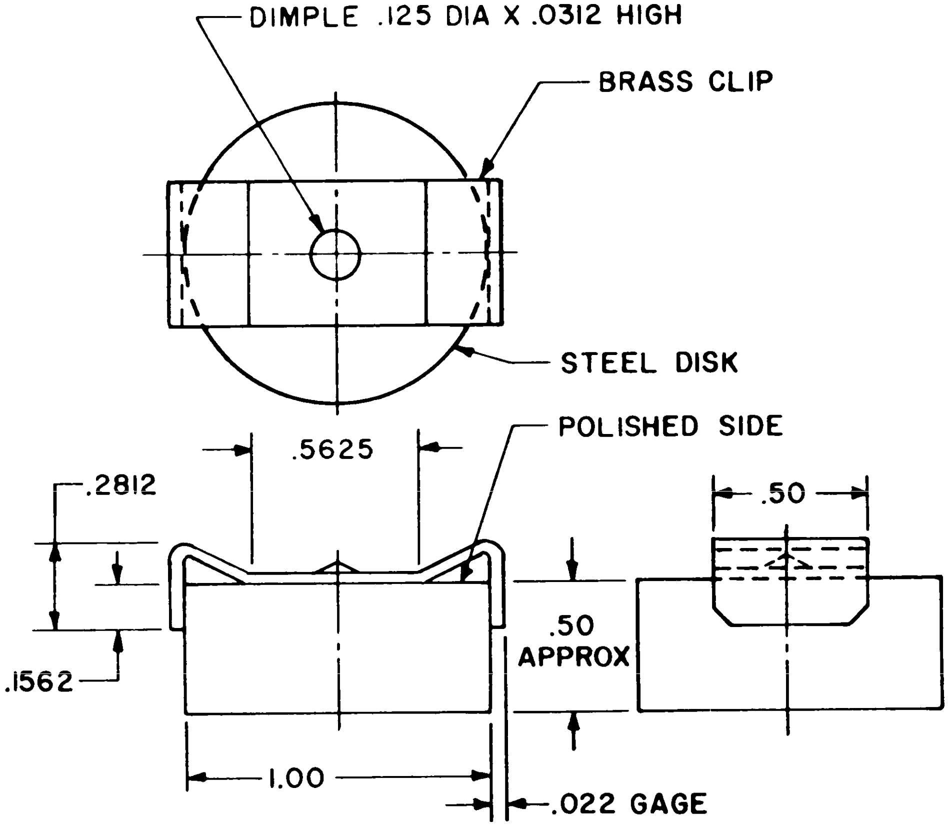

NOTES:
1. DIMENSIONS IN INCHES.
2. TOLERANCE ± .0312.

FIGURE 1. Corrosivity test setup.

X-4397

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FUEL SYSTEM ICING INHIBITOR IN HYDROCARBON FUELS

(IODOMETRIC METHOD)

1. SCOPE

1.1 This method is used for determination of 0.05 to 0.20 volume percent ethylene glycol monomethyl ether (EGME), $CH_30(CH2)20H$, and 0.05 to 0.20 volume percent diethylene glycol monomethyl ether (DGME), $CH_30(CH_2)20(CH_2)_20H$, in hydrocarbon fuels.

2. SUMMARY

2.1 Two compounds are approved as fuel system icing inhibitors (FSII) in hydrocarbon fuels. In this method, FSII will denote EGME or DGME. The test consists of removing the FSII from the hydrocarbon fuel by extraction with water. The water solution is allowed to react with an excess of standard potassium bichromate solution in the presence of sulfuric acid, and the excess bichromate is determined iodometrically.

3. SAMPLE SIZE

3.1 25.0 mL of hydrocarbon fuel.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Erlenmeyer flask. so-d l

4.2 Hotplate

4.3 Iodine flask. 500-mL.

4.4 Separator funnels. 125-mL, pear shaped with supporting and stand.

4..5 Test tubes. pyrex 2.2 x 17.5 cm, with support rack.

4.6 Volumetric glassware.

4.6.1 Burets, 25-, 50-mL.

4.6.2 Pipets, 5-, 10-, 25-mL.

4.6.3 Flasks, 100-, 500-, 1000-mL.

4.7 Glass stoppered bottles.

4.8 Interval timer.

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5. MATERIALS

Unless otherwise indicated, all reagents shall conform to the specification. established by the committee on analytical reagents of the American Chemical Society where such specifications are available. References to water shall be understood to mean distilled or deionized water.

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The Chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measure, and spill practices of each chemical are explained.

5.2 Crushed ice.

5.3 FSII standard solution. Both EGME and DGME [u,u,u] are subject to degradation on storage. The FSII solution must be prepared from fresh reagent immediately prior to use. Pipet 10.00 mL of FSII into a 1-L volumetric flask. Dilute to volume with water and mix thoroughly. Pipet 10.00 mL of the diluted additive into a 100-mL volumetric flask, dilute to volume with water and mix thoroughly. The final solution contains 0.10 percent by volume of FSII.

5.4 Potassium dichromate solution, standard 0.2000 N. Dissolve exactly 4.9035g of potassium bichromate (dried 1 hour at 110° C) in water. Transfer to a 500-mL volumetric flask and dilute to volume with water. Mix thoroughly [1,0,1].

5.5 Potassium iodide crystals.

5.6 Sodium thiosulfate solution, standard 0.100 N. Dissolve 25 + O.lg of sodium thiosulfate ($Na_2S_2O_3 \cdot 5H_2O$) [u,u,u] in 1 L of Water. Add 0.10g of sodium carbonate [u,u,u] to stabilize the solution and mix thoroughly. Allow the solution to stand 24 hours before standardizing. This solution should be standardized every two weeks. To standardize, pipet 10.00 mL of 0.2000 N potassium bichromate [1,0,1] into a 500-mL iodine flask, add 5.00 mL of concentrated sulfuric acid [3,0,2] slowly from a buret. Add about 50 mL of water and cool to room temperature. Add approximately 3g of potassium iodide [u,u,u] and mix thoroughly. Titrate with the sodium thiosulfat.e solution, swirling the liquid constantly until a brown color has changed to a yellowish green. Add 2 mL of starch indicator solution and contiue the titration until the color changes from dark blue to a light bluish-green. When approaching the end point be careful to swirl the iodine flask and contents vigorously after the addition of each drop of thiosulfate. Calculate the normality of the sodium thiosulfate solution (see 7.1).

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5.7 Starch indicator solution. Mix 4 g of soluble starch and 10 mg of mercuric iodide [u,u,u] preservative with 10 mL of water, and add the suspension slowly to 1 L of boiling water. Boil for 5 minutes. cool the solution and store in a glass stoppered bottle.

5.8 Sulfuric acid. Concentrated, sp. gr. 1.84 [3,0,2].

6. PROCEDURE.

6.1 Determination of factor F. Definition: Factor F = mL FSII per mini-equivalent of potassium dichrromate. Pipet 5.00 mL of the FSII standard solution (5.3) into a 2.2 x 17.5 cm test tube. Add from a pipet 10.0 mL of 0.2000 N potassium bichromate solution and place the test tube in the ice bath. After the solution has been chilled add from a buret 5.00 mL of concentrated sulfuric acid while constantly swirling the test tube in the ice bath. THOROUGH MIXING OF THE ACID AND AQUEOUS PHASES WITHOUT OVERHEATING IS IMPERATIVE. After the solution has cooled, place the test tube in a bath of boiling water for exactly 10 minutes. Return the test tube to the ice bath and allow to cool to room temperature or below. Transfer the contents of the test tube to a 500-mL iodine flask. Wash the test tube 4 times with 5-mL portions of water and add the washings to the iodine flask. Add approximately 3g of potassium iodide and titrate with the standard 0.1 N sodium thiosulfate solution to a starch end point. The starch end point is described in 5.6. When approaching the end point be careful to swirl the iodine flask vigorously after the addition of each drop of thiosulfate. Make three determinations of Factor F and calculate the average value (see 7.2). None of the three should differ from the average by more than ±0.0001.

6.2 Analysis of hydrocarbon fuel. Pipet 25.0 mL of sample into a dry 125-mL separatory funnel, and add from a pipet 25.0 of water. Stopper the funnel and shake vigorously for 2 minutes. Allow the two phases to separate, and drain the water layer into a dry 50-mL Erlenmeyer flask. Pipet 5.00 mL of this solution into a 2.2 x 17.5 cm test tube. Add from a buret or pipet 10.00 mL of 0.2000 N potassium bichromate solution, and place the test tube in an ice bath. After the solution has been chilled, add from a buret 5.00 mL of concentrated sulfuric acid while constantly swirling the test tube in the ice bath. THOROUGH MIXING OF THE ACID AND AQUEOUS PHASES WITHOUT OVERHEATING IS IMPERATIVE. After the solution has cooled, place the test tube in a bath of boiling water for exactly 10 minutes. Cool the solution to room temperature in an ice bath. Quantitatively transfer the solution to a 500-mL iodine flask, rinsing the test tube four times with 5 mL portions of water and adding the washings to the flask. Add approximately 3g of potassium iodide, and titrate with standard 0.1 N sodium thiosulfate solution to a starch end point. The starch end point is described in 5.6. When approaching the end point be careful to swirl the iodine flask vigorously after the addition of each drop of the thiosulfdte. THE METHOD IS NOT APPLICABLE IF THE VOLUME OF THIOSULFATE USED IN THE TITRATION IS LESS THAN 5.0 mL.

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6.3 Make a blank determination by repeating the above procedure using a sample of the fuel (under test) taken before the introduction of the additive.

6.4 Calculate tile value of the blank in the same manner as for the sample.

6.5 Subtract the blank value from that obtained in 7.3 to obtain tile corrected volume percent of FSII for reporting. If consistently high FSII values are obtained on the finished blend at the point of receipt, it is recommended that the local quality control office be requested to obtain a sample of the uninhibited fuel from the source of supply to use in making blank determinations on this product.

7. CALCULATIONS

7.1 Calculate the normality of the sodium thiosulfate solution as follows: .

$$\text{Normality (N) of } Na_2S_20_3 = \frac{V_K * N_K}{V_T}$$

V_K = m_L Of K_2Cr_207
N_K = Normality of K_2Cr_207
V_T = m_L of Na_2S_203

7.2 Calculation of the Factor F or m_L FSII per milli-equivalent of potassium bichromate is performed as follows:

$$F = \frac{0.005}{(V_DN_D)-(V_TN_T)} = \frac{0.005}{2.00 - (V_TN_T)}$$

0.005 = m_L of FSII in aliquot of standard solution analyzed
V_D = m_L of potassium bichromate
ND . normality of potassium bichromate
V_T = m_L of sodium thiosulfate
N_T = normality of sodium thiosulfate

7.3 Calculate the FSII content of the hydrocarbon fuel as follows:

$$\text{Volume \% FSII} = \frac{100 \text{ F L}(V_DN_D) - (V_TN_T)]}{A\ S}$$

where:

F = factor defined in 7.2.
V_D = m_L of potassium bichromate.
N_D = normality of potassium dichromate.
V_T = m_L of sodium thiosulfate.
N_T = normality of sodium thiosulfate.
A = aliquot fraction of water extract used.
S = m_L of hydrocarbon fuel sample.

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When the instructions in this method are followed exactly, the equation may be reduced to:

$$\text{Volume \% FSII} = 20\ F\ [2.000 - (V_T N_T)]$$

8. REPORTING.

8.1 Test results shall be reported in accordance with ASTM D 1655, using the standard ASTM form entitled “Inspection Data on Aviation Turbine Fuels”.

9. PRECISION.

9.1 Duplicate determinations, by the same operator, should not differ from the mean by more than ± 0.005 in the range of 0.05 to 0.20 volume percent FSII.

Method prepared by:

Air Force - AFWAL/POSF - 1986

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METHOD 5329.2
September 30, 1986

CORROSION-PROTECTION (HUMIDITY CABINET)

1. SCOPE

1.1 This method is used for determining the effectiveness of corrosion-inhibiting oils and compounds under conditions of high humidity.

2. SUMMARY

2.1 The test consists of dipping steel test panels in the test sample and then placing them in a humidity cabinet. After the specified exposure time the panels are removed and examined for the presence of rust.

3. SAMPLE SIZE

3.1 Approximately 500 mL of the oil to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Standards.

4.1.1 ASTM D 1748 Rust Protection By Metal Preservatives In the Humidity Cabinet.

4.2 Humidity cabinet conforming to appendix I of ASTM D 1748 where the following standard conditions must be maintained.

a. Air temperature:

  Inside the cabinet: 49° C +1° C (120° F+2° F).
  Outside the cabinet: 24° C_+5°C (75° F±10°F).

b. Rate of air to the cabinet: 868 +28 L (31 +1 cu ft) per hour at 25° C (77° F) and 76 cm of mercury.

c, Water in cabinet:

  Level - 20.3 +0.6 cm (8 +1/4 inch)
  pH -5.5. to 7.5
  Oil content - clear with no evidence of oil
  Chlorides - less than 20 ppm
  Sulfates & sulfites - less than 20 ppm.

d. Speed of rotating stage - 0.33 ±0.03 rpm.
e. Cover - close fitting.
f. Cloth layers in cover - shall not be torn, contaminated, nor contain droplets of water.
g. Cover opening - to a height of 35.6 cm (14 inches) at the front.

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h. Open the cabinet twice each day, except Saturday and Sunday, once for 15 minutes and again for 5 minutes. (A period of approximately 5 hours should elapse between openings).
i. Check the rate of air to the cabinet, air temperatures, pH, and water level and regulate, if necessary, in the morning and afternoon of each day.
j. Check remaining standard conditions once each week.

4.3 Desiccator, containing an indicating desiccant.

4.4 Panel hook, stainless steel (for handling panels during processing).

4.5 Hooks, monel or stainless steel (for supporting steel panels).

4.6 Sandblast cabinet (a suitable apparatus for sandblasting test panels).

4.7 Beakers, tall-form, 500-mL.

4.8 Controlled atmosphere (to provide a temperatue of 25° c ±3° C [77° F ±5° F] and a maximum relative humidity of 50 percent).

4.9 Shaded fluorescent light. (A 15-watt balance illuminator type that will permit the panel to be viewed from all angles at a distance of 7.6 cm [3 inches]).

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be mandled carefully. Federal Test Method 10000, Material Handling Safety precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and **Storage** precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.3 Methyl alcohol (0-M-232) [l,3,0].

5.4 Silica sand, white, dry, sharp. (The size shall be such that it meets the following sieve requirements of RR-S-366.)

a. 100 hundred percent must pass through a No. 10 sieve.
b. Minimum of 90 percent must pass through a No. 20 sieve.
c. Maximum of 10 percent permitted to pass through a No. 50 sieve.

5.5 Test panels, FS 1009 steel, fabricated from open-hearth, "killed" type Low carbon, No. 4 soft-temper, cold-rolled sheet or strip conforming to QQ-S-698. Dimensions of the panels shall conform to appendix I of ASTM D 1748. Cold drawn bar stock is not satisfactory.

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5.6 Surgical gauze.

6. PROCEDURE

6.1 Clean the steel panels as follows:

a. Round the edges and ream out the suspension holes in accordance with Appendix I of ASTM D 1748.
b. Wipe the surfaces with solvent soaked rags and scrub with surgical swabs in a beaker of hot naphtha.

Note 1. Caution. Naphtha is flammable. Use only in a well ventilated area. Keep all flames away from the naphtha.

c. Rinse in a beaker of hot methyl alcohol.

Note 2. Caution. Methyl alcohol is both toxic and flammable. Use only in a well ventilated area. Do not allow it to come in contact With the skin or breathe its fumes. Keep all flames away from methanol.

d. Cool the panels in a desiccator until further processing.
e. Test panels must be handled with a panel hook at all times, avoiding contact with any type of contaminated surface.
f. Maintain the solvents at a temperature high enough to keep the temperature of the panels above the dew point during the cleaning operation.

6.2 Sandblast the panels as follows:

a. Sandblast the edges and lightly sandblast the back of the panels with silica sand.
b. Sandblast the unnumbered side, or test surface, of the panels to a fresh, uniformly abraded surface.
c. Immediately after sandblasting, place the panels in a beaker of anhydrous methanol.
d. Heat the methyl alcohol so that the solvent will evaporate from the panels immediately upon withdrawal from the solvent.
e. Remove remaining residue by holding the panels in a rack at 20 degrees from the vertical and spraying downward with naphtha.
f. Spray the test surface, then the back of the panel and the test surface again.
g. Rinse the panels in hot naptha and hot methyl alcohol and store in a desiccator until cool.
h. panels are to be used the same day as prepared.

6.3 Three test panels are processed as follows:

a. Dip the test panels in the test sample at a temperature of 25° C ±3° C (77° F ±5° F) and agitate gently for one minute.

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b. Suspend the panels by means of monel or stainless steel hooks and drain for two hours at 25° C ±3° C (77° F ±5° F) and a maximum of 50 percent relative humidity.
c. Place the panels in the humidity cabinet described in Appendix I of ASTM D 1748 for the time required by the applicable specification.
d. Dumuy panels, fabricated from monel or stainless steel, are used to fill all spaces not occupied by test panels. They are also placed under the three arm supports of the rotating stage.

6.4 At the end of the exposure period, remove the panels and rinse in methyl alcohol. Follow with a rinse in naphtha and methyl alcohol and examine the significant area of the test surface as defined in Appendix I of ASTM D 1748, using a 15-watt, shaded fluorescent light.

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Record the extent of corrosion as follows:

a. The number of rust dots, 0.1 cm in diameter or less.
b. The number of rust spots, 0.1 to 0.2 cm in diameter.
c. The nuuber of rust areas, greater than 0.2 cm in diameter.

9. PRECISION

9.1 precision data have not been developed for this method.

Method Prepared by:

Army - AR - 1986

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METHOD 5330.2
September 30, 1986

FUEL-SYSTEM ICING-INHIBITOR IN HYDROCARBON FUEL (CALORIMETRIC METHOD)

1. SCOPE

1.1 This method is intended for the visual determination of fuel-system icing-inhibitor in hydrocarbon fuels, in the range of 0.04 to 0.16 percent by volume, when the inhibitor is composed of ethylene glycol monomethyl ether, $CH_3O(CH_2)_2OH$,(EGME). The common name for this substance is methyl cellosolve.

2. SUMMARY

2.1 The method consists of extracting the Fuel-System Icing Inhibitor (FSII) from hydrocarbon fuel by using water as the extract. The extract is calorimetrically compared to color discs representing known concentrations of FSII.

3. SAMPLE SIZE

3.1 Ten m_L of hydrocarbon fuel with suspected FSII contaminate.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Four glass vials of 10-dram (37 mL) capacity. The following item, or an eqivalent item, shall be used in this determination: Bottle, vial, "Tite Seal”. Capacity, 10 drams (37 mL); height, 9.85 cm diameter, 2.9 cm Preiser Scientific Inc. Catalog No. 10-5935. Each vial should be scored at the 5.0, 10.0, 15.0, and 20.0 mL levels for ease of measurement.

NOTE 1: To ensure reproducibility of results, the outside diameter of the vial used shall always be 2.9 cm.

4.2 Analytical balance (accurate to 0.1 mg).

4.3 Hot plate.

4.4 Hot water bath (a 400-mL Griffin low form beaker will be satisfactory).

4.5 Pyrex 1.0-L volumetric flask with a glass stopper.

4.6 Drying oven.

4.7 Color comparator, picket, 2.6-cm light path for two 10-mL cuvettes FSN 6630-023-2299.

4.8 Color disc, fuel-system icing-inhibitor, for concentrations of 0.04, 0.06, 0.08, 0.10, 0,12, 0.14, and 0.16 percent by volume. FSN 6630-023-2298.

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4.9 Hatched 10mL cuvettes, 2.6-cm light path, FSN 6850-822-6559.

4.10 Interval timer. (With audible signal at the conclusion of a set time.)

4.11 Transfer pipette. 5.00-mL capacity.

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storabe precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Potassium Dichromate, ASC grade [1,0,1].

5.3 Sulfuric Acid, Cone., ASC grade [3,0,2].

5.4 Distilled or deionized water.

6. PROCEDURE

6.1 Prepare potassium bichromate–sulfuric acid ($K_2cR_2O_2$-H_2SO_4) solution. Dry 5.1 grams of potassium bichromate in a drying oven at 110° C for 1 hour. Cool, by placing in an ice bath, 500 mL of water in a 1-L volumetric flask. To prevent excessive heating, very carefully add 375 mL of sulfuric acid (H_2SO_4) in small increments (10 to 20 mL), mix by swirling cne vessel and cool after each addition of acid. Weigh accurately 4.9035 grams of dry potassium bichromate and add it to the water-sulfuric acid solution. Dilute the solution with water to within 10-15 mL short of the 1-L mark. Cool the solution gradually to room temperature and dilute with water to the 1-L mark on the flask. Mix the solution well after all the potassium bichromate has dissolved. This solution is stable indefinitely if not contaminated.

NOTE 2: Make each determination in duplicate.

6.2 Fill a vial with water to the 10-mL mark. Then add fuel to the 20-mL mark.

6.3 Stopper the vial. Shake the tightly stoppered vial for 2 minutes to extract the methyl cellosolve-glycerin content into the water phase for 2 minutes to separate the two phases.

6.4 Using the transfer pipette or a hypodermic syringe carefully withdraw a 5-mL portion of the bottom (water) phase and fill to the 5.0-mL mark on a vial. Care must be taken to assure that no fuel is transferred with the water phase.

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6.5 Slowly add potassium bichromate-sulfuric acid solution to the water solution until the liquid level reaches the 15-mL mark on the vial. Swirl the vial to mix the contents.

6.6 Immediately place the vial in a boiling water bath and heat for 10 min +30 seconds. Use the interval timer to control the reaction time in the boiling water bath. Remove the vial from the bath and cool gradually to room temperature.

NOTE 3: If the solution cannot be placed in the boiling water at once, it must be maintained in an icewater bath until just prior to heating. The use of the ice bath will prevent excessive oxidation of the bichromate solution which would give erroneously high results.

6.7 Transfer the solution obtained in 6.6 into a 10-mL cuvette. Fill the second cuvette with 5.0 mL of distilled water. Insert the ampoules in the color comparator with the distilled water in the left compartment. Hold the color comparator with the eyepiece approximately 15 cm from the eye with the back of the comparator toward a light source (window or daylight lamp). Turn the color disc in the comparator until the nearest color match is obtained. Read the concentration in the upper left hand corner on the front of the comparator. If the color of the sample fails between the color of two color standards, report the results as half way between the two standards such as if color is between 0.06 and 0.08, report as 0.07. Repeat the color comparison with the duplicate sample from 6.6

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Report the average of the two results as volume percent fuel system icing inhibitor to the nearest 0.01 percent.

9. PRECISION

9.1 Precision data have not been developed for this method.

Method prepared by:
Air FOrce-AFWAL/POSF-1986

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CORROSION PROTECTION OF STEEL AGAINST SULFUROUS ACID-SALT SPRAY BY SOLID FILM LUBRICANTS

1. SCOPE

1.1 This method is used to evaluate the corrosion preventive properties of dry, solid-film lubricant under the combined conditions of salt, sulfurous acid, and humidity environment.

2. SUMMARY

2.1 A steel disk having solid film lubricant deposited on one surface is subjected to the cycling effect of salt spray and drying. After each cycle of salt spray and drying, the disks are examined for evidence of corrosion.

3. SAMPLE SIZE

3.1 180 mL of solid-film lubricant of a sprayable consistency.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Air Supply - filtered, 69 gage kPa to 103 gage kPa (10 to 15 psig).

4.2 Air flow regulator - capable of regulating air flow at 472 mL/s (1 ft^3/min).

4.3 Spray Nozzle (Figure 1) - corrosion resistant with a 13 cm (5 in) diameter acrylic baffle which prevents direct impingement of the spray, but allows a fine mist full contact with the disks.

4.4 Turntable Assembly which consists of:

a. Turntable - corrosion resistant, 26.7 cm diameter with holes for mounting test holders and specimens.
b. Driving Mechanism - capable of mechanically rotating turntable at 1/3 RPM by an electric motor (slow speed), encased within a protective acrylic box and mounted above jar on an arrangement of flexaframe support rods.

4.5 Specimen Holders - holder cap (Figure 2) and ice jacket (aluminum) that is so placed as to be in direct contact with back of test specimen.

4.6 Jar - 30.5 cm I.D. and 30.5 cm high.

4.7 Support Rods - flexaframe or equivalent.

4.8 Flexible Tygon Tubing - 0.96 cm I.D.

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5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Steel Specimen – disk with 5.4 cm diameter and thickness of 0.16 cm, made of carbon steel conforming to FS 1010 with a 0.08 cm hole for handling disk with wire.

5.3 Synthetic Sea Water-Sulfurous Acid Test Solution – synthetic sea water (Formula ASTM D 1141 - 41.95 g/L, 900 mL with 2 mL sulfurous acid [not less than 6.0 percent assay as $S0_2$]).

5.4 Aluminum Oxide Cloth - 240 grit.

5.5 1,1,1 Trichloroethane (MIL-T-81533) [2,1,0].

5.6 Distilled Water (ASTM D 1193 - Type III).

5.7 Sulfurous acid, ACS [u,u,u].

6. PROCEDURES

6.1 prepare test speciment as follows:

a. Degrease test Specimens in 1,1,1–trichloroethane (MIL-T-81533).
b. Hand polish surface to be tested with 240 grit aluminum oxide cloth to a surface finish of (0.25 to 0.50 urn).
c. Repeat step a.
d. Allow specimens to dry and store in a dust–free container.
e. Apply solid-film lubricant to surface of steel specimen by spraying to produce a film thickness between 0.0005 cm - 0.0013 cm (0.0002 - 0.0005 in) and cure film in accordance with specification requirements.
f. Handle the specimen at all times with a hook.

6.2 Prepare the apparatus (Figure 3) as follows:

a. Fill botton 5 cm of jar with the synthetic sea water-sulfurous acid solution and then lower the turntable assembly into jar.
b. Place disk in specimen holder (Figure 2) with ice jacket on top.
c. Mount the complete specimen assembly in one of the holes of the turntable and start the turntable.
d. Turn on the air and regulate rate of flow to 472 mL/s (1 ft^3/min).

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e. Two minutes after the spray has started, place ice in ice jackets in order to cause a fine condensate to form on the surfaces of disks.

6.3 perform test as follows:

a. Continue spraying for two hours with a rate of flow of approximately 0.4 mL/s.
b. Discontinue the spray at the end of two hours; remove the ice jackets; and raise the turntable above the jar to allow specimens to dry for two hours at room temperature. the two-hour spray and two-hour drying period shall constitute one cycle.
c. Rinse the test specimens after each full cycle, while still retained in the holder, with distilled water (ASTM D 1193 - Type III) and dry with a stream of air.
d. After each cycle examine test specimen for evidence of visible corrosion, pitting or staining.
e. Repeat the test cycle until failure occurs. Failure is defined as the first visible sign of corrosion, pitting or staining.

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Report the number of test cycles completed prior to failure. Report the amount and type of corrosion present.

9. PRECISION

9.1 precision data have not been developed for this method.

Method Prepared by:

Navy - NADC - 1986

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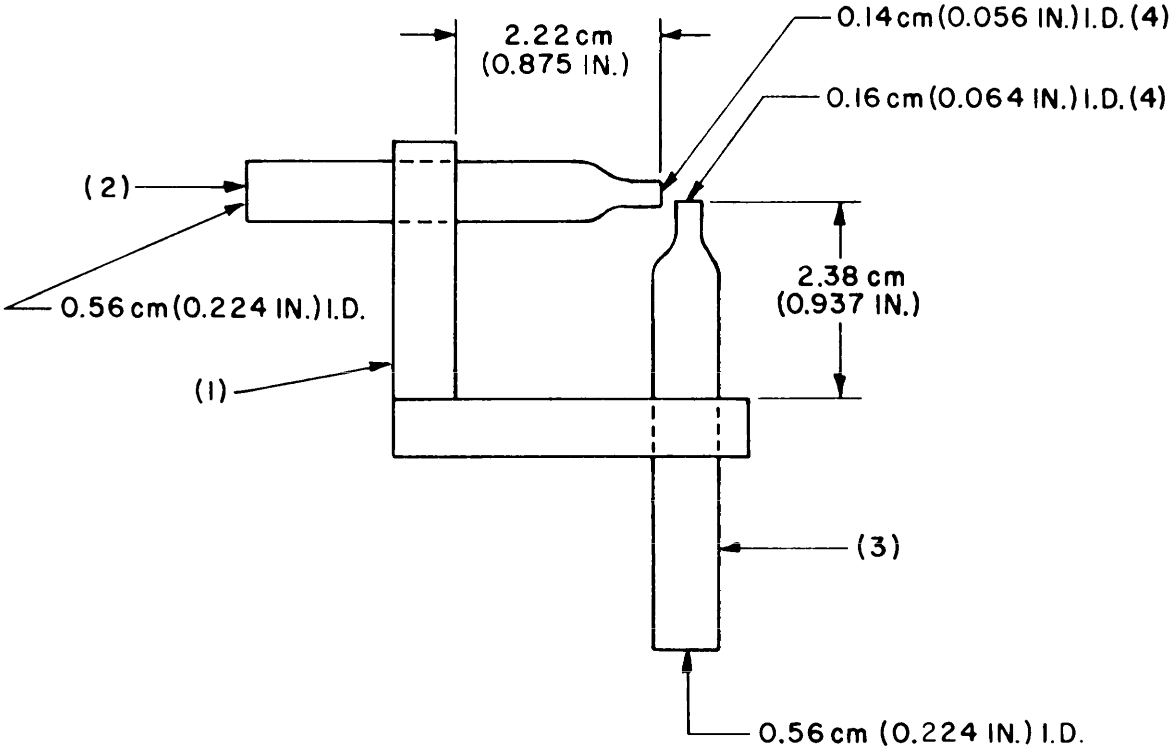

NOTES:
1. 0.637 cm (0.25 IN.) A CRYLIC MATERIAL.
2. FILTERED AIR SOURCE.
3. LIQUID PICK-UP TUBE.
4. ORIFICE.

FIGURE 1. Spray nozzle.

X-4398

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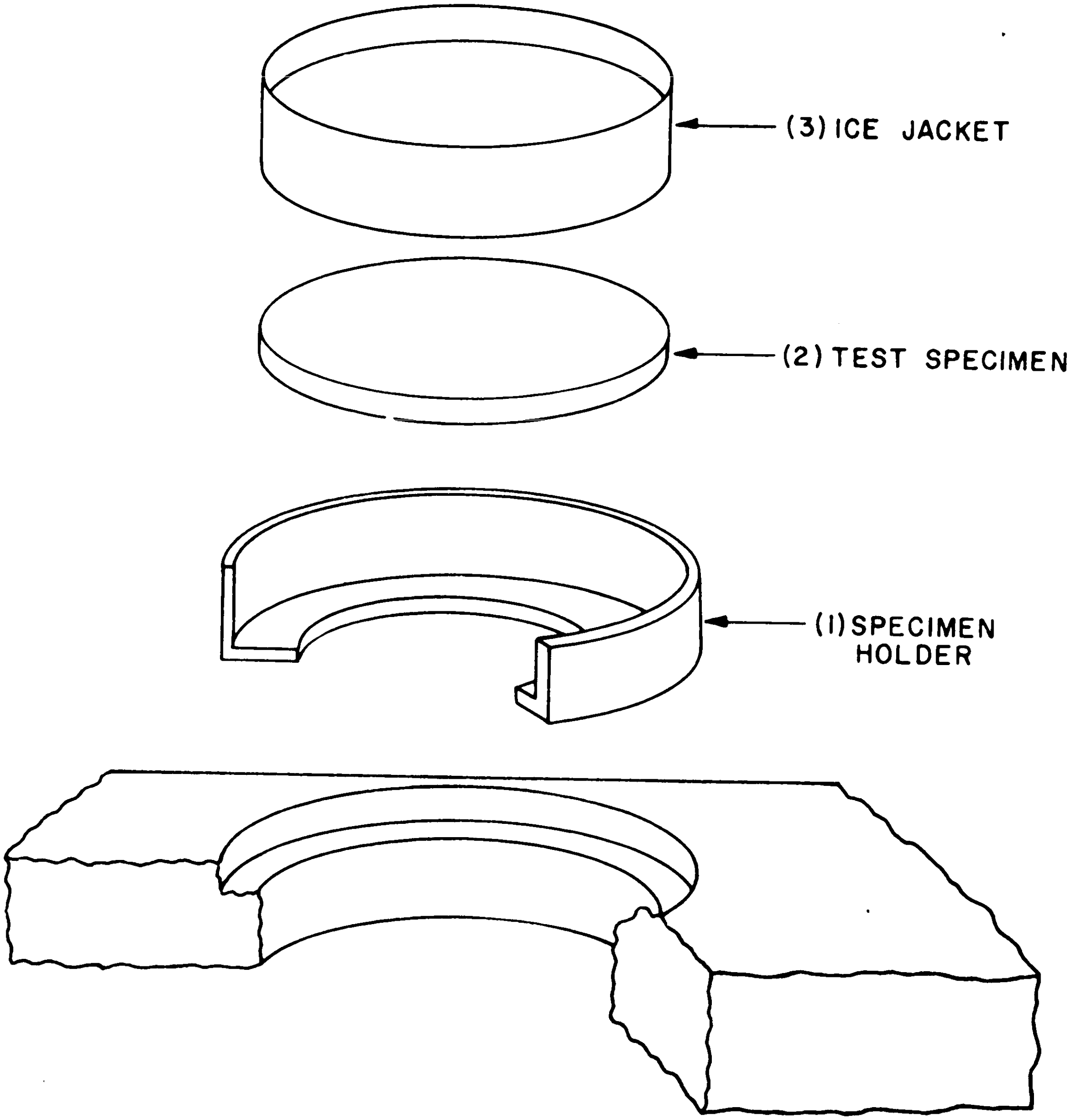

FIGURE 2. Test specimen holder assembly.

X-4399

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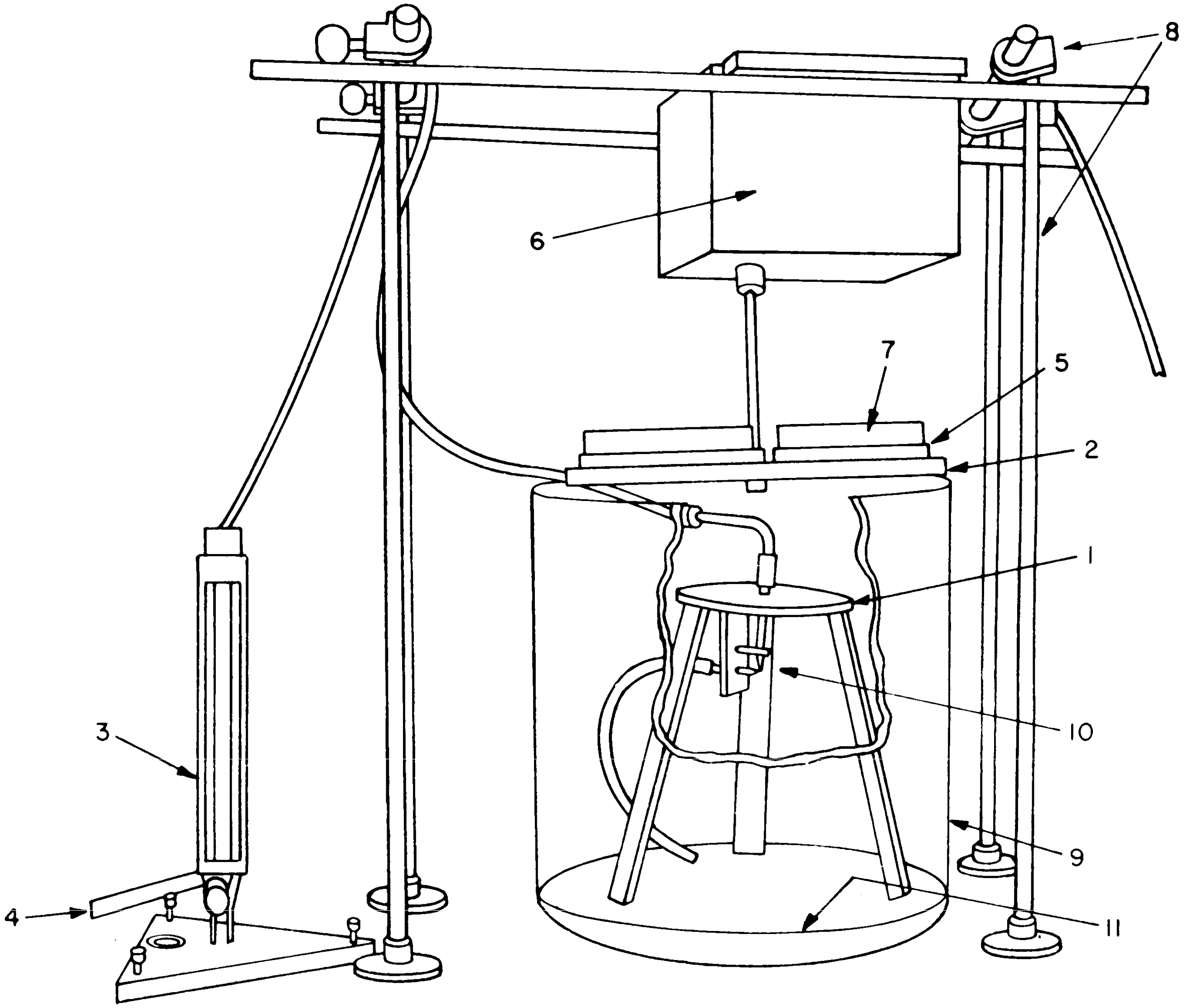

1. BAFFLE
2. TURN TABLE
3. REGULATOR
4. AIR SOURCE
5. SPECIMEN HOLDER
6. MOTOR
7. ICE JACKETS
8. SUPPORT RODS
9. JAR
10. NOZZLE
11. SOLUTION

FIGURE 3. Synthetic sea water-spray test apparatus.

X-4400

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METHOD 5333.1
September 30, 1986

FUEL SYSTEM ICING INHIBITOR BY FREEZING POINT DEPRESSION METHOD

1. SCOPE

1.1 This method is used to determine the amount of fuel system icing inhibitor (FSII), ethylene glycol monomethyl ether (EGME), in hydrocarbon fuel.

2. SUMMARY

2.1 The method consists of extracting the fuel system icing inhibitor from a known volume of fuel with a known volume of water and accurately determining the freeze point of the extract. The freeze point of the water will be depressed in direct proportion to the amount of inhibitor present. The concentration is determined from the enclosed graph (Figure 1).

3. SAMPLE SIZE

3.1 A minimum of 500 mL of fuel sample is required.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Test Tube, 1.6 cm X 15 cm.

4.2 Separator funnel, 1000-mL.

4.3 Pipet, 10-mL.

4.4 Beaker, 250-mL.

4.5 Ring Stand.

4.6 Test tube holder, clip type.

4.7 Ring holder.

4.8 Thermometer, ASTM 89-C.

4.9 Wire, stainless steel.

4.10 Agitating ring to fit test tube.

4.11 Rubber stopper, #O.

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000,

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Material Handling Safety precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spili practices of each chemical are explained.

5.2 Sodium chloride (table salt) [0,0,2].

5.3 Crushed ice.

6. PROCEDURE

6.1 Extract the inhibitor from fuel as follows:

a. Attach a clip type test tube holder to a ring stand.
b. Approximately 15 cm above the test tube holder, attach a ring type holder.
c. Place a test tube into the clip type holder.
d. Place a l00&mL separator funnel in the ring type holder.
e. Accurately measure 500 mL of fuel sample and pour into a separator funnel.
f. Pipette 10 mL of demineralized or distilled water into the separator funnel.
g. Stopper the separator funnel and shake vigorously for three minutes. Return the separator funnel to the ring stand and allow the water and fuel to separate. This will take at least five minutes.

6.2 Determine the freeze point as follows:

a. Fill a 250-mL beaker with crushed ice (or snow) and add approxilAd~elj 50 g of salt and enough water to form a slushy mixture. This will provide a bath at approximately -20° C.
b. Place the beaker under the test tube and lower the test tube into the ice mixture.
co Gently remove the stopper from the separatory funnel. The water phase will be in the bottom of the funnel. Drain approximately 8 mL of the water into the test tube.
d. Insert the thermometer, wire agitation ring, and stopper into the test tube until the Stopper is snug. Be sure the thermometer is immersed in the water in the test tube as much as possible without touching the bottom or sides. NOTE: The thermometer Should be stored in the refrigerator when not in use.
e. Agitate the water in the tube by raising and lowering the wire agitator gently and rapidly, about 60 cycles per minute.
f. The temperature of the water in the test tube will fall rapidly to a point below freezing.
g. AS the water begins to freeze, a sudden rise in temperature will occur.
h. This rise will cease at a point betweem 0° and -2° C and will remain steady for several minutes.

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i. Read and record the stabilized temperature to the nearest 0.1 degree. The thermometer is graduated in tenths of degrees.

6.3 Determine the inhibitor concentration by referring to Figure 1. Along the left side, reading vertically, is the temperature scale. Locate on that scale the temperature reading that was taken from the thermometer. Read across to the point on the graph where the reading intercepts the precomputed line. From this point of interception, drop vertically to the horizontal scale at the bottom of the sheet. The reading at this point will give the concentration of inhibitor in the fuel sample. For example, if the temperature reading were -1 degree, the inhibitor concentration of the sample would be 0.104 percent. If the temperature reading were -1.2 degrees, the concentration of inhibitor in the fuel sample would read 0.124 percent. It is not necessary to read to the third decimal place, and you would report 0.12 percent.

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Report fuel system icing inhibitor (FSII) concentration rounded off to the nearest two decimal digits.

9. PRECISION

9.1 Precision data have not been developed for this method.

Method Prepared by:

Air Force - SFTL - 1986

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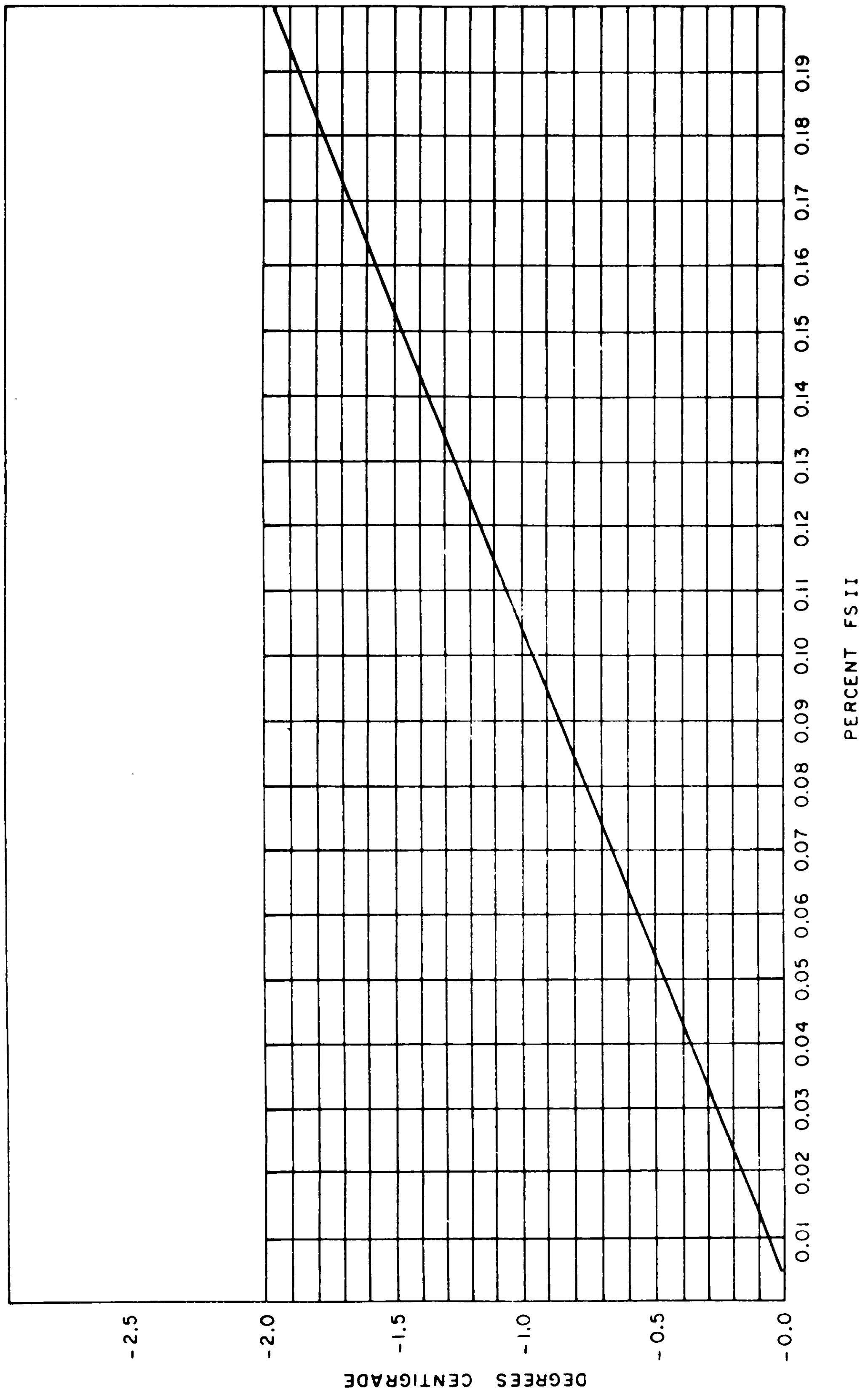

FIGURE 1. Percent fuel system icing inhibitor (FSII).

X-4401

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FUEL SYSTEM ICING INHIBITOR IN HYDROCARBON FUELS

(Refractometer Method)

1. SCOPE

1.1 This method is used for the determination of 0.05 to 0.20 volume percent ethylene glycol monomethyl ether (EGME), $CH_30(CH2)20H$ and 0.05 to 0.20 volume percent diethylene glycol monomethyl ether (DGME), $CH_30(CH_2)20(CH_2)_20H$, as icing inhibitors in turbine fuels. Refer to MIL-I-27686 for details on EGME and to MIL-I-85470 for details on DGME.

2. SUMMARY

2.1 Two compounds are approved as fuel system icing inhibitors (FSII) in hydrocarbon fuels. In this method FSII will denote EGME or DGME. The test consists of removing the FSII from the hydrocarbon fuel by extraction with water. The amount of icing inhibitor in the extract is determined by measuring the difference between its refractive index and that of the water used in making the extraction.

3. SAMPLE SIZE

3.1 Eight hundred mL of hydrocarbon fuel with FSII.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Portable differential refractometer kit. The kit includes the differential refractometer and all other equipment necessary to perform the evaluation. All items except the differential refractometer are standard laboratory items available from supply house.

NOTE 1: There is no known supplier for the portable differential refractometer kit. Seiscor Division of Seismograph Service Corp. discontinued manufacture of the kit several years ago. No alternate source has been located. The test method is maintained for those laboratories already equipped with such a kit, or where a suitable substitute refractometer may be used.

4.2 20-mL beaker.

4.3 Ring stand.

4.4 Separator funnel (1-L).

4.5 Graduated cylinder (200-mL).

4.6 Syringe and needle for cell cleaning.

4.7 Polyethylene wash bottle.

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4.8 polyethylene bottle for distilled water.

4.9 Glass bottle.

4.10 Four glass vials.

4.11 Stopcock grease.

4.12 Differential refractometer.

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. Tne materials references and standards listed in this section must be handled carefully. Federal_ Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. the synonyms, life hazard, flammability, hdndling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Ethylene glycol monomethyl ether, ACS grade [u,u,u].

5.3 Diethylene glycol monomethyl ether, ACS grade.

5.4 Commercial liquid dishwashing detergent.

5.5 Distilled water.

6. PROCEDURE

6.1 Prepare FSII standard solution by pipetcing 8.0 mL of FSII solution into 500.0 mL of distilled water (volumes must be accurate) and mix thoroughly the final solution is equivalent to 0.10 volume percent of FSII in fuel. Repeat using 4.0, 12.0, and 16.0 mL of FSII solution in the first step, thereby making standard solutions of equivalent 0.05, 0.15, and 0.20 volume percent in fuel. (These solutions should be made in a laboratory where necessary equipment is available).

6.2 Prepare a weak water-detergent solution consisting of 1 part commercial liquid dishwashing detergent to 100 parts distilled water.

6.3 preliminary steps in zeroing instrument. With light switch released, zero potentiometer with the screw located directly below the scale. Fill all the cells of the cell block with distilled water. place cell blocK in light path and close cover. Zero the meter with the adjusting screw located near the upper right corner of the potentiometer. Clean and dry center cell of cell block. (Use weak detergent, rinse with distilled water, and dry with syringe and needle provided).

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6.4 Calibration curve. This is prepared by determining differential refractive index measurements on the known solutions listed in 6.1, and plotting the vernier reading against the known amount of icing inhibitor. Once a curve has been prepared for a given ceil and instrument, it can be used indefinitely. (If batteries are changed, or minor repairs made, checking of one point on the calibration curve should be sufficient. If the cell block is replaced, a new calibration curve should be drawn).

6.5 Extraction of hydrucdrbon fuel. Measure 800 mL of hydrocarbon fuel to be tested into a 1-L separator funnel. Measure 50 mL of distilled water into the fuel in the 1–L separatory funnel. Shake the separatory funnel vigorously by hand for 3 minutes. place the funnel in a ring holder so that the layers may separate. Then draw off most of the water layer intO d previously cleaned and dried 20 mL beaker. TAKE CARE NOT TO DRAW OFF ANY OF THE HYDROCARBON LAYER.

6.6 Differential refractive index measurement. Using the syringe and special needle supplied, rinse the center cell three times with the extract. Fill the center cell with the extract and place the cell block in the refractometer. Depress the light switch located near the left front corner of the instrument. Zero the potentiometer by rotating the vernier scale. Note reading on vernier scale and apply to calibration curve to obtain volume percent FSII in the sample of fuel.

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Report the volume percent of FSII to the nearest 0.01 percent found in the hydrocarbon fuel.

9. PRECISION

9.1 Duplicate determinations should not differ from the mean by more than +0.005 in the range of 0.05 to 0.20 volume percent FSII.

Method prepared by:
Air Force-AFWAL/POSF-1986

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METHOD 5341
September 30, 1986

FUEL SYSTEM ICING INHIBITOR IN HYDROCARBON FUELS

(REDOX METHOD)

1. SCOPE

1.1 This method is used for determination of 0.05 to 0.20 volume percent ethylene glycol monomethyl ether (EGME), $CH_30(CH_2)20$, and 0.05 to 0.20 volume percent diethylene glycol monomethyl ether (DGME), $CH_30(CH_2)20(CH_2)20H$, in hydrocarbon fuels.

2. SUMMARY

2.1 Two compounds are approved as fuel system icing inhibitors (FSII) in hydrocarbon fuels. In this method, FSII will denote EGME or DGME. The test consists of removing the FSII from the hydrocarbon fuel by extraction with water. The water solution is allowed to react with an excess of standard potassium bichromate solution in the presence of sulfuric acid and a redox titration determines the excess bichromate.

3. SAMPLE SIZE

3.1 25.0 mL of hydrocarbon fuel with icing inhibitor.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Erlenmeyer flask. 50-mL.

4.2 Hotplate.

4.3 Erlenmeyer flask. 500-mL.

4.4 Separator funnels. 125-mL, pear shaped with supporting and stand.

4.5 Test tubes. Pyrex 2.5 x 15 cm, with support rack.

4.6 Volumetric glassware.

4.6.1 Burets, 25, 50-mL

4.6.2 Pipets, 5-, 10-, 25-mL.

4.6.3 Volumetric flasks, 100-, 500-, 1000-mL.

4.7 Glass stoppered bottles.

4.8 Interval timer.

5. MATERIALS

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Unless otherwise indicated, all reagents shall conform to the specification established by the Committee on Analytical Reagents of the American Chemical Society where such specifications are available. References to water shall be understood to mean distilled or deionized water.

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Crushed ice.

5.3 FSII standard solution. Both EGME and DGME [u,u,u] are subject to degradation on storage. The FSII solution must be prepared from fresh reagent immediately prior to use. Pipet 10.00 mL of FSII into a I-L volumetric flask. Dilute to volume with water and mix thoroughly. Pipet 10.00 mL of the diluted additive into a 100-mL volumetric flask, dilute to volume with water and mix thoroughly. The final solution contains 0.10 percent by volume of FSII.

5.4 Potassium bichromate solution, standard 0.2000 N. Dissolve exactly 9.8064 g of potassium bichromate (dried 1 hour at 110° C) in water. Transfer to a 1000-mL volumetric flask and dilute with water to volume. Mix thoroughly [1,0,1].

5.5 Ferroin Indicator (1, 10 phenanthroline - Ferrous Complex) [u,u,u].

5.6 Ferrous Ammonium Sulfate solution, 1.1000 N. Into a 1-L volumetric flask dissolve 39.3 g of ferrous ammonium sulfate [$FeS0_4 \bullet (NH_4)2 \bullet 6H_20$] [u,u,u] in approximately 500 mL of distilled water, add 7 mL of concentrated sulfuric acid [3,0,2], dilute to the one L mark, and mix thoroughly. To standardize the Ferrous ammonium sulfate solute, pipet 10.00 mL of 0.2000 N potassium bichromate [1,0,1] into a 500 mL-Erlenmeyer, add 5 mL of concentrated sulfuric acid slowly from a buret or pipet, add approximately 50 mL of distilled water, cool to ambient temperature, add three drops of the ferroin indicator, titrate with the ferrous ammonium sulfate solution (constantly swirling the flask), to a red end point . The color progression is through various shades of green to a sharp dark red end point. Near the end point stop titrating and rinse the wall of the flask with distilled water then continue the titration to the red end point with ferrous ammonium sulfate. Calculate the normality of the ferrous ammonium sulfate (see 7.1).

5.7 Sulfuric acid. Concentrated, sp. gr. 1.84 [3,0,21.

6. PROCEDURE

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6.1 Determination of factor F. Definition: factor F = mL of FSII per mini-equivalent of potassium bichromate. Pipet 5.00 mL of the FSII standard solution (5.3) into a 2.2 x 17.5 cm test tube. Add from a pipet 10.0 mL of 0.2000 N potassium bichromate solution and place the test tube in an ice bath. After the solution has been chilled add from a buret 5.00 mL of concentrated sulfuric acid while constantly swirling the test tube in the ice bath. THOROUGH MIXING OF THE ACID AND AQUEOUS PHASES WITHOUT OVERHEATING IS IMPERATIVE. After the solution has cooled, place the test tube in a bath of boiling water for exactly 10 minutes. Return the test tube to the ice bath and allow to cool to room temperature or below. Transfer the contents of the test tube to a 500-mL flask. Wash the test tube 4 times with 5-mL portions of water and add the washings to the flask. Add with the standard 0.1 N ferrous ammonium sulfate solution to a red end point. The ferroin end point is described in 5.6. When approaching the end point be careful to swirl the flask vigorously after the addition of each drop of ferrous ammonium sulfate. Make three determinations of factor F and calculate the average value (see 7.2). None of the three should differ from the average by more than ± 0.0001.

6.2 Analysis of hydrocarbon fuel. Pipet 25.0 mL of sample into a dry 125-mL separator funnel, and add from a pipet 25.0 mL of water. Stopper the funnel and shake vigorously for 2 minutes. Allow the two phases to separate, and drain the water layer into a dry 50-mL Erlenmeyer flask. Pipet 5.00 mL of this solution into a 2.5 x 15 cm test tube. Add from a buret or pipet 10.00 mL of 0.2000 N potassium dichromate solution, and place the test tube in an ice bath. After the solution has been chilled add from a buret 5.00 mL of concentrated sulfuric acid while constantly swirling the test tube in the ice bath. THOROUGH MIXING OF THE ACID AND AQUEOUS PHASES WITHOUT OVERHEATING IS IMPERATIVE. After the solution has cooled, place the test tube in a bath of boiling water for exactly 10 minutes. Cool the solution to room temperature in an ice bath. Quantitatively transfer the solution to a 500-mL flask, rinsing the test tube four times with 5 mL portions of water and adding the washings to the flask. Add three drops of the ferroin indicatcr and titrate with standard 0.1 N ferrous ammonium sulfate solution to a red end point. The ferroin indicator end point is described in 5.6. When approaching the end point be careful to swirl the flask vigorously after the addition of each drop of the ferrous ammonium sulfate. THE METHOD IS NOT APPLICABLE IF THE VOLUME OF FERROUS AMMONIUM SULFATE USED IN THE TITRATION IS LESS THAN 5.0 MILLILITERS.

6.3 Make a blank determination by repeating the above procedure using a sample of the fuel (under test) before the introduction of the additive.

6.4 Calculate the FSII content of the hydrocarbon fuel (see 7.3).

6.5 Calculate the value of the blank in the same manner as for the sample.

6.6 Subtract the blank value from that obtained in 6.1 to obtain the corrected volume percent of FSII for report. If normally high values are obtained on the finished blend at the point of receipt, it is recommended that the local Quality

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Control office be requested to obtain a sample of the uninhibited fuel from the source of supply to use in making blank determinations on this product.

7. CALCULATIONS

7.1 Calculate the normality of the ferrous ammonium sulfate as follows:

$$N_T = \frac{V_D * N_D}{V_T}$$

N_T = Normality of $FeSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$
V_T = mL of $FeSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$
N_D = Normality of $K_2Cr_2O_7$
V_D = mL of $K_2Cr_2O_7$

7.2 Calcuate factor F as follows:

$$F = \frac{0.005}{(V_DN_D) - (V_TN_T)} = \frac{0.005}{2.00-(V_TN_T)}$$

F = Factor F
0.005 = mL of EGME in aliquot of standard solution analyzed.
V_D = mL of potassium dichromate.
N_D = Normality of potassium dichromate.
V_T = mL ferrous ammonium sulfate.
N_T = Normality of ferrous ammonium sulfate.

7.3 Calcuate the FSII content of the hydrocarbon fuel as follows:

Volume % FSII =

$$\frac{100\ F[(V_DN_D) - (V_TN_T)]}{AS}$$

Where:

F = Factor defined in 6.1.
V_D = mL of potassium bichromate.
ND = Normality of potassium bichromate.
V_T = mL of ferrous ammonium sulfate.
N_T = Normality of ferrous ammonium sulfate.
A = Aliquot fraction of water extract used.
S = mL of hydrocarbon fuel sample.

When the instructions in this method are followed exactly, the equation may be reduced to:

Volume % FSII = $20F[2.000-(V_TN_T)]$

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8. REPORTING

8.1 Report fuel system icing inhibitor present in fuel in volume percent rounded off to nearest second decimal digit.

9. PRECISION

Duplicate determinations should not differ from the mean by more than ± 0.005 in the range of 0.05 to 0.20 volume percent FSII.

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METHOD 5342
September 30, 1986

FUEL SYSTEM ICING INHIBITOR IN HYDROCARBON FUELS
(HAND REFRACTOMETER METHOD)

1. SCOPE

1.1 This method is used for the determination of fuel system icing inhibitor (FSII) content in hydrocarbon fuels. The test can be used in the range of 0.00 to 0.20 volume percent FSII. The test utilizes equipment which can easily be adapted to field use.

2. SUMMARY

2.1 The test consists of removing the FSII from the hydrocarbon fuel by extraction with a fixed ratio of water. This extraction procedure includes sufficient agitation and contacting time to ensure that equilibrium mixtures are obtained. The refractive index of the water extract is measured and compared against a standard scale.

2.2 Fuel system icing inhibitors are required in aircraft fuel to prevent ice blockage in the fuel system. FSII functions are a cryostat, depressing the freezing point of water that may be present in the fuel system. In order to be effective, the FSII content must fall in a certain concentration range. Too low of a concentration may result in decreased anti-icing effectiveness. Too high of a concentration may result in the separation of large amounts of pure additive which can cause damage in certain aircraft fuel systems.

2.3 The hand refractometer is a test for ensuring that fuel contains an acceptable amount of FSII without requiring laboratory facilities.

3. SAMPLE SIZE

3.1 One liter (one quart) of hydrocarbon fuel.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 References.

4.1.1 MIL-I-27686(AS) inhibitor, icing, fuel systems.

4.1.2 MIL-I-8547C inhibitor, icing, fuel system, high flash.

4.2 Apparatus.

4.2.1 Portable refractometer kit. The kit includes a hand held, temperature compensated refractometer and all other equipment necessary to perform the evaluation. The refractometer is capable of direct readout of volume percent

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FSII for both ethelyne glycol mortomethal ether (EGME) and di-ethelyne glycol monomethyl ether (DGME). All items, except for the refractometer are standard laboratory items available from supply houses.

NOTE: The kit used in this test method is available from H.B. Enterprises, 2737 Helen Drive, Glenview, IL 60025. The kit contains, in addition to the refractometer, a ring stand, a 250-mL separator funnel, a 250–mL graduate, 5 piston pipets, and 100 aluminum dishes. All of the above are housed in a plastic luggage type case.

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials, references, and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Commercial liquid dishwashing detergent.

5.3 Distilled water.

5.4 Lens tissue.

6. PROCEDURE

6.1 Set up the ring stand assembly.

6.2 In a clean, dry container, take a one liter (one quart) sample of the hydrocarbon fuel to be tested.

6.3 Fill an aluminum dish half full with tap water.

6.4 Fill the graduate and the separatory funnel about one-third full with the fuel. Rinse thoroughly and empty.

6.5 Fill the graduate with exactly 160 mL of the fuel sample.

6.6 Check to see if the drain cock on the separator funnel is closed. If not , close it and pour the 160 mL from the graduate into the separator funnel.

6.7 Using one of the piston pipets, add exactly 2 mL of water from the aluminum dish to the separator funnel. Place the cap on the funnel and shake it vigorously for approximately three minutes. Place the funnel in the assembled ring stand.

6.8 Open the hinged plastic cover of the refractometer’s window. Flake sure that the window and cover are clean and place several drops of water on it. If

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they are not clean, wipe them with lens tissue. Close the cover and look through the eyepiece. Observe the shadow line. Remove the blast plastic rod from the bottom of the refractometer. Using the rod, or a suitable screwdriver, adjust the set screw on the bottom of the refractometer until the shadow line meets the zero line of the scale.

6.9 Open the plastic cover and wipe off the water from the cover and window with lens tissue.

6.10 Carefully turn the drain cock so that several drops of water can trickle into a clean, dry aluminum dish.

6.11 Open the plastic cover again and place two or three drops of water on the window. Close the cover. Look through the eyepiece and read the point where the shadow line is on the scale. Read FSII volume percent DGME on left side and EGME on the right side.

6.12 Empty the funnel and properly dispose of the fuel. Clean the funnel, graduate, and aluminum dish with liquid detergent and tap water. Wipe the water from the refractometer and thoroughly dry all items. Avoid damage to the refractometer lens and window parts.

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Report the type of FSII and the volume percent of FSII to the nearest 0.01 percent found in the hydrocarbon fuel.

9. PRECISION

9.1 Precision data for this method have not yet been established.

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METHOD 5350.1
September 30, 1986

SILTING INDEX OF HYDROCARBON FUELS

1. SCOPE

1.1 This test measures the tendency of a fluid to cause silting in close tolerance devices as the result of fine particles and gelatinous materials suspended in the fluid. It expresses this tendency as a "silting index".

2. SUMMARY

2.1 The Silting Index Apparatus is a device which permits the filtration of a contaminated liquid sample through a known filter area at constant pressure so that flow decay due to filter clogging may be recorded as a function of time. When a liquid is passed at uniform high pressure through a membrane filter of 0.8 micrometer porosity, all particles entrained in the fluid larger than the filter pore size will be retained on the filter surface. Very large particles will form a loose, open flowing cake, but particles 5 micrometers and smaller, and stable gels, will tend to block the filter openings and reduce the rate of flow in a mathematically predictable, and easily measured manner.

3. SAMPLE SIZE

3.1 Approximately 100 mL of the fuel to be tested.

4. REFERENCES, STANDARDS AND APPARATUS

4.1 Silting Index Apparatus (Millipore Corp., Bedford, Mass., No. XX68-013-60, or equivalent).

NOTE 1: This apparatus should be the most recent modification: I.E. Syringe barrel should have threaded fitting for silting heads in place of Lure lock, stainless steel syringe plunger has Teflon fitting on end in place of O-ring. The weights supplied with the apparatus are 2418 g ±1 percent. These weights are also available as catalogue No. XX68-013-22 to modify older apparatus.

4.2 Beaker, Griffin, 150-mL.

4.3 Sample bottle, 4-oz, wide mouth.

4.4 Split hand stopwatch or other timer capable of being read with accuracy to 1/100 second.

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms,

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life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Precipitation naphtha ASTM D 91 11,4,0].

5.3 Filters, 0.8 micrometer membrane (Millipore Corp. Type AA, White, plain, 13 mm dia. cat. No. AAWP-013-SI, or equivalent).

6. PROCEDURE

6.1 prepare the apparatus as follows:

a. Clean apparatus thoroughly before each sample with precipitation napnthd. Particular care should be given to the syringe barrel, three-way valve with hose and sinker, and the silting head.
b. Place syringe with plunger installed in the clamped support arm so that the graduations face toward the operator.
c. Attach three-way valve with hose and sinker to the syringe.
d. Using forceps, place 0.8 inicrometer membrane filter in tne selected silting head. Moisten filter with one drop of the fluid to be tested and assemble the silting head. Do not install on syringe.

NOTE 2: Because of the wide variation in the amount of suspended fine contaminant encountered ill actual practice, four silting heads are provided having increasingly larger effective filtering areas. This is because some measurable flow decay must occur, even in very clean fluids, but essentially 100 percent clogging must be avoided. The choice of a Silting Head to be used is dictated by the requirement that the flow decay ill the course of the test must be depreciable - but it must not approach 100 percent. This in turn is controlled by the presence of particulate matter (less than 5 micrometers) and gelatinous materials in the fluid being tested. If the Silting Index is negative or less than 0.50, the next smaller silting head should be used. If the flow virtually stops because of clogging, the next larger Silting Head must be used. In general, for most fuels Silting Head NO. 1 is appropriate.

e. Shake sample bottle vigorously for 15 seconds immediately prior to each determination.
f. Insert nose into sample container. With valve in "INTAKE" position, pull fluid to be tested through the nose, and into the syringe to the “FILL” line. Turn the valve to “FLOW” position and exhaust into a beaker. Repeat flushing cycle three times.
g. Install silting head on syringe. Turn valve to "INTAKE" position, and pull test fluid into syringe until the fluid level reaches the “FILL” line. Then turn valve to “OFF’” position.

6.2 Conduct the test as follows:

NOTE 3: The test must never be run in direct sunlight or close to heat sources which may change temperature (and therefore viscosity) during the test.

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a. Carefully place weight on syringe so that the top of the syringe plunger is in the circular recess of the weight cross bar.
b. Turn valve handle to vertical ("FLOW") position. Start timer when plunger passes "O".

NOTE 4: Greater precision in the timing of the cycle will be achieved if the air bubbles are dispelled from the test chamber. Times art? read to an accuracy of minutes and hundredths of a minute.

c. Record (T_1) when plunger passes "v_1". If T_1 is less than 0.10 minutes, the third decimal place must be estimated.
d. Record time (T_2) when plunger passes "v_2".
e. Record time (T_3) when plunger passes "v_3".

6.3 Make three determinations omitting the flushing procedure for the duplicate tests and average the resulting silting indices for an overall silting index.

7. CALCULATIONS

7.1 Calculation of the silting index.

a. Calculate the silting index by the formula:

$$S.I. = \frac{T_3 - 2T_2}{T_1}$$

Express the results in terms of the silting head used to conduct the test: e.g.

$S.I._2$ = 5.7 (for silting head number 2).

8. REPORTING

8.1 Report the silting index as required by the specification."

9. PRECISION

9.1 precision data have not been developed for this method.

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RESISTANCE OF GREASE TO FUEL

1. SCOPE

1.1 This method is used for determining the resistance of grease to the solvent action of fuel.

2. SUMMARY

2.1 The test consists of determining the volubility of the grease in a standard test fluid, and observing for physical changes caused by an 8-hour immersion in the test fluid.

3. SAMPLE SIZE

3.1 Approximately 4 g of grease to be tested (duplicate 2 g samples).

4. REFERENCE, STANDARDS, AND APPARATUS

4.1 Centrifuge, approximately 650 rpm, swing diameter (tip to tip of whirling tubes) approximately 40 cm, or equivalent.

> Note. An equivalent centrifuge must be capable of having its speed adjusted according to the following formula:

$$rpm = \sqrt{\frac{40}{d}} \times 650$$

d = diameter (tip to tip) of whirling tubes centimeters

4.2 Shaker, mechanical, stroke approximately 3.8 cm (1-1/2 in), speed approximately 1350 rpm.

4.3 Centrifuge tube, 200-mL, with stopper.

4.4 Evaporation dish, 100-mL.

4.5 Pipet, 50-mL.

4.6 Test tube, approximately 1.5 cm (1/2 in) OD by 7.5 cm (3 in) long, with stopper.

4.7 Steam bath (to accommodate evaporating dish).

4.8 Oven, approximately 100° C (212° F).

4.9 Balance, sensitivity 0.2 mg.

4.10 Spoon type spatula.

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5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Standard Test fluid (TT-S-735, Type III).

5.3 Aluminum strip (QQ-A-250/4, tempers T-3 or T-4), 5.08 cm by 1.3 cm by 0.04 cm.

6. PROCEDURE

6.1 Determine the volubility of the sample in the standard test fluid as follows:

a. Clean, dry and weigh a centrifuge tube to within +0.2 mg accuracy. With a spoon spatula spread approximately two g of grease in a thin film inside the tube and weigh to within ±0.2 mg; add 100 mL of the test fluid and stopper the tube.
b. Using the mechanical shaker, shake tube until sample appears to be thoroughly dispersed (approximately 1/2 hour).
c. Centrifuge the tube until fluid and sample are completely separated, and the fluid portion is clear and transparent.
d. Weigh evaporating dish to within 0.2 mg.
e. Pipet 50 mL of the clear fluid from the centrifuge tube into evaporating dish. place dish 011 steam bath until liquid is evaporated. Then dry dish in oven for one-half hour at approximately 100° C.
f. After drying, remove dish from oven and reweigh to within 0.2 mg. Determine the weight of residue, and calculate the percent of sample soluble in test fluid (see 7.1).

6.2 Determine the deterioration of the sample due to the test fluid as follows:

a. Fill test tube to a depth of approximately 2.5 cm with test fluid. Spread the grease evenly on both sides of the aluminum strip, and place the strip in the test tube so that it is half immersed in the test fluid. Stopper test tube, and allow it to stand for 8 hours at room temperature (approximately 25° C).
b. After 8 hours, remove strip from test tube (being careful not to disturb sample), and dip once into fresh test fluid. Examine sample while wet for swelling, loss of adhesion, blistering, cracking, or deterioration, and report observations.

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c. Allow strip to dry for 24 hours at room temperature (approximately 25° C), then re-examine the sample for the signs of deterioration, and report observations.

7. CALCULATIONS

7.1 Calculate the percent of sample soluble in test fluid as follows:

$$\text{percent Volubility} = \frac{200A}{B}$$

A = Weight of sample, mg (see 6.1 f).
B = Weight of original sample, mg.

8. REPORTING

8.1 Report percent volubility as determined under 6.1 f.

8.2 Report condition of grease on strip as determined under 6.2. b and c.

9. PRECISION

9.1 Precision data have not be developed for this method.

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METHOD 5415.1
September 30, 1986

RESISTANCE OF GREASE TO WATER AND A 1:1 WATER-ETHANOL SOLUTION

1. SCOPE

1.1 This method is used for determining the resistance of a grease to the solvent action of water.

2. SUMMARY

2.1 The test consists of storing two portions of grease, one in distilled water and the other in an ethyl alcohol-water solution, for one week, and examining the grease for disintegration.

3. SAMPLE SIZE

3.1 Approximately 4 g of grease to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Containers (2), glass, 250-mL, with stoppers.

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemcial materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Alcohol, Ethyl, Specially Denatured, Aircraft (MIL-A-6091) [0,3,0].

5.3 Distilled water.

6. PROCEDURE

6.1 Place 200 mL of distilled water into one container, and 200 mL of an alcohol-distilled water solution (1 to 1 by volume) into the other.

6.2 Place a single globule of grease (approx 2 g) into each of the two containers, stopper the containers tightly, and allow both to stand for one week.

6.3 At the end of one week, shake each container once or twice, and then visually examine each portion of grease for disintegration.

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7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Report the degree of disintegration of the grease in each container.

9. PRECISION

9.1 Precision data have not been developed for this method.

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NITRATE-TYPE IGNITION IMPROVERS IN DIESEL FUEL

1. SCOPE

1.1 This method of test covers the determination of organic nitrate ester-type cetane improver additives used in diesel fuel. It is intended as a screening test for those diesel fuel inspection test procedures that are affected by the presence of cetane improvers; namely, ASTM D 524 Standard Method of Test for Ramsbottom Carbon Residue of Petroleum Products and D 976 Standard Methods for Calculated Cetane Index of Distillate Fuels.

2. SUMMARY

2.1 A diesel fuel sample is saponified in a potassium hydroxide-l-butanol mixture and then filtered through a glass fiber filter disk. The material remaining on the disc is treated with diphenylamine reagent after drying. The presence of a nitrate ester cetane improver is revealed by the formation of a blue ring or blue-black spot due to oxidation of diplenylamine to intense blue quinoidal compounds by the nitrate salt. No color change confirms the absence of a cetane improver.

3. SAMPLE SIZE

3.1 A 10 mL sample of diesel fuel is required.

4. REFERENCES, STANDARDS, AND APPARATUS.

4.1 Reaction bottle - screw-cap bottle, 29.6 mL (1 fl oz) capacity, wide mouth, flint glass, with screw-cap lined with tin or tetrafluoroethylene (TFE) resin.

4.2 Glass fiber filter paper - 3.7 cm diameter, Grade 934 AH (H. Reeve Angel, Inc., Clifton, NJ, or equivalent).

4.3 Pipette - 10-mL capacity, fitted with pipetting bulb. Several types and makes of pipetting bulbs and assemblies are available. One of the following is suggested: Fisher Cat. No. 13-681, Safety Pipet Filler, or equal; Fisher Cat. No. 13-681-50, Pipet Filler, or equal.

4.4 Graduated cylinders - 10-mL and 25-mL capacity.

4.5 Suction flask with a suitable holder to accommodate a 60-mL glass - fritted crucible.

4.6 Crucible - 60-mL capacity, glass-fritted, medium porosity.

4.7 Oven suitable for drying filter discs at 110° C.

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5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Saponification Mixture (lN) - Prepared by mixing 6.5 g potassium hydroxide (ACS grade) [3,0,1] with 100 mL absolute n-butyl alcohol (ACS grade) [1,3,0] and heating to dissolve the KOH. After the solution cools, the mixture is filtered through the glass fiber filter paper.

5.3 Diphenylamine (1 percent) Solution - Prepared by dissolving 0.250 g diphenylamine (ACS indicator grade) [3,1,0] in 25 mL sulfuric acid (sp gr 1.834) [3,0,2].

5.4 Toluene (ACS Reagent grade) [2,3,0].

NOTE. Toluene is flammable and toxic. Avoid breathing vapors or contact with skin.

6. PROCEDURE

6.1 Pipette 10 mL of sample into the reaction bottle and add 5 mL of toluene followed by 10 mL of the saponification mixture.

NOTE: Oral pipetting techniques should not be used because of the toxicity of the substances involved. A pipetting bulb or assembly similar to one of those described in 4.3 should be used.

6.2 Affix cap to the reaction bottle tightly and, after mixing the contents, place it in an oven maintained at 110° C for four hours.

6.3 Remove the reaction bottle from the oven and allow it to cool to 25° ± 3° C.

6.4 Filter the contents of the reaction bottle through the 60-mL glass-fritted crucible fitted with the glass fiber filter disc.

6.5 Wash the reaction bottle with 25 mL of toluene and transfer it to the glass-fritted crucible.

6.6 Carefully remove the glass fiber filter disc and dry it in oven at 110° C for 15 minutes.

6.7 Remove the filter disc and cool it to 25° ± 3° C.

6.8 Add three drops of diphenylamine solution to the center of the disc and observe whether a blue or blue-black color forms.

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7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 The presence of organic nitrate ester-type cetane improvers will be reported if the formation of a blue color occurs. Reference samples of diesel fuels containing 0.5 percent by volume of any one of the approved cetane improvers (amyl nitrate, cyclohexyl nitrate, hexyl nitrate and isopropyl nitrate) give an intense blue to blue-black color throughout the reagent spot whereas those samples containing only 0.1 percent by volume produce a blue ring at the outer boundry of the reagent. If a positive reaction occurs (i.e., a blue or blue-black coloration), the carbon residue determination (ASTM D 524) must be performed on a neat or base fuel blend.

9. PRECISION

9.1 Precision data have not been developed for this method.

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METHOD 6052.1
September 30, 1986

HIGH-TEMPERATURE--HIGH-PRESSURE SPRAY IGNITION

1. SCOPE

1.1 This method is used for determining the relative flammability of liquids.

2. SUMMARY

2.1 The method consists of forcing the test fluid sample through a 0.0368 cm (0.0145 inch) orifice at 6.98 MPa gage (1000 psig), attempting to ignite the spray with a torch and noting the characteristics of the resulting flame.

3. SAMPLE SIZE

3.1 Sufficient liquid to be tested to fill cylinder of spray test setup.

4. REFERENCES, STANDARDS AND APPRARATUS

4.1 Apparatus.

4.1.1 Spray test setup. A setup similar to Figure 1 shall be assembled so as to supply a constant pressure of 6984 ±69 kPa gage (1000 ±10 psig) to the sample.

4.l.2 Torch. An oxyacetylene torch equipped with a No. 3 tip or equal.

4.1.3 Nozzle. A nozzle 0.163 cm (0.064 in.) thick by 0.965 cm (0.38 in.) minimum diameter with a centered orifice approximately 0.0368 cm (0.0145 in.) diameter having sharp, square edges (see Figure 1).

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Nitrogen. A cylinder of nitrogen fitted with a regulator capable of supplying 6890 kPa gage (1000 ±10 psig) of pressure to the system.

6. PROCEDURE

6.1 Fill the fluid cylinder of the spray test setup with test fluid at 15.6 to 37.8° C (60 to 100° F) and adjust nitrogen pressure to produce a liquid pressure of 6894 ±kPa gage (1000 ±10 psig).

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6.2 Adjust the torch to deliver a neutral flame.

6.3 Open the quick-opening valve at the orifice and attempt to ignite the spray with the torch at the nozzle.

6.4 If the spray does not ignite gradually move the torch away from the nozzle until ignition takes place (45.7 cm max.)

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Report whether the spray ignites. If the spray does ignite, also report:

a. The distance from torch to nozzle at ignition.
b. Whether the spray flashes readily or with difficulty.
c. Whether the flame produced is self extinguishing or sustained.

9. PRECISION

9.1 Precision data have not been developed for this method.

Method Prepared By:

Army - ME - 1986

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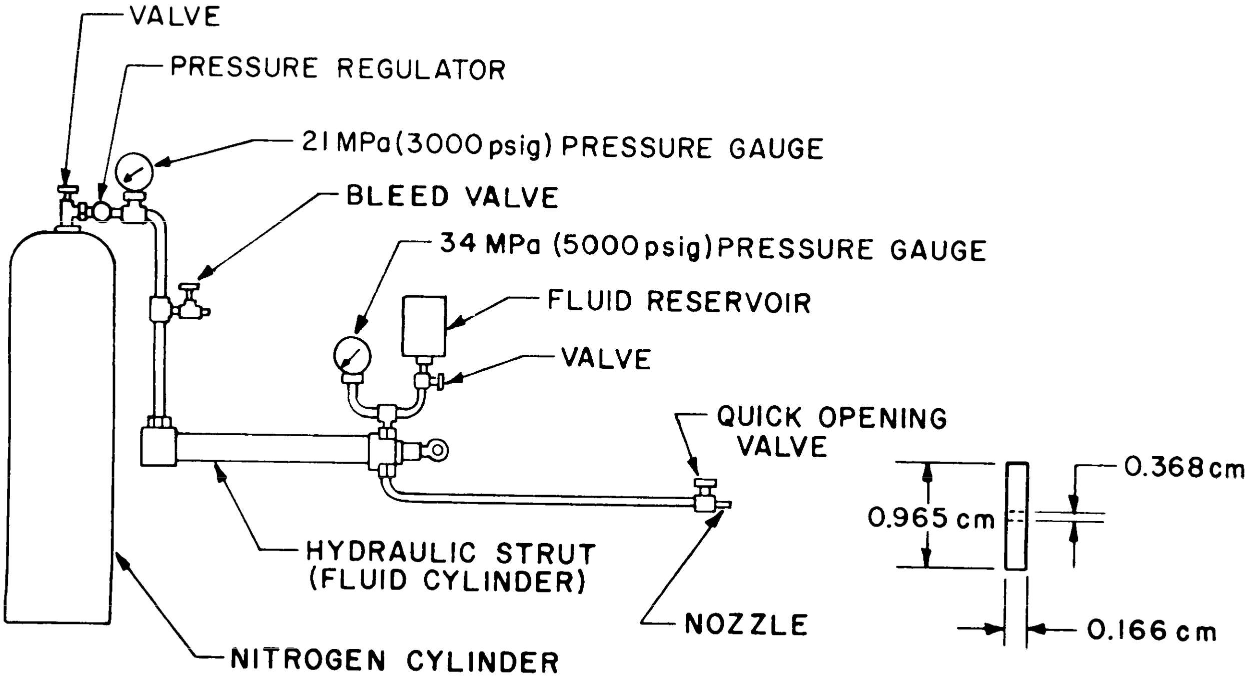

FIGURE 1. Spray test setup.

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METHOD 6053.1
September 30, 1986

MANIFOLD IGNITION TEST

1. SCOPE

1.1 This method is used for determining the relative flammability of a liquid in contact with a hot surface.

2. SUMMARY

2.1 The test method consists of dropping the flammable fluid on a hot surface and observing the presence of a flame.

3. SAMPLE SIZE

3.1 15 mL per test run.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Simulated manifold test set up (Figure 1), fabricated from 7.6 cm (3 inch) OD corrosion-resistant steel tubing of 0.114 (0.045 inch) wall thickness. The exterior of the tube shall be sandblasted. A 1/8 inch diameter 18–8 corrosion-resistant rod 25 cm (10 inches) long shall be tacked to the stack on the exterior surface. Opposite the steel rod, tack, weld or suitably attach a thermocouple, and insulate the leads. Care should be taken in this attachment to provide a minimum additional radiating surface.

4.2 Heating element, electrical, "globar" type or equivalent, (Carborundum Company, AT, 31 x 12 x 1, 0.633 ohm unit, or equal), with suitable means for controlling the temperature of the tube to 704° C (1300° F).

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Steel wool (FF-S-740).

6. PROCEDURE

6.1 Clean the outside surface of the tube of the test setup (Figure 1), using steel wool.

6.2 Mount the heating element centrally in the tube, and adjust the voltage so that the temperature of the tube is maintained at 704° C (1300° F).

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6.3 Wnen the tube has reached the correct temperature, drop 10 ML portions of the test liquid at a rate of 10 mL in 40 to 60 seconds from various heigts onto various points on the tube, and observe the ignition characteristics of the. liquid. (Clean the tube with steel wool before each 10 mL application of the liquid.)

7. CALCULATIONS

7.1 This section is not applicable to the test procedure.

8. REPORTING

8.1 Report results as follows:

a. Flashes or burns on the tube, but does not after dripping from the tube.
b. Does not flash or burn on tube, but does after dripping from the tube.
c. Does not flash or burn on the tube or after dripping from the tube.

9. PRECISION

9.1 Precision data have not been developed for this method.

Method prepared by:
Army - ME - 1986

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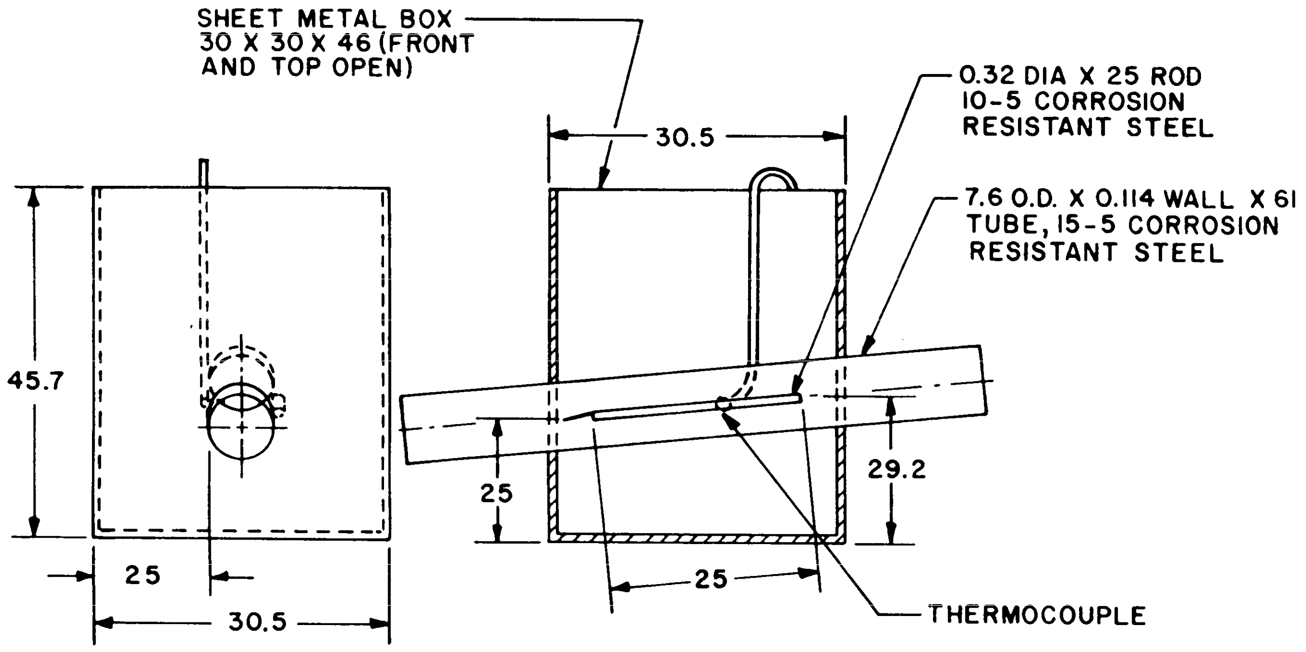

NOTE: DIMENSIONS IN CENTIMETERS.

FIGURE 1. Simulated manifold test setup.

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METHOD 6505.2
September 30, 1986

LOAD-CARRYING CAPACITY OF UNIVERSAL GEAR LUBRICANTS BY THE TIMKEN MACHINE

1. SCOPE

1.1 This procedure is intended for use in determining the load-carrying capacity of universal gear lubricants by the Timken machine.

2. SUMMARY

2.1 The tester is operated with a steel test cup rotating against a steel test block. The rotating speed is 122 m/min (400 ft/min) which is equivalent to a spindle speed of 800 +5 rpm. Fluid samples are preheated to 51.7° ±2.5° C (125 35° F) before starting the test.

2.2 Two determinations are made: the minimum load (score value) that will rupture the lubricant film being tested between the rotating cup and the stationary block and cause scoring or seizure; and the maximum load (OK value) at which the rotating cup will not rupture the lubricant film and cause scoring or seizure between the rotating cup and the stationary block.

3. SAMPLE SIZE

3.1 Approximately 7.6 L (2 gallons) of the gear lubricant to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 The apparatus (Figure 1) shall consist of the following:

a. Lubricant testing machine, extreme-pressure (Timken Roller Bearing Co., Canton, Ohio).
b. Test cups, surface finish between 0.51 and 0.76 micrometers (20 and 30 microinches) (Timken part No. T-48651).
c. Test blocks (for use with Timken lubricant testing machine.
d. Mechanical loading device for applying loads (Pavlik Brothers Machine Shop, Kenilworth, Illinois, or equal).
e. Microscope, Brinell.

4.2 An apparatus to check the rpm, either a hand-held tachometer or a strobe light are suggested.

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference

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which lists all toxic and hazardous materials cited in FTMS- 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Kerosene, (ASTM D 3699) [u,u,u].

5.3 Naphtha, (TT-N-95, types I or II) [1,4,0].

NOTE 1: Caution. Kerosene and naphtha are flammable. Keep them away from flames. Naphtha is toxic. Do not breath its fumes nor allow it to come in contact with the skin.

6. PROCEDURE

6.1 prior to testing each lubricant, clean the machine by draining any lubricant from the oil reservoirs, and then circulating naphtha or kerosene through the pump until the machine is clean. The naphtha or kerosene shall be drained.

6.2 Charge approximately 470 mL (one pint) of the lubricant to be tested into the machine, circulate it through the pump for two or three minutes, and discard.

6.3 Clean test cup and test block of packing compound using naphtha or kerosene and allow them to air dry.

6.4 The test lubricant at a temperature of 51.7° +2.5° c (125° +5° F) shall be circulated through the machine for a period of 15–minutes prior–to beginning the test procedure. The lubricant can be heated in the machine or may be heated to designated temperature prior to placing in the reservoir. The reservoir shall be filled with the lubricant to within approximately 7.6 cm (3 inches) of the top.

6.5 After the lubricant has been circulated, mount the test cup on the mandrel and the test block in the holder, and adjust so that all knife edges are in perfect alignment. The test cup and block are covered with the lubricant to be tested. Turn the machine a few revolutions by hand, and if the parts are in alignment, the lubricant will be cleaned oft the cup over its entire width. Do not fasten the cup too tightly as this will cause distortion. ,

6.6 Open the valve and allow the lubricant to flood the test cup and block. When the small reservoir (the one containing knife edges) is about nalf full of Lubricant, start the motor. The mandrel holding the test cup shall revolve at 800 rpm. This produces a rubbing speed on the test cup of 122 m/min (400 fpm)]. Check the rpm frequently.

NOTE 2: If the machine is belt driven, be sure there is no slippabe, especially at heavier loads. The use of an endless belt or a v-belt is recommended.

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6.7 Apply the desired load, for example 15.0 kg (33 pounds), on the lever arm. It is very important that the entire load be applied at one time, and not built up gradually. Allow the machine to run 10 minutes, unless a score is noticeable before that period has expired. Wnen heavy loads are added, usually when a rupture of the lubricant film occurs, there is a deep score, and the load must be removed immediately to prevent damage to the machine.

6.8 As soon as the 10 minute period has expired, remove the load from the lever, and turn off, first the flow of lubricant, and then the motor driving the tester.

6.9 Remove the load lever arm, and inspect the test pieces for the condition of the contacting surfaces. If there is no score or pickup of metal, a new surface of the test block is placed in the block holder, a new CUP is placed on the mandrel, and the test repeated with a heavier load. If there is evidence of failure, the test is repeated with a lower load. When testing extreme-pressure lubricants, increments of approximately 4.5 kg (10 pounds) lever loads should give the desired results.

6.10 For measuring the width of the scar produced on the test block a Brinell microscope is used. From the width of the scar and the chart furnished with the machine, the load at the end of the test can be calculate (see 7.1).

7. CALCULATIONS

7.1 Calculate the load as follows:

$$CP = \frac{L(W+G)gc}{d \cdot s}$$

CP = contact pressure in gage pa.
L = 10 = mechanical advantage of load-lever arm.
w = weight in kg placed on weight pan.
G = load-lever constant.
gc = gravitational constant, 9.807 (n@^{2})
d = length of test scar, m
s = average width of test scar, m

$$\text{Contact pressure, psig} = \frac{L(W+G)}{d \cdot s}$$

L = 10 = mechanical advantage of load-lever arm.
G = load-lever constant
w = weight placed on weight pan, pounds.
d = length of test scar, inches.
s = average width of test scar, inches.

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8. Reporting

8.1 The load carrying capacity of the test lubricant is reported in gage kPa (psig) at the maximum load, in kg (pounds), that could be applied at the end of the lever arm without causing a score or pickup of metal.

9. PRECISION

9.1 Precision data have not been developed for this method.

Method prepared by:
NvVy - NAPC - 1986

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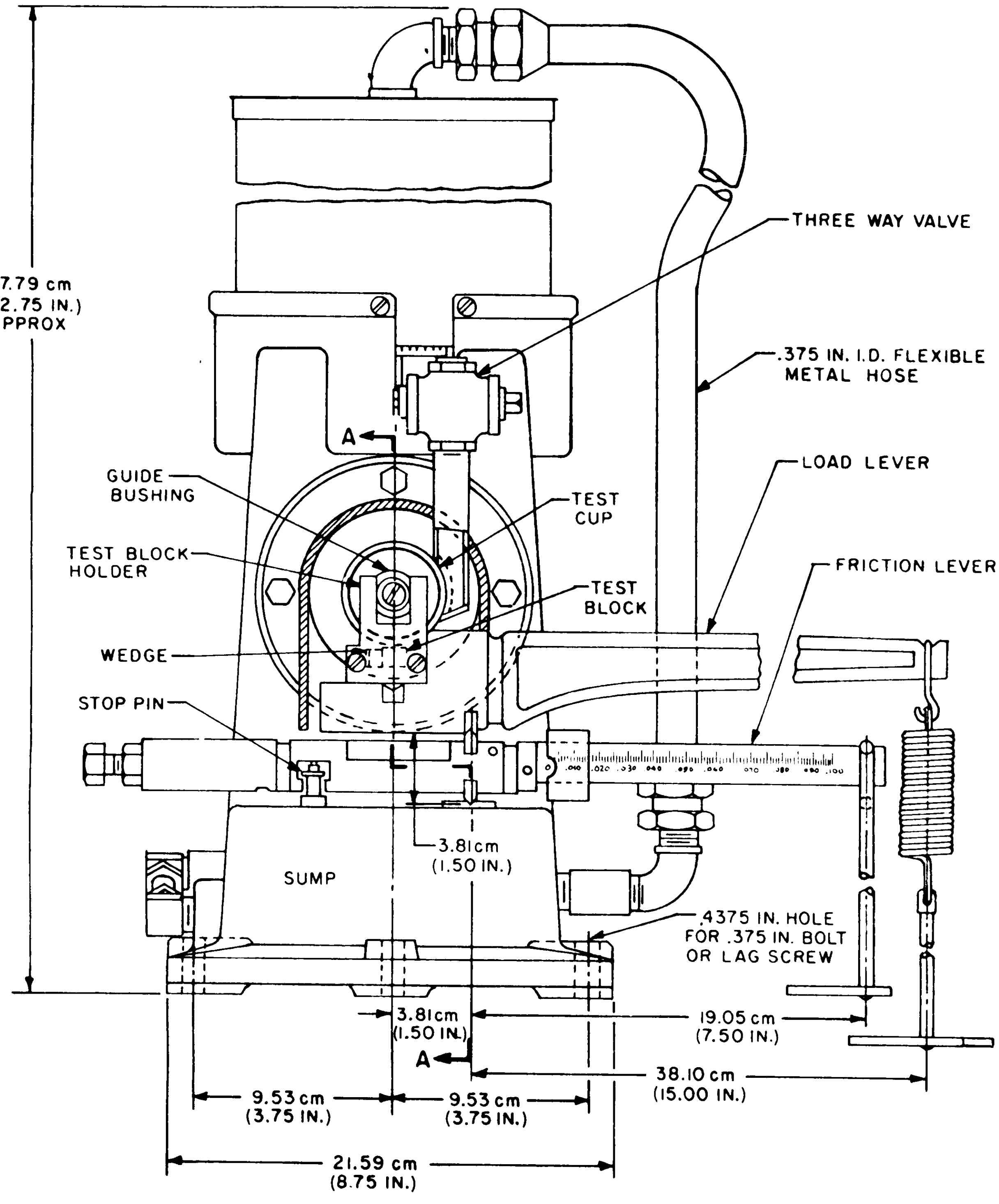

FIGURE 1. Timken tester. -Continued

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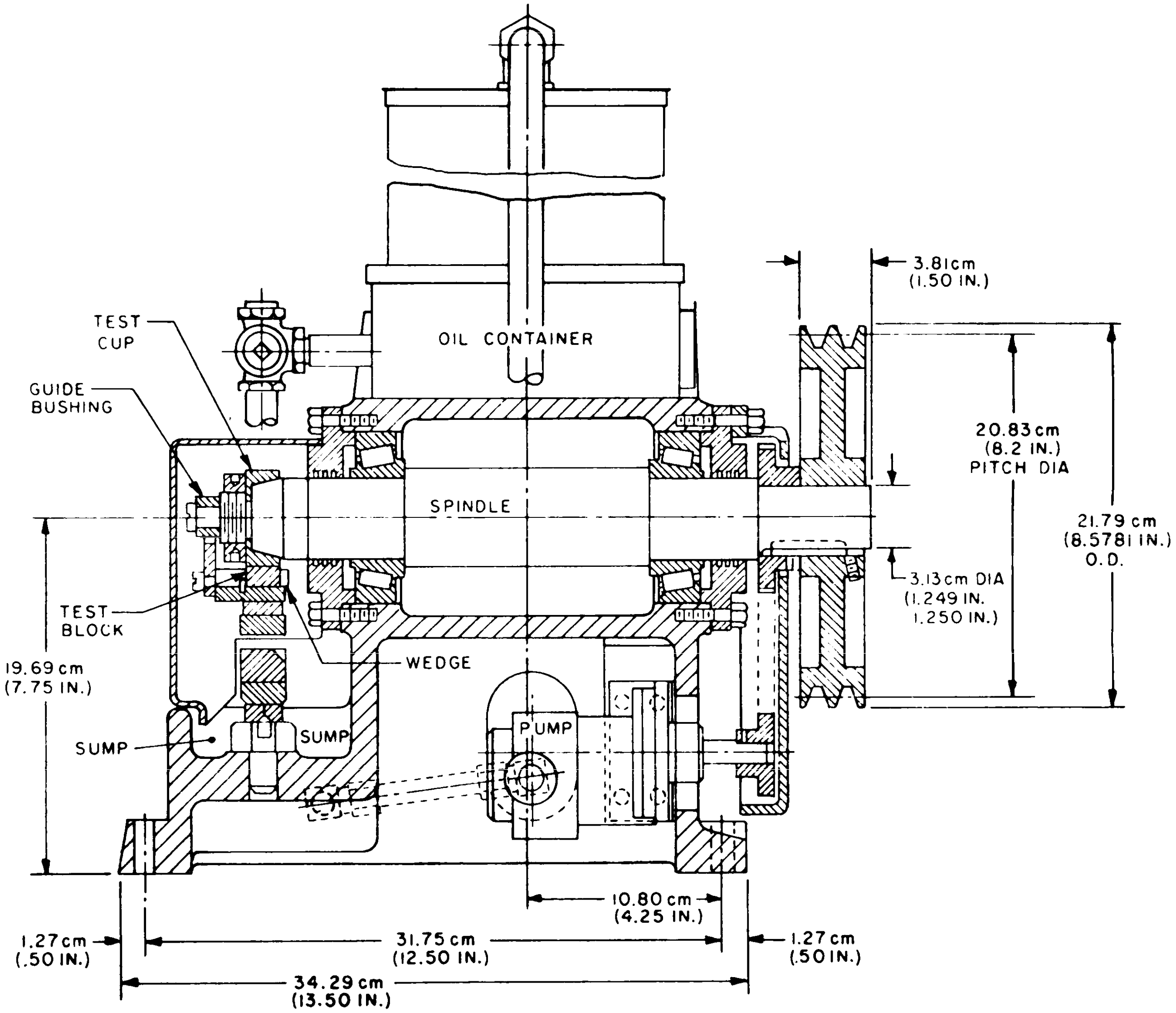

SECTION A-A

FIGURE 2. Timken tester.

X-4404

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LOAD CARRYING CAPACITY OF LUBRICATING OILS
(Ryder Gear Machine)

1. SCOPE

1.1 This method describes a procedure for determining the load carrying ability of lubricating oils with reference to gears.

2. SUMMARY

2.1 The test consists of incremental increasing the pressure between gears to measure the resultant scuffing. The ability of the test oil to impair scuffing is measured by the maximum pressure when operating at 10,000 rpm.

3. SAMPLE SIZE

3.1 Approximately 2 L of test oil.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Test unit. The apparatus used in this method is the Ryder gear-Erdco universal tester (Figure 1), and test gears available from Erdco Engineering Corp., Addison, Ill. This tester comprises a special test machine known as the Ryder gear machine, a drive system, a support and load oil system, a test oil system, and the necessary instruments and controls. Figure 2 illustrates the control console.

4.1.1 Ryder gear machine. The Ryder gear machine operates on the so called "four square” principle. As shown in Figure 3, two parallel shafts (P and Q) are connected by two slave gears (R and S) and two test gears (T and U) to form a “square”, so that the power required to operate the machine is only that required to overcome the friction losses in the gear and bearings. The slave gears are helical gears made integral to the shafts, (see Figure 4). The replaceable test gears are spur gears, shown installed on the shaft in Figure 5. Load on the test gears is obtained through the application of a controlled oil pressure in two load champers (Figure 3, Y and Z) which causes an axial movement of one shaft relative to the other. Because of the integral helical slave gears, a torsional load is thus applied on the shafts thereby loading the test gears. The relation between the tooth load on the test gears and the load oil pressure is obtained by arithmetic calculation, calibration, or both. Arithmetic calculation is used herein.

4.1.2 Test gears. The test gears are special spur gears, made of AMS 6260 steel, case hardened and ground, having 28 teeth 8.88 cm (3.5 inches) pitch diameter, 8 diametral pitch, 22.5 degree pressure angle, and zero tip relief. Each set of test gears comprises gears of two different widths. The narrow test gear is used for rating purposes. The malting gear is wider in order to maintain

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a constant contact width between the two gears at different tooth loads. Both sides of the test gear are used for testing. The “A” side of the gear refers to the side obtained by installing the tests gears with the serial numbers facing the end cover as shown in Figure 5. The “B” side is obtained by reversing’ the gear (serial numbers facing away from the end cover). Test gears can be used once only on each side and then discarded.

4.1.3 Support and load–oil system. The support and load-oil system, shown in Figure 6, serves two purposes: to provide lubrication to all parts except the test gears and to apply load to the test gears. The system is charged with approximately 30 L (8 gallons) of lubricating oil, MIL-L-6082, grade 1100. It is recommended that the oil be changed every 200 hours of running time under normal circumstances. A support oil pressure pump and a relief valve furnish oil to the distributing manifold at a specified support oil pressure of 758 +69 gage kPa (110 +10 psig). The support oil temperature, also measured at the distributing manifold, is maintained at a specified value of 73.9 +2.5° C (165° ±5° F) by electric heaters located in the sump and by a water cooler located after the pump, through the action of thermoswitches. Pressure lines from the distributing manifold lubricate the bearings and helical gears of the machine as well as the adapter housing and the stepup gear box. The pressure to the latter is reduced to 172 to 207 kPa gage (25 to 30 psig) by a throttle valve. Three scavenge pumps scavenge oil from the machine, the adapter housing, and the step–up gear box, back to the support oil sump. The action of the load oil circuit can be seen in Figures 3 and 6. Oil from the distributing manifold (Figure 6) enters the Ryder gear machine at points W and X (Figures 3 and 6). After lubricating the bearings and slave gears, the oil enters the load chambers Y and Z (Figure 3). For a given pressure in the distributing manifold, the pressure in the load chambers is dependent on the flow restriction offered by the circuit downstream of the load chambers. Figure 6 shows that the oil, upon leaving the load chambers at J and J, must pass through a control in the load oil circuit before returning to the support oil sump. Two pressure gages (a low range and a high range) located near the outlet points J and J, read the so called “load oil pressure”, i.e. the pressure in the load chambers’s The load oil circuit contains three valves. Of these the load bypass valve is an open or shut valve which is closed during the test run. The load oil pressure is controlled by regulating the load oil adjusting valve. The bleeder valve is normally slightly open, its function being to decrease the sensitivity of the load adjusting valve, thus facilitating the control of load oil pressure. The load bypass valve is opened when it is desired to quickly release the load on pressure, such as at the end of a test run.

4.1.4 Test oil system. A schematic diagram of the test oil system is shown in Figure 7. The capacity is 500 mL. Test oil is supplied to the test gears by a pressure pump through a jet located on the unmeshing side of the gears. Oil temperature to test gears is maintained at 73.9 +2.5° C (165° +5° F) by a line heater actuated by a thermoswitch and controlled–by a thermocouple close to the oil jet. The bypass circuit is arranged to permit the use of the graduated sump

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for the determination of the test oil flow rate. The bypass circuit also facilitates inspection of the narrow test gear without stopping test oil circulation.

4.1.5 Drive system. As shown in Figure 1, the Ryder Gear machine (A) is driven by a 50 hp induction motor (B) through a dynamic coupling (C), a step-up gear box (D), and an adapter (E). The test gear speed is controlled by adjusting the field excitation of the dynamic coupling. By this means, accurate speed control from standstill to well over the specified test speed of 10,000 rpm can be attained.

4.2 Instrumentation and controls. All of the instruments and controls that require constant attention during test are located on the control console (Figure 2). Items that do not require frequent attention are located on the test stand. The functions of most of the instruments and controls are apparent. Therefore, only selected items will be explained further.

4.2.1 Speed measurement and control. An electronic counter (Figure 2, item 4), located on the control panel, measures the speed. This instrument is actuated by pulses supplied by a variable reluctance pickup (the variable reluctance being provided by a 60 tooth gear operated from the driven shaft of the step-up gear box). The rpm adjustment control (Figure 2, item 20), located on the console, regulates the field excitation of the dynamic coupling and thus the gear speed.

4.2.2 Control of test run duration. An electric timer (Figure 2, item 10) located on the console, is used to control the duration of each test run. As soon as the desired test load has been reached the timer is started at the determined test duration setting. After the run is over the timer automatically turns off the drive motor and opens the load-bypass valve. The timer switch must be turned to the “stop” position prior to the next run.

4.2.3 Support–oil controls. The support-oil pump buttons (Figure 2, item 11) on the console are connected to the support-oil pressure pump as well as the three scavenge pumps. Pressing the start or stop button controls all four pumps at the same time. The support-oil heater buttons (Figure 2, item 12) control both the electric heaters and the water cooler through the action of thermoswitches (Figure 6). The support–oil chamber vacuum is measured by a water manometer located on the test stand. A valve connecting the chamber to a vent (Figure 6) should be adjusted to give a chamber vacuum of 2.5 to 10.2 cm (1 to 4 inches) of water under normal test conditions. If this value cannot be maintained, the shaft and shaft seals should be inspected for leakage.

4.2.4 Control of load oil pressure. The control of load oil pressure has been explained in 4.1.3. Of the three valves in the load oil circuit (Figure 6) only the bleeder valve is not remote controlled. However, this valve need only be set to give the desired sensitivity for load control during installation of

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the tester. As a rule, adjustments are seldom necessary thereafter. The load adjusting valve is air actuated and is controlled by the load adjust control (Figure 2, item 9) located on the console. The load bypass valve is solenoid actuated and is controlled by the load bypass switch (Figure 2, item 13) on the console. During the test run the load bypass switch is in the “close” position and the load bypass valve is closed. At the end of a run, the solenoid circuit will automatically be opened by the electric timer. This opens the load-bypass valve, but the load bypass switch on the console remains in the “close” position. For this reason, the switch should be turned to the “open” position prior to the next run.

4.2.5 Emergency stop. The emergency stop button (Figure 2, item 18) on the console stops the drive motor and turns off all the controls except those for instruments . The timer switch and the load bypass switch remain in the positions to which they were originally set.

4.3 Scuff rating equipment. A microscope and a light source for visual inspection of the narrow test gear are provided as standard equipment with the Ryder gear-Erdco universal tester. A camera with accessories for photographing the gear teeth is available as optional equipment. To inspect or photograph the narrow test gear the machine is stopped, but the test oil is kept circulating through the bypass circuit. The inspection or photographing can then be accomplished through special inspection holes provided in the gear case without taking off the end cover. These holes are closed with corks during the test run.

4.4 Inspection equipment. The microscope provided with the tester is an 18 power stereoscopic microscope. A high intensity light source is provided for use with the microscope. Figure 8 shows the inspection equipment in position for use. The left eyepiece of the microscope contains a net reticule which divides the gear tooth area lengthwise into five 20 percent sections as shown in Figure 10. These 20 percent grids provide a convenient means for the visual estimation of the percentage of gear tooth area that has been scuffed. Scuffing of individual gear teeth is estimated to the nearest 5 percent.

4.5 Photographic equipment. This is optional equipment consisting of a Leica camera with a copying attachment, a viewer, and an electronic flash unit synchronized with the camera shutter. Figure 9 shows this equipment installed for use.

4.6 Gear tooth indexing rachet. An indexing rachet (Figures 1 and 8) is used to rotate the test gears so that the teeth of the narrow gear can be brought into position one by one for inspection or photography.

4.7 Additional instruments.

a. Stop watch for measurement of test oil flow rate.
b. Micrometer 0. to 2.5 cm (0 to 1 inch) for measurement of the gross tooth width of the narrow test gear.
c. Set of conventional mechanical tools as necessary for assembly, disassembly, maintenance and repair.

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5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Lubricating oil, MIL-L-6082, grade 1100.

5.3 Flushing solvents.

5.3.1 Dry cleaning (ASTM D 484, type I) [0,2,0].

5.3.2 Petroleum ether (O-E-751) [1,4,0].

5.4 Test gear retaining nut lock washer, Fafnir WO–6 (Erdco Engineering Corporation, Addison, ILL, or any commercial supplier of Fafnir parts).

5.5 O-rings. An O-ring is used between the main case and the end cover of the Ryder gear machine. National No. 622710 O-rings 0.238 x 1.27 x 1.75 cm (3/32 x 1/2 x 11/16 inch) are recommended. It is recommended that a new O-ring be used each time the end cover is installed. These rings can be obtained from Erdco Engineering Corp., Addison, ILL, or any commercial supplier of National O-rings.

5.6 Shaft seals. The shaft seals recommended for the Ryder Gear machine are Garlock seals (obtained from Erdco Engineering Corp., Addison, ILL, or the Garlock Packing Co., Palmyra, NY) with the following part numbers and dimensions:

a. Klozure 63 x 359 with 9478 element and light-weight spring 2.86 x 5.08 x 0.952 cm (1-1/8 x 2 x 3/8 inch).
b. Klozure 63 x 1200 with 9478 element and light–weight spring 5.08 x 7.30 x 1.27 cm (2 x 2-7/8 x 1/2 inch).

6. PROCEDURE

6.1 Operating condition.

6.1.1 Throughout the entire test, the variables listed in Table I should be controlled within the limits specified. With the tester operating within the specified limits, the test gears are loaded first to 34 kPa gage (5 psig) load oil pressure, and then at successive increments of 34 kPa (5 psi). The duration of each loading period is 10 minutes +5 seconds. At the end of each loading period, the tester is stopped and each tooth of the narrow test gear is examined to determine the percent of tooth area scuffed.

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TABLE I. Operating conditions.

Condition	Value	
Test gear speed, rpm	10,000 +10	10,000 +10
Test oil inlet temperature	73.9° +2.5° C"	165° +5° F
Test oil flow rate	270 +5–mL/min	270 ± mL/min
Support oil inlet temperature	73.9° +2.5° C	165° +5° F
Support oil pressure	758 +6; kPa gage	110 ±10 psig
Step-up gear box pressure	172 to 207 kPa gage	25 to 30 psig
Support oil chamber vacuum	2.5 to 10.2 cm of water	1 to 4 inch of water

6.2 Preparation for test.

1. Record pertinent information such as test number, test oil code, operator’s name, etc., on suitable data sheets (Figure 11).
2. Turn on main electric switch to test cell.
3. Turn on main water valve to test cell.
4. Push instruments button “ON”.
5. Push support oil heaters button “ON”.
6. Make sure that the test oil system has been thoroughly flushed with Stoddard solvent and petroleum ether after the last test. See 6.3.2 steps (17) through (25) for the flushing procedure. Use the flushing solvent once and discard.
7. Remove gear case end cover.
8. Inspect shaft seals. Replace with new seals if necessary.
9. Inspect shafts for any nicks or other damage in the area of the seals. Damage must be repaired before machine is used for testing.
10. Clean a set of new test gears with dry cleaning solvent and discard solvent. Measure gross tooth width of the narrow test gear, and record the measurement.
11. Install test gears with the serial number facing outward, matching timing marks on shafts and gears. (See Figure 5.) Check for proper seating of the retaining nut, and lock the lock washer.
12. Install new O-ring in position.
13. Reinstall gear case end cover.
14. Start test oil pressure pump.
15. Flush test oil system with test oil, as follows:

    a. Turn 3-way valve L to “DRAIN”.
    b. Turn 3-way valve M to running position.
    c. Turn 3-way valve N to running position.
    d. Fill test oil sump with about 750 mL of test oil. Watch drop of level in sump. Allow 400 mL to drain through L.

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e. Drain the next 100 mL by opening drain K also. Then close drain K.
f. Turn valve L to running position, so as to permit flushing of that section of the test oil system between valve L and sump.
g. Drain the remaining 250 mL by turning valve M to bypass the Ryder gear machine, and turning valve N to “DRAIN”.

NOTE 1: The test oil for flushing is to be discarded after use. If the supply test oil is limited, a reduced quantity may be used for flushing.

16. Turn valves L, M, and N to running position.
17. Fill test oil sump with a new charge of test oil (500 mL).
18. Push test oil heaters button “ON”.
19. Close valve to support oil chamber vacuum manometer.
20. Allow at least 20 minutes to elapse since the support oil heaters were turned on (step 5). Then start support oil pumps.
21. Turn timer switch to “STOP” position.
22. Set electric timer to 10 minutes and 0 seconds. Then lock timer dial.
23. Turn rpm adjust control to “ZERO” position.
24. Check calibration of electronic rpm counter by setting the input sensitivity control to “CHECK” position, and the gate selector switch to “ONE SECOND” position. The counter should read 60. After checking, turn input sensitivity control to about midscale.
25. Turn load bypass control to “OPEN” position.
26. When the test oil and support oil temperature are up to the specified value of 73.9° +2.5° C (165° +5° l?), check support oil chamber vacuum 2.5 to 10.2 cm ([l to 4 inches], of water, see 4.2.3).
27. Check test oil flow rate as follows:

    a. Turn 3-way valve L to stop flow from the Ryder gear machine. By noting the drop of oil level in the test oil sump, measure the time required for 270 mL of test oil to accumulate in the Ryder gear machine. Then turn valve L back to running position.
    b. Adjust the variable speed transmission to vary the speed of the test oil pressure pump, until the specified flow rate at 270 ±5 mL per minute is obtained.

6.3 Test procedure.

6.3.1 Test on "A” side of test gears.

NOTE 2: The “A” side of the gear refers to the side obtained by installing the test gears with the serial numbers facing the end cover. The “B” side is obtained by reversing the gear (serial numbers facing away from the end cover).

1. Check all temperatures and pressures for the specified limits. (See paragraph 3.) Recheck test oil flow rate if necessary.

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2. Make sure that the gear-tooth indexing rachet is locked in disengaged position.
3. Make sure that the load adjust control is wide open (counterclockwise).
4. Start drive motor.
5. Increase gear speed by turning the rpm adjust control clockwise until the specified 10,000 ±100 rpm is obtained. Measure speed with the electronic rpm counter.
6. Turn load bypass control to "CLOSE" position.
7. Apply load slowly by turning the load adjust control clockwise. stop when the load oil pressure is 34 kPa gage (5 psig).

NOTE 3: In adjusting load oil pressure, take care not to overshoot the desired pressure.

8. Check gear speed.
9. Turn timer switch to "START" position. The 10 minute test run now begins .
10. Record all pertinent data about midway into the 10 minute test run.
11. At the end of the 10 minute run, the electric timer will automatically stop the drive motor and open the load bypass valve. However, the timer switch on the control console will remain in "START" position, the load bypass control will remain in "CLOSE" position, and the rpm adjust control will remain in running position. To restore these to their respective off positions:

    a. Turn load bypass control to "OPEN" position.
    b. Turn timer switch to "STOP" position.
    c. Turn rpm adjust control to "ZERO" position.

12. Make visual scuff inspection of the narrow test gear, as follows:

    a. Turn 3 way valve M to bypass flow around the Ryder gear machine.
    b. Remove corks from inspection holes on the gear case.
    c. Blow off excess oil from the test gear with compressed air through the inspection hole.
    d. Install microscope and inspection light.
    e. Focus microscope and adjust the 20 percent grid lines over the contact area of the tooth. (See Figure 10).
    f. Set indexing ratchet wheel to "No. 1" position.
    g. Estimate the percent scuff on No. 1 tooth to the nearest 5 percent, and record the value (See Figure 12).
    h. Operate indexing ratchet to give No. 2 tooth, then No. 3 tooth, etc., repeating step (g) until all 28 teeth have been examined.
    i. Remove microscope and light. Replace corks in the holes.
    j. Turn 3 way valve M to running position.
    k. Lock indexing ratchet in disengaged position.

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13. Repeat steps (3) through (12) at the next test load of 170 kPa (10 psig) load oil pressure.
14. Continue the test at 34 kPa (5 psi) load oil pressure increments, until the average scuffed area for all 28 teeth is closest to 22.5 percent. At this juncture, visually estimate the percent effective tooth width to the nearest 1 percent, and record the value.
15. Also at this juncture, install photographic equipment and take a photograph of each gear tooth. Make the first frame a test identification frame.

NOTE 4: Step (15) is optional. Photographic records of the scuffed gear teeth are not required in current test specifications. Using the photographic equipment as supplied (see 4.5), and PLus-X film, the camera should be set at a lens aperture (“f” value) of 16. The actual exposure time is controlled by the electronic flash unit; but to insure adequate exposure, the camera speed should be set at 1/25 second.

16. Further continue the test at 34 kPa (5 psi) load oil pressure increments , until an approximate average scuffed area of 40 percent or more is obtained.
17. Push test oil heaters button “OFF”.
18. Drain all test oil by first opening 3-way valve L and then valves K and N.
19. Close all drains.
20. Stop test oil pressure pump.
21. Push support oil heaters button "OFF".
22. Stop support oil pumps.

NOTE 5: Leave other controls on if test on “B” side will proceed after a short midday break. Otherwise, push instruments button “OFF”, and turn off main electric switch and main water valve to test cell.

6.3.2 Test on “B” side of test gears.

NOTE 6: The “B” side refers to the side obtained by reversing the gear (serial numbers away from end cover).

1. Push support oil heaters button “ON”.
2. Remove gear case end cover.
3. Remove O-ring.
4. Blow out test oil jet with compressed air.
5. Blow out line screen filters with compressed air.
6. Reverse test gears so that the serial numbers face inward, again matching timing marks on shafts and gears. Check for proper seating of the retaining nut, and lock the lock washer.

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7. Install new O-ring.
8. Reinstall gear case end cover.
9. Start test oil pressure pump.
10. Flush test oil system with test oil, in accordance with 6.2, step (15).

NOTE 7: If the supply of test oil is limited, this flushing between tests on "A" and "B" sides of the gears may be omitted.

11. Turn valves L, M, and N to running position.
12. Fill test oil system with a new charge of test oil (500 mL). Then push test oil heaters button "ON".
13. Allow at least 20 minutes to elapse since the support oil heaters were turned on (step 1). Then start support oil pumps.
14. When the test oil and support oil temperatures are up to the specified value of 73.9° +2.5° C (165° +5° F) check support oil chamber vacuum 2.5 to 10.2 cm (1 to 4 inches) of water.
15. Check test oil flow rate as described in 6.2, step (27).
16. Proceed on test on "B" side of the test gears, by following the procedure outlined in 6.3.1 steps (1) through (18).
17. Flush test oil system with Stoddard solvent, as follows:

    a. Turn 3 way valve M to running position.
    b. Turn 3 way valve N to running position.
    c. Fill test oil sump with about 750 mL of the solvent. Watch drop of level in sump. Slowly turn the test gears by operating the indexing ratchet. Allow about 400 mL to drain through L.
    d. Drain the next 100 mL by opening drain K also. Then close drain K.
    e. Turn valve L to running position, so as to permit flushing Of that section of the test oil system between valve L and sump.
    f. Drain the remaining 250 mL by turning valve M to bypass the Ryder gear machine , and turning valve N to "DRAIN".

NOTE 8: The flushing fluid is to be used only once and then discarded.

18. Flush test oil system with petroleum ether, by repeating step (17).
19. . Operate test oil pressure pump in reverse for about 60 seconds, and then resume normal rotation. To reverse pump, adjust the variable speed transmission.
20. Stop test oil pressure pump.
21. Remove gear case end cover.
22. Remove O-ring.
23. Remove used test gears.
24. Blow out gear case and test oil jet with compressed air.
25. Blow out line screen filters with compressed air.
26. Reinstall gear-case end cover (without test gears).
27. Push support oil heaters button "OFF". Then stop support oil pumps.
28. Push instruments button "OFF".
29. Turn off main electric switch to test cell.

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30. Turn off main water valve to test cell.

6.3.3 Sequence for repeat test. Repeat test on the same oil may be conducted by omitting steps (26) through (30) of the sequence for "B" side of the test gears (6.3.2. Instead, proceed from step (8) of the sequence for preparation (6.2), and continue through the complete test sequence (6.3).

6.3.4 Emergency stop.

1. Push emergency stop button.
2. Push instruments button "OFF".
3. Turn off main electric switch to test cell.
4. Turn off main water valve to test cell.
5. Investigate and take appropriate action.

6.4 Inspection and rating.

6.4.1 Scuffed area. The scuffed area of a gear tooth is that area from which the axial grinding marks have been removed by scratching, scoring, abrasion, and wear. As shown in Figure 10, areas A and B are scuffed; area C is not scuffed. Note that only the actual working portion (areas A plus B plus C) of the tooth surface is considered in the definition of areas.

6.4.2 Percent of tooth area scuffed. The percent of tooth area scuffed is that portion of the working surface of a gear tooth that has been scuffed. Referring to Figure 10,

$$\text{Percent tooth area scuffed} = \frac{\text{scuffed area}}{\text{working area}} \times 100$$

$$= \frac{A + B}{A + B + C} \times 100$$

The percent of tooth area scuffed is estimated visually as accurately as possible, but at least to the nearest 5 percent, for each idividual tooth, with the aid of a net reticule mounted in the eyepiece of the inspection microscope.

6.4.3 Average percent of tooth area scuffed. The average percent of tooth area scuffed is the algebraic average of the percent of scuffed area of all 28 teeth of the narrow test gear. Calculate this value to the nearest 1 percent.

6.4.4 Effective tooth width. The effective tooth width is the actual width of the narrow gear tooth that is in contact with the tooth of the wide gear. To determine the effective tooth width, measure the gross tooth width by means of a micrometer, and estimate the ratio of effective tooth width to gross tooth width by visual examination or with the aid of a suitable scale, referring to Figure 10, and 7.1.

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6.4.5 Load carrying ability. The load-carrying ability, or the scuff limited load, of a lubricant is defined as the gear tooth load at which the average percent of tooth area scuffed is 22.5 percent for the narrow test gear as determined by the method outlined herein.

6.4.6 Data sheets. The suggested data sheets are shown in Figures 11 and Note that the gear teeth inspection data sheet (Figure 12) has provision for computing the average percent of tooth area scuffed. This sheet also contains a column for entering the results obtained from the examination of the optional photographic records taken at a load giving approximately 22.5 percent scuff.

6.4.7 Determination of load carrying ability.

1. Plot the average percent of tooth area scuffed for the narrow test gear versus the load oil pressure. The use of a semilogarithmic paper is recommended for this purpose. Figure 13 is a suggested plot and calculations sheet, showing typical results from tests on both sides of a test gear.
2. Determine from the plotted curve the load oil pressure at which the average percent of tooth area scuffed is 22.5 percent. In Figure 13, this condition is represented by point X for "A" side, and point Y for "B" side of the test gear.

3* Calculate load carrying ability (see 7.2).

6.4.8 Relative rating procedure. This procedure consists of reporting the load carrying ability of an oil under test as a percentage of the load carrying ability of a standard reference oil, both ratings being determined by the procedure outlined in 6.4.7. Details of this comparative procedure are given in the following paragraphs.

NOTE 9: Standard reference oil can be obtained from Southwest Research Institute, P.O. Drawer 28510, San Antonio, TEX 78228.

6.4.9 Determination of the average rating on standard Ryder gear test reference oil.

1. For a new rig, at least eight determinations (four gears) shall be made) according to the foregoing procedure, on the standard reference oil. If the high and low values obtained do not differ by more than 1400 N/cm (800 lb/in) the average is taken as the reference oil rating. If the high and low values differ by more than 1400 N/cm (800 lb/in) four additional determinations (two gears) shall be made and the average of the 12 determinations taken as the reference oil rating.
2. After a major overhaul to a rig such as a bearing or shaft replacement, four determinations (two gears) shall be made on the standard reference

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oil. If the average of these ratings does not differ from the average obtained prior to the overhaul by more than 525 N/cm (300 lb/in) and the high and low values obtained do not differ by more than 1400 N/cm (800 lb/in) this average will be taken as the reference oil rating. If the ratings obtained do not meet the above criteria, four additional determinations (two gears) shall be made and the average of all eight determinations taken as the reference oil rating.

3. At least two determinations (one gear) shall be made on the standard reference oil for each 20 determinations made on oils under test. The reference oil rating is a progressive rating in that it will consist of the average value obtained on the last eight determinations, i.e., when two new determinations are made, the two oldest determinations of the eight determinations used in determining the previous reference oil rating are dropped, the two new ratings replacing them and a new reference oil average rating obtained. The sole exception to the above is where it is necessary to run 12 determinations to establish an average on a new rig. (See item 1, 6.9).

NOTE 10: Maximum and minimum acceptable average ratings for the reference oil are 5780 N/cm (3300 lb/in) and 4030 N/cm (2300 lb/in), respectively. Rigs which do not give an average reference oil rating within these limits shall not be considered as being satisfactory. Faulty maintenance practices, improper test procedures, and/or the need for major overhaul can be indicated if the average on the reference oil does not fall within these limits.

4. Determinations, as necessary, shall be made on the oil under test and an average obtained. Should the high and low values of these determinations differ by more than 1400 N/cm (800 lb/in) additional determinations should be made to establish an acceptable average.

7. CALCULATIONS

7.1 Calculate the effective tooth width (cm, inches)

$$W_2 = W_1 \times R$$

W_2 = effective tooth width in cm or inches.
W_1 = measured gross tooth width in cm or inches.
R = W_2/W_1 = estimated ratio.

7.2 Calculate load carrying ability by the following formula:

$$P = \frac{KL}{W_2}$$

P = load carrying ability (or scuff limited load) of the lubricant, N/cm (lb/in).
K = Ryder gear machine constant (4.1.1).

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L = Load oil pressure, gage Pa (psig).
W_2 = effective tooth width, cm (in).

7.3 Calculate the percent relative rating using the following formula:

$$\text{Relative rating, percent} = \frac{\text{test oil average rating}}{\text{reference oil average rating}} \times 100$$

8. REPORTING

8.1 Report the percent relative rating (see 7.3).

9. PRECISION

9.1 Repeatability. Results from one apparatus and operator should be considered suspect if the relative ratings differ from their mean by more than 10 percent.

9.2 Reproducibility. Results from different apparatus and/or operators should be considered suspect if the relative ratings from each apparatus and/or operator differ from their mean by more than 5 percent.

Method prepared by:
Navy - NAPC - 1986

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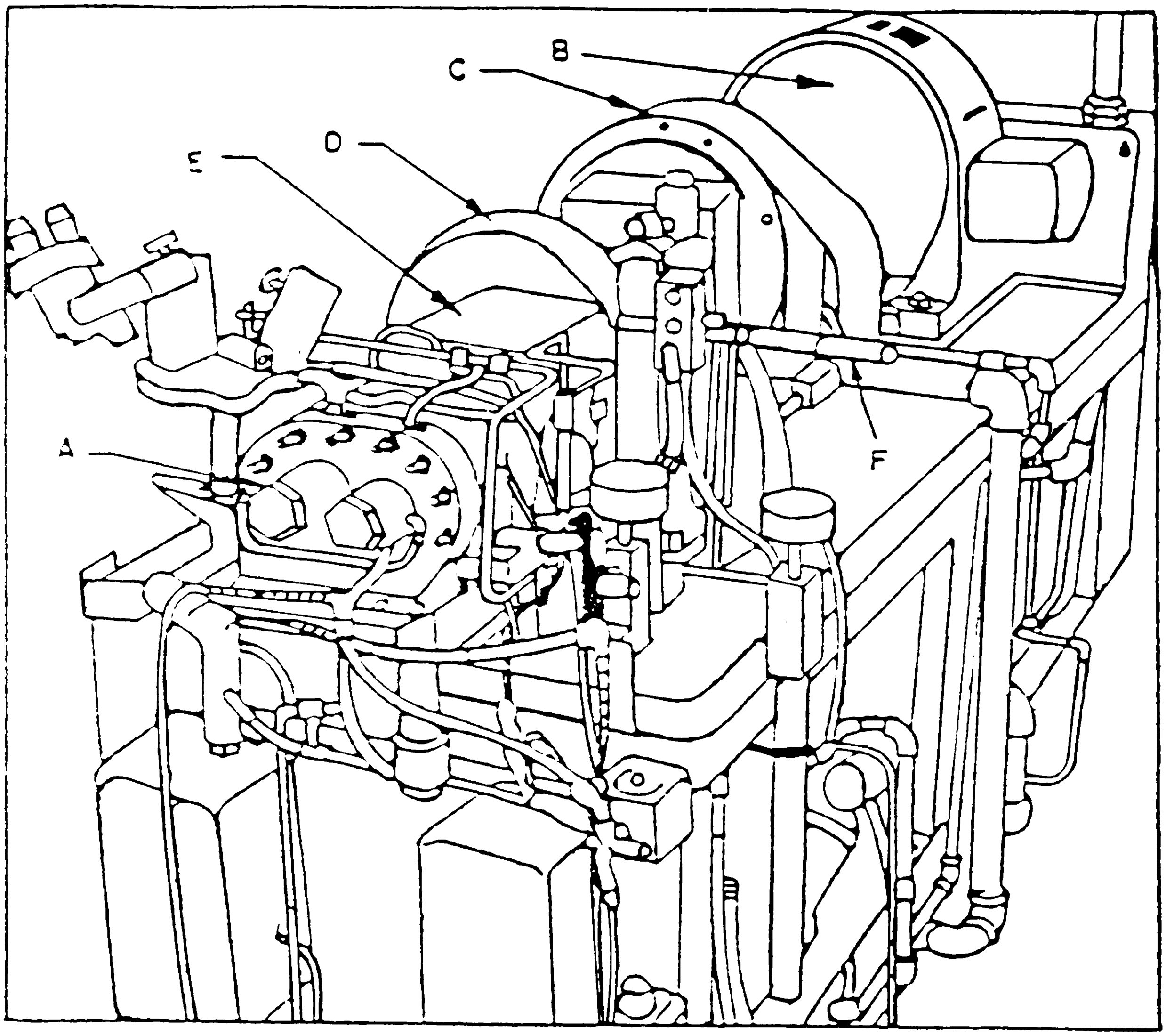

A. RYDER GEAR MACHINE
B. DRIVE MOTOR
C. DYNAMATIC COUPLING
D. STEP-UP GEAR BOX
E. ADAPTOR
F. INDEXING RATCHET

FIGURE 1. Ryder gear - ERDCO universal tester.

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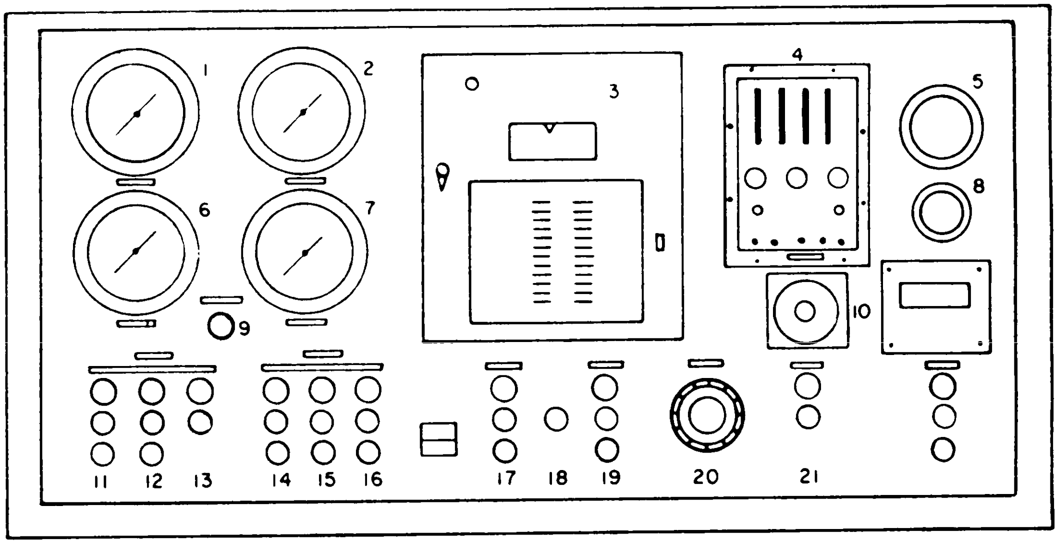

Support-oil pressure gage
Test-oil pressure gage
Multi-point temperature indicator
Electronic rpm counter
Gear-box pressure gage
Load-oil pressure gage (high range)
Load-oil pressure gage (low range)
Running-time meter
Load-adjust control
Electric timer
Support-oil pumps start-stop buttons

12. Support-oil heaters on-off buttons
13. Load bypass open-close switch
14. Test-oil pressure pump start-stop buttons
15. Test-oil scavanger pump start-stop buttons
16. Test-oil heaters on-off buttons
17. Instruments on-off button
18. Emergency stop button
19. Drive motor start-stop buttons
20. RPM-Adjust control
21. Timer start-stop switch

FIGURE 2. Gear machine control console.

X-4422

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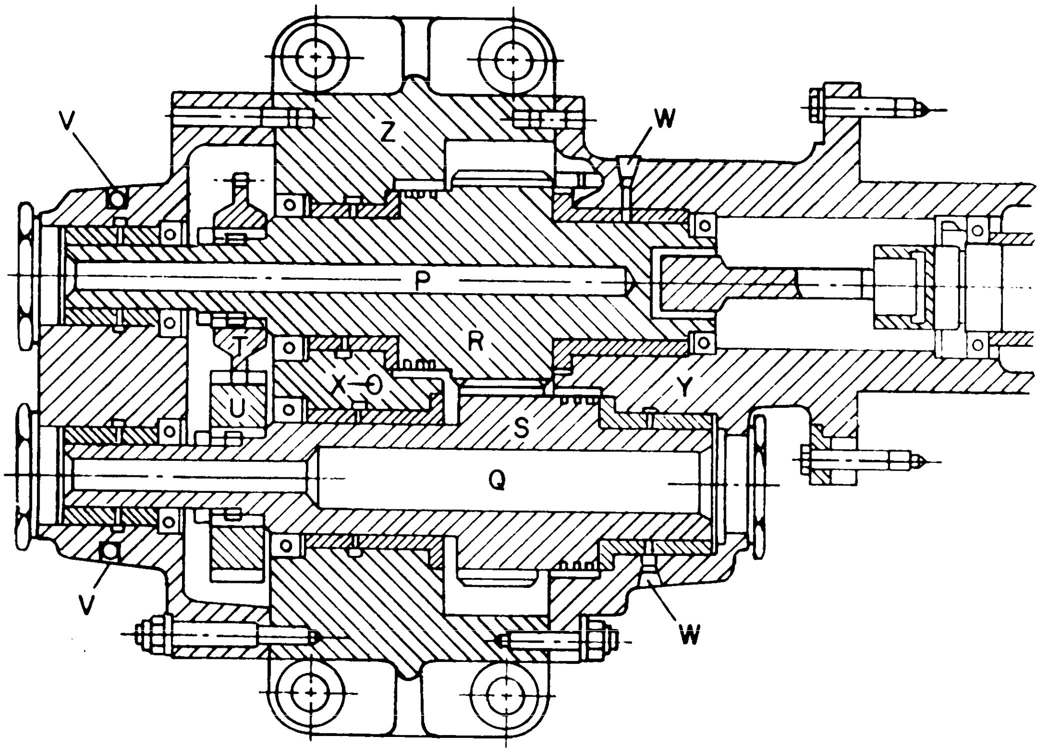

FIGURE 3. Ryder gear machine (section).

X-4407

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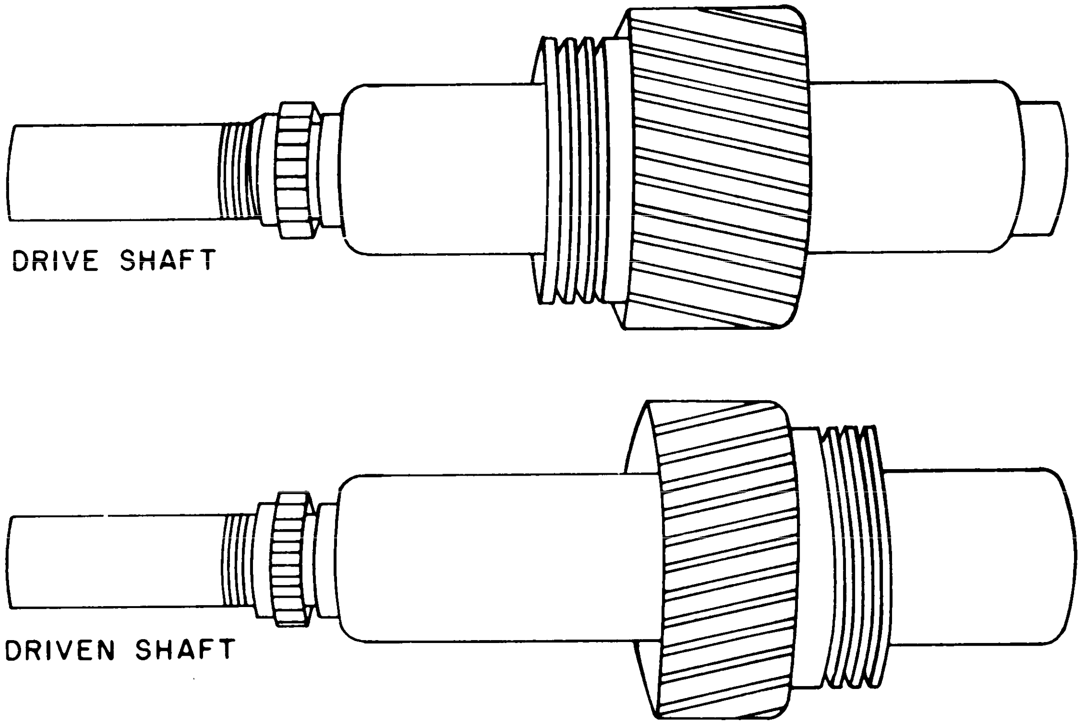

FIGURE 4. Slave gears.

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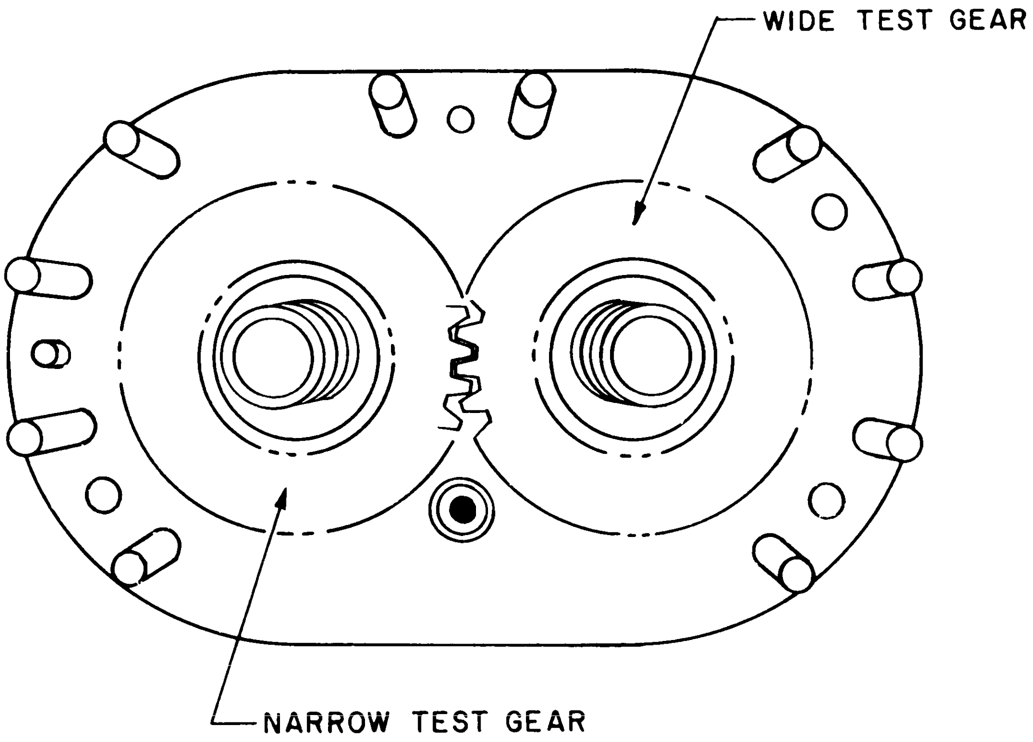

FIGURE 5. Test gears installed.

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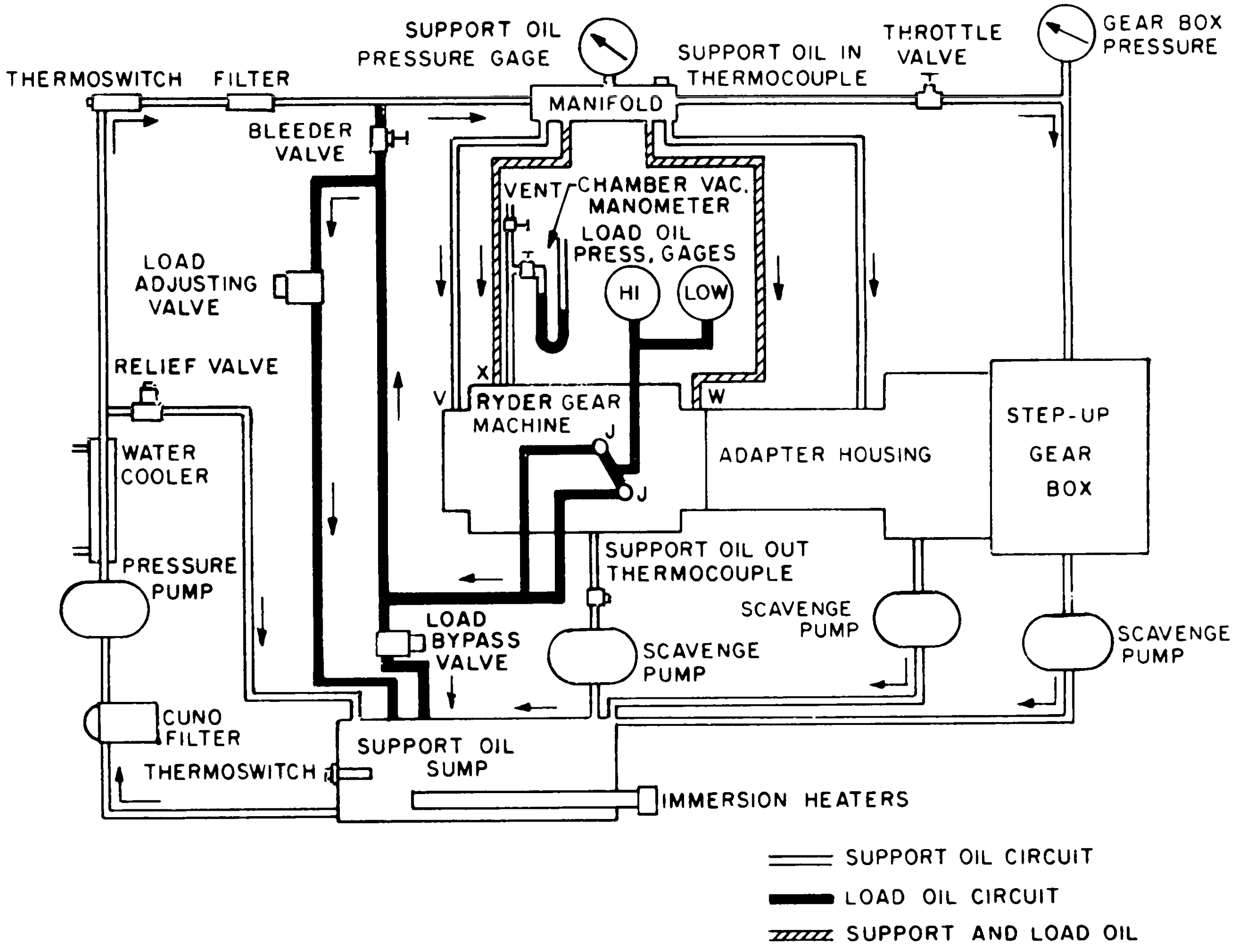

FIGURE 6. Support and load oil system.

X-4410

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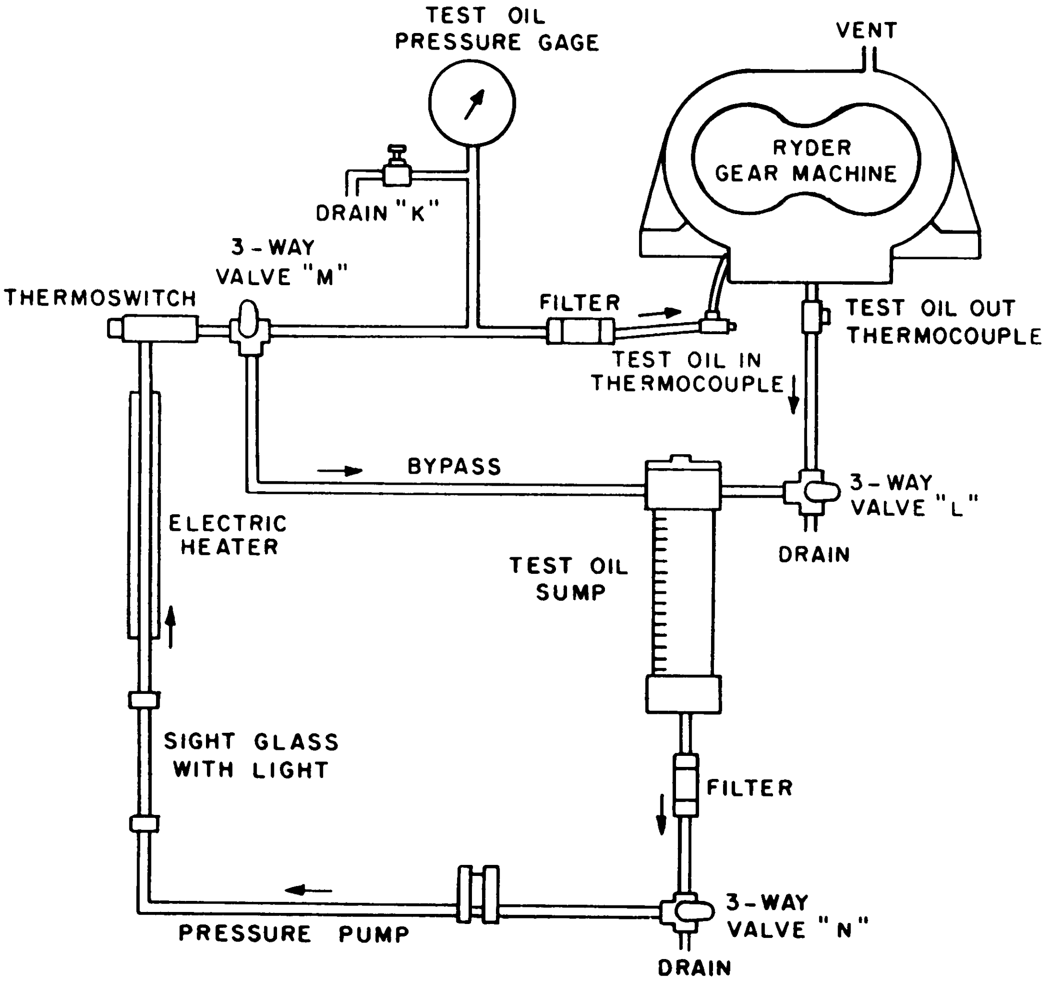

FIGURE 7. Test oil system.

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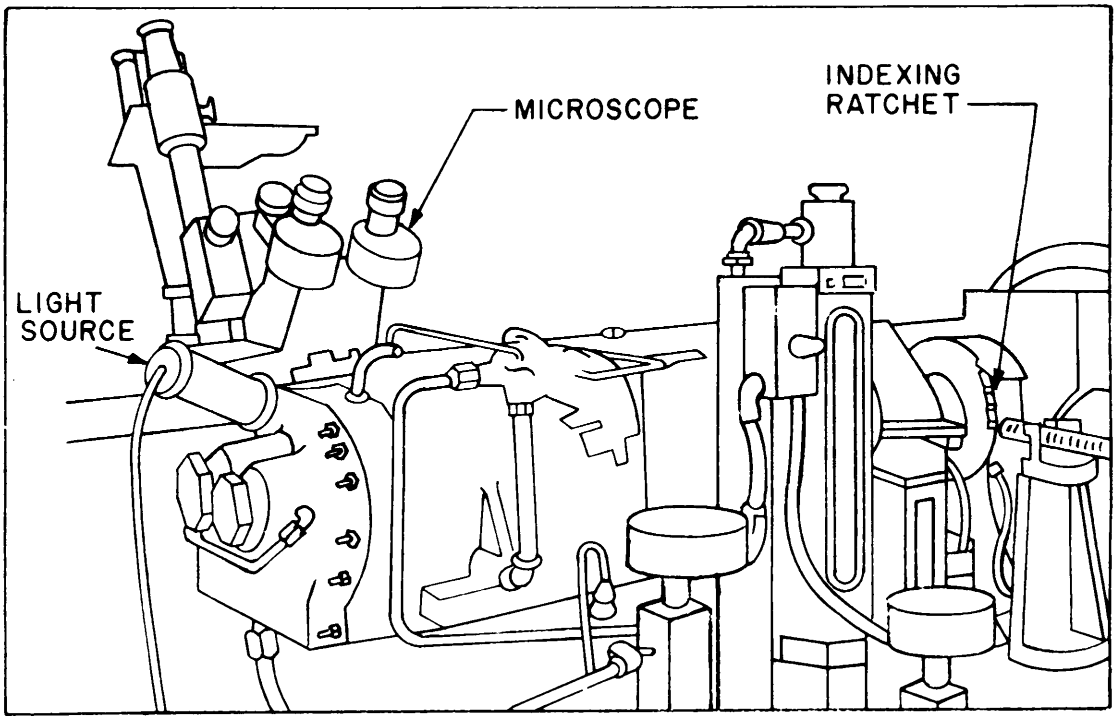

FIGURE 8. Inspection equipment.

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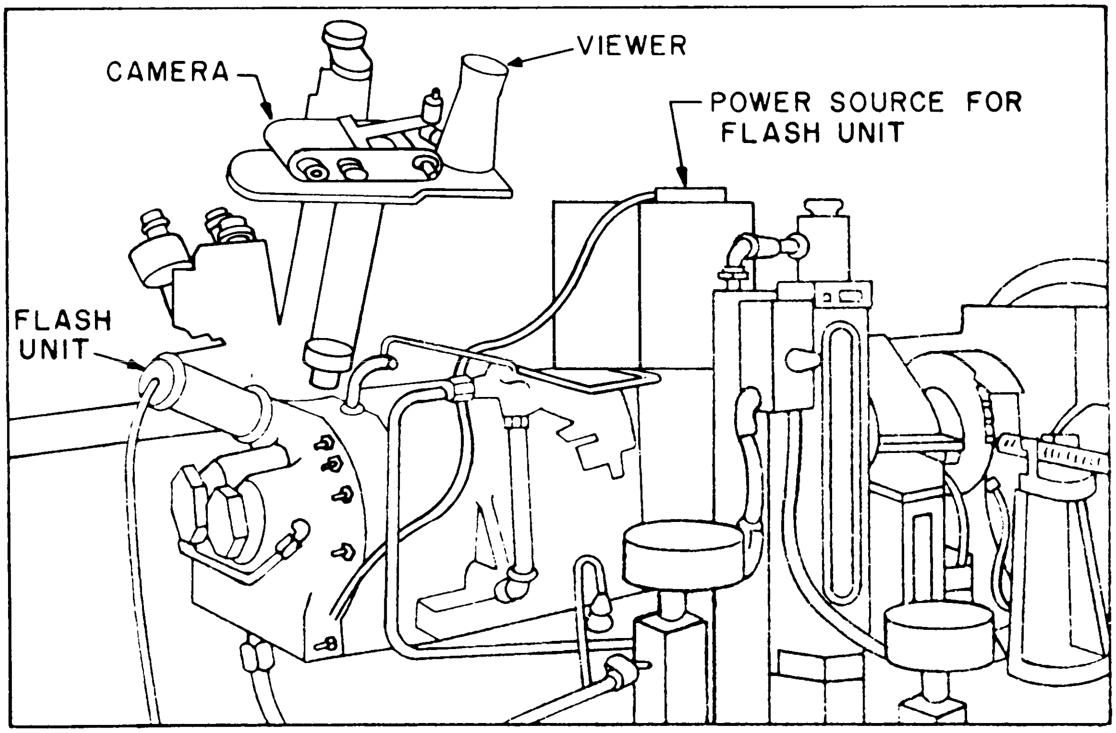

FIGURE 9. Photographic equipment.

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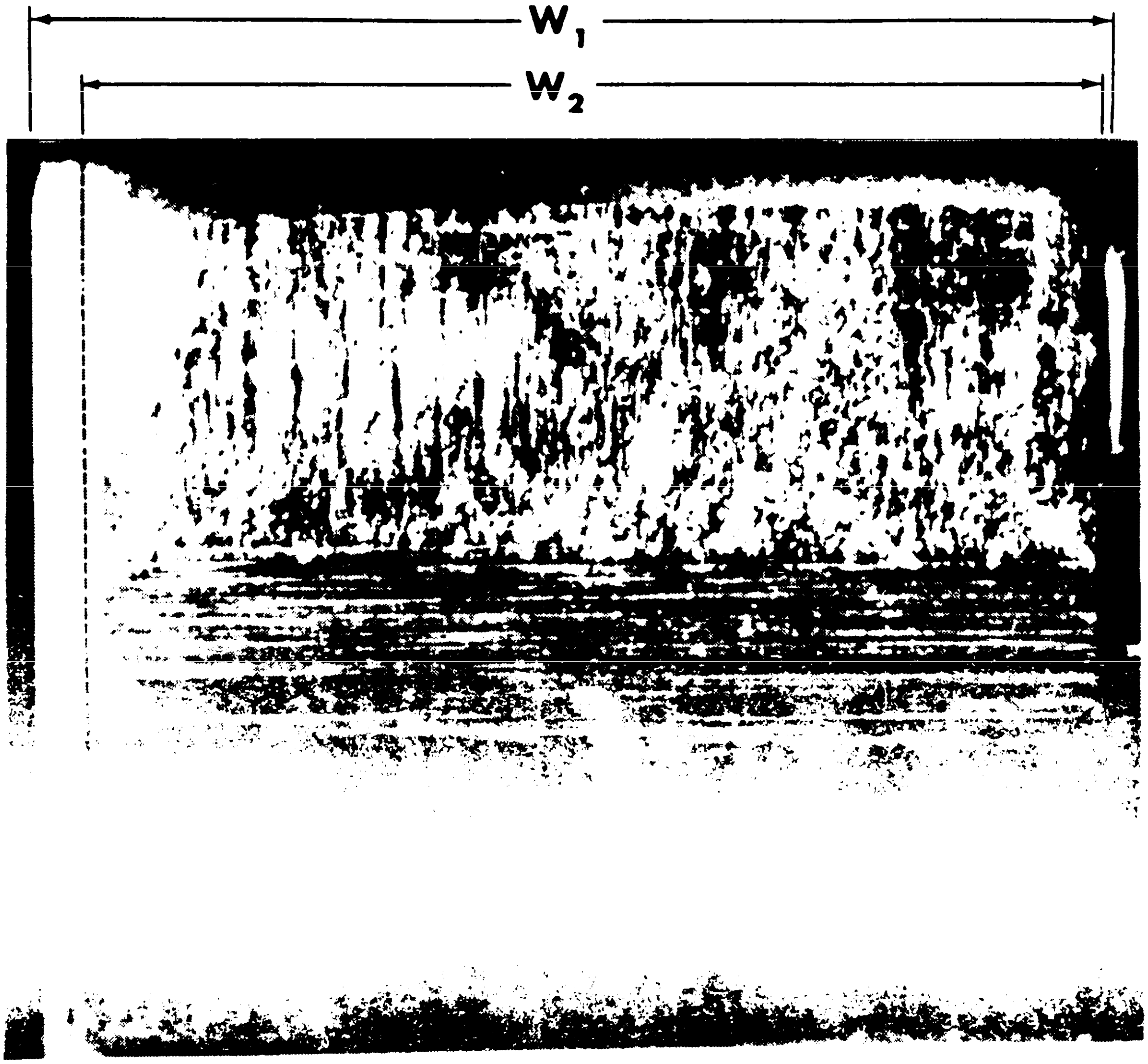

Area "A" .... Scuffed
Area "B" .... Scuffed
Area "C" .... Not Scuffed

W_1 = Gross tooth width
W_2 = Effective tooth width

Figure 10. Scuffed Tooth (Enlarged)

X-4414

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Test No. ______
Sheet No. ______

LOAD-CARRYING ABILITY TEST
OPERATING CONDITIONS DATA SHEET

OIL CODE ______________________ TEST SPECIFICATION ______________________

DATE ______________________ OPERATOR ______________________

TESTER NO. ______________________ MACHINE NO. ______________________

TEST GEARS: NARROW GEAR T-116286 ______ SERIAL NO. ______________________

WIDE GEAR T-116287 ______ SERIAL NO. ______________________

GEAR SIDE: ______________ "A" SIDE
______________ "B" SIDE

Record the following after 5 minutes operation at each load

Load Oil Pressure Gage kPa (psig)	34 (5)	69 (10)	103 (15)	138 (20)	172 (25)	207 (30)	241 (35)	276 (40)	310 (45)	345 (50)	379 (55)	414 (60)	448 (65)	483 (70)	517 (75)
Time															
R.P.M.															
Support Oil Pressure Gage kPa (psig)															
Test Oil Pressure Gage kPa (psig)															
Test Oil "In" Temp. °C (°F)															
Test Oil "Out" Temp. °C (°F)															
Support Oil "In" Temp °C (°F)															
Support Oil "Out" Temp. °C (°F)															

TEST OIL FLOW TIME FOR 270 mL ______________ MINUTES ______________ SECONDS

TEST OIL SUMP LEVEL, mL: START OF TEST ______________________
END OF TEST ______________________
CONSUMPTION ______________________

CHAMBER VACUUM, cm (IN.) OF WATER: START OF TEST ______________________
END OF TEST ______________________

REMARKS: ____

____

____

FIGURE 11. Operating conditions data sheet.

X-4415

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Test No. ________
Sheet No. ________

LOAD-CARRYING ABILITY TEST
GEAR TEETH INSPECTION DATA SHEET

OIL CODE ____________________
DATE ____________________
GROSS TOOTH WIDTH ____________ cm (INCHES)
PERCENT EFFECTIVE TOOTH WIDTH ____________

TEST SPECIFICATION ____________
OPERATOR ____________
GEAR SIDE ____ "A" SIDE
____ "B" SIDE

Tooth No.	Percent of Tooth Area Scuffed at Load Oil Pressure Gage kPa (psig) of															Photographs
	34 (5)	69 (10)	103 (15)	138 (20)	172 (25)	207 (30)	241 (35)	276 (40)	310 (45)	345 (50)	379 (55)	414 (60)	448 (65)	483 (70)	517 (75)	
1																
2																
3																
4																
5																
6																
7																
8																
9																
10																
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18																
19																
20																
21																
22																
23																
24																
25																
26																
27																
28																
Sum of Percent																
Average Percent																

FIGURE 12. Gear teeth inspection data sheet.

X-4416

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TEST NO. ________

SHEET NO. ________

LOAD CARRYING ABILITY TEST
PLOT AND CALCULATION SHEET

OIL CODE ____________________ TEST SPECIFICATION ____________________

DATE ____________________ ENGINEER ____________________

	"A" SIDE	"B" SIDE
EFFECTIVE TOOTH WIDTH, cm (INCHES)		
LOAD OIL PRESSURE AT 22.5% SCUFF, GAGE kPa (psig)		
LOAD-CARRYING ABILITY, N/m (lb/inch)		

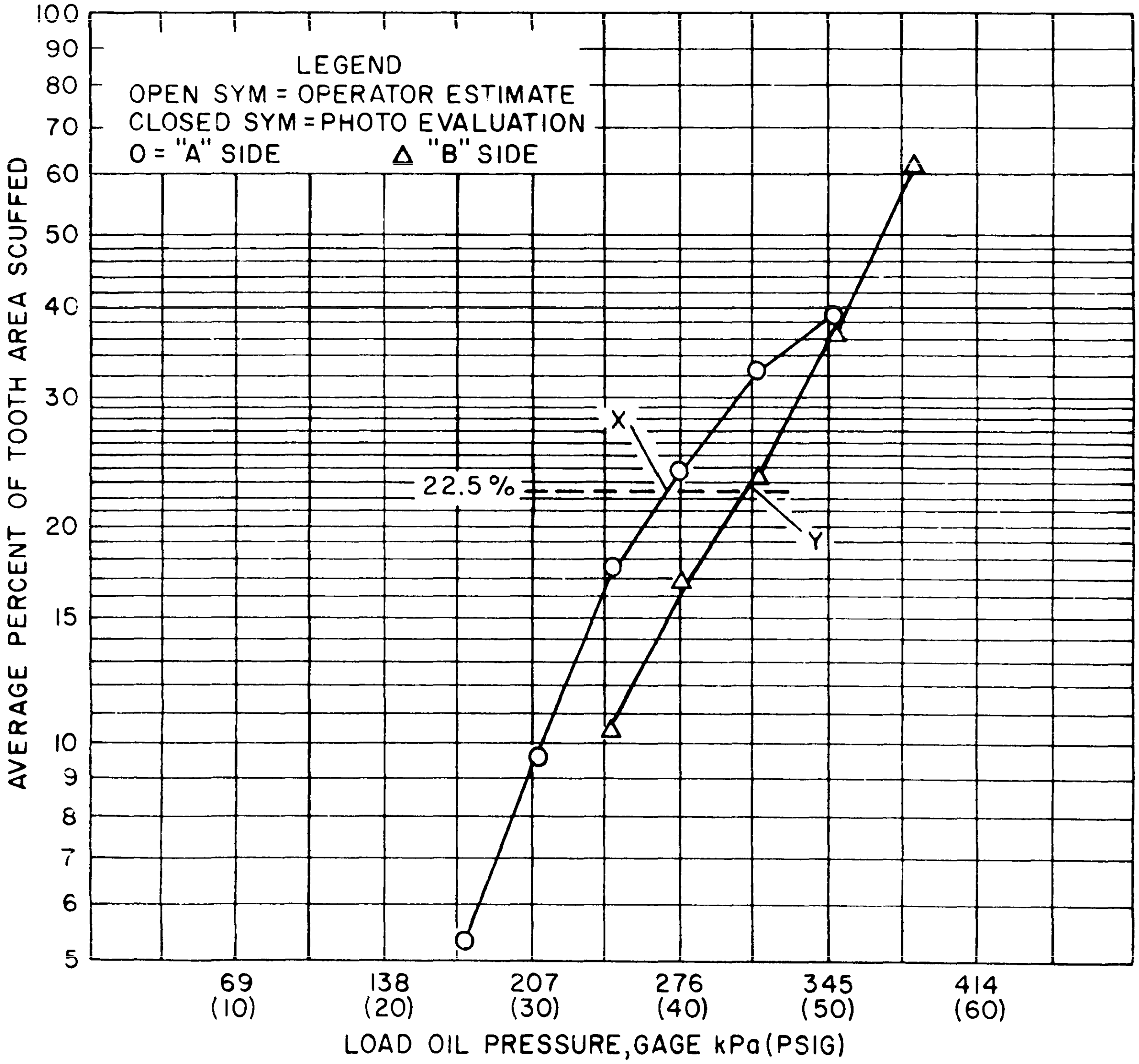

FIGURE 13. Plot and calculation sheet,

X-4417

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METHOD 6509.2
September 30, 1986

GEAR-FATIGUE CHARACTERISTICS OF AIRCRAFT GAS TURBINE LUBRICANTS AT 204° C

1. SCOPE

1.1 This method describes a procedure for determining the fatigue characteristics of aircraft gas turbine lubricating oils at 204° C (400° F) with respect to gears.

2. SUMMARY

2.1 The method consists of subjecting the lubricant to a series of 204° C (400° F) controlled test cycles at constant gear-tooth load on a set of special spur gears, examining the teeth of one of the gears after each cycle to determine the scuffed area and to note the presence of fatigue pits, and rating the fatigue life of the lubricant from the length of time (running at specified condition) that is necessary for the development of "B" sized pits on three nonconsecutive teeth on the narrow test gear.

NOTE 1: "B" sized pits are defined as pits which are readily discernible to the naked eye.

3. SAMPLE SIZE

3.1 Approximately 2 L of test oil.

4. REFERENCES, STANDARDS AND APPARATUS

4.1 Test unit. The apparatus used in this method is the WADD high-temperature gear machine. This apparatus consist of a WADD high-temperature gear head adapted to a modified Ryder gear-Erdco universal drive system, support and load oil systems and controls.

4.1.1 WADD high–temperature gear head. The WADD high-temperature gear head operates on the same principle as the Ryder gear head, the so called “four square" principle. As shown in Figure 1, two parallel shafts (P and Q) are connected by two slave gears (R and S) and two test gears (T and U) to form a “square” so that the power required to operate the machine is only that required to overcome the friction losses in the gears and bearings. The slave gears are helical gears and are made as integral parts of the two shafts; t-he test gears are spur gears and are replaceable. Load on the test gears is obtained through the application of a controlled oil pressure in the load chamber (x), which causes an axial movement of one shaft relative to the other. A torsional load is thus applied upon the shafts due to the helical slave gears, thereby loading the test gears. The relation between the tooth load on the test gears and the load oil pressure can be obtained by arithmetic calculation, calibration, or both. Arithmetic calibration is used herein.

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4.1.2 Test gear set, Nitralloy N, heat-treated and ground, 28 teeth, 8.88 cm (3.5 inch) pitch diameter, 8 diametral pitch, 22.5 degree pressure angle, and zero tip relief (Sier Bath Gear and Pump Co., North Bergen, NJ or equal).

NOTE 2: Each set of test gears comprises gears of two different tooth face widths. The narrow test gear only is used for rating purposes. cloth sides of the test gear are used for testing; test gears can be used once only on each side and then are discarded.

4.1.3 Support oil system. The support oil system serves two purposes: to provide lubrication to all parts except the test gears, and to supply load oil pressure for the application of load to the test gears. A dual temperature support oil system, shown in Figure 2 and outlined in 4.1.3.1 and 4.1.3.2, is used with the WADD high temperature gear machine.

4.1.3.1 Low temperature support oil section. The low temperature section is maintained at 74 +5.5° C (165° +10° F) during test. This section provides lubrication for the stepup gear–box and the two bearings on the jack shaft in the rear of the high temperature head. The low temperature sump is charged with approximately 7.6 L (2 gallons) of lubricating oil, type MIL-L-7808 or MIL-L-9236. A support oil pressure pump and pressure regulators furnish oil to the jack shaft bearings at 207 kpa gage (30 psig) and to the step gear box at 103 kPa gage (15 psig). The temperature of the oil in this section is maintained at 74° ±5.5° C (165° ±10° F) by an electric heater located in the sump and a cooler located before scavenge pump, through the action of thermoswitches. One scavenge pump scavenges the oil from both the stepup gear box and the adapter housing.

4.1.3.2 High temperature support oil section. The high temperature section is maintained at 204 +5.5° C (400° +10° F) during test. This section supplies load oil pressure and–provides lubrication for all remaining bearings and gears in the high temperature test head except for the test gears. The high temperature sump is charged with approximately 23 L (7 gallons) of lubricating oil, type MIL-L-7808 or MIL-L-9236 (same as that used in the low temperature section). A support oil pressure pump and pressure regulators furnish oil to the load adjust valve, located on the control panel, at 827 +69 KPa gage (120 +10 psig) and to the combination filter screen and distributing manifold at 207 ±14 kPa gage (30 +2 psig). The temperature of the oil in this section is maintained at 204° +5.5° C (400° +10° F) by a heat exchanger placed inside the sump. The flow of the heating fluid through the heat exchanger is controlled by a thermocouple located in the distributing manifold which controls the heating fluid pump cycle through the action of an off-on controller. The temperature of the heating fluid is maintained at approximately 288° C (550° F) by an electric heater located in the heating fluid tank, through the action of d thermoswitch. It is advisable to exclude air from the heating fluid tank by the use of dry, oxygen-free nitrogen to prevent deterioration of the heating fluid by oxidation. One pump scavenges the oil from the center section of the high temperature gear head.

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4.1.3.3 Load oil system. The load oil pressure in the load chamber is changed or adjusted by a load control valve located on the control panel. Turning the load control valve counterclockwise opens the valve, thereby increasing the load oil pressure in the load chamber. Conversely, the load oil pressure is reduced by turning the load control valve clockwise.

4.1.4 209° C (400° F) test oil system. A schematic diagram of 209° C (400° F) test oil system is shown in Figure 3. The test oil is supplied by the pressure pump to the test gears by a jet located on the unmeshing side of the gears. There is no requirement on the test oil pressure. Instead a test oil flow rate of 270 mL per minute is specified. The flow rate is checked by closing the solenoid valve in the drain line from the head end cover and measuring the time required to fill the flow check chamber to the tip of the bare wire thermocouple. The thermocouple is so positioned in the flow check chamber that a filling time of the chamber of 30 seconds represents a flow of 270 mL per minute. The test oil flow rate is changed by adjusting the bypass valve located on the top of the test oil sump. The flow of the heating fluid through the heat exchanger is controlled by the test “oil-in” thermocouple which controls the heating fluid pump cycle through the action of an on-off controller. The temperature of the heating fluid is maintained at approximately 288° C (550° F) by an electric heater located in the heating fluid tank, through the action of a thermoswitch. It is advisable to exclude air from the nesting fluid tank by the use of dry, oxygen-free nitrogen to prevent deterioration of the heating fluid by oxidation.

4.1.5 Drive system. A modified Ryder Erdco universal test drive system is used to drive the WADD high temperature gear head. Figure 4 is a photograph of the drive system with the high temperature gear head installed. As shown in Figure 4, the high temperature gear head (A) is driven by a 50-hp induction motor (B) through a dynamic coupling (C), a step-up gear box (D) and an adapter (E). The test gear speed is controlled by adjusting the field excitation of the dynamic coupling. By this means an accurate speed control can be obtained at the specified test speed of 10,000 rpm. The modifications to the Ryder Erdco universal test drive system include the following items:

a. Modification of the standard adapter block includes drilling one 0.6 cm (1/4-inch) vent hole in the side of the adapter block and relocation of the gear head mounting studs in the end of the adapter block.

b. The step-up gear box scavenge line is changed from the end of the gear box housing to the bottom. Four 0.102 cm (.04-inch) jets provide lubrication to the four bearings in the gear box and two 0.102 cm (0.04-inch) jets provide lubrication to the gears. The oil to the step–up gear box is maintained at 103 gage kPa (15 psig).

4.1.6 Instrumentation and controls. All of the instruments and controls which require constant attention during tests are located on the control console which is shown in Figure 5. Items which do not require frequent attention are

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located on the test stand. The function of most of the instruments and controls are apparent. Selected items are described in subsequent paragraphs.

4.1.6.1 Speed measurement and control. An electronic counter (Figure 5, item 4), located on the control console, measures the gear speed. This instrument is actuated by pulses supplied by a variable reluctance pickup, the variable reluctance being supplied by a 60-tooth gear operated from the driven shaft of the step-up gear box. The rpm adjust control (Figure 5, item 20), iocated oil the control console, regulates the field excitation of the dynamatic coupling and thus the gear speed.

4.1.6.2 Control of duration of test run. An electric timer (Figure 5, item LO), located on the control console, is used to control the duration of each test run. The timer should be set at the beginning of the test to 10 minutes and locked in position. As soon as the desired test load has been obtained, the timer is started by turning the timer switch (Figure 5, item 21) oil the control console to the “Start” position. After the 10 minute run is over, the timer will automatically turn off the drive motor. However, the timer switch will remain in the "Start” position. It must be turned to the “stop” position in preparation for the next run.

4.1.6.3 Support oil controls. The support oil pump buttons (Figure 5, item 11) on the control console are connected to the 204° C (400° F) support oil pump and to the 74° C (165° F) support oil pump as well as to the two scavenge pumps. Pressing the “Start” or “Stop” button will start or stop all four pumps at the same time. The support oil heater buttons (Figure 5, item 12) control the electric heater located in the heating medium tank and also the electric heater in the 74° C (165° F) support oil pump. The support oil heating medium pump control system is also actuated by the support oil heater buttons.

4.1.6.4 Test oil controls. The test oil pump buttons (Figure 5, itme 14) on the control console start or stop the test oil pump. The test oil heater buttons (figure 5, item 16) control the electric heaters located in the heating medium tank. The test oil heating medium pump buttons (Figure 5, item 15) actuate the control system for the heating medium pump.

4.1.6.5 Load oil pressure control. See 3.1.3.3.

4.1.6.6 Emergency stop. The emergency stop button (Figure 5, Item 18) on the control console stops the drive motor and turns off all controls except those for instruments. The timer switch wiil remain in the position to which it was originally set.

4.1.6.7 Scuff rating equipment. A microscope and a light source are used for visual inspection of the narrow test gear. To inspect the narrow gear, the machine is first stopped. The inspection can then be made through special inspection holes provided in the gear case end cover. These holes are closed by corks during the test run.

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4.1.6.8 Inspection equipment. The standard 18 power microscope furnished with the Ryder gear Erdco universal tester is slightly modified by the addition of a supplementary lens in the right objective lens opening. The right eyepiece of the microscope contains a net reticule that divides the gear tooth area lengthwise into seven sections. The grid lines provides a convenient means for the visual estimation of the percent of gear tooth area that has been scuffed.

4.1.6.9 Gear tooth indexing ratchet. An indexing ratchet (F, Figure 4) is used for rotating the test gears so that the teeth of the narrow test gear can be inspected individually.

4.1.6.10 Additional instruments:

a. Stop watch for oil flow rate check.
b. Micrometer O to 2.5 cm (O to 1 inch) for the measurement of the gross tooth width of the narrow gear.
c. Scale with divisions of 0.04 cm (1/64 inch).

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Lubricating oil, MIL-L-7808.

5.3 Lubricating oil, MIL-L-9236.

5.4 Dry cleaning solvent, (ASTM D 484, type I) [0,2,0].

5.5 Cleaning compound, special (Penetone ECS; Penetone Corporation, 74 Hudson Avenue, Tenafly, New Jersey 07670 or equivalent) [u,u,u].

5.6 Household cleaner.

6. PROCEDURES

6.1 Operating conditions.

6.1.1 Throughout the entire test the variables listed in Table I should be controlled within the limits specified. With the tester operating within the specified limits, the test gears are loaded first to 34 kPa gage (5 psig) load oil pressure, and then at successive increments of 34 kPa (5 psi). The duration of each loading period is 10 minutes +5 seconds. At the end of each loading period the tester is stopped and each-tooth of the narrow gear is examined to determine the percent of tooth area scuffed.

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6.2 TEST PROCEDURE

6.2.1 Preparation for test.

1. Turn on main electric switch and main water valve to test cell.
2. Push instrument button to "On" position.
3. Adjust nitrogen pressure to heating medium tanks to 14 to 27 kPa gage (2 to 4 psig).
4. Push heating medium tank heater buttons to "On" position. This also turns on the heater in the 74° C (165° F) Support Oil sump.
5. Inspect test oil system to see that it was thoroughly cleaned and dried after previous test.
6. Remove gear case end cover.
7. Clean a set of new test gears with dry cleaning solvent, and dry with air.
8. Measure gross tooth width of the narrow test gear with a micrometer, and record.
9. Install test gears on proper shafts with the serial number facing outward (narrow gear on drive shaft, wide gear on driven shaft) matching timing marks on shafts and gears. Check for proper seating of the retaining nuts, and lock one tang of each lock washer.
10. Loosen the locknut on the driven shaft adjusting pin (at rear of gear case), and unscrew adjusting pin until driven shaft is free to move to the extreme rearward position without touching the adjusting pin. Using a scale having divisions of 0.04 cm (1/64 inch) set adjusting *pin* so that the driven shaft can move through only one-half of the normal free travel (from extreme rearward position to extreme forward position). Tighten locknut on adjusting pin.
11. Reinstall gear case end cover.
12. Turn on air to nonrubbing seals. Adjust to approximately 48 kPa gage (7 psig).
13. Fill test oil sump with approximately 7.6 L (2 gallons) of test oil.
14. Push support oil heating medium pump button to the "On" position after heat medium fluid has reached 93.3° C (200° F).
15. Push test oil heating medium pump button to "On" position after heat medium has reached 93.3° C (200° F).
16. Allow the heating medium fluid to circulate approximately 20 minutes, then push support oil pump button to the "On" position. This also starts the 74° C (165° F) support oil pump.
17. Open test oil bypass valve.
18. Start test oil pump, and immediately open test oil drain line from test oil pressure gage to allow new test oil to fill the line to the gage.
19. Turn timer switch to "STOP" position.
20. Set electric timer to 10 minutes and 0 seconds, then lock timer dial.
21. Turn rpm adjust control to "ZERO" position.
22. Check calibration of the rpm counter by setting the input sensitivity control to the "CHECK" position and the gate selector switch to the "ONE SECOND" position. The counter should read "60". After checking, turn the input sensitivity control to about midscale.

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23. When the test oil and the high temperature support oil temperatures are up to the specified value of 204° +5.5° C (400° +10° F) check the test oil flow rate as follows: adjust the test oil by-pass valve until test oil flow is approximately 270 mL per minute. Actuate the solenoid valve to a closed position, and measure the time required to fill the flow check chamber to the tip of the bare wire thermocouple. The time required should be 30 seconds. Actuate the solenoid valve to the open position to allow the test oil to drain to the test oil sump. If the time required to fill the flow check chamber to the tip of the bare wire, thermocouple varies from the 30 second requirement by more than one second readjust the bypass valve and recheck test oil flow rate as above.

NOTE 3: The visual method of checking oil flow rate is satisfactory for the initial flow check when changes in the bypass valve setting are anticipated. However, quick checks of the flow rate may be made before or during test run by actuating the solenoid valve from the control console switch, and recording the time required to fill the flow check chamber to the tip of the bare wire thermocouple. An instant increase in temperature will be noted on the temperature indicator when the hot oil rises to the level of the tip of the thermocouple.

6.2.2 Test sequence on “A” side of test gears.

NOTE 4: The “A” side of the gear refers to the side obtained by installing the test gears with the serial numbers facing the end cover. The “B” side is obtained by reversing the gear (serial numbers facing away from the end cover).

1. Check all temperatures and pressures and, if necessary, adjust to specified limits.
2. Recheck test oil flow rate, and readjust if necessary.
3. Make sure that the gear tooth indexing ratchet is locked in the disengaged position.
4. Make sure that the load control valve is closed (extreme clockwise position).
5. Start drive motor.
6. Increase gear speed by turning rpm - adjust control clockwise until the specified 10,000 +100 rpm is obtained.
7. Apply load slowly—by turning the load control valve counterclockwise. Stop when the load oil pressure is 34 kpa gage (5 psig).

CAUTION

Extreme care should be exercised when adjusting the load oil pressure so as not to overshoot the desired pressure.

8. Check gear speed, and adjust if necessary.
9. Turn timer switch to “START” position. The 10 minute test run now begins.

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10. Record all pertinent data about midway into the test run.
11. At the end of the 10 minute run, the electric timer will automatically stop the drive motor. However, the timer switch will remain in the "START" position, and the rpm adjust control will remain in the running position. Restore these to their respective off positions.

TABLE I. Operating conditions.

Condition	Value	
Test gear speed	10,000 +100 rpm	10,000 +100 rpm
Test oil in temperature	204.4° +5.5°c	400 +16° F
Support oil temperature (low-temperature section)	73.95 +5.5° c	165 ±10° F
Support oil temperature (high temperature)	204.4 +5.5° C	400 +10° F
Support oil pressure to gear machine	207 kPa gage	30 psig
Support oil pressure to load system	827 kPa gage	120 psig
Support oil pressure to step-up gear box	103 kPa gage	15 psig
Gear load (fatigue cycle only)	7250 N/cm of tooth-face width	4140 pounds/inch of tooth-face width

12. Reduce load oil pressure manually to a load oil pressure of 34 kPa gage (5 psig) while machine is coasting to a stop.

NOTE 5: A load oil pressure of 34 kPa gage (5 psig) is normally maintained during starting and stopping of the gear machine and during visual scuff inspection.

13. Make visual scuff inspection of the narrow test gear as follows:

   a. Remove corks from inspection holes in the gear case end cover.
   b. Install microscope and inspection light.
   c. Focus microscope and adjust grid lines over the contact area of the tooth.
   d. Set indexing ratchet wheel to "No. 1" position.
   e. Estimate the percent scuff of No. 1 tooth as accurately as possible but at least to the nearest 5 percent, and record the value. Also examine for presence of "B" pits. (Refer to 2.1, note 1).
   f. Operate the indexing rachet to give No. 2 tooth, and repeat step (e). Repeat for No. 3 tooth etc., until all 28 teeth have been examined.

NOTE 6: The test oil pump may be turned off during inspection of gear teeth if excessive smoke or test oil hampers the visual inspection.

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g. Remove microscope and light. Replace corks in holes.
h. Lock indexing ratchet pawl in disengaged position.

14. Repeat steps (1) through (13) at the next test load of 239 kPa (20 psig) load oil pressure.
15. Continue to test at 69 kPa (10 psi) load oil pressure increments until a load oil pressure of 620 kpa gage (90 psig) is next to be run. At this point, duration of cycles is increased to 2 hours. The test continues from this point as given below starting with step (16).
16. Set timer at 120 minutes.
17. Repeat steps (1) through (6).
18. Apply load slowly by turning load control valve counterclockwise. stop when the load oil pressure reaches 620 kpa gage (90 psig) (equivalent to 7250 N/cm [4140 pounds per inch] of tooth face width).

CAUTION

Extreme care should be exercised when adjusting the load oil pressure so as not to overshoot the desired pressure.

19. Check gear speed, and adjust if necessary.
20• Turn timer switch to “START” position. The 2 hour test run now begins.
21. Record all pertinent data at 15 minute intervals.
22. At the end of the 2 hour run, the timer automatically stops the drive motor. Restore timer switch and rpm adjust control to their respective “OFF” positions.
23. Reduce load oil pressure to 34 kPa gage (5 psig) while machine is coasting to a stop.
24. Repeat step (13) except that in addition to estimating percentage of scuffed area on each tooth, examine each tooth also for fatigue pits. Record scuff and fatigue pits for each tooth.
25. Repeat steps (16) through (24) until "B"-sized pits (2.1, note 1) develop on three nonconsecutive teeth of the narrow test gear. This terminates the test on the “A” side of the test.

NOTE 7: After each 4 hours of testing at the specified fatigue load, the oil level in the test oil sump should be brought up to the original 7.6 L (2 gallon) level by the addition of a measured portion of fresh test oil. At the end of the test, add sufficient oil to bring level in sump to original mark. Record amount of oil used for each addition.

26. Push test oil and support oil pumps button “OFF”.
27. Push test oil heating medium pump button “OFF”.
28. Drain out used test oil through valve at bottom of test oil sump.
29. Flush test oil system as follows:

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a. After sump has cooled sufficiently, pour approximately 7.6 L (2 gallons) of dry cleaning solvent into it.
b. Start test oil pressure pump, and allow solvent to circulate through the test oil system for 5 minutes.
c. Drain off solvent through valve at bottom of the test oil sump, and discard.
d. Pour approximately 3.8 L (one gallon) of new test oil into test oil sump.
e. Start test oil pressure pump, and allow oil to circulate through test oil system for 5 minutes.
f. Drain test oil through valve at the bottom of the test oil sump, and discard.

30. Remove gear case end cover.
31. Blow out test oil jet with compressed air.
32. Reverse test gears so that their serial numbers face the body of the gear head, again matching timing marks on shafts and gears. Check for proper seating of the retaining nut, and lock one tang of each lock-washer.
33. Reinstall gear case end cover.

6.2.3 Test sequence on “B” side of test gears.

NOTE 8: The “B” side refers to the side obtained by reversing the gear (serial numbers facing away from the end cover).

1. Push support oil pump button “ON”.
2. Push test oil heating medium pump button “ON”.
3. Push test oil pump button “ON”.
4. When the test oil and support oil temperatures are up to the specified 209° ±5.5° C (400° ±10° F) check test oil flow rate as described in 6.2.1, step (23). Adjust to specified value.
5. Proceed with test on “B” side of the test gear by following the procedure outlined in 6.2.2, steps (1) through (25).
6. Push support oil heating medium pump button “OFF”.
7. Push test oil heating medium pump button “OFF”.
8. Push test oil and support oil pump buttons “OFF”.
9. Turn off air to nonrubbing seals.
10. Remove gear case end cover.
11. Remove used test gears, and discard.
12. Remove complete test oil system for cleaning.
13. Push instrument button “OFF”.
14. Turn off nitrogen to heating medium tanks.
15. Turn off main electric switch to test cell.
16. Turn off main water valve to test cell.

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6.2.4 Cleaning procedure.

1. Disassemble test oil system, including pump, filter, and valve.
2. Soak all disassembled parts of test oil system in hot 49° C (120° F) special cleaning compound for approximately 3 hours.
3* Remove parts from cleaner, and rinse thoroughly with water.
4. Inspect all parts to see that they are completely clean. If any indication of residue is present, scrub all parts well with household cleanser, then rinse thoroughly with water.
5. Dry all parts with compressed air.
6. Reassemble test oil system.
7. Clean inside of gear case end cover with household cleanser, and rinse thoroughly with water.
8. Dry gear case end cover with compressed air.
9. Blow out test oil jet with compressed air.
10. Check position of test oil jet, and adjust to proper position, if necessary, by bending jet.

6.3 Inspection and rating

6.3.1 Scuffed area. The scuffed area of a gear tooth is that area from which the axial grinding marks have been removed by scratching, scoring, abrasion, and wear. As shown in Figure 6, areas A and B are scuffed; area C is not scuffed. Note that only the actual working portion (areas A plus B plus C) of the tooth surface is considered in the definition of areas.

6.3.2 Percent of tooth area scuffed. The percent of tooth area scuffed is that portion of the working surface of a gear tooth that has been scuffed. Referring to Figure 6.

$$\text{Percent tooth area scuffed} = \frac{\text{scuffed area}}{\text{working area}} \times 100$$

$$= \frac{A + B}{A + B + C} \times 100$$

The percent of tooth area scuffed is estimated visually as accurately as possible, but at least to the nearest 5 percent for each individual tooth, with the aid of a net reticule mounted in the eyepiece of the inspection microscope.

6.3.3 Average percent of tooth area scuffed. The average percent of tooth area scuffed is the algebraic average of the percent of scuffed area of all 28 teeth of the narrow test gear. Calculate this value to the nearest 1 percent.

6.3.4 Effective tooth width. The effective tooth width is the actual width of the narrow gear tooth that is in contact with the tooth of the wide gear. To determine the effective tooth width, measure the gross tooth width by means of a

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micrometer, and estimate the ratio of effective tooth width to gross tooth width by visual examination or with the aid of a suitable scale. Referring to Figure 7 and paragraph 7.1.

6.3.5 Load carrying ability. The load carrying ability, or the scuff limited load, of a lubricant is defined as the gear tooth load at which the average percent of tooth area scuffed is 22.5 percent for the narrow test gear as determined by the method outlined herein.

6.3.5.1 Determination of load carrying ability. Using semilog paper (Figure 9), plot the average percent of tooth area scuffed for the narrow test gear versus the load oil pressure. Determine from the plotted curve the load oil pressure at which the average percent of tooth area scuffed is 22.5 percent. In Figure 9, for example, this condition is represented by point X for "A" side and point Y for "B" side of the narrow test gear. Calculate load carrying ability (see 7.2).

6.4 Data Sheets

6.4.1 The suggested data sheets are shown in Figures 7 and 8. Figure 7 is the operating conditions data sheet, and Figure 8 is the gear tooth inspection data sheet. The intended use of each is obvious.

7. CALCULATIONS

7.1 Calculate the effective tooth width (cm, inches) from the following equation:

$$W_2 = W_1 \times R$$

W_2 = effective tooth width in cm (inches).
W_1 = measured gross tooth width in cm (inches).
$R = W_2/W_1$ = estimated ratio.

7.2 Calculate the load carrying ability from the following equation:

$$P = \frac{KL}{W_2}$$

P = load carrying ability of the lubricant N/cm (pounds per inch) of tooth face width.
K = WADD high temperature gear machine constant (11.5 by definition).
L = Load oil pressure, gage Pa (psig).
W_2 = effective tooth face width in cm (inches).

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8. REPORTING

8.1 Report individual ratings of “A” and “B’” sides of all gears tested in n/cm (pounds per inch) of tooth face width for each increment of load and each 2 hour fatigue cycle. Also report average values of each individual rating for each load increment and fatigue cycle. Report number of consecutive teeth pitted, the total number of teeth pitted, and the total number of pits on all teeth (“B” sized pits as defined herein) at the conclusion of each increment of load and each 2 hour fatigue cycle.

9. PRECISION

9.1 Precision data have not been developed for this method.

Method prepared by:
Navy - NAPC - 1986

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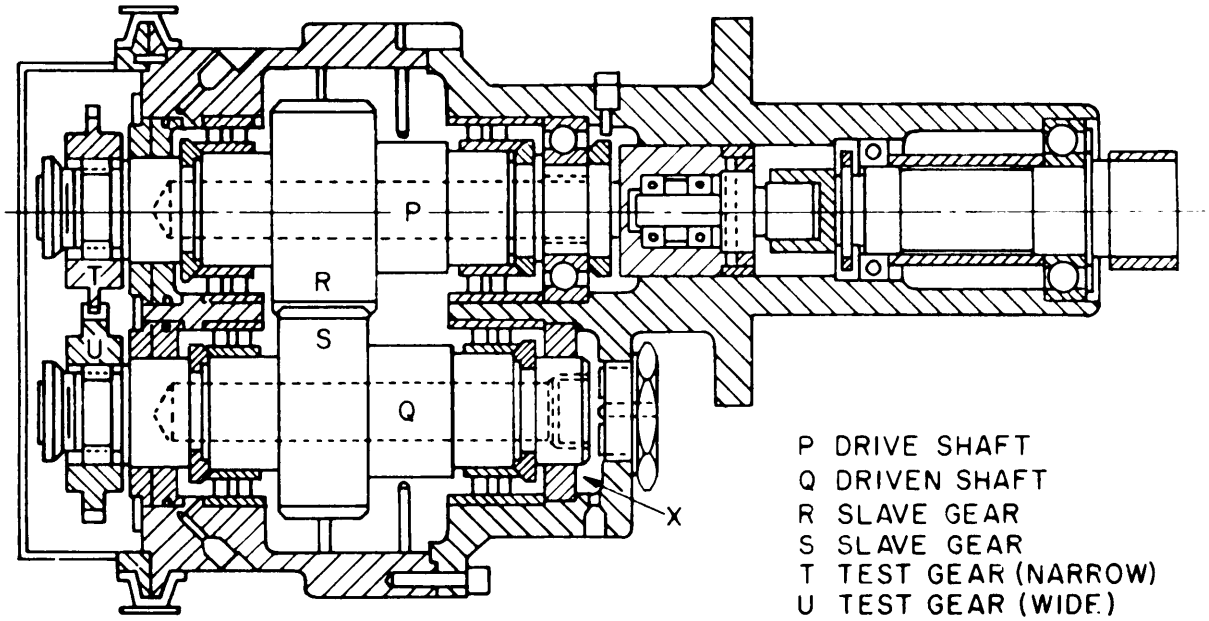

P DRIVE SHAFT
Q DRIVEN SHAFT
R SLAVE GEAR
S SLAVE GEAR
T TEST GEAR (NARROW)
U TEST GEAR (WIDE)
X LOAD CHAMBER

FIGURE I. WADD high-temperature gear machine (section).

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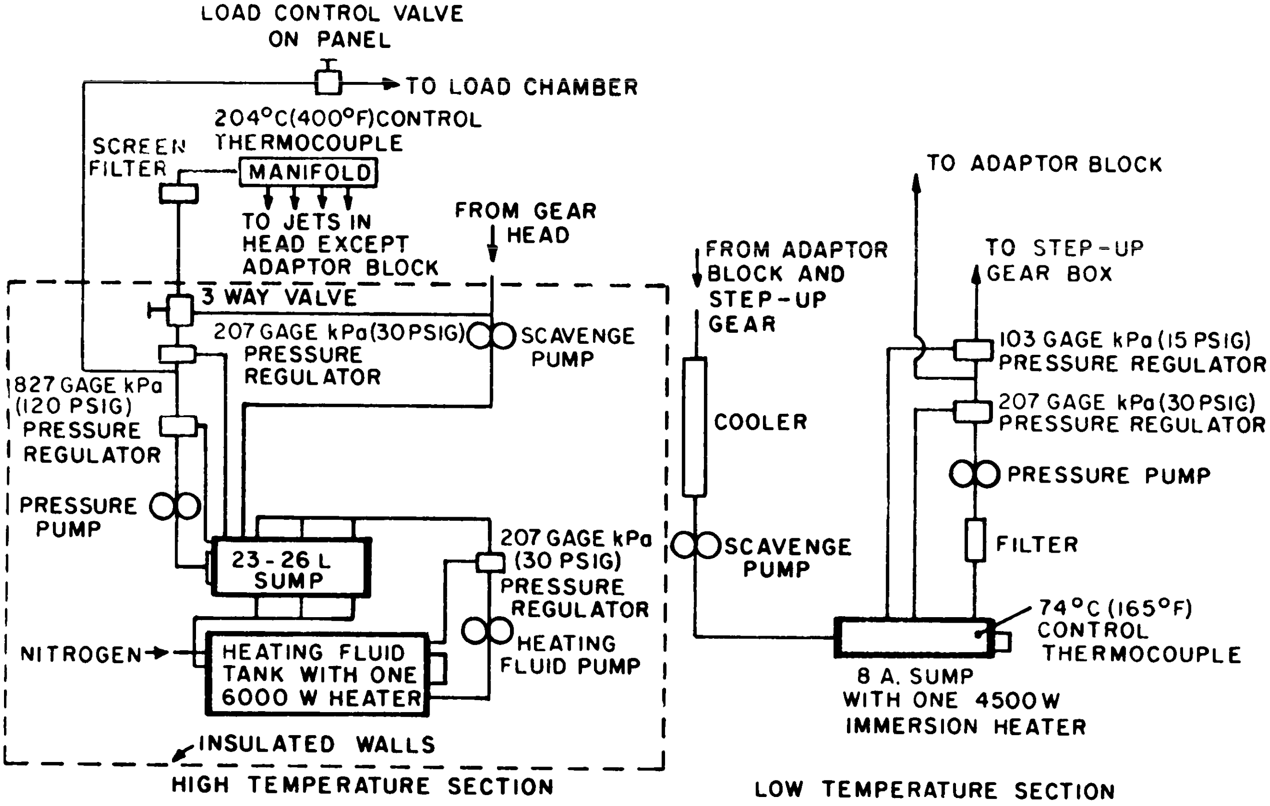

FIGURE 2. Support-oil system.

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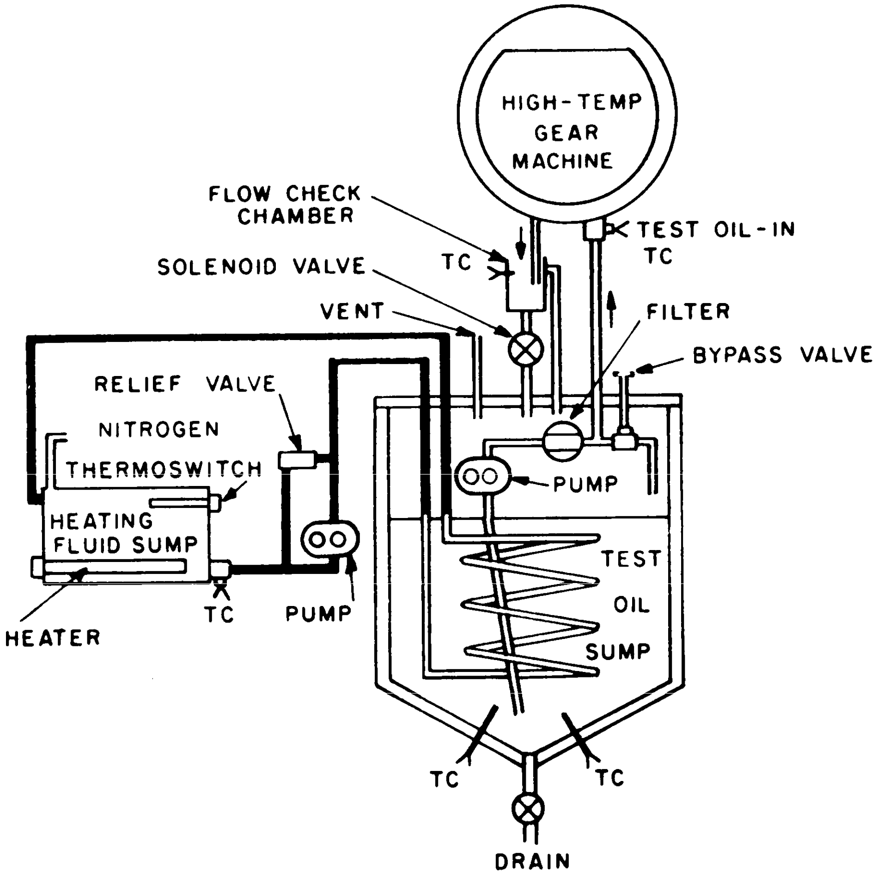

FIGURE 3. Test-oil system.

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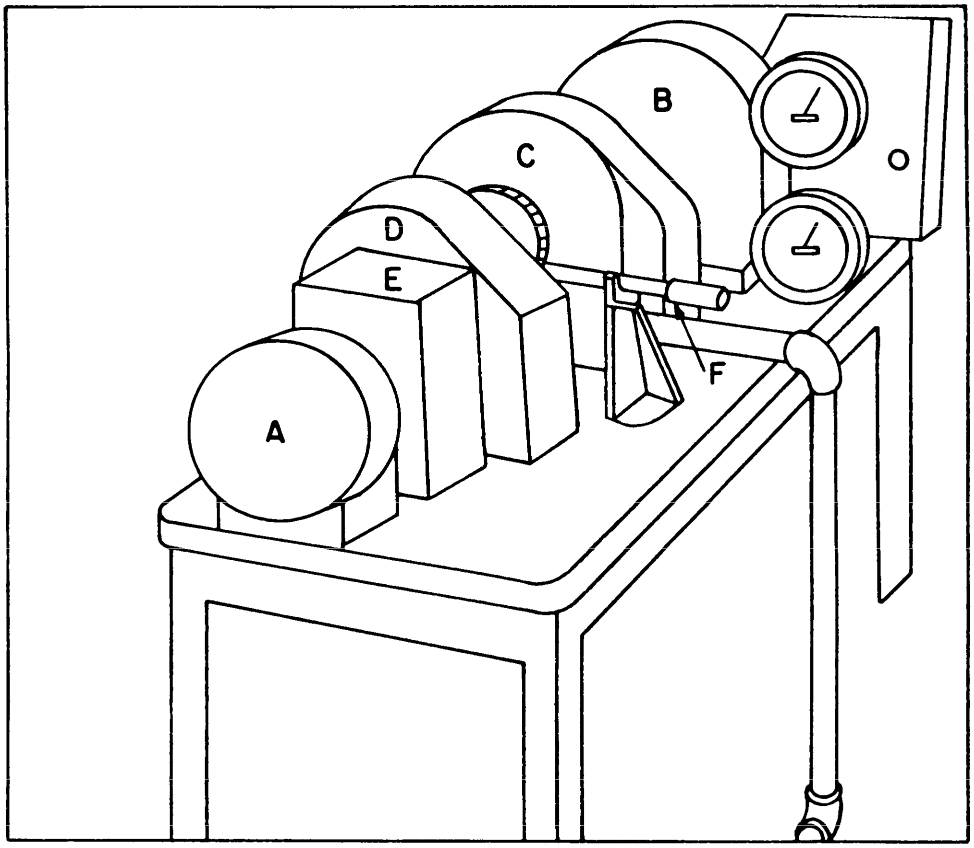

A. HIGH-TEMPERATURE GEAR MACHINE
B. DRIVE MOTOR
C. DYNAMATIC COUPLING
D. STEP-UP GEAR BOX
E. ADAPTOR
F. INDEXING RATCHET

FIGURE 4. Gear machine drive system.

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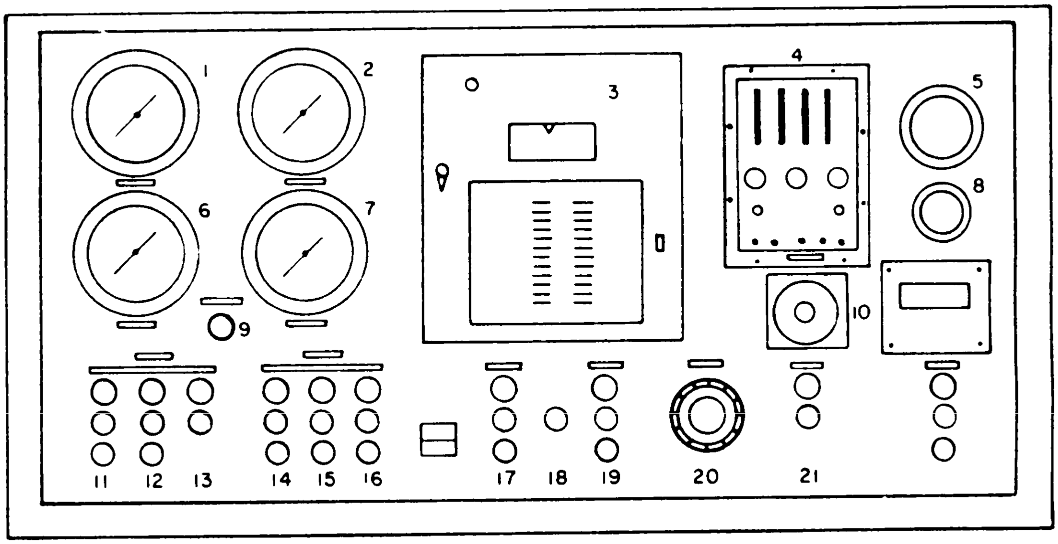

1. Support-oil pressure gage
2. Test-oil pressure gage
3. Multi-point temperature indicator
4. Electronic rpm counter
5. Gear-box pressure gage
6. Load-oil pressure gage (high range)
7. Load-oil pressure gage (low range)
8. Running-time meter
9. Load-adjust control
10. Electric timer
11. Support-oil pumps start-stop buttons
12. Support-oil heaters on-off buttons
13. Load bypass open-close switch
14. Test-oil pressure pump start-stop buttons
15. Test-oil scavanger pump start-stop buttons
16. Test-oil heaters on-off buttons
17. Instruments on-off button
18. Emergency stop button
19. Drive motor start-stop buttons
20. RPM-Adjust control
21. Timer start-stop switch

FIGURE 5. Gear machine control console.

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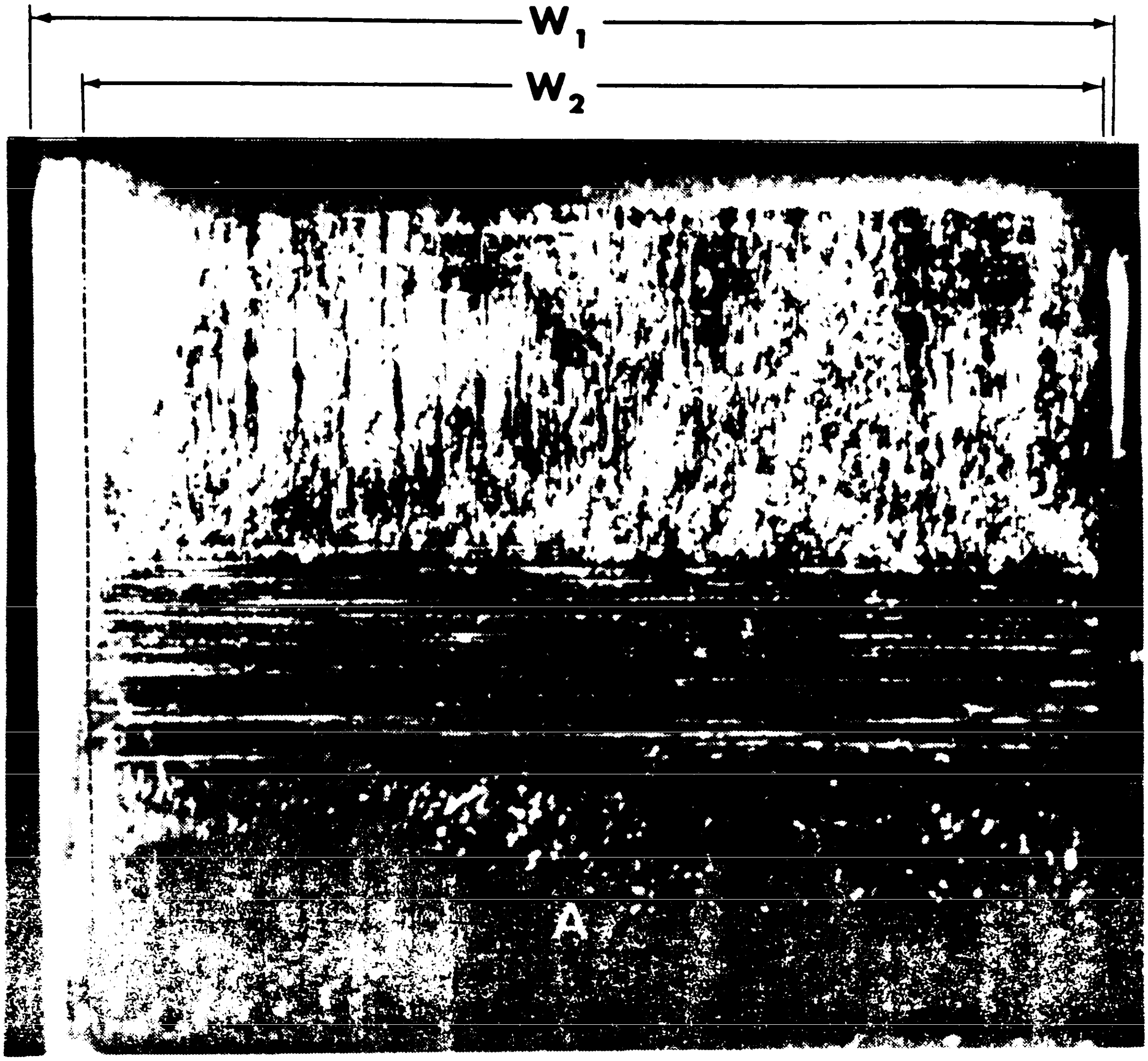

Area "A" . . . . Scuffed
Area "B" . . . . Scuffed
Area "C" . . . . Not Scuffed

W_1 = Gross tooth width
W_2 = Effective tooth width

Figure 6. Scuffed Tooth (Enlarged)

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204°C (400°F) LOAD-CARRYING CAPACITY TEST
OPERATING CONDITIONS DATA SHEET

RIG NO. ______ MACHINE NO. ______ TIME METER AT START OF TEST ______ TEST NO. ______

WIDE GEAR NO. ______ NARROW GEAR NO. ______ GEAR SIDE ______

RECORD THE FOLLOWING AFTER 5 MINUTES AT EACH LOAD

LOAD GAGE kPa, (PSIG)	34 (5)	69 (10)	103 (15)	138 (20)	172 (25)	207 (30)	241 (35)	276 (40)	310 (45)	345 (50)	379 (55)	414 (60)	448 (65)	483 (70)	517 (75)	551 (80)	586 (85)	620 (90)	655 (95)	689 (100)	723 (105)	758 (110)	792 (115)	827 (120)
TIME																								
S.O. PRESS GAGE kPa, (PSIG)																								
T.O. PRESS GAGE kPa, (PSIG)																								
T.O. "IN" TEMP °C, (°F)																								
S.O. "IN" TEMP °C, (°F)																								
S.O. "OUT" TEMP °C, (°F)																								
T.O. SUMP TEMP °C, (°F)																								
S.O. SUMP TEMP °C, (°F)																								
OPERATOR'S INITIALS																								

TEST OIL FLOW, TIME FOR 270 mL: ______ SECONDS

REMARKS: ______

FIGURE 7. Operating conditions data sheet.

X-4424

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204°C (400° F) LOAD-CARRYING CAPACITY TEST
GEAR TEETH INSPECTION DATA SHEET

TEST OIL CODE ______ DATE ______ WIDE GEAR NO. _____ NARROW GEAR NO. _____ TEST NO. _____

GROSS TOOTH WIDTH ______________ ESTIMATED TOOTH WIDTH __________ °/o GEAR SIDE ______

TOOTH NO.	PERCENT OF TOOTH AREA SCUFFED																							
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120
1																								
2																								
3																								
4																								
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24																								
25																								
26																								
27																								
28																								
TOTAL °/o																								
AVE °/o																								

FIGURE 8. Gear teeth inspection data sheet.

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204°C(400°F)LOAD CARRYING ABILITY TEST
PLOT AND CALCULATIONS SHEET

OIL CODE ______________________ TEST NO. ______________________

DATE ______________________ ENGINEER ______________________

	"A" SIDE	"B" SIDE
EFFECTIVE TOOTH WIDTH, cm (INCHES)	______	______
LOAD OIL PRESSURE AT 22.5% SCUFF, PSI	______	______
LOAD-CARRYING ABILITY, N/m (lb/inch)	______	______

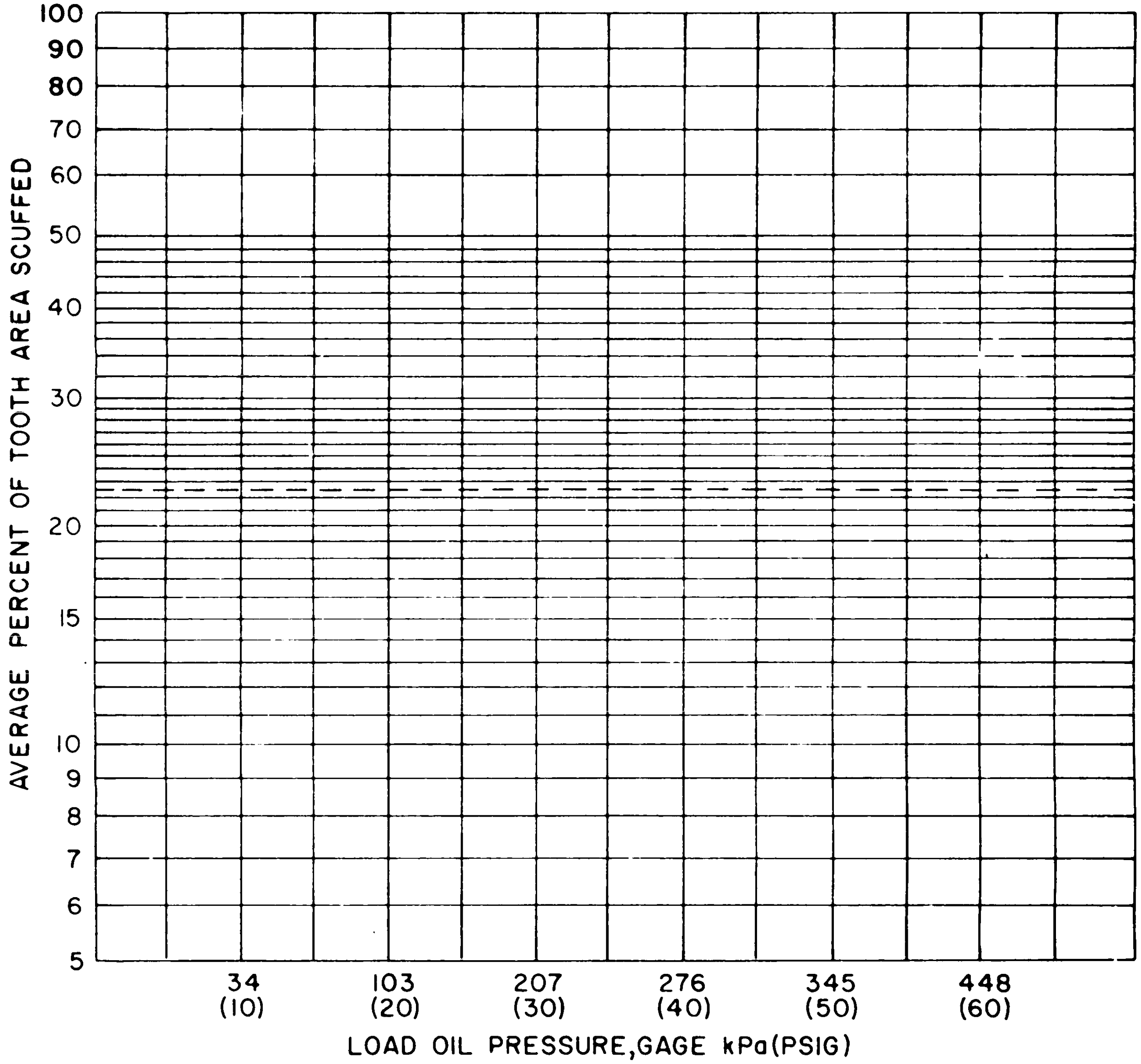

FIGURE 9. Plot and calculations sheet.

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LOAD-CARRYING CAPACITY OF LUBRICATING OILS AT 204° C

1. SCOPE

1.1 This method describes a procedure for determining the load carrying ability of lubricating oils at 204° C (400° F) with respect to gears.

2. SUMMARY

2.1 The method consists of subjecting the lubricant to a series of 204° C (400° F) controlled tests at increasing gear tooth loads on a set of special spur gears, examining the teeth of one of the gears to determine the scuffed area, and rating the load carrying ability of the lubricant in accordance with the percent of the tooth working area scuffed.

3. SAMPLE SIZE

3.1 Approximately 2 L of test oil.

4. REFERENCES, STANDARDS AND APPARATUS

4.1 Test unit. The apparatus used in this method is the WADD high temperature gear machine. This apparatus consists of a WADD high temperature gear head adapted to a modified Ryder gear Erdco universal drive system, support and load oil systems, a test oil system, and the necessary instruments and controls.

4.1.1 WADD high temperature gear head. The WADD high temperature gear head operates on the same principle as the Ryder gear head, the so called “four square” principle. As shown in Figure 1, two parallel shafts (P and Q) are connected by two slave gears (R and S) and two test gears (T and U) to form a “square” so that the power required to operate the machine is only that required to overcome the friction losses in the gears and bearings. The slave gears are helical gears and are made as integral parts of the two shafts; the test gears are spur gears and are replaceable. Load on the test gears is obtained through the application of a controlled oil pressure in the load chamber (X), which causes an axial movement of one shaft relative to the other. A torsional load is thus applied upon the shafts due to the helical slave gears, thereby loading the test gears. The relation between the tooth load on the test gears and the load oil pressure can be obtained by arithmetic calculation, calibration, or both. Arithmetic calibration is used herein.

4.1.2 Test gear set. Nitralloy N, heat treated and ground, 28 teeth, 8.8 cm (3.5 inch) pitch diameter, 8 diametral pitch, 22.5 degree pressure angle, and zero tip relief (Sier Bath Gear and Pump Co., North Bergen, N.J., or equal).

NOTE 1: Each set of test gears comprises gears of two different tooth face widths. The narrow test gear only is used for rating purposes. Both sides of

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the test gear are used for testing; test gears can be used once only on each side and then are discarded.

4.1.3 Support oil system. The support oil system serves two purposes: To provide lubrication to all parts except the test gears, and to supply load oil pressure for the application of load to the test gears. A dual temperature support oil system, shown in Figure 2 and outlined in 4.1.3.1 and 4.1.3.2, is used with the WADD high temperature gear machine.

4.1.3.1 Low temperature support oil section. The low temperature section is maintained at 74° +5.5° C (165° +10° F) during test. This section provides lubrication for the step-up gear box and the two bearings on the jack shaft in the rear of the high temperature head. The low temperature sump is charged with approximately 7.6 L (2 gallons) of lubricating oil, type MIL-L-7808 or MIL-L-9236. A support oil pressure pump and pressure regulators furnish oil to the jack shaft bearings at 207 gage kPa (30 psig) and to the stepup gear box at 103 gage kpa (15 psig). The temperature of the oil in this section is maintained at 74° +5.5° C (165° +10° F)by an electric heater located in the sump and a cooler located before–scavenge pump, through the action of thermoswitches. One scavenge pump scavenges the oil from both the stepup gear box and the adapter housing.

4.1.3.2 High temperature support oil section. The high temperature section is maintained at 204° +5.5° C (400° +10° F) during test. This section supplies load oil pressure and provides lubrication for all remaining bearings and gears in the high temperature test head except for the test gears. The high temperature sump is charged with approximately 23 L (7 gallons) of lubricating oil, type MIL-L-7808 or MIL-L–9236 (same as that used in the low temperature section). A support oil pressure pump and pressure regulators furnish oil to the load adjust valve, located on the control panel, at 827 +69 kpa gage (120 +10 psig), and to the combination filter screen and distributing manifold at 207° +14 kPa gage (30 +2 psig). The temperature of the oil in this section is maintained at 204° +5.5 C (400° +10° F) by a heat exchanger placed inside the sump. The flow of the heating fluid through the heat exchanger is controlled by a thermocouple located in the distributing manifold which controls the heating fluid pump cycle through the action of an off–on controller. The temperature of the heating fluid is maintained at approximately 280° C (550° F) by an electric heater located in the heating fluid tank, through the action of a thermoswitch. It is advisable to exclude air from the heating fluid tank by the use of dry, oxygen-free nitrogen to prevent deterioration of the heating fluid by oxidation. One pump scavenges the oil from the center section of the high temperature gear head.

4.1.3.3 Load oil system. The load oil pressure in the load chamber is changed or adjusted by a load control valve located on the control panel. Turning the load control valve counterclockwise opens the valve, thereby increasing the load oil pressure in the load chamber. Conversely, the load oil pressure is reduced by turning the load control valve clockwise.

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4.1.4 204° C (400° F) test oil system. A schematic diagram of 204° C (400° F) test oil system is shown in Figure 3. The test oil is supplied by the pressure pump to the test gears by a jet located on the unmeshing side of the gears. There is no requirement on the test oil pressure. Instead a test oil flow rate of 270 mL per minute is specified. The flow rate is checked by closing the solenoid valve in the drain line from the head end cover and measuring the time required to fill the flow check chamber to the tip of the bare wire thermocouple. The thermocouple is so positioned in the flow check chamber that a filling time of the chamber of 30 seconds represents a flow of 270 mL per minute. The test oil flow rate is changed by adjusting the bypass valve located on the top of the test oil sump. The flow of the heating fluid through the heat exchanger is controlled by the test “oil-in” thermocouple which controls the heating fluid pump cycle through the action of an on-off controller. The temperature of the heating fluid is maintained at approximately 288° C (550° F) by an electric heater located in the heating fluid tank, through the action of a thermoswitch. It is advisable to exclude air from the heating fluid tank by the use of dry, oxygen free nitrogen to prevent deterioration of the heating fluid by oxidation.

4.1.5 Drive system. A modified Ryder Erdco Universal Test Drive system is used to drive the WADD high temperature gear head. Figure 4 is a photograph of the drive system with the high temperature gear head installed. As shown in Figure 4, the high temperature gear head (A) is driven by a 50 hp induction motor (B) through a dynamatic coupling (C), a stepup gear box (D) and an adapter (E). The test gear speed is controlled by adjusting the field excitation of the dynamatic coupling. By this means an accurate speed control can be obtained at the specified test speed of 10,000 rpm. The modifications to the Ryder Erdco universal test drive system include the following items:

a. Modification of the standard adapter block includes drilling one 0.6 cm (1/4 inch) vent hole in the side of the adapter block and relocation of the gear head mounting studs in the end of the adapter block.
b. The step-up gear box scavenge line is changed from the end of the gear box housing to the bottom. Four 0.102 cm (0.04 inch) jets provide lubrication to the four bearings in the gear box and two 0.102 cm (0.04 inch) jets provide lubrication to the gears. The oil to the stepup gear box is maintained at 103 gage kPa (15 psig).

4.1.6 Instrumentation and controls. All of the instruments and controls which require constant attention during tests are located on the control console which is shown in Figure 5. Items which do not require frequent attention are located on the test stand. The function of most of the instruments and controls are apparent. Selected items are described in subsequent paragraphs.

4.1.6.1 Speed measurement and control. An electronic counter (Figure 5, item 4), located on the control console, measures the gear speed. This instrument is actuated by pulses supplied by a variable reluctance pickup, the variable

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reluctance being supplied by a 60 tooth gear operated from the driven shaft of the stepup gear box. The rpm adjust control (Figure 5, item 20), located on the control console, regulates the field excitation of the dynamatic coupling and thus gear speed.

4.1.6.2 Control of duration of test run. An electric timer (Figure S, item 10), located on the control console, is used to control the duration of each test run. The timer should be set at the beginning of the test to 10 minutes and locked in position. As soon as the desired test load has been obtained, the timer is started by turning the timer switch (Figure 5, item 21) on the control console to the “Start” position. After the 10 minute run is over, the timer will automatically turn off the drive motor. However, the timer switch will remain in the “Start” position. It must be turned to the “Stop” position in preparation for the next run.

4.1.6.3 Support oil controls. The support oil pump buttons (Figure 5, item 11) on the control console are connected to the 204° C (400° F) support oil pump and to the 74° C (165° F) support oil pump as well as to the two scavenge pumps. Pressing the “Start” or “Stop” button will start or stop all four pumps at the same time. The support oil heater buttons (Figure 5, item 12) control the electric heater located in the heating medium tank and also the electric heater in the 74° C (165° F) support oil sump. The support oil heating medium pump control system is also actuated by the support oil heater buttons.

4.1.6.4 Test oil controls. The test oil pump buttons (Figure 5, item 14) on the control console start or stop the test oil pump. The test oil heater buttons (Figure 5, item 16) control the electric heaters located in the heating medium tank. The test oil heating medium pump buttons (Figure 5, item 15) actuate the control system for the heating medium pump.

4.1.6.5 Load oil pressure control. See 4.1.3.3.

4.1.6.6 Emergency stop. The emergency stop button (Figure 5, item 18) on the control console stops the drive motor and turns off all controls except those for instruments. The timer switch will remain in the position to which it was originally set.

4.1.6.7 Scuff rating equipment. A microscope and a light source are used for visual inspection of a narrow test gear. To inspect the narrow gear, the machine is first stopped. The inspection can then be made through special inspection holes provided in the gearcase end cover. These holes are closed by corks during the test run.

4.1.6.8 Inspection equipment. The standard 18 power microscope furnished with the Ryder gear Erdco universal tester is slightly modified by the addition of a supplementary lens in the right objective lens opening. The right eyepiece of the microscope contains a net reticule that divides the gear tooth area

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lengthwise into seven sections. The grid lines provide a convenient means for the visual estimation of the percent of gear tooth area that has been scuffed.

4.1.6.9 Gear tooth indexing ratchet. An indexing ratchet (F, Figure 4) is used for rotating the test gears so that the teeth of the narrow test gear can be inspected individually.

4.1.6.10 Additional instruments:

a. Stop watch for oil flow rate check.
b. Micrometer O to 2.5 cm (O to 1 inch) for the measurement of the gross tooth width of the narrow gear.
c. Scale with divisions of 0.04 cm (1/64 inch).

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Lubricating oil, MIL-L-7808.

5.3 Lubricating oil, MIL-L-9236.

5.4 Dry cleaning solvent, (ASTM D 484, type I) [0,2,01.

5.5 Cleaning compounds, special (Penetone ECS; Penetone Corporation, 74 Hudson Avenue, Tenafly, New Jersey 07670 or equivalent) [u,u,u].

5.6 Household cleaner.

6. PROCEDURE

6.1 Operating conditions.

6.1.1 Throughout the entire test the variables listed in Table I should be controlled within the limits specified. With the tester operating within the specified limits, the test gears are loaded first to 34 gage kPa (5 psig) load oil pressure, and then at successive increments of 34 kPa (5 psi). The duration of each loading period is 10 minutes + 5 seconds. At the end of each loading period the tester is stopped and each–tooth of the narrow gear is examined to determine the percent of tooth area scuffed.

6.2 Test procedure.

6.2.1 Preparation for test.

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1. Turn on main electric switch and main water valve to test cell.
2. Push instrument button to “On” position.
3. Adjust nitrogen pressure to heating medium tanks to 14 to 28 kPa gage (2 to 4 psig).
4. Push heating medium tank heaters buttons to “On” position. This also turns on the heater in the 74° C (165° F) support oil sump.
5. Inspect test oil system to see that it was thoroughly cleaned and dried after previous test.
6. Remove gear case end cover.
7. Clean a set of new test gears with dry cleaning solvent, and dry with air.
8. Measure gross tooth width of the narrow test gear with a micrometer, and record.
9. Install test gears on proper shafts with the serial number facing outward (narrow gear on drive shaft, wide gear on driven shaft), matching timing marks on shafts and gears. Check for proper seating of the retaining nuts, and lock one tang of each lock washer.
10. Loosen the locknut on the driven shaft adjusting pin (at rear of gear case), and unscrew adjusting pin until driven shaft is free to move to the extreme rearward position without touching the adjusting pin. Using a scale having divisions of 0.04 cm (1/64 inch) set adjusting pin so that the driven shaft can move through only one half of the normal free travel (from extreme rearward position to extreme forward position). Tighten locknut on adjusting pin.
11. Re-install gear case end cover.
12. Turn on air to non-rubbing seals. Adjust to approximately 48 gage kPa (7 psig).
13. Fill test oil sump with approximately 7.6 L (2 gallons) of test oil.
14. Push support oil heating medium pump button to the “On” position after heat medium fluid has reached 93.3° C (200° F).
15. Push test oil heating medium pump button to “On” position after heat medium has reached 93.3° C (200° F).
16. Allow the heating medium fluid to circulate approximately 20 minutes then push support oil pump button to the "On” position. This also starts the 74° C (165° F) support oil pump.
17. Open test oil bypass valve.
18. Start test oil pump, and immediately open test oil drain line from test oil pressure gage to allow new test oil to fill the line to the gage.
19. Turn timer switch to “STOP” position.
20. Set electric timer to 10 minutes and 0 seconds, then lock timer dial.
21. Turn rpm-adjust control to "ZERO” position.
22. Check calibration of the rpm counter by setting the input sensitivity control to the "CHECK” position and the gate selector switch to the “ONE SECOND” position. The counter should read "60”. After checking, turn the input sensitivity control to about midscale.
23. When the test oil and the high temperature support oil temperatures are Up to the specified value of 204° +5.5° C (400° ±10° F), check the test oil flow rate as follows: Adjust the test oil bypass valve until test

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oil flow is approximately 270 mL per minute. Actuate the solenoid valve to a closed position, and measure the time required to fill the flow check chamber to the tip of the bare *wire* thermocouple. The time required should be 30 seconds. Actuate the solenoid valve to the open position to allow the test oil to drain to the test oil sump. time required to fill the flow check chamber to the tip of the bare wire thermocouple varies from the 30 second requirement by more than one second, readjust the bypass valve and recheck test oil flow rate as above.

NOTE 2: The visual method of checking oil flow rate is satisfactory for the initial flow check when changes in the bypass valve setting are anticipated. However, quick checks of the flow rate may be made before or during test run by actuating the solenoid valve from the control console switch, and recording the time required to fill the flow check chamber to the tip of the bare-wire thermocouple. An instant increase in temperature will be noted on the temperature indicator when the hot oil rises to the level of the tip of the thermocouple.

6.2.2 Test sequence on “A” side of test gears.

NOTE 3. The "A” side of the gear refers to the side obtained by installing the test gears with the serial numbers facing the end cover. The “B” side is obtained by reversing the gear (serial numbers facing away from the end cover).

1. Check all temperatures and pressures and, if necessary, adjust to specified limits.
2. Recheck test oil flow rate, and readjust if necessary.
3. Make sure that the gear tooth indexing ratchet is locked in the disengaged position.
4. Make sure that the load control valve is closed (extreme clockwise position).
5. Start drive motor.
6. Increase gear speed by turning rpm adjust control clockwise until the specified 10,000 +100 rpm is obtained.
7. Apply load slowly–by turning the load control valve counterclockwise. Stop when the load oil pressure is 34 kPa gage (5 psig).

CAUTION

Extreme care should be exercised when adjusting the load oil pressure so as not to overshoot the desired pressure.

8. Check gear speed, and adjust if necessary.
9. Turn timer switch to “START” position. The 10 minute test run now begins.
10. Record all pertinent data about midway of the test run.

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11. At the end of the 10 minute run, the electric timer will automatically stop the drive motor. However, the timer switch will remain in the "START" position, and the rpm adjust control will remain in the running position. Restore these to their respective off positions.
12. Reduce load oil pressure manually to a load oil pressure of 34 kPa gage (5 psig) while machine is coasting to a stop.

NOTE 4: A load oil pressure of 34 kPa gage (5 psig) is normally maintained during starting and stopping of the gear machine and during visual scuff inspection.

TABLE 1. Operating conditions.

Condition	Value	
Test gear speed	10,000 ±100 rpm	10,000 ±100 rpm
Test "oil in" temperature	204° ±5.5°C	400 ±10° F
Support oil temperature (low temperature section)	73.9 ±5.5° c	165 ±10° F
Support oil temperature (high temperature section)	204° ± 5.5° C	400 ±10° F
Support oil pressure to gear machine	207 kPa gage	30 psig
Support oil pressure to load system	827 kPa gage	120 psig
Support oil pressure to stepup gear box	103 kPa gage	15 psig
Gear load (fatigue cycle only)	7250 N/cm of tooth of face width	4140 pounds/incl of tooth-face width

13. Make visual scuff inspection of the narrow test gear as follows:

    a. Remove corks from inspection holes in gear case end cover.
    b. Install microscope and inspection light.
    c. Focus microscope and adjust grid lines over the contact area of the tooth.
    d. Set indexing ratchet wheel to "No. 1" position.
    e. Estimate the percent scuff of No. 1 tooth as accurately as possible but at least to the nearest 5 percent, and record the value.
    f. operate the indexing ratchet to give No. 2 tooth and repeat step (e). Repeat for No. 3 tooth etc. until all 28 teeth have been examined.

NOTE 5: The test oil pump may be turned off during inspection of gear teeth if excessive smoke or test oil hampers the visual inspection.

    g. Remove microscope and light. Replace corks in holes.
    h. Lock indexing ratchet pawl in disengaged position.

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14. Repeat steps (1) through (13) at the next test load of 170 kPa (10 psig) load oil pressure.
15. Continue to test at 34 kPa (5 psi) load oil pressure increments until the average scuffed area for all teeth is closest to 22.5 percent. At this juncture it is mandatory to visually estimate the percent scuff of the effective tooth face width to the nearest one percent. Record the value.
16. Continue the test at 34 kPa (5 psi) load oil pressure increments until an approximate average scuffed area of 40 percent or more is obtained. Record all values.
17. Push test oil and support oil pump buttons “OFF”.
18. Push test oil heating medium pump button “OFF’”.

NOTE 6: If test oil has degraded appreciably, it may be necessary at this point to drain used test oil from the test oil sump, and flush the system with 7.6 L (two gallons) of dry cleaning solvent. This is circulated through the test oil system for 5 minutes. The solvent is then drained and a 3.8 L (one gallon) portion of unused test oil is similarly circulated, then drained and discarded. The sump is then charged with a fresh 7.6 L (2 gallon) portion of test oil. If it is not necessary to change the test oil, leave original portion intact for "B” side of test gear.

19. Remove gear case end cover.
20. Blow out test oil jet with compressed air.
21. Reverse test gears so that their serial numbers face the body of the gear head, again matching timing marks on shafts and gears. Check for proper seating of the retaining nut, and lock one tang of each lockwasher.
22. Reinstall gear case end cover.

6.2.3 Test sequence on “B” side of test gears.

NOTE 7: The “B” side refers to the side obtained by reversing the gear (serial numbers facing away from the end cover).

1. Push support oil pump button “ON”.
2. Push test oil heating medium pump button “ON”.
3. Push test oil pump button “ON”.
4. When the test oil and support oil temperatures are up to the specified 204° ±5.5° C (400° ±10° F) check test oil flow rate as described in 6.2.1, step (23). Adjust to specified value.
5. Proceed with test on “B” side of the test gear by following the procedure outlined in 6.2.2 steps (1) through (16).
6. Push support oil heating medium pump button “OFF”.
7. Push test oil heating medium pump button “OFF”.
8. Push test oil and support oil pump buttons “OFF”.
9. Turn off air to nonrubbing seals.
10. Remove gear case end cover.
11. Remove used test gears, and discard.

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12. Remove complete test oil system for cleaning.
13. Push instrument button “OFF”.
14. Turn off nitrogen to heating medium tanks.
15. Turn off main electric switch to test cell.
16. Turn off main water valve to test cell.

6.2.4 Cleaning procedure.

1. Disassemble test oil system, including pump, filter, and valve.
2. Soak all disassembled parts of test oil system in hot 49° C (120° F) special cleaning compound for approximately 3 hours.
3. Remove parts from cleaner, and rinse thoroughly with water.
4. Inspect all parts to see that they are completely clean. If any indication of residue is present, scrub all parts well with household cleanser, then rinse thoroughly with water.
5. Dry all parts with compressed air.
6. Reassemble test oil system.
7. Clean inside of gear case end cover with household cleanser, and rinse thoroughly with water.
8. Dry gear case end cover with compressed air.
9. Blow out test oil jet with compressed air.
10. Check position of test oil jet, and adjust to proper position, if necessary, by bending jet.

6.3 Inspection and rating.

6.3.1 Scuffed area. The scuffed area of a gear tooth is that area from which the axial grinding marks have been removed by scratching, scoring, abrasion, and wear. As shown in Figure 6, areas A and B are scuffed; area C is not scuffed. Note that only the actual working portion (areas A plus B plus C) of the tooth surface is considered in the definition of areas.

6.3.2 Percent of tooth area scuffed. The percent of tooth area scuffed is that portion of the working surface of a gear tooth that has been scuffed. Referring to Figure 6,

$$\text{percent tooth area scuffed} = \frac{\text{scuffed area}}{\text{working area}} \times 100$$

$$= \frac{A + B}{A + B + C} \times 100$$

The percent of tooth area scuffed is estimated visually as accurately as possible, but at least to the nearest 5 percent for each individual tooth, with the aid of a net reticule mounted in the eyepiece of the inspection microscope.

6.3.3 Average percent of tooth area scuffed. The average percent of tooth area scuffed is the algebraic average of the percent of scuffed area of all 28 teeth of the narrow test gear. Calculate this value to the nearest 1 percent.

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6.3.4 Effective tooth width. The effective tooth width is the actual width of the narrow gear tooth that is in contact with the tooth of the wide gear. To determine the effective tooth width, measure the gross tooth width by means of a micrometer, and estimate the ratio of effective tooth width to gross tooth width by visual examination or with the aid of a suitable scale. Referring to Figure 7 and section 7.1.

6.3.5 Load carrying ability. The load carrying ability, or the scuff limited load, of a lubricant is defined as the gear tooth load at which the average percent of tooth area scuffed is 22.5 percent for the narrow test gear as determined by the method outlined herein.

6.3.5.1 Determination of load carrying ability. Using semilog paper (Figure 9), plot the average percent of tooth area scuffed for the narrow test gear versus the load oil pressure. Detemine from the plotted curve the load oil pressure at which the average percent of tooth area scuffed is 22.5 percent. In Figure 9, for example, this ccndition is represented by point X for “A” side and point Y for “B” side of the narrow test gear. Calculate load carrying ability, see 7.2.

6.4 Data sheets.

6.4.1 The suggested data sheets are shown in Figures 7 and 8. Figure 7 is the operating conditions data sheet, and Figure 8 is the gear tooth inspection data sheet. The intended use of each is obvious.

7. CALCULATIONS

7.1 Calculate the effective tooth width using following equation:

$$W_2 = W_1 \times R$$

W_2 = effective tooth width in cm (inches).
W_1 = measured gross tooth width in cm (inches).
R = W_2/W_1 = estimated ratio.

7.2 Calculate the load carrying ability from the following equation:

P = load carrying ability of the lubricant in N/cm (pounds per-inch) of tooth face width.
K = WADD high temperature gear machine constant (11.5 by definition).
L = load oil pressure gage Pa (psig).
W_2 = effective tooth face width in cm (inches).

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8. REPORTING

8.1 Report individual rating of “A” and “B” sides of all gears tested in N/cm (pounds per inch) of tooth face width. Also report the average of all individual rating.

9. PRECISION

9.1 Precision data have not been developed for this method.

Method prepared by:
Navy - NAPC - 1986

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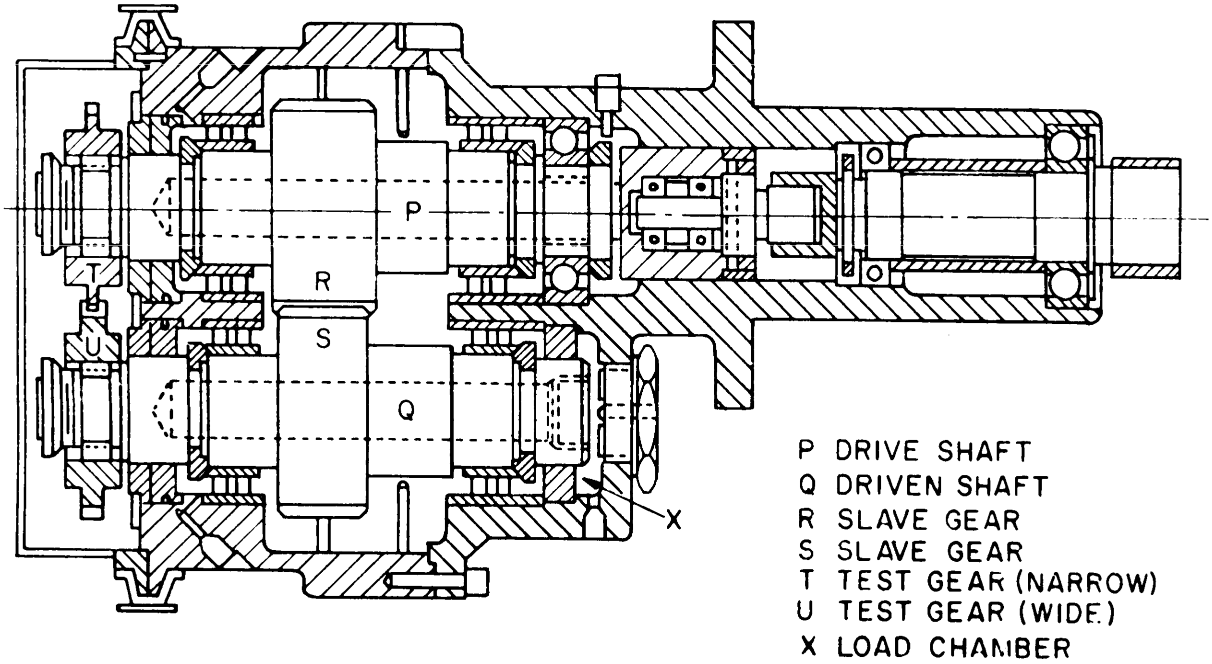

FIGURE 1. WADD high-temperature gear machine (section).

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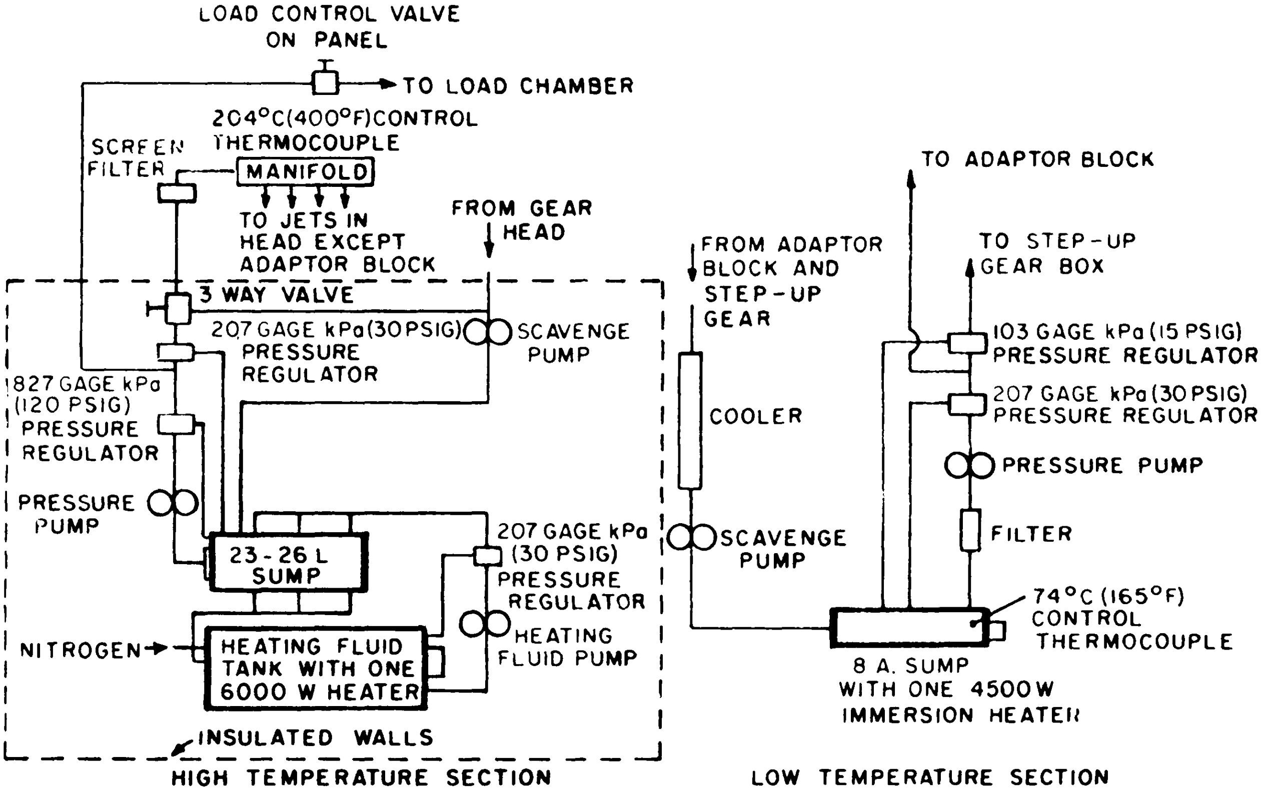

FIGURE 2. Support-oil system.

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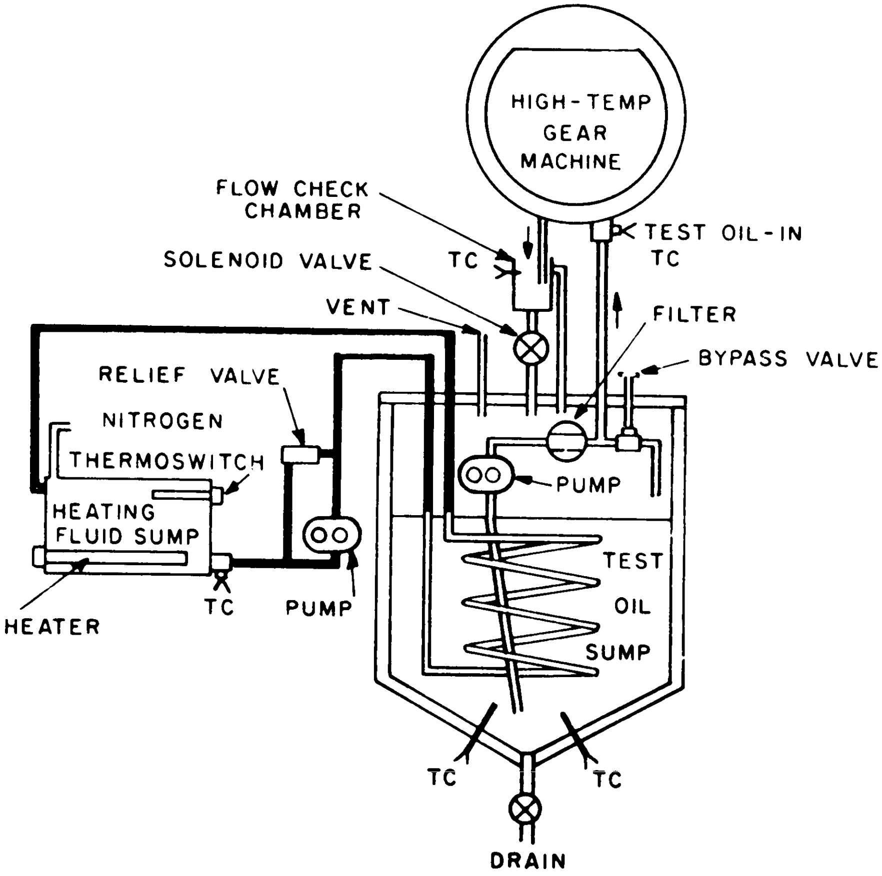

FIGURE 3. Test-oil system.

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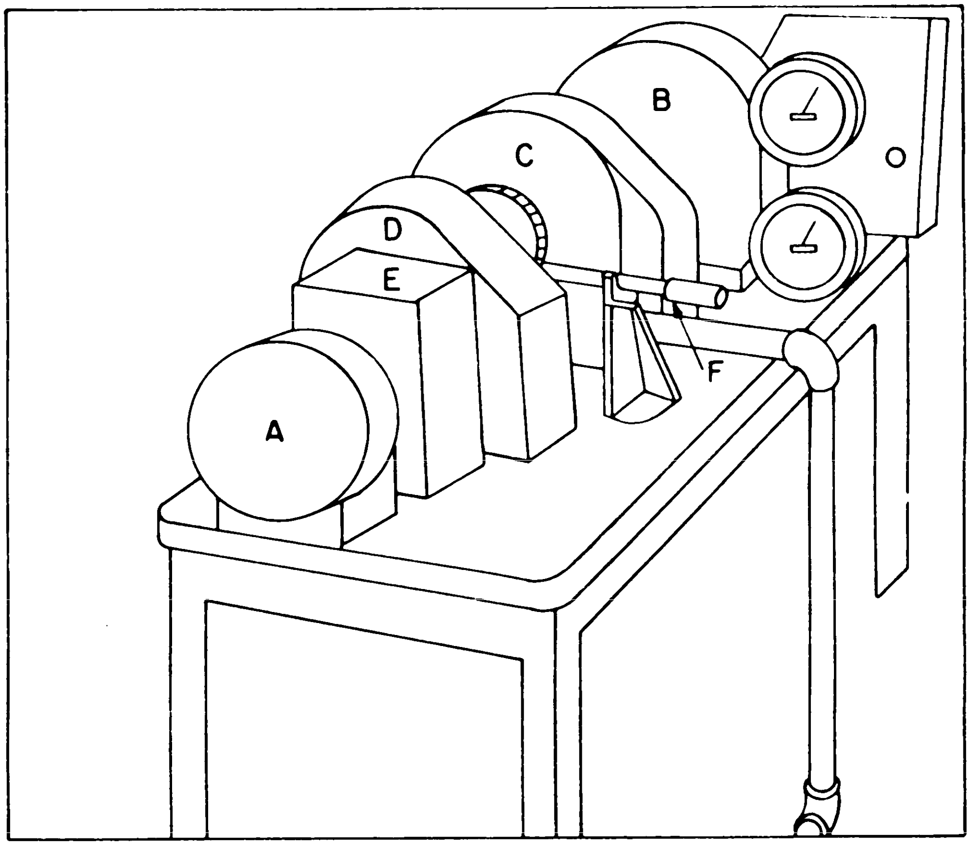

A. HIGH-TEMPERATURE GEAR MACHINE
B. DRIVE MOTOR
C. DYNAMATIC COUPLING
D. STEP-UP GEAR BOX
E. ADAPTOR
F. INDEXING RATCHET

FIGURE 4. <u>Gear machine drive system.</u>

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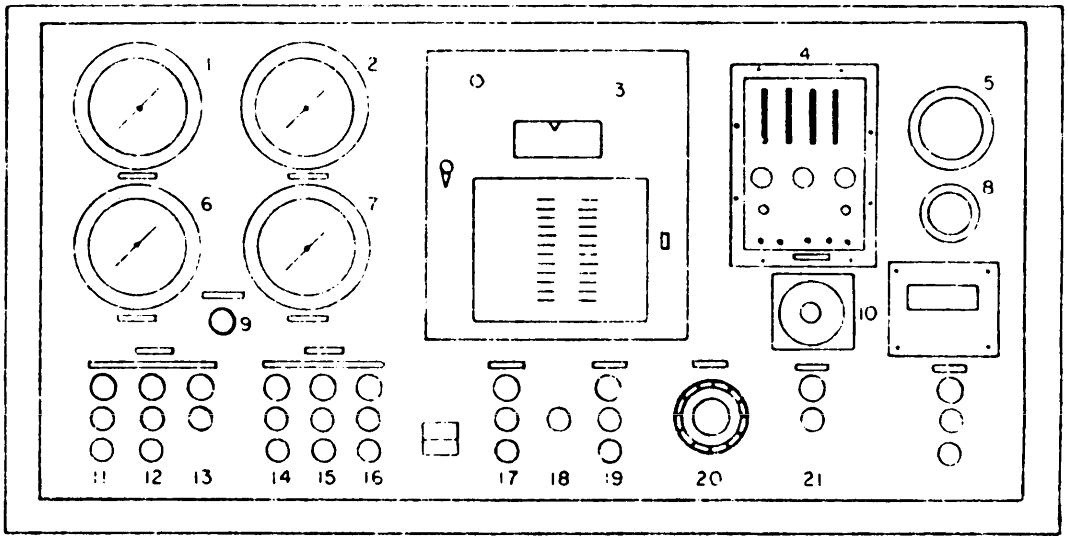

1. Support-oil pressure gage
2. Test oil pressure gage
3. Multi-point temperature indicator
4. Electronic rpm counter
5. Gear-box pressure gage
6. Load-oil pressure gage (high range)
7. Load-oil pressure gage (low range)
8. Running-time meter
9. Load-adjust control
10. Electric timer
11. Support-oil pumps start-stop buttons
12. Support-oil heaters on-off buttons
13. Load bypass open-close switch
14. Test-oil pressure pump start-stop buttons
15. Test-oil scavanger pump start-stop buttons
16. Test-oil heaters on-off buttons
17. Instruments on-off button
18. Emergency stop button
19. Drive motor start-stop buttons
20. RPM-Adjust control
21. Timer start-stop switch .

FIGURE 5. Gear machine control console.

X-4422

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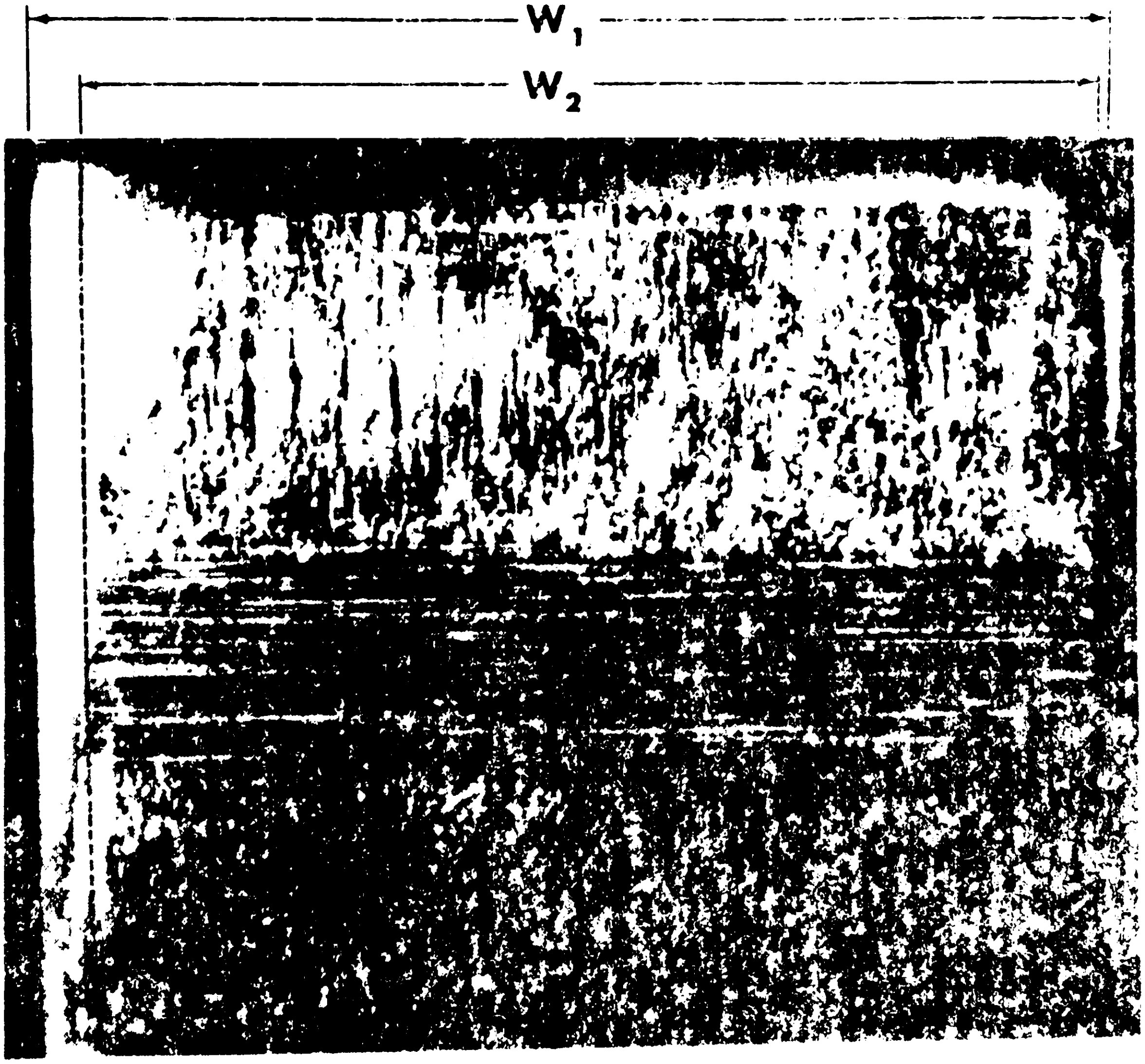

Area "A" ....Scuffed
Area "B" ....Scuffed
Area "C" .... Not Scuffed

W_1 = Gross tooth width
W_2 = Effective tooth width

Figure 6. Scuffed Tooth (Enlarged)

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204°C (400°F) LOAD-CARRYING CAPACITY TEST
OPERATING CONDITIONS DATA SHEET

RIG NO. ______ MACHINE NO. ______ TIME METER AT START OF TEST ______ TEST NO. ______

WIDE GEAR NO. ______ NARROW GEAR NO. ______ GEAR SIDE ______

RECORD THE FOLLOWING AFTER 5 MINUTES AT EACH LOAD

LOAD GAGE kPa, (PSIG)	34 (5)	69 (10)	103 (15)	138 (20)	172 (25)	207 (30)	241 (35)	276 (40)	310 (45)	345 (50)	379 (55)	414 (60)	448 (65)	483 (70)	517 (75)	551 (80)	586 (85)	620 (90)	655 (95)	689 (100)	724 (105)	758 (110)	793 (115)	827 (120)
TIME																								
T.G. PRESS GAGE kPa, (PSIG)																								
S.G. PRESS GAGE kPa, (PSIG)																								
T.G. "IN" TEMP °C, (°F)																								
S.G. "IN" TEMP °C, (°F)																								
S.G. "OUT" TEMP °C, (°F)																								
T.G. SUMP TEMP °C, (°F)																								
S.G. SUMP TEMP °C, (°F)																								
OPERATOR'S INITIALS																								

TEST OIL FLOW, TIME FOR 270 mL: ______ SECONDS

REMARKS: ______

FIGURE 7. Operating conditions data sheet.

X-4424

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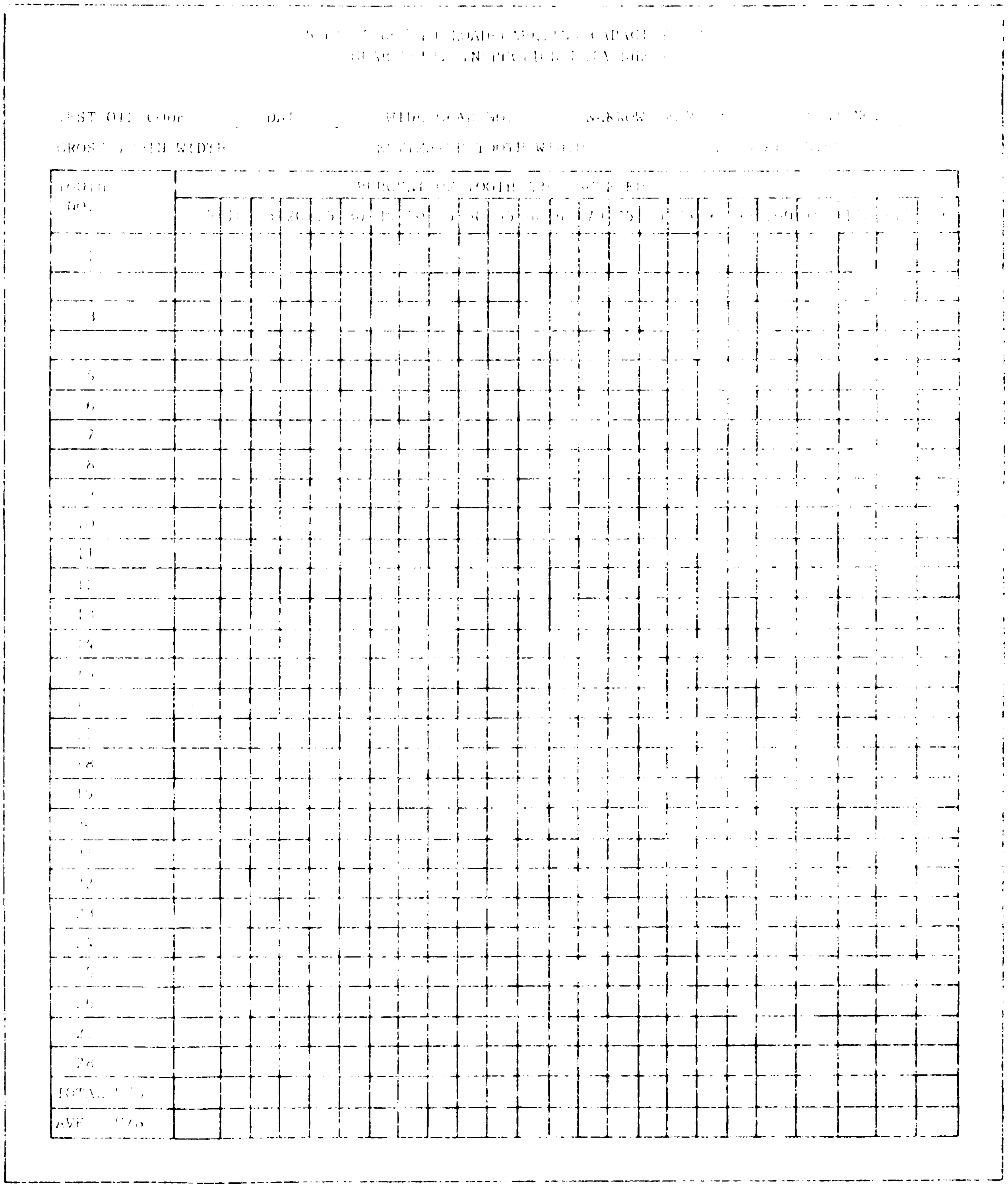

FIGURE 8. Gear teeth inspection data sheet.

X-4425

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204°C (400°F) LOAD CARRYING ABILITY TEST
PLOT AND CALCULATIONS SHEET

OIL CODE ____________________ TEST NO. ____________________
DATE ____________________ ENGINEER ____________________

	"A" SIDE	"B" SIDE
EFFECTIVE TOOTH WIDTH, cm (INCHES)	______	______
LOAD OIL PRESSURE AT 22.5% SCUFF, PSI	______	______
LOAD-CARRYING ABILITY, N/m (lb/inch)	______	______

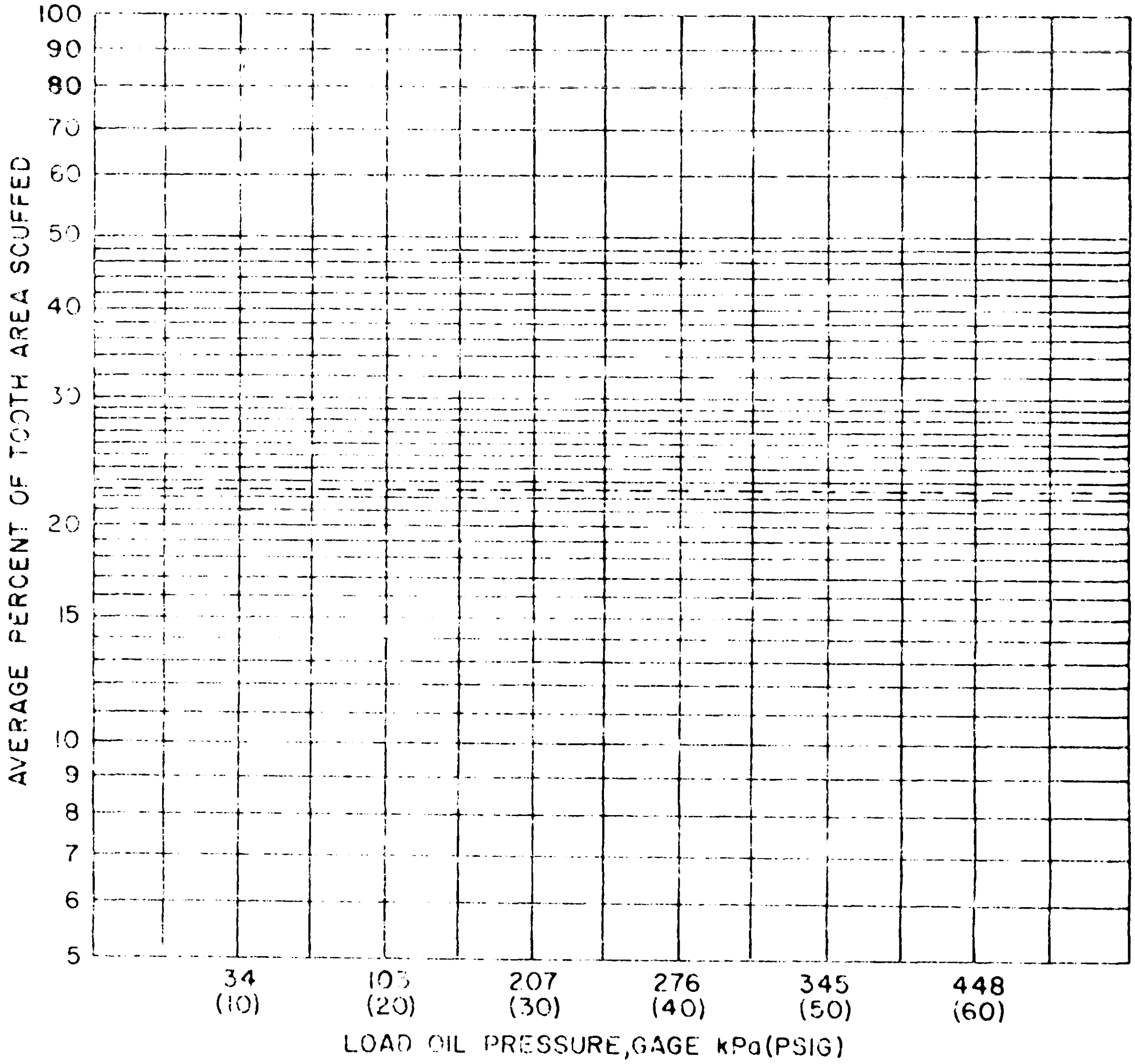

FIGURE 9. Plot and calculations sheet.

X-4426

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OSCILLATION TEST OF GREASE IN HELICOPTER BEARINGS

1. SCOPE

1.1 This method describes a procedure for determining the ability of the grease to provide adequate lubrication for helicopter bearings having oscillatory motion of small amplitude.

2. SUMMARY

2.1 The method consists of oscillating a tapered roller bearing at small amplitude under load. Failure is indicated when the drag exceeds a specified limit.

3. SAMPLE SIZE

3.1 Approximately 250 g of lubricant to be tested.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 The Sikorsky Aircraft Friction Oxidation Testor, Model No. SKP-1721-1 shall be utilized for this test. The equipment consists of a hydraulic loading system; a driving mechanism and a tester assembly (Figure 1). The tester assembly (Figure 2) houses a test shaft which is activated by a crank arm. The test shaft has four bearings mounted upon it. The two outer bearings, Timken 2687/2631 cones and cups are the test bearings. The outer races of these bearings are mounted in the ears of the test assembly. Between the ears is a loading yoke in which the outer races of the load are mounted. The test bearings are loaded by means of the hydraulic system, which applies a force through the load yoke and load bearing, to the test shaft, and consequently loads the test bearings.

4.2 Hypodermic syringe and needle.

5. MATERIALS

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS. The chemical materials listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Dry cleaning solvent, ASTMD 484, type I, [0,2,0].

5.3 Test bearings

(a) Timken Cone NO. 2687
(b) Timken Cup No. 2631

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5.4 Hydraulic fluid, MIL-H-5606.

6. PROCEDURE

6.1 Prepare the apparatus as follows:

(a) Clean test bearings, cones and cups with dry cleaning solvent. Dry bearing using dry compressed air. Do not rotate bearing. (See Note 1).

Note 1. CAUTION. Dry cleaning solvent is both toxic and flammable. Use only in a well ventilated area. Do not breathe its fumes or allow it to come in contact with the skin. Keep all flames away from the dry cleaning solvent.

(b) Immediately after cleaning, lubricate cones with 5.0 ±0.1 g of test grease as follows:

(1) Using a hypodermic needle and syringe, inject 4.0 g of grease in the space between the cone and the cage, evenly distributed among the rollers.
(2) Using a narrow-faced spatula, apply 1.0 g of grease on the rollers and cage. Distribute the grease evenly among the rollers in the shape of a wedge along the two sides of each roller where it meets the cage, making certain that the greased area does not extend beyond ends of the rollers.
(3) Do not apply grease to cup.

(c) Remove load bearings RBC ESJ7295, wipe clean of old grease and repack by hand, using grease found to be the best by the oxidation friction tester. Return the bearings to the load yoke (SKP-748).

6.2 Make a test run as follows:

(a) Assemble test bearing cups to ears of the tester assembly, making certain they are well sealed against the inner shoulders. Similarly, install oil seal.
(b) Assemble the cone of the rear test bearing to the test shaft, apply the washer, seat, and locknut sufficiently to hold cone lightly against the shoulder of the shaft. Positon the load yoke between the ears of the tester assembly. Insert the test shaft from rear to front, though the cups, load bearings, and seals, being careful to see that seals are properly seated on the rings on the shaft. The use of a “thimble” to guide the shaft through the seals is desirable.
(c) Position the cover plate between the ears of the tester and tighten the holddown screws.

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(d) Holding the test shaft at the locknut, to prevent it from sliding back, install the front test bearing cone (2687), washer (SW-751-S) seal assembly (SKP-751-3), seat (SKP-751-10) and nut (SAE No. 5). While restraining the test shaft from turning, tighten the nut (SAE No. 5) until it presses the cone of the front test bearing solidly against the test shaft shoulder, backing off the locknut at the other end of the test shaft as necessary. Leave rear locknut lightly tightened against the test bearing cone.

(e) Rotate test shaft ten turns in each direction manually. Alternate two turns in each direction.

(f) Place the crank arm assembly (SKP-2413) on the test shaft. Tighten crank arm to test shaft, making certain that alignment exists with proving ring arm. The end of the the proving ring arm assembly must pass freely between the bearings of the crank arm without interference before inserting the connecting pin. Connect crank arm to proving ring assembly (SKP-2423). Apply grease found to be best by the Friction Oxidation Tester to the connecting pin (SKY-2411) and bearings (Torrington B-88).

(g) Remove locknut and washer from rear of tester shaft. Apply one drop of sealant (see note 2) to the annular space between the bearing surface of the test shaft and the cone of the rear test bearing. Do not remove the bearing for this operation. By placing the drop of sealant at one side of the shaft at a point level with the center of the shaft, the sealant will run toward the bottom of the shaft, capillary action carrying sufficient sealant into the space between shaft and bearing cone. Replace washer and locknut.

(h) Tighten rear locknut to a torque of 81 N°m (60 foot lbs), slack off nut, retighten to 68 N°m (50 foot lbs) and hold this torque for five or six seconds. Do not include prevailing torque (drag due to friction between nut and shaft in the 68 N°m [50 foot lbs]) value.

(i) Apply radial load by pumping up the hydraulic pressure to 10.3 MPa gage (1500 psig) (see note 3). Then start the machine.

(j) Take reading of total peak-to-peak drag on the load ring. If the drag is between 13.6 kg (30 lbs) and 15.9 kg (35 lbs), allow tester to run. If drag is beyond these limits, loosen locknut and retorque carefully. If drag is still beyond these limits, check whole machine including drag reading instrumentation. Should the drag remain beyond the limits of 13.2 kg (29 lbs) and 16.4 kg (36 lbs) disassemble and make new setup.

(k) Complete assembly of tester.

(1) Take readings of peak-to-peak drag twice a day, plotting drag against time. When drag reaches 27.3 kg (60 lbs) the bearings are considered failed and runs are complete (see note 4).

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Note 2. The sealant is a polymer which hardens only after being confined between closely fitted mating parts. Catalytic action of the metal, aided by absence of air, hardens the material in approximately four to six hours to a shear value of up to 6.9 MPa gage (1000 psig). It is sold under the trade name of Loctite Sealant, Type “A”, by American Sealants Company, Hartford 6, Connecticut. The sealant assures that the cone of the inner bearing will turn with the shaft, but does not interfere with the action of preload on test bearings.

Note 3. Air pressure in the hydraulic resevoir should be maintained at about 6.9 - 8.3 MPa gage (1000 - 1200 psig) for easy application of the load, and to reduce the amount of makeup fluid (MIL-H-5606 Hydraulic Fluid) required.

Note 4. If more than one tester is available, they should be run concurrently. This will minimize the effects of temperature variation, faulty instrumentation and unpredictable human variables, as well as reducing time of completion of tests.

LIST OF FIGURES:

7. CALCULATIONS

7.1 This section is not applicable to the test procedure,

8. REPORTING

8.1 Report the hours to failure.

9. PRECISION

9.1 Precision data have not been developed for this method.

Method Prepared by:

Navy - NADC - 1985

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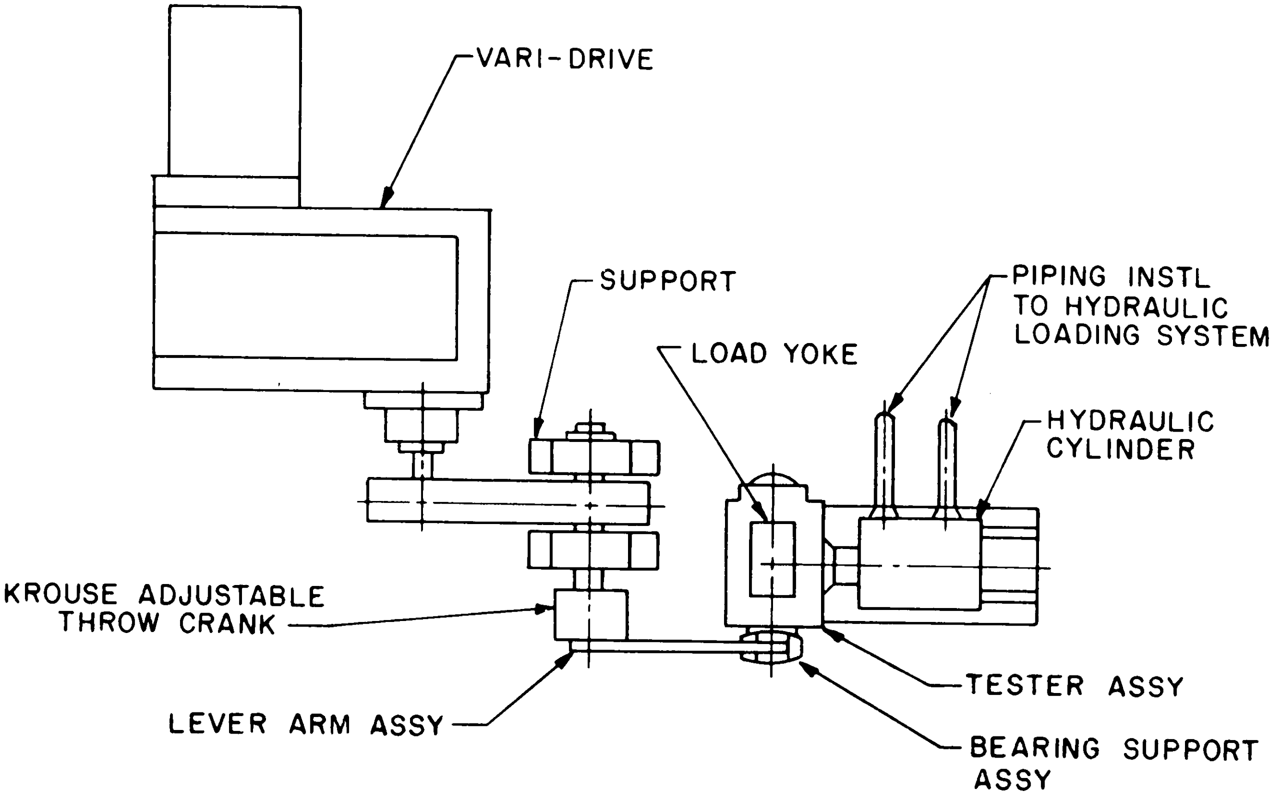

FIGURE 1. Sikorsky aircraft friction oxidation tester- SKF-1721-1.

X-4427

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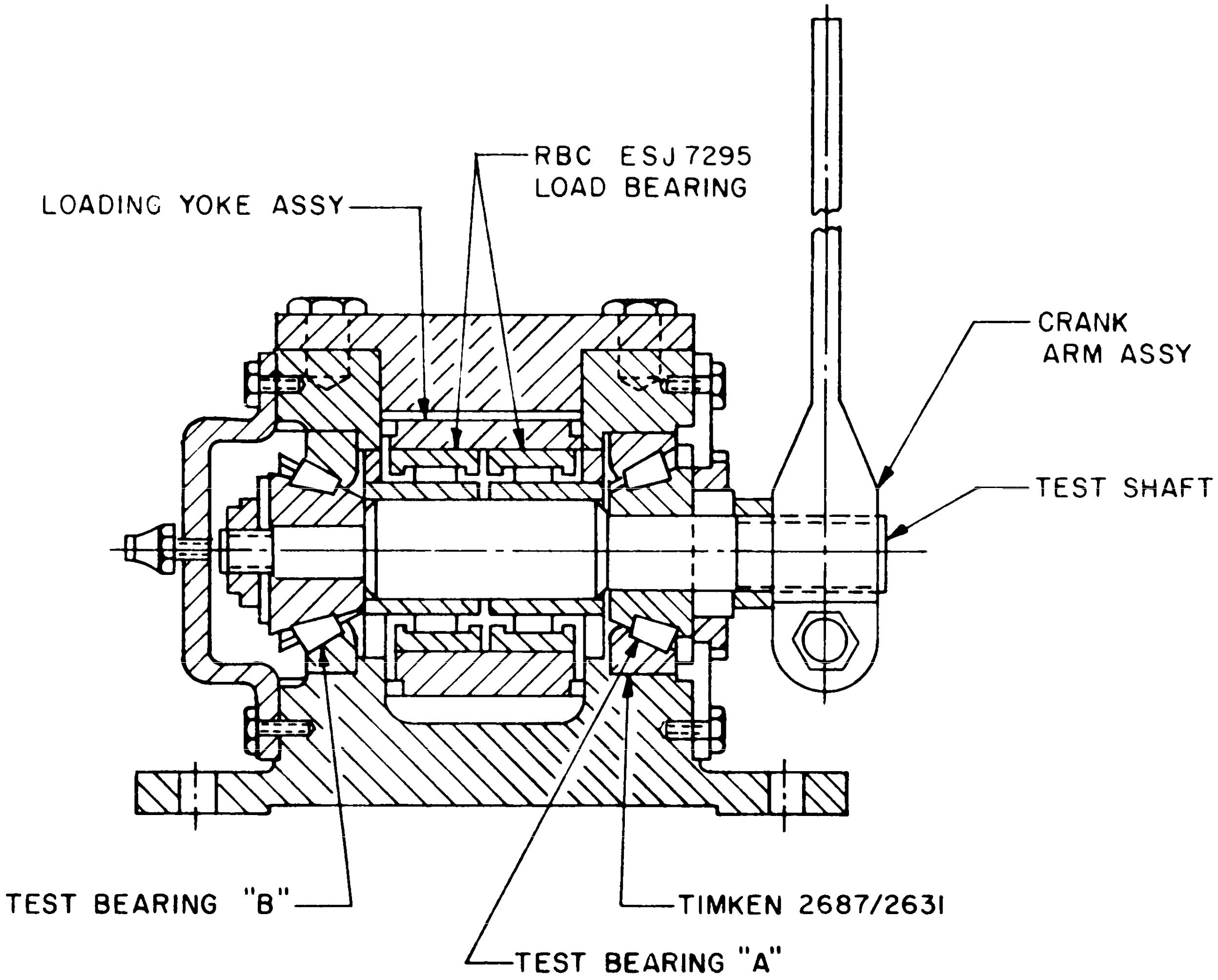

FIGURE 2. Bearing tester assembly-SKP-1903.

X-4428

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METHOD 6517
September 30, 1986

HIGH-TEMPERATURE GEAR LOAD-CARRYING CAPACITY OF LUBRICATING OILS

1. SCOPE

1.1 This method describes a procedure for determining the gear load-carrying capacity of lubricating oils at controlled test gear temperatures of 220° C (428° F) through 371° C (700° F).

2. SUMMARY

2.1 The method consists of subjecting the lubricant to a series of controlled temperature tests at increasing gear–tooth loads using a set of special spur test gears. Each tooth of one of the gears is examined to determine the working area scuffed after each load step. The load-carrying capacity of the lubricant is determined by the load, in pounds per inch of tooth width, required to produce 22.5 percent average scuff of the total working area of the examined test gear.

3. SAMPLE SIZE

3.1 Approximately 2L of test oil.

4. REFERENCES, STANDARDS, AND APPARATUS

4.1 Test unit. The apparatus in this method is the WADD gear machine, or equivalent, available from Erdco Engineering Corp. , Addison, IL. This apparatus consists of a WADD gear machine adapted to a modified Erdco universal tester drive stand, a support and load-oil system, a test-oil system, a radiometer, and induction heater, and the necessary instruments and controls.

4.1.1 WADD gear machine. The WADD gear machine operates on the same principle as the Ryder gear machine, the so-called “four-square” principle. However, improvements in material and design permit its operation at test gear temperatures up to 371° C (700° F). Double-row roller bearings are used to support the two parallel shafts, and screw-thread type nonrubbing seals are used to separate the test oil and support oil chambers. As shown on Figure 1, the two parallel shafts (P and Q) are connected by two slave gears (R and S) and two test gears (T and U) to form a “Square” so that the power required to operate the machine is only that required to overcome the friction losses in the gears and bearings. The slave gears are helical gears and are made as integral parts of the two shafts; the test gears are spur gears and are replaceable. Load on the test gears is obtained through the application of a controlled oil pressure in the load chamber (X), which causes an axial movement of one shaft relative to the other. A torsional load is thus applied upon the shafts due to the helical slave gears, thereby loading the test gears. The relation between the tooth load on the test gears and the load-oil pressure can be obtained by arithmetic calculation, calibration, or both. Arithmetic calculation is used herein.

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4.1.2 Test gears. The test gears are special spur gears, made of AMS 6475 steel, nitrided and ground, having 28 teeth, 8.89cm (3.5-inch) pitch diameter, 8 diametral pitch, 22.5 degree pressure angle, 0.0000 to 0.00025cm (0.000-to. 0.0001-inch) tip relief, and 0.0279 to 0.0356cm (0.011-to 0.014-inch) backlash. (Sier-Bath Gear Co., Inc., North Bergen, N.J., 07047, part No. SB-19293-AN, narrow gear; SB-19469-AN, wide gear; or equivalent.)

Note 1: The working area of the gear teeth is finish ground to the required profile after nitriding to remove the “white-layer” formed during the nitriding process.

Note 2: Each set of test gears comprises gears of two different widths. The narrow test gear is used for rating purposes. The mating gear is wider in order to maintain a constant contact width between the two gears at different tooth loads. Both sides of the test gears are used for testing. The “A” side of the gears refers to the side obtained by installing the test gears with the serial numbers facing the end cover. The “B” side is obtained by reversing the gears (serial numbers facing away from the end cover). Test gears can be used only once on each side and then discarded.

4.1.2.1 The entire web of each side of the narrow test gear must be electroplated with black chromium. The black chromium rings thus formed, extending from the root diameter of the gear teeth approximately 0.64cm (1/4-inch) toward the center of the gear, provides a continuous black body radiation surface for accurate test gear temperature measurement during test.

4.1.3 Drive system. An Erdco universal drive system, or equivalent, is used to drive the WADD gear machine. A 50-hp induction motor drives the machine through a variable speed dynamatic coupling, a step-up gearbox, and an adapter block to which the WADD gear machine is attached. The only modification required to the drive system is the relocation of the mounting studs in the end of the adapter block to match the holes in the WADD gear machine mounting flange. The test gear speed is controlled by adjusting the field excitation of the dynamatic coupling. By this means accurate speed control can be obtained at the specified test speed of 10,000 rpm.

4.1.4 Support and load-oil system. The support and load-oil system used with the WADD gear machine serves two purposes: To provide lubrication to all necessary parts except the test gears, and to supply load-oil pressure to the load chamber, and thus, the application of load to the test gears. A schematic diagram of the support and load-oil system is shown on Figure 2.

4.1.4.1 The system is charged with approximately 30 L (8 gallons) of lubricating oil, type MIL-L-7808 or MIL-L-6082, grade 1100. The support oil temperature measured at the distributing manifold, is maintained at a specified value of 74 ±2.8° C (165° +5° F), by means of electrical heaters located in the sump, and a water cooler located after the pump, through the action of thermoswitches.

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Pressure lines from the distributing manifold lubricate the bearings and helical gears, as well as the adapter housing and the step-up gearbox back to the support oil sump.

4.1.4.2 The action of the load oil circuit for the WADD gear machine is shown on Figures 2 and 3. Oil from the load adjusting valve, Figure 2, enters the WADD gear machine through the load chamber located at the rear of the driven shaft. Sufficient oil is provided to maintain a constant “load-oil pressure," and to allow for leakage past the load chamber seal. The load bypass valve is opened when it is desired to release the load-oil pressure quickly, such as at the end of a test run. The optional automatic recording load oil system, shown on Figure 3, affords automatic loading of the machine and a continuous recording of the load-oil pressure. In operation, the desired load is set on the indicator, the load is then automatically changed at a constant rate to the preset value and is recorded. The load is automatically released at the end of each test run by solenoid valves which release the control air pressure to the pneumatic valves allowing the valves to return to their respective normally closed and normally open positions.

4.1.5 Test-oil system. A test–oil system capable of maintaining a test-oil temperature of 205° C (401° F) is used with the WADD gear machine for high-temperature gear load-carrying capacity evaluations. A schematic diagram of the test-oil system is shown on Figure 4. The capacity of the test-oil system is 1 liter. Test oil is supplied to the test gears by means of a pressure pump through an inline filter and then to the jet, located on the unmeshing side of the gears. The oil is gravity drained from the test section through the flow check chamber and returned to the sump. Oil temperature to the test gears is maintained at 205° +2.8° C (401° +5° F) by means of two electrical band heaters located on the outside of the test-oil sump.

4.1.6 Radiometer. A Barnes R-4D1 industrial radiometer, or equivalent, is used in conjunction with the WADD gear machine to measure the narrow test gear temperature during test. The industrial radiometer consists of two components: (1) the temperature sensing optical head which is located inside the test cell, approximately 137cm (54-inchs) from the end cover of the WADD gear machine, and is aimed at the web of the narrow test gear through the hole provided in the gear machine end cover, and (2) the electronics and readout unit which is located in the control console of the test rig.

4.1.7 Induction heater. A Lepel T-5N-3, or equivalent, induction heater having a 5kW output at 450 kHz with a wide range continuous grid control is used to heat the test gears to the desired test temperature.

4.1.7.1 A load coil transformer is used in conjunction with the induction heater to minimize power loss from the induction heater. The load coil transformer is mounted inside the test cell approximately 38cm (15-inches) to one side of the WADD gear machine. The test gear heating coil, shown in Figure 5 without the end cover, is mounted inside the end cover of the WADD gear machine

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and is connected directly to the load coil transformer output terminals by removable, silver-plate connectors.

4.1.8 Instrumentation and controls. All except one of the instruments and controls that require constant attention during test are located on the control console, as shown on Figure 6. The one item requiring constant attention and not included in the control console is the induction heater. The induction heater power supply is normally located abutting the control console for convenience. Attention should be directed to the instruction manual for the specific induction heater used to determine the exact control method to use. Items that do not require frequent attention are located inside the test cell. The functions of most of the instruments and controls are apparent. Therefore, only selected items will be explained further.

4.1.8.1 Speed measurement and control. An electronic counter (Figure 6, item 10), located on the control panel, measures the speed. This instrument is actuated by pulses supplied by a variable reluctance pickup (the variable reluctance being provided by a 60-tooth gear operated from the driven shaft of the step-up gearbox). The rpm adjustment control (Figure 6, item 28), located on the console, regulates the field excitation of the dynamic coupling and thus the gear speed.

4.1.8.2 Control of test-run duration. An electric timer (Figure 6, item 16), located on the console, is used to control the duration of each test run. As soon as the desired test load and test gear temperature has been reached, the timer is started. After the 10-minute run is over, the timer automatically turns off the drive motor and opens the load-bypass valve. The timer switch must be moved to the “stop” position immediately following coast down of the machine.

4.1.8.3 Support-oil controls. The support–oil pump buttons (Figure 6, item 18) on the console are connected to the support-oil pressure pump as well. as the scavenge pumps. Pressing the start or stop button controls all pumps at the same time. The support-oil heater buttons (Figure 6, item 19) control both the electric heaters and the water cooler through the action of thermoswitches. The support-oil chamber vacuum is measured by a water manometer located on the test stand. A valve connecting the chamber to a vent (Figure 2) should be adjusted to give a chamber vacuum of approximately 2.54cm (l-inch) of water under normal test conditions.

4.1.8.4 Control of load-oil pressure. The control of load-oil pressure has been explained in 4.1.4.2. The load adjusting valve is air actuated and is controlled by the load-adjust control (Figure 6, item 6 or 15) located on the console. The load-bypass valve, is solenoid actuated and is controlled by the load-bypass switch (Figure 6, item 20) on the console. At the end of a run, the solenoid circuit will automatically be open by the electric timer. This opens the load-bypass valve, but the load-bypass switch on the console remains in the “close” position. For this reason, the switch must be turned to the “open” position prior to the next run.

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4.1.8.5 Emergency stop. The emergency stop button (Figure 6, item 26) on the console stops the driver motor and turns off all the controls except those for instruments . The timer switch and the load-bypass switch remain in the positions to which they were originally set.

4.1.8.6 Scuff rating equipment. A microscope and a light source are used for visual inspection of the narrow test gear. An optional closed circuit television camera and monitor (Figure 6, item 4) may be used for inspection of the narrow test gear. To inspect the narrow gear, the machine is first stopped. The inspection can then be made through special inspection holes provided in the gear-case end cover. These holes are closed by corks during the test run.

4.1.8.7 Inspection equipment. The standard 18-power microscope furnished with the Erdco Ryder gear machine, or euivalent, is slightly modified by the addition of a supplementary lens in the right objective-lens opening. The right eyepiece of the microscope contains a net reticule that divides the gear-tooth area lengthwise into seven sections. The grid lines provide a convenient means for the visual estimation of the percent of gear-tooth area that has been scuffed.

4.1.8.8 Gear-tooth indexing ratchet. An indexing ratchet is normally used for rotating the test gears so that the teeth of the narrow test gear can be inspected individually. If the optional closed circuit television camera and monitor are used, a television antenna rotor may be adapted to engage the output shaft of the step-up gearbox and provide the rotation of the narrow test gear for remote inspection.

4.1.8.9 Additional instruments:

a. Stop watch for oil flow-rate check.
b. Micrometer 0. to 2.5cm (0 to l-inch) for the measurement of the gross tooth width of the narrow gear.
c. Scale with divisions of 0.04cm (1/64-inch).
d. Set of conventional mechanical tools as necessary for assembly, disassembly, maintenance, and repair.

4.2 Test gear plating procedure.

4.2.1 The following procedure is used to plate the black chromium rings on the web of the narrow test gears:

1. Clean the gear with drycleaning solvent and rinse with petroleum ether.
2. Mask the area to be plated with masking tape. (The area to be plated includes the flat area on both sides of the narrow test gear between the root diameter of the gear teeth and the OD of the test gear hub, not including the fillet.)
3. Place the gear in a wire holder and immerse in hot platers wax. Dip the gear successively until the wax has formed a coating approximately 0.32cm (1/8-inch) thick on all gear surfaces.

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4. Allow the wax coating to cool and harden. Cut a groove in the wax coating with a knife to expose the masking tape.
5. Remove the masking tape to expose the area to be plated.
6. Lightly sand blast the exposed portion of the test gear using No. 30 grit aluminum oxide.
7. Immediately following the sand blast, the gear must be rinsed thoroughly with distilled water and placed in the nickel strike for 2 minutes.
8. Rinse the gear again with distilled water and place in the nickel plate batb. The nickel is plated to a thickness of approximately 0.0025cm (0.001 inch) (approximately 6 minutes).
9. Rinse the gear thoroughly with distilled water. It is important that all of the liquid nickel solution be removed from the gear and wire holder prior to proceeding to the chrome plate bath.
10. After thoroughly rinsing the gear in distilled water, place it in the chrome plate bath and plate until the nickeled area is uniformly covered with black chromium (approximately 20 minutes).
11. Rinse the gear thoroughly with distilled water. Remove the platers wax from the gear.
12. Clean the gear with dry cleaning solvent and rinse with petroleum ether.
13. Dip the cleaned test gear in standard reference oil and store in suitable container until required for test.

NOTE 3: Organic contamination of the nickel solution will produce a wrinkled, brittle-plated surface which flakes easily. Organic or chloride contamination of the chrome bath will produce a yellowish-brown plate which is unacceptable. If contamination of either bath exists, discard the solution and prepare new plating solution.

4.2.2 Test gear nickel strike and plating solution. Approximately 4 liters of nickel strike and plating solution is required, as follows:

a. Prepare the nickel strike and plating solution in a clean borosilicate glass beaker.
b. Add 3 L distilled water to 896 g purified crystalline nickelous chloride ($NiC1_2$) and dissolve the crystals.
c. Add 308 g reagent grade hydrochloric acid (HC1) to the solution.
d. Add additional distilled water to make approximately 3.785 L of solution.

4.2.3 Black chromium plating solution. Approximately 3.8L (one gallon) of black plating solution is required, as follows:

a. Prepare the chromium plating solution in a clean borosilicate glass beaker.
b. Dissolve 1 kg reagent grade crystalline chromium trioxide ($Cr0_3$) in 3.785 L distilled water.
c. Add 1/4 g reagent grade crystalline silver nitrate ($AgN0_3$). Stir solution, cover and place in a dark area for 4 hours.

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d. Decant and discard precipitate.
e. Add 1 g reagent grade barium carbonate ($BaC0_3$). Stir solution, cover and place in dark area for 4 hours.
f. Decant and discard precipitate.
g. Add 1 g hydrochloric acid. Stir solution, cover and store in dark area until bath solution is required for plating.

4.2.4 Plating apparatus. The following apparatus is required for plating the test gear:

a. Ring stand or other suitable rack from which the wire gear holder may be suspended.
b. DC power supply (6 to 8 volts with variable power output of 0 to 20 amperes).
c. Nickel bar stock, approximately 5cm (2 inches) X 15cm (6 inches) X 0.64cm (1/4 inch), is used for electrodes in the nickel strike and nickel plate bath.
d. Sheet lead, approximately 15cm (6 inches) X 20cm (8 inches) X 0.32cm (1/8 inch) thick, is used for electrodes in the black chrome plate bath.
e. Plastic covered, 9 gage, copper wire is used to connect the power supply to the electrodes.

4.2.5 Plating conditions. The following conditions are used for the strike and plating baths:

	Solution temp.	Plating time, min	Power, amp	Gear polarity
Nickel strike	68.3° +2.8° C (155° ±5° F)	2	0.5	Positive
Nickel plate	68.3 ±2.8° C (155° ±5° F)	6	0.5	Negative
Black chrome plate	29.4° ±2.8° C (85° ±5° F)	20	13.0	Negative

5. MATERIALS

5.1 CAUTION - SOME MATERIALS ARE TOXIC AND HAZARDOUS. The materials references and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precautions, is a reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Lubricating oil, MIL-L-7808 or MIL-L-6082/ Grade 1100.

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5.3 Dry cleaning solvent (ASTM D 484, type I)[0,2,0].

5.4 Petroleum ether (60° C-90° C)[1,4,0].

5.5 Platers wax [u,u,u].

5.6 No. 30 grit aluminum oxide.

5.7 Purified crystalline nickelous chloride ($NiC1_2$)[u,u,u].

5.8 Reagent grade hydrochloric acid (HC1)[3,0,0].

5.9 Reagent grade crystalline chromium trioxide ($Cr0_3$)[u,u,u].

5.10 Reagent grade crystalline silver nitrate ($AgN0_3$)[u,u,u].

5.11 Reagent grade barium carbonate ($BaC0_3$)[u,u,u].

5.12 Hydrochloric acid [3,0,0].

5.13 Nickel bar stock [u,u,u].

5.14 Sheet lead [u,u,u].

5.15 Standard reference oil to be obtained from USAF Aero Propulsion Lab, AFWAL/POSL, Wright-Patterson AFB, OH 45433-6563 [u,u,u].

6. PROCEDURE.

6.1 Operating Conditions

6.1.1 Throughout the entire test, the test gear temperature is controlled at 220° +2.8° C (428° +5° F), or the value required by the applicable lubricant specification. Table 1 presents a list of additional operating conditions which are also controlled within the limits specified. With the tester operating within the specified limits, the test gears are loaded first to 34.5 kPa gage (5 psig) load oil pressure (nominal 230 lb/in tooth load), and then at successive increments of 34.5 kPa gage (5 psi). The duration of each loading period is 10 minutes ±5 seconds. At the end of each 10-minute loading period, the tester is stopped and each tooth of the narrow test gear is examined to determine the percent of tooth area scuffed.

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Table 1. Operating Conditions.

Condition	Value
Test gear temperature.	220° ±2.8° C (428° ±5° F)
Test gear speed, rpm.	10,000 ±10
Test-oil inlet temperature.	205° ±2.8° C (401° ±5° F)
Test-oil flow rate, mL/min.	(270 ±5)
Test-oil pressure.	103.4 +34.5 kPa gage (15 ±5–psig)
Support-oil inlet temperature.	73.9° +2.8° C (165° ±5° F)
Support-oil pressure. To load-oil system.	827.4 ±69 kPa gage (120 ±10 psig)
To stepup gearbox. To WADD gear machine.	241 ±34.5 kPa gage (35 ±5 psig)
Airflow to seals.	0.33 ±0.047 L/see (0.70 ±0.10 cfm)

6.2 Test Procedures.

6.2.1 Preparation for test.

1. Turn on main electric switch and main water valve to test cell.
2. Push instrument button to “ON” position.
3. Push support oil sump heater button to “ON” position.
4. Turn radiometer function switch to “READY” position.
5. Turn on power supply to induction heater and place induction heater filament switch in “ON” position.
6. Inspect test-oil system to see that it was thoroughly cleaned and dried after previous test.
7. Remove gear-case end cover.
8. Clean a set of new plated test gears with petroleum ether, and dry with air.
9. Measure gross tooth width of the narrow test gear with a micrometer, and record.

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10. Install test gears on proper shafts with the serial number facing outward (narrow gear on drive shaft, wide gear on driven shaft), matching timing marks on shafts and gears. Check for proper setting of the retaining nuts and lockwashers. After tightening the retaining nuts, bend one tang of each lock washer to lock the retaining nuts in position.
11. Loosen the locknut on the driven-shaft adjusting pin (at rear of gear case), and unscrew adjusting pin until driven shaft is free to move to the extreme rearward position without touching the adjusting pin. Using a scale set adjusting pin so that the driven shaft can move through only one-half of the normal free travel (from extreme rearward position to extreme forward position). Tighten locknut on adjusting pin.
12. Reinstall gear-case end cover with induction heating coil.
13. Connect induction heating coil in end cover to load coil transformer. Visually check position of induction heating coil relative to the test gear hubs.

NOTE 4. The induction heating coil should not touch either test gear and should be insulated from the test end cover. An ohm meter may be used to insure that the coil is insulated from the end cover and test gears.

14. Turn on water supply to induction heater load coil transformer and induction heating coil.
15. Turn on ventilating blower in load coil transformer.
16. Turn on ventilating blower connected to gear-case end cover.
17. Turn on air to nonrubbing seals. Adjust to approximately 6.9 kPa gage (1 psig).

NOTE 5: Approximately 0.33 L/see (0.7cfm) of air (total for both air seals) is required for the nonrubbing air seals to function correctly.

18. Fill test-oil sump with approximately 1 L of test oil.
19. Start test-oil pump motor, and immediately open test-oil drain line from test-oil pressure gage and pressuretrol to allow new test oil to fill the line to the gage and pressuretrol. Close test-oil drain line.
20. Push test-oil heater button to “ON” position.
21. Allow approximately 20 minutes to elapse after turning support oil sump heaters on (step 3). Then start support oil pumps.
22. Turn timer switch to “STOP” position.
23. Check electric timer to insure it is set to 10 minutes and O seconds, then lock timer dial.
24. Turn rpm-adjust control to “ZERO” position.
25. When the support–oil temperature is up to the specified value of 73.9° +2.8° C (165° +5° F), adjust the support oil supply pressure to the required values.

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26. Check calibration of the rpm counter by setting the input-sensitivity control to the "CHECK" position and the gate-selector switch to the "ONE SECOND" position. The counter should read "60." After checking, turn the input-sensitivity control to about midscale.

27. When the test-oil temperature is up to the specified value of 205° +2.8° C (401° +5° F), check the test-oil flow rate as follows: Adjust the speed of the test-oil pump motor until the test-oil flow is approximately 270 mL per minute. Turn flow-check valve (Figure 4) to the closed position, and measure the time required to fill the flow-check chamber to the tip of the wire indicator. The time required should be 30 seconds. Turn flow-check valve to the open position to allow the test oil to drain to the test-oil sump. If the time required to fill the flow-check chamber to the tip of the wire indicator varies from the 30-second requirement by more than one second, readjust the test-oil pump motor speed and recheck test-oil flow rate as above.

NOTE 6: The test-oil in pressure is maintained at 103.4 +34.5 kPa gage (15 +5 psig). If the test-oil pressure is outside the specified–range, a different size test-oil jet must be used. The test-oil jet sizes normally used are 0.066 and 0.081cm (0.26- and 0.032-inch) diameter, depending upon the test oil viscosity.

28. Turn radiometer function switch to "NORMAL RANGE" positon.
29. Check radiometer temperature detector spot position on narrow test gear. Refocus temperature detector if necessary.

NOTE 7: The radiometer temperature detector must be focused accurately on the black chromium ring of the narrow test gear to insure correct test gear temperature indication.

6.2.2 Test sequence on "A" side of test gears.

NOTE 8: The "A" side of the gear refers to the side obtained by installing the test gears with the serial numbers facing the gear-case end cover. The "B" side is obtained by reversing the test gears such that the serial numbers face the gear case.

1. Turn radiometer function switch to "READY" position.
2. Recheck test-oil flow rate as in step 27 of 6.2.1.
3. Determine radiometer reference temperature using null meter on radiometer

NOTE 9: The reference temperature must be subtracted from the predetermined test gear operating temperature. After determining this difference, use this value to determine from a temperature/radiometer reading calibration chart the radiometer reading which must be maintained during the test run.

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4. Set radiometer scale selector to appropriate scale for test temperature desired.
5. Turn radiometer function switch to “NORMAL RANGE” position.
6. Turn on air supply to automatic load-control unit.
7. Check to see that the rotating device of the gear-tooth inspection equipment is in the disengaged position.
8. Check automatic load-control set point to see that load set point is on “O.“
9. Start drive motor.
10. Increase gear speed by turning rpm-adjust control clockwise until the specified 10,000 +100 rpm is obtained.
11. Turn on power to induction heater plate and slowly adjust plate control until the radiometer reading determined in step 3 is obtained.
12. Set automatic load-control set point to 34.5 kPa gage (5-psi) load-oil pressure.
13. Check gear speed, and adjust if necessary.
14. Check gear temperature, and adjust plate control if necessary.
15. Turn timer switch to “START” position. The 10-minute run now begins.
16. Maintain the test gear temperature and speed at the predetermined specified values.
17. Record all pertinent data about midway of the test run.
18. At the end of the 10-minute run, the timer will automatically turn the power off to the drive motor and reduce the load to zero. However, the timer switch will remain in the “START” position, the rpm-adjust will remain in the running position, and the load set point will remain at the previously set load position. Restore these to their respective “OFF” positions.
19. Turn induction heater plate power off.
20. Make visual scuff inspection of each tooth of the narrow test gear as follows:

    a. Turn 3-way valve (Figure 4) to bypass the gear machine and return the test oil to the sump.
    b. Remove corks from inspection holes in the gear-case end cover.
    c. Install microscope or television camera and inspection light.
    d. Focus microscope and adjust grid lines over the contact area of the tooth.
    e. Set indexing–rachet wheel to “No. 1“ position.
    f. Estimate the percent scuff of No. 1 tooth as accurately as possible but at least to the nearest 5 percent, and record the value (see Figure 7).
    g. Operate the test gear rotating device to give No. 2 tooth, and repeat f. Repeat for No. 3 tooth, etc, until all 28 teeth have been examined.
    h. Remove inspection equipment and replace corks in holes.
    i. Lock test gear rotating device in disengaged position.
    j. Turn 3-way valve to running position.

21. Repeat step 3 of 6.2.2.
22. Repeat steps 7 through 20 at the next test load of 69 kPa gage (10 psig) load-oil pressure.

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23. Continue the test at 34.5 kPa gage (5-psi) load-oil pressure increments until the average scuffed area for all 28 teeth is close to 22.5 percent. At this juncture, visually estimate the percent effective tooth width to the nearest 1 percent, and record the value.
24. Further continue the test at 34.5 kPa gage (5-psi) load-oil pressure increments , until an approximate average scuffed area of 30 percent or more is obtained.
25. Push test-oil heater button to “OFF” position.
26. Push support-oil heater button to “OFF” position.
27. Push support-oil pressure button to “OFF” position.
28. Turn radiometer function switch to “READY” position.
29. Switch induction heater power supply to “OFF” position.
30. Turn off water supply to induction heater load coil transformer and induction heating coil.
31. Turn off ventilating blower connected to gear-case end cover.
32. Remove test-oil sump, take 50-mL test-oil sample, and measure the amount of test-oil remaining. Record the amount of test-oil measured plus the 50-mL sample.
33. Disconnect induction heating coil from load coil transformer.
34• Disconnect ventilating blower from gear-case end cover.
35. Remove gear-case end cover.
36. Reverse test gears so that the serial numbers face toward the gear case again matching the timing marks on the shafts and test gears. Check for proper seating of the retaining nuts and lockwashers. After tightening the retaining nuts, bend one tang of each lockwasher to lock the retaining nuts in position.
37. Adjust driven shaft in accordance with 6.2.1, step 11.
38. Rinse face of gear case and test gears with petroleum ether and blow off with compressed air.
39. Rinse inside of gear-case end cover, including the test-oil jet, with petroleum ether and blow off with compressed air.
40. Blow out test-oil jet with compressed air.
41. Reinstall gear-case end cover and connect induction heating coil to load coil transformer.
42. Reinstall ventilating blower to gear-case end cover.
43. Clean test-oil line screen filter with petroleum either. Blow out line screen filter with compressed air.
44. Rinse test-oil sump, lines, pump, and inlet filter with petroleum ether and blow off with compressed air.
45. Reassemble test-oil system.

6.2.3 Test sequence on “B” side of test gears.

1. Turn on water supply to induction heater load coil transformer and induction heating coil.
2. Turn on ventilating blower connected to gear-case end cover.

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3. Proceed on "B" side of the test gears by following the procedure outlined in 6.2.1, steps 18 through 29, and 6.2.2, steps 1 through 35.
4. Remove used test gears.
5. Rinse gear-case face and shaft ends with petroleum ether.
6. Rinse gear-case end cover and test-oil jet with petroleum ether.
7. Reinstall gear-case end cover (without test gears).
8. Turn radiometer function switch to "OFF" position.
9. Place induction heater filament switch in "OFF" position.
10. Turn off power supply to induction heater.
11. Turn rpm counter to "OFF" position.
12. Push instruments button "OFF".
13. Turn off main electric switch to test cell.
14. Turn off main water valve to test cell.

6.2.4 Emergency stop.

1. Push emergency stop button.
2. Push instruments button "OFF."
3. Turn off induction heater power supply.
4. Turn off main water valve to test cell.

6.3 Inspection and rating.

6.3.1 Scuffed area. The scuffed area of a gear tooth is that area from which the axial grinding marks have been removed by scratching, scoring, abrasion, and wear. As shown on Figure 7, area A and B are scuffed; area C is not scuffed. Note that only the actual working portion (areas A plus B plus C) of the tooth surface is considered in the definition of areas.

6.3.2 Percent of tooth area scuffed. The percent of tooth area scuffed is that portion of the working surface of a gear tooth that has been scuffed.

Referring to Figure 7,

$$\text{Percent tooth area scuffed} = \frac{\text{scuffed area X 100}}{\text{working area}}$$

$$= \frac{A \pm B}{A \pm B \pm C} \text{ X } 100$$

The percent of tooth area scuffed is estimated visually to the nearest 5 percent for each individual tooth, with the aid of a net reticule mounted in the eyepiece of the inspection microscope, or a grid placed over the monitor tube.

6.3.3 Average percent of tooth area scuffed. The average percent of tooth area scuffed is the algebraic average of the percent of scuffed area of all 28 teeth of the narrow test gear. Calculate this value to the nearest 1 percent.

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6.3.4 Effective tooth width. The effective tooth width is the actual width of the narrow-gear tooth that is in contact with the tooth of the wide gear. For test gears currently available, the percentage effective tooth width may be taken as 98 percent of the gross tooth width by means of a micrometer. See 7.1 for calculation.

6.3.5 Load-carrying capacity. The load-carrying capacity of a lubricant is defined as the gear-tooth load at which the average percent of tooth area scuffed is 22.5 percent for the narrow test gear as determined by the method outlined herein.

6.3.5.1 Determination of load-carrying capacity. Using semilog paper (Figure 10), plot the average percent of tooth area scuffed for the narrow test gear versus the load-oil pressure. Determine from the plotted curve the load-oil pressure at which the average percent of tooth area scuffed is 22.5 percent. Calculate load-carrying capacity, see 7.2.

6.4 Relative rating procedure. This procedure consists of reporting the load-carrying capacity of an oil under test as a percentage of the load-carrying capacity of a standard reference oil obtained using the same test apparatus. Details of this relative rating procedure are given in the following paragraphs:

6.4.1 Determination of reference oil average rating.

NOTE 10: All load-carrying capacity tests on the standard reference oil are conducted in accordance with ASTM D 1947 using AMS 6260 steel test gears at 165° F test temperature conditions.

6.4.1.1 For a new rig, at least eight determinations (four gears) shall be conducted on the standard reference oil. If the high and low values obtained do not differ by more than 140 N/m (800 lb/in), the average is taken as the reference oil rating. If the high low values differ by more than 140 N/m (800 lb/in), four additional determinations (two gears) shall be conducted and the average of the 12 determinations taken as the reference oil rating.

6.4.1.2 After a major overhaul to a rig such as a bearing or shaft replacement, four determinations (two gears) shall be conducted on the standard reference oil. If the average of these ratings does not differ from the average obtained prior to the overhaul by more than 52.56 N/m (300 lb/in), and the high and low valves obtained do not differ by more than 140 N/m (800 lb/in), this average will be taken as the reference oil rating. If the ratings obtained do not meet the above criteria, four additional determinations (two gears) shall be conducted and the average of all eight determinations taken as the reference oil rating.

6.4.1.3 At least two determinations (one gear) shall be conducted on the standard reference oil for each 20 determinations made on oils under test. The reference oil rating is a progressive rating in that it consists of the average

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value obtained on the last eight determinations, i.e. , when two new determinations are conducted, the two oldest determinations of the eight determinations used in determining the previous reference oil rating are dropped, the two new ratings replace them and a new reference oil rating are dropped, the two new ratings replace them and a new reference oil average rating is obtained. The sole exception to the above is where it is necessary to run 12 determinations to establish an average on a new rig. (See 6.4.1.1)

NOTE 11: Maximum and minimum acceptable average ratings for the reference oil are 578.1 N/m (3300 lb/in) and 438 N/m (2500 lb/in), respectively. Rigs which do not give an average reference oil rating within these limits shall not be considered as being satisfactory. Faulty maintenance practices, improper test procedures, or the need for major overhaul can be indicated if the average on the reference oil does not fall within these limits.

6.5 Data Sheets

6.5.1 The suggested data sheets are shown on Figures 8 and 9. These sheets have areas provided to enter all pertinent information obtained during test and inspection.

7. CALCULATIONS

7.1 Calculate the effective tooth width using following equation:

$$W_2 = 0.98W_1$$

W_2 = effective tooth width in cm (inches).

W_1 = measured gross tooth width in cm (inches).

7.2 Calculate the load carrying capacity from the following equation:

$$P = \frac{KL}{W_2}$$

P = load-carrying capacity of the lubricant in N/cm (pounds per inch) of tooth-face width.

K = WADD gear machine constant (11.5 by definition).

L = load-oil pressure Pa gage (psig).

W_2 = effective tooth-face width in cm (inches).

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8. REPORTING

8.1 Report the following items:

a. The individual ratings of the test oil obtained from the "A" and "B" sides of all gears tested in N/cm (pounds per inch) of the tooth-face width (6.3.5.1).

b. The average rating of the test oil in N/cm (pounds per inch) of tooth-face width.

c. The standard reference oil average rating in N/cm (pounds per inch) of tooth-face width (6.4.1).

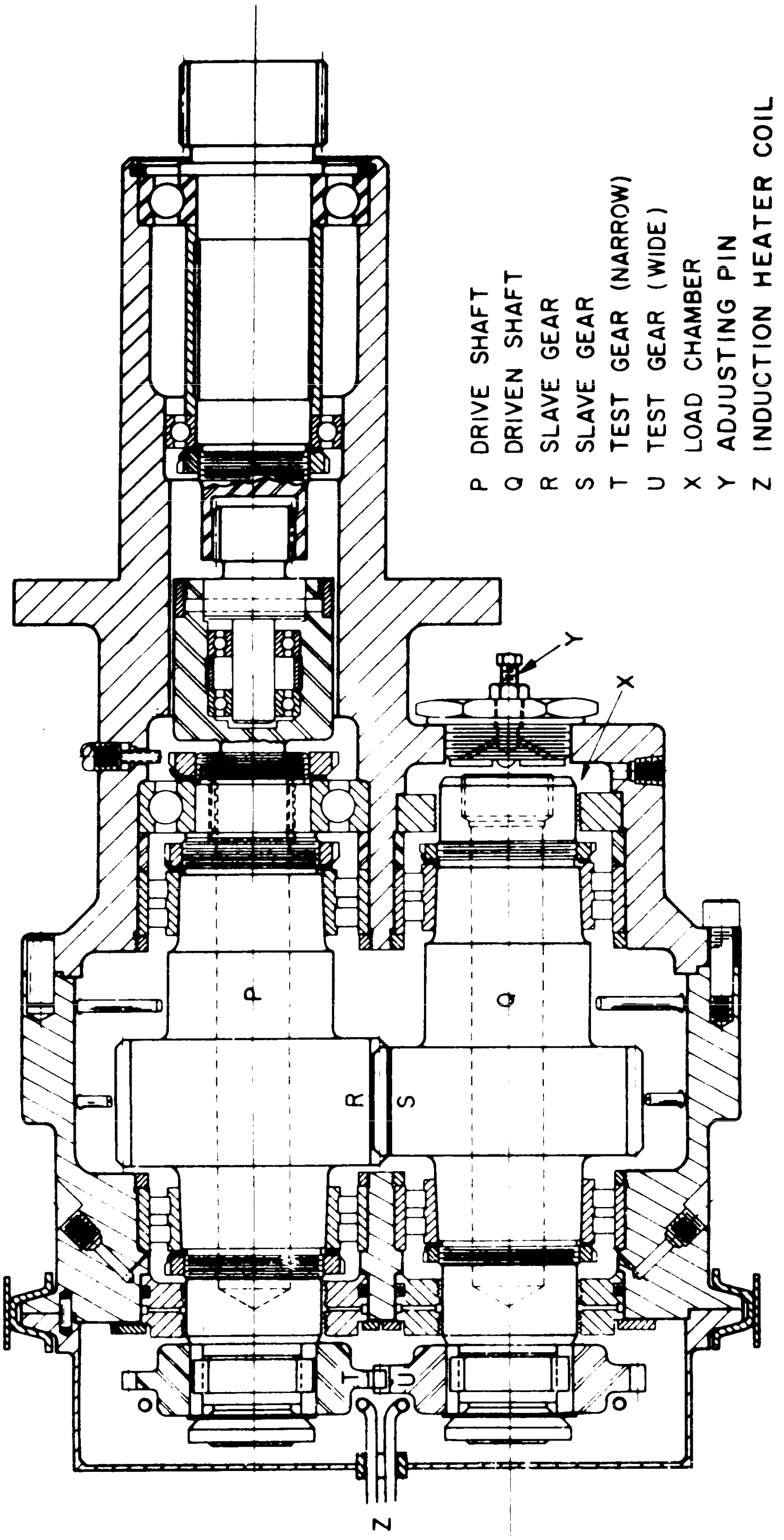
d. The relative rating of the test oil in percent

$$= \frac{\text{Test oil average rating}}{\text{reference oil average rating}} \times 100$$

9. PRECISION

9.1 Precision data have not been developed for this method.

Method prepared by:
Air Force - AFWAL/POSL - 1986



P DRIVE SHAFT
Q DRIVEN SHAFT
R SLAVE GEAR
S SLAVE GEAR
T TEST GEAR (NARROW)
U TEST GEAR (WIDE)
X LOAD CHAMBER
Y ADJUSTING PIN
Z INDUCTION HEATER COIL

FIGURE I. Cross section of WADD gear machine.

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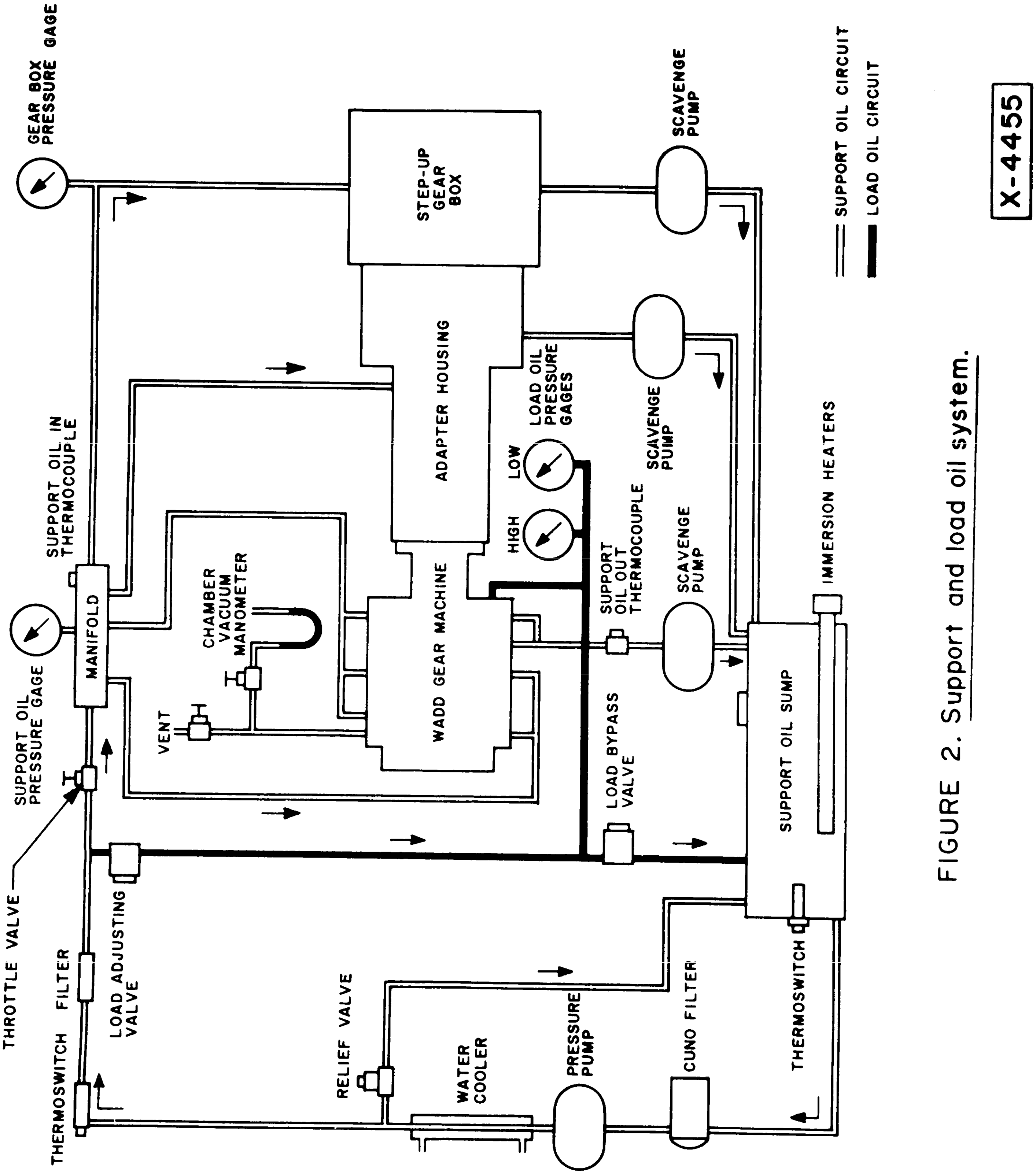

FIGURE 2. Support and load oil system.

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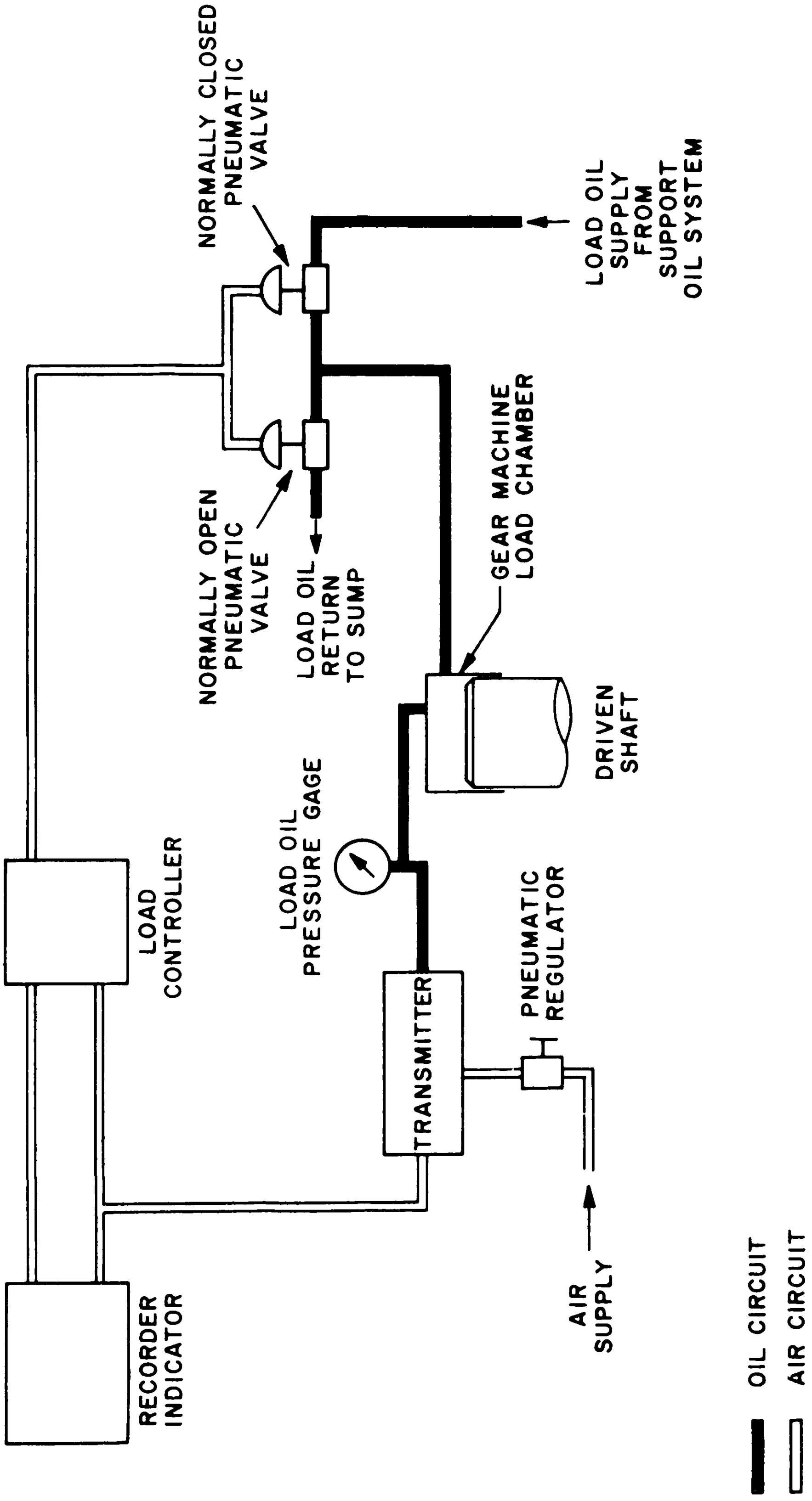

FIGURE 3. Optional automatic-recording load oil system.

X-4456

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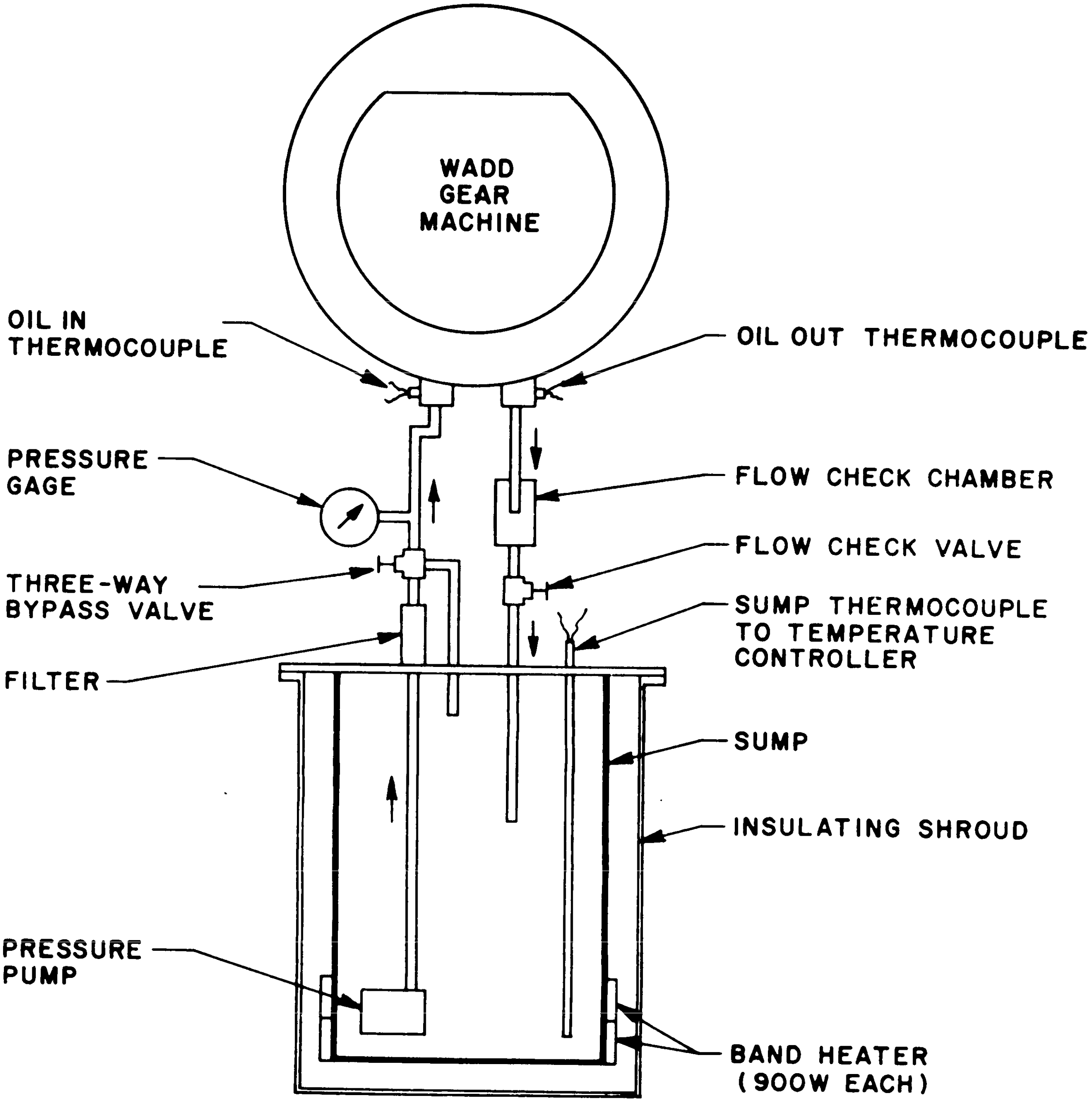

FIGURE 4. Test oil system.

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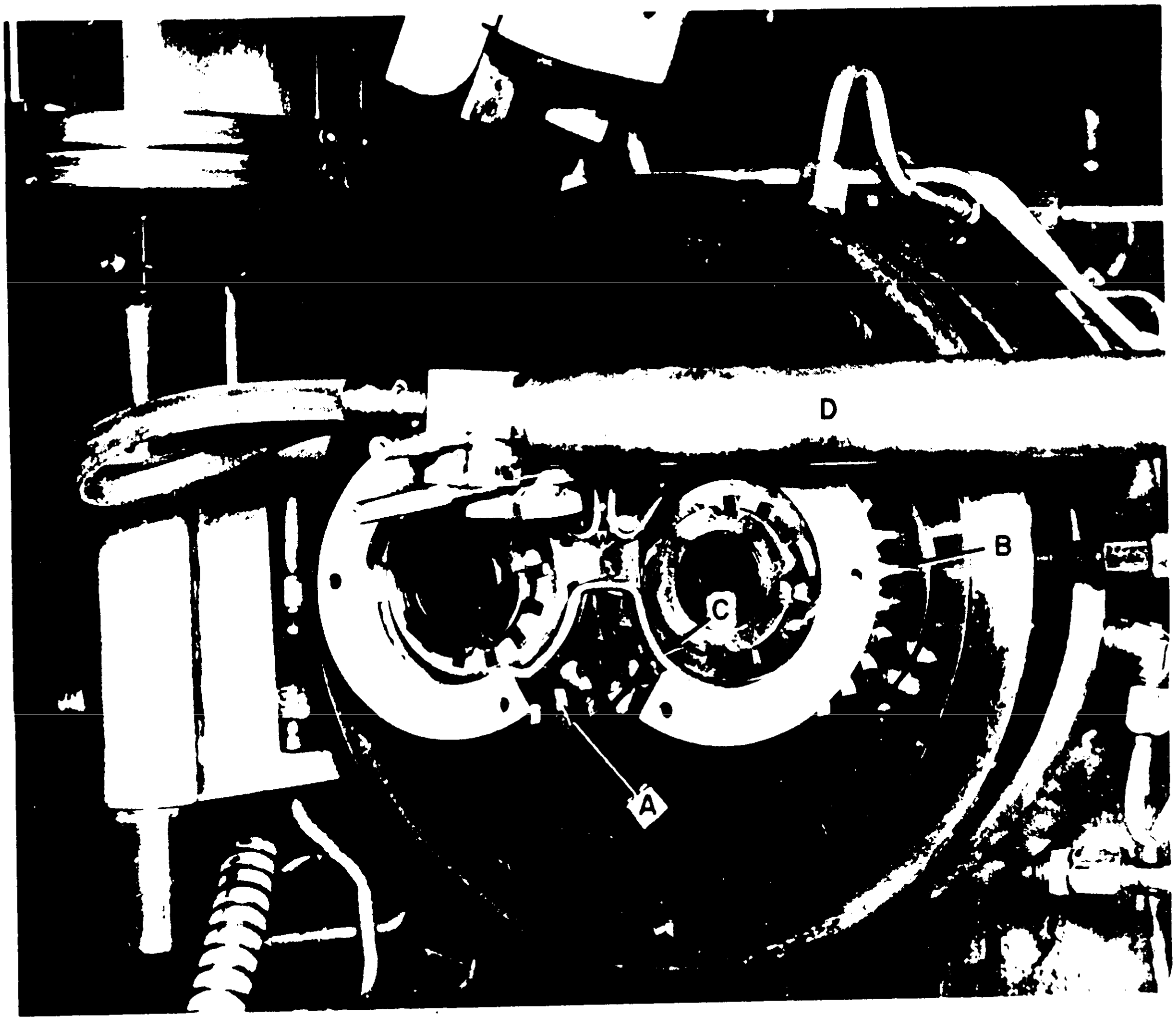

A. Narrow test gear
B. Wide test gear
C. Induction heating coil
D. Connector from load coil transformer

FIGURE 5. WADD gear machine with high-temperature test gears and induction heating coil installed.

X-4458

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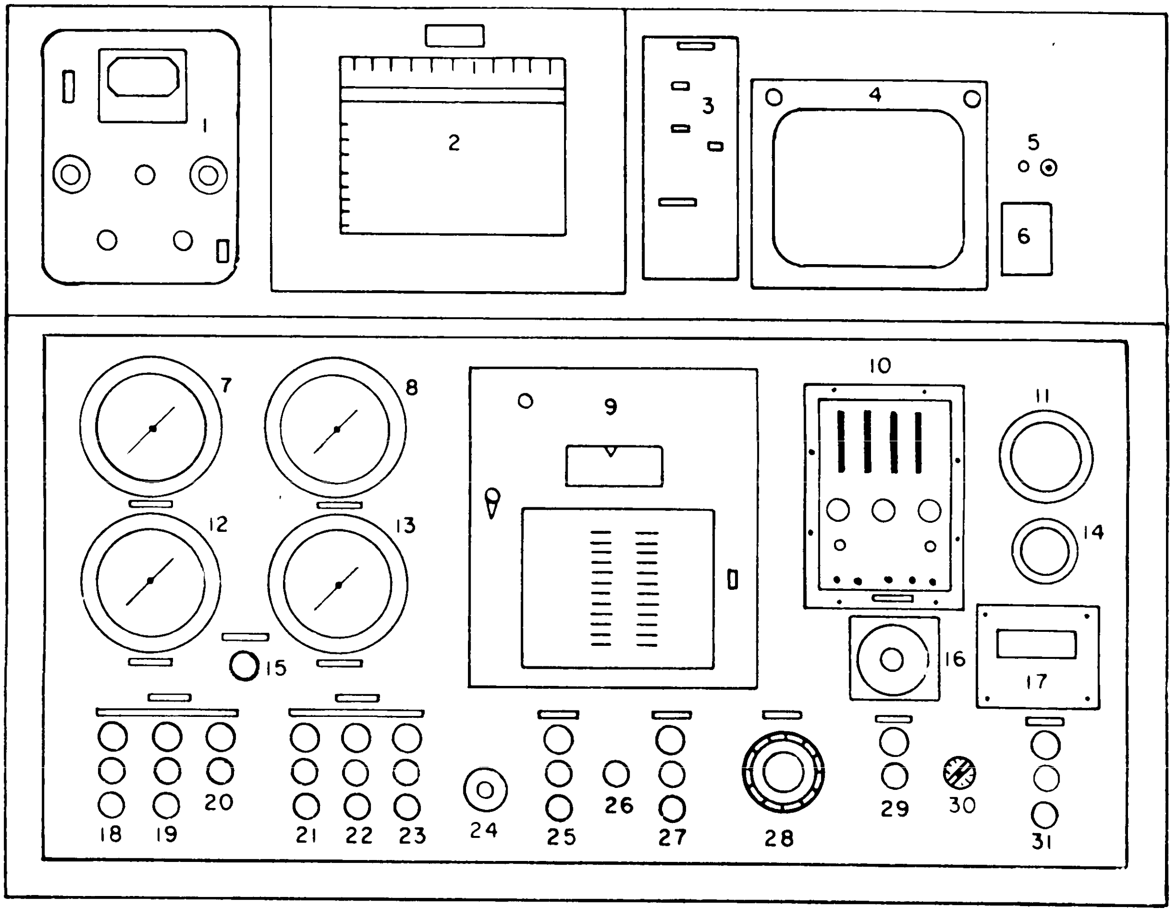

1. Radiometer
2. Radiometer output recorder
3. Television monitor controls
4. Television monitor
5. Automatic load-adjust control on-off switch
6. Optional automatic load-adjust control and recorder
7. Support-oil pressure gage
8. Test-oil pressure gage
9. Multi-point temperature indicator
10. Electronic rpm counter
11. Gear-box pressure gage
12. Load-oil pressure gage (high range)
13. Load-oil pressure gage (low range)
14. Running-time meter
15. Standard load-adjust control
16. Electric timer
17. Test-oil sump temperature controller
18. Support-oil pumps start-stop buttons
19. Support-oil heaters on-off buttons
20. Load bypass open-close switch
21. Test-oil pressure pump start-stop buttons
22. Not used
23. Test-oil heaters on-off buttons
24. Air supply valve
25. Instruments on-off buttons
26. Emergency stop button
27. Drive motor start-stop buttons
28. RPM-adjust control
29. Timer start-stop switch
30. Inspection light voltage control
31. Not used

FIGURE 6. WADD gear machine control console.

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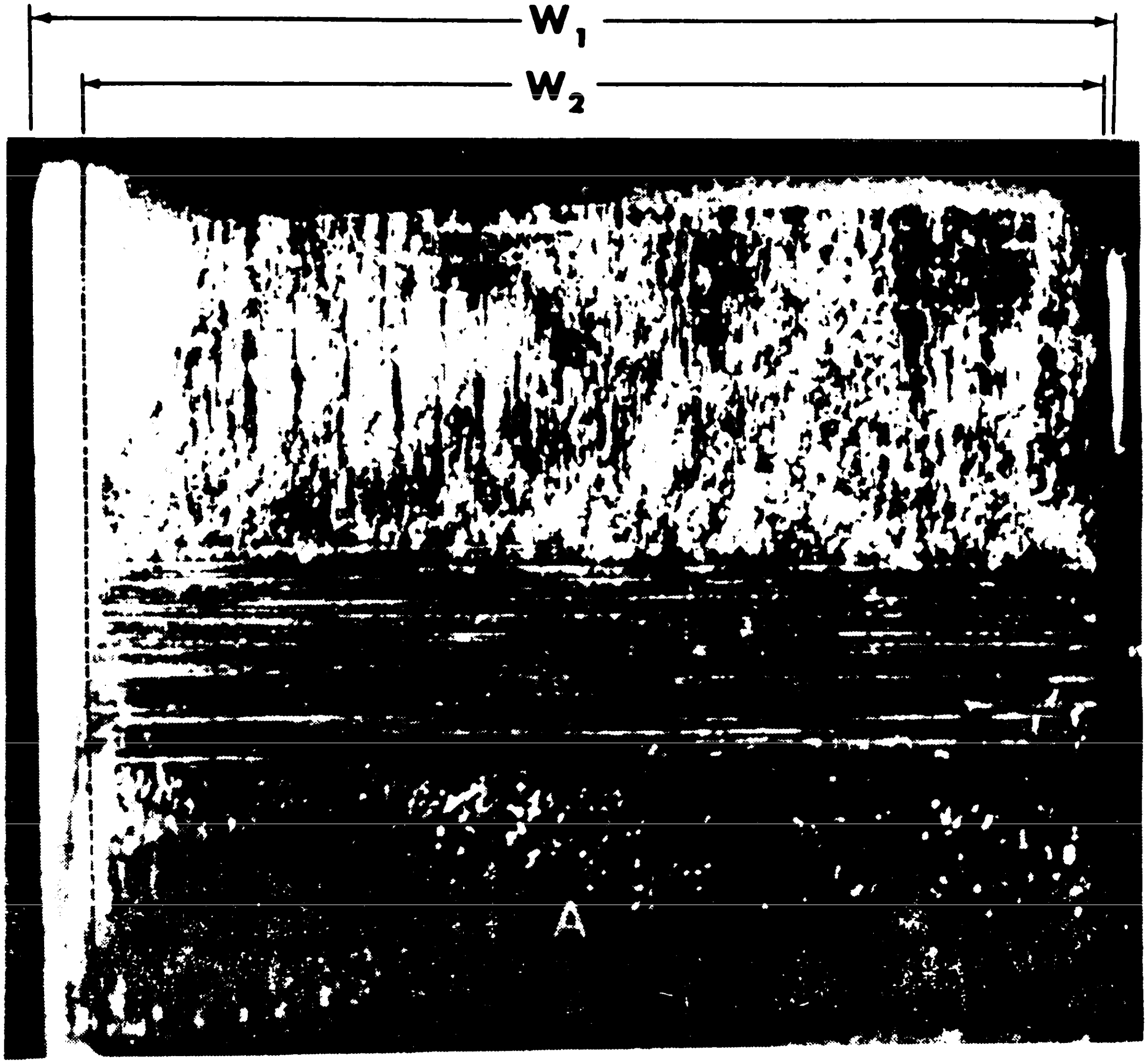

Area "A" .... Scuffed
Area "B" .... Scuffed
Area "C" .... Not Scuffed

W_1 = Gross tooth width
W_2 = Effective tooth width

Figure 7. Scuffed Tooth (Enlarged)

X-4414

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204°C (400°F) LOAD-CARRYING CAPACITY TEST
OPERATING CONDITIONS DATA SHEET

RIG NO. ____________ MACHINE NO. ____________ TIME METER AT START OF TEST ________ TEST NO. ____________

WIDE GEAR NO. ____________ NARROW GEAR NO. __________ GEAR SIDE __________

RECORD THE FOLLOWING AFTER 5 MINUTES AT EACH LOAD

LOAD GAGE kPa, (PSIG)	34 (5)	69 (10)	103 (15)	138 (20)	172 (25)	207 (30)	241 (35)	276 (40)	310 (45)	345 (50)	379 (55)	414 (60)	448 (65)	483 (70)	517 (75)	551 (80)	586 (85)	620 (90)	655 (95)	689 (100)	723 (105)	758 (110)	792 (115)	827 (120)
TIME																								
S.O. PRESS GAGE kPa, (PSIG)																								
T.O. PRESS GAGE kPa, (PSIG)																								
T.O. "IN" TEMP °C, (°F)																								
S.O. "IN" TEMP °C, (°F)																								
S.O. "OUT" TEMP °C, (°F)																								
T.O. SUMP TEMP °C, (°F)																								
S.O. SUMP TEMP °C, (°F)																								
OPERATOR'S INITIALS																								

TEST OIL FLOW, TIME FOR 270 mL: ____________ SECONDS

REMARKS: ____

FIGURE 8. Operating conditions data sheet.

X-4424

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204°C (400° F) LOAD-CARRYING CAPACITY TEST
GEAR TEETH INSPECTION DATA SHEET

TEST OIL CODE ______ DATE ______ WIDE GEAR NO. _____ NARROW GEAR NO. _____ TEST NO. _____

GROSS TOOTH WIDTH ____________ ESTIMATED TOOTH WIDTH ___________ % GEAR SIDE _________

TOOTH NO.	PERCENT OF TOOTH AREA SCUFFED																							
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120
1																								
2																								
3																								
4																								
5																								
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22																								
23																								
24																								
25																								
26																								
27																								
28																								
TOTAL %																								
AVE %																								

FIGURE 9. Gear teeth inspection data sheet.

X-4425

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204°C(400°F)LOAD CARRYING ABILITY TEST
PLOT AND CALCULATIONS SHEET

OIL CODE ______________________ TEST NO. ______________________
DATE ______________________ ENGINEER ______________________

	"A" SIDE	"B" SIDE
EFFECTIVE TOOTH WIDTH, cm (INCHES)	______	______
LOAD OIL PRESSURE AT 22.5% SCUFF, PSI	______	______
LOAD-CARRYING ABILITY, N/m (lb/inch)	______	______

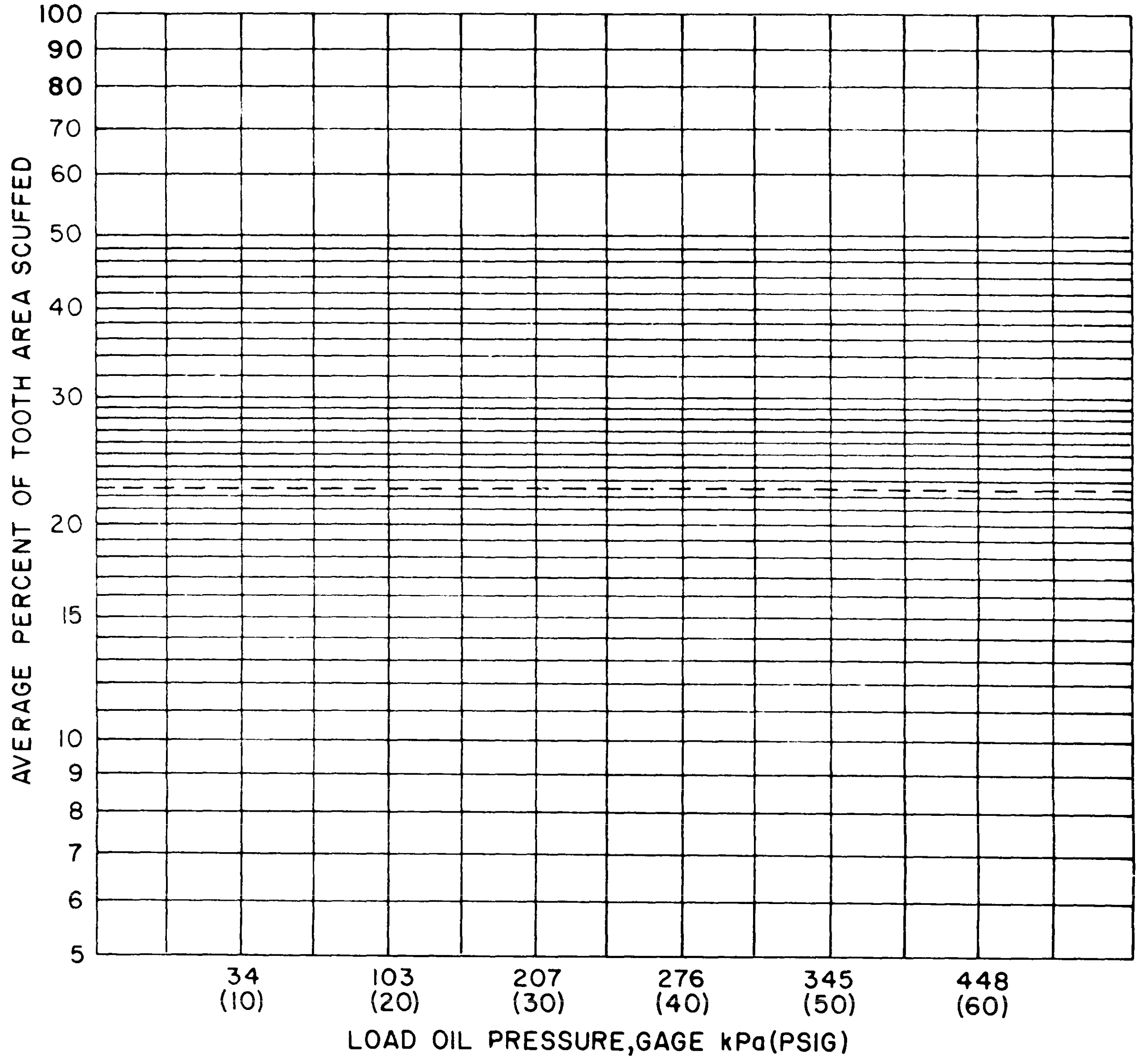

FIGURE 10. Plot and calculations sheet.

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EXTREME PRESSURE PROPERTIES OF LUBRICANTS (FOUR BALL TESTER)

1. SCORE

1.1 This method describes a procedure for the determination of the load carrying capacity of lubricating greases and lubricating oils by means of the Four-Ball Extreme pressure Lubricant Tester.

2. SUMMARY

2.1 The tester is operated with one steel ball under load rotating against three steel balls held stationary in the form of a cradle. The rotating speed is 1770 +60 rpm. Lubricating fluids are brought to 27° +8° C (80° +15° F) and then subjected to a series of tests of 10-second duration at increasing loads until welding occurs.

3. SAMPLE SIZE

3.1 Approximately 300 mL of oil or 300 g of grease.

4. REFERENCES, STANDARDS AND APPARATUS

4.1 Four-Ball Extreme Pressure Lubricant Tester. (Precision Scientific Co., Catalog No. 75015 and Roxana Machine Works EP Tester have been found satisfactory for this purpose).

NOTE 1: It is important to distinguish between the Four Ball EP Tester and the Four Ball Wear Tester. The Four Ball Wear Tester can be used under a variety of test conditions at loads up to 50 kg. The Four-Ball EP Tester is designed for testing under more severe conditions and lacks the sensitivity necessary for the Four Ball Wear Test.

4.2 Microscope, preferably binocular, 60 diameter magnification with eye piece micrometer calibrated against a stage micrometer ruled in 0.001 mm increments over a range of O to 4.0 mm. (Precision Scientific CO., Catalog Nos. 73605 and 73607 have been found satisfactory for this purpose).

4.3 Timer, graduated in tenths of a second.

NOTE 2: Optional equipment with Four Ball apparatus consists of a friction measuring device electrically driven and graduated in ten second markings.

5. MATERIAL

5.1 CAUTION: SOME MATERIALS ARE TOXIC AND HAZARDOUS: The materials references and standards listed in this section must be handled carefully. Federal Test Method 10000, Material Handling Safety Precaution, is a

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reference which lists all toxic and hazardous materials cited in FTMS 791. The synonyms, life hazard, flammability, handling and storage precautions, emergency treatment and measures, and spill practices of each chemical are explained.

5.2 Dry cleaning solvent (Stoddard solvent or 60° C [140° F] solvent). Solvent materials conforming to ASTM D 484, type I or type II are satisfactory for use in this test method [0,2,0].

5.3 Hexane, technical grade [1,3,0].

5.4 Test balls. AISI-C-52100 steel, AFBMA Grade 2.5 EP, extra polish (Precision Scientific Co., test balls, Catalog No. 75017 halve been found satisfactory for this purpose).

6. PROCEDURE

6.1 The following definitions are applicable to this test method:

a. Load carrying capacity of a lubricant, under the conditions of this test, is the Mean Hertz Load, which is the average corrected load in kilograms (kg) applied to the three stationary bails for the 10 runs prior to the weld point.
b. Weld point of a lubricant, under the conditions of this test, is the applied load in kg at which the rotating ball seizes and then welds to the three stationary balls.
c. Corrected load is the average applied load in kg for each run, and equals the actual load multiplied by the ratio of Hertz scar diameter to measured wear scar diameter at the actual load.
d. Hertz scar diameter is the diameter, in millimeters (mm), of a static indentation caused by deformation of the balls under load (prior to test).
e. Compensation scar diameter is the average diameter, in mm, of the wear scars on the three stationary balls caused by the rotating ball under those loads which, in the presence of a lubricating grease or oil do not cause seizing or welding.
f. Hertz line is a plotted line on logarithmic paper, as shown in Figure 1, where the coordinates are Hertz scar diameter in mm and applied load in kg under static conditions.
g. Compensation line is a plotted line on logaritmnic paper as shown in Figure 1, where the coordinates are compensation scar diameter in mm and applied load in kg under dynamic conditions.
h. Last non-seizure load, as shown in Figure 1, is the last applied load in kg whose average measured wear scar diameter differs less than 0.015 mm from the compensation scar diameter given in Table I.

6.2 Thoroughly clean four new test balls, ball pot, and chuck assemblies by first washing them in dry cleaning solvent, then hexane, and allow them to dry in air.

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NOTE 3: Dry cleaning solvent and hexane are flammable. Use only in d well ventilated area. Keep all flames away from these materials.

NOTE 4: Do not clean components with chlorinated hydrocarbons or other solvents possessing inherent load carrying properties that may affect test results.

6.3 Lower the cross head of the tester by raising the lever arm. Lock the lever arm in the raised position by means of the locking arrangement for that purpose.

6.4 Bring the lubricant to be tested to 27° ±8° C (80 ±15° F).

6.5 Fill the ball pot 3/4 full with the lubricating grease to be tested and embed three of the cleaned balls in the grease. Place the lock ring carefully over the three balls and screw down the lock nut securely. Remove the excess grease pushed onto the lock nut. If a lubricating oil is to be tested, cover the balls with the oil after securing the balls in the ball pot.

6.6 press the remaining cleaned ball into the ball chuck (note 5) and mount chuck into chuck holder.

NOTE 5: Examine the ball chuck carefully before each run. The chuck is continually subjected to wear and seizure and should be replaced when it will not fit into the ball chuck holder tightly enough to support its own weight.

6.7 Install the ball pot assembly on the test apparatus in contact with the fourth ball. Place mouuting disk between ball pot and thrust bearin~.

6.8 Place weight tray and weights on the horizontal arm in correct notch for a base test load of 40 Kg. Release the lever arm and gently apply (note 6) the test load to the balls, making certain the ball pot assembly and mounting disk is centered. If the optional friction measuring device is used, connect. the calibrated arm on the ball pot to the indicator spring by means of the clip and wire, placing clip and indicator support over the numbers which correspond to the applied load.

NOTE 6: Shock loading must be avoided as it may deform the balls permanently.

6.9 Start the motor and run it for 10 +0.2 seconds. The time required to “coast” to a stop is not considered.

6.10 Remove the load from the balls by raising the lever arm and locking it in a raised position. If the friction measuring device is used, remove clip and wire. Remove the ball pot assembly. Remove the cluck and discard the ball.

6.11 Measure the scar diameter of the test balls by either (6.11.1) or (6.11.2):

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6.11.l Remove the lock nut and release the test balls. Clean the balls with dry cleaning solvent and hexane (note 3) and wipe dry with a soft cloth'. Place the individual balls on a suitable holder and by means of a microscope, measure to the nearest 0.01 mm the scar diameters both parallel (horizontal) anti normal (vertical) to the striations in the scar surface of each of the three balls.

6.11.2 Retain the balls in the ball pot. Wipe excess grease or oil from the balls and ball pot. Wash the ball surfaces with dry cleaning solvent and hexane (note 3). Measure to the nearest 0.01 mm the scar diameters, both parallel (horizontal) and normal (vertical) to the striations in tile scar surface of each of the three balls with the microscope.

6.12 Calculate and record (Table I, column 5) for the 40 kg load the average scar diameter obtained in 6.11.1 or 6.11.2. Compare this average scar diameter with the compensation scar diameter (Table I, column 7). If the average scar diameter obtained in the test is not more than 0.045 mm. from the compensation scar diameter, repeat the test at the next higher load (Table I, column 1) and again compare scar diameters. This procedure is continued until the last non-seizure load is determined.

NOTE 7: When the optional friction measuring device is used, the last non-seizure load is detected by a gradual transverse movement of the indicating pin.

6.13 If the measured scar diameter for the 40 kg load is greater than the compensation scar diameter, the next run if made at the next lower load Table I, column 1). This procedure is continued until the last non-seizure load is determined.

6.14 Make additional runs at consecutively higher test loads (Table I, column 1) until welding occurs (note 8). Make a check run at this point. If welding does not occur on the check run, repeat the test at the next higher load until welding is verified.

NOTE 8: Weiding may be determined by any one or all of the following symptoms:

a. It the optional friction measuring device is used, a sharp transverse movement of the indicating pin.
b. Increased noise level of the motor.
c. Smoking from the ball pot.
d. A sudden drop in the lever arm.

If welding occurs, shut the motor off immediately to prevent damage to the tester.

7. CALCULATIONS

7.1 Mean Hertz Load. Calculate (Table I, column 9) the corrected loads for those test loads in which seizure occurs using the formula:

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$$\text{Corrected load in kg} = \frac{LD_H}{X}$$

where: L = Actual load applied in kg. Total weight applied (tray and weights) multiplied by lever arm ratio.
DH = Hertz scar diameter in mm.
X = Average wear spot diameter in mm.

From Table II (note 9) obtain total of compensation line corrected load by noting the intersection of values of last non-seizure load and weld load. value plus the total of the seizure corrected load values is recorded as total "A".

NOTE 9: For convenience, Table II has been constructed to facilitate the determination of the total of the corrected loads for the line of compensation portion of the Mean Hertz load curve. When this total compensation corrected load value is added to the corrected loads for the seizure portion of the curve, the total corrected load necessary for the determination of the Mean Hertz Load value is obtained.

7.2 Calculate the average of the corrected loads (if any) made with applied loads greater than 315 kg.

7.3 Calculate the Mean Hertz Load in Kg using the formula:

$$\text{mean Hertz load (in kg)} = \frac{A+A(A/2)}{10}$$

where:

A = Total A
B = Average B

8. REPORTING

8.1 Report the corrected load as determined in 7.1.

8.2 Report the mean Hertz Load as found in 7.3

8.3 Report the verified weld point as found in 6.14

9. PRECISION

9.1 Precision data have not been developed for this method.

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TABLE I. Data sheet.

Applied load, kg. (L)	1M$_1$ 2	1M$_2$ 2	1M$_3$ 2	Avg. scar dia. mm (X)	DH mm	Compensation scar dia. mm	LDH factor	Corrected load, kg $\frac{LDH}{X}$
(Column 1)	(Column 2)	(Column 3)	(Column 4)	(Column 5)	(Column 6)	(Column 7)	(Column 8)	(Column 9)
6					0.158		0.95	
8					0.175		1.397	
10					0.188	0.21	1.881	
13					0.205	0.23	2.669	
16					0.220	0.25	3.520	
20					0.237	0.27	4.739	
24					0.252	0.28	6.043	
32					0.277	0.31	8.867	
40					0.299	0.33	11.94	
50					0.322	0.36	16.08	
63					0.347	0.39	21.88	
80					0.376	0.42	30.10	
100					0.405	0.46	40.52	
126					0.438	0.50	55.15	
160					0.474	0.54	75.83	
200					0.511	0.59	102.1	
250					0.550		137.4	
315					0.594		187.0	
								Total A
400					0.644		257.4	
500					0.693		346.7	
620					0.745		461.6	
800					0.811		648.6	
								Average B

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TABLE II. Total of compensation line corrected loads.

Last non-seizure load, kg	800	620	500	400	315	250	200	160	126	100	80
200	583.22	639.32	683.99	720.17	748.77	770.35					
160	410.17	466.27	510.94	547.12	575.72	597.30	614.85				
126	269.76	325.86	370.53	406.71	435.31	456.89	474.44	488.52			
100	159.73	215.83	260.50	296.68	325.28	346.86	364.41	378.49	390.09		
80	71.64	127.74	172.41	208.59	237.19	258.77	276.32	290.40	302.00	310.96	
63		56.10	100.77	136.95	165.55	187.13	204.68	218.76	230.36	239.32	246.67
50			44.67	80.85	109.45	131.03	148.58	162.66	174.26	183.22	190.57
40				36.18	64.78	86.36	103.91	117.99	129.59	138.55	145.90
32					28.60	50.18	67.73	81.81	93.41	102.37	109.72
24						21.58	39.13	53.21	64.81	73.77	81.12
20							17.55	31.63	43.23	52.19	59.54
16								14.08	25.68	34.64	41.99
13									11.60	20.56	27.91
10										8.96	16.31
8											7.35

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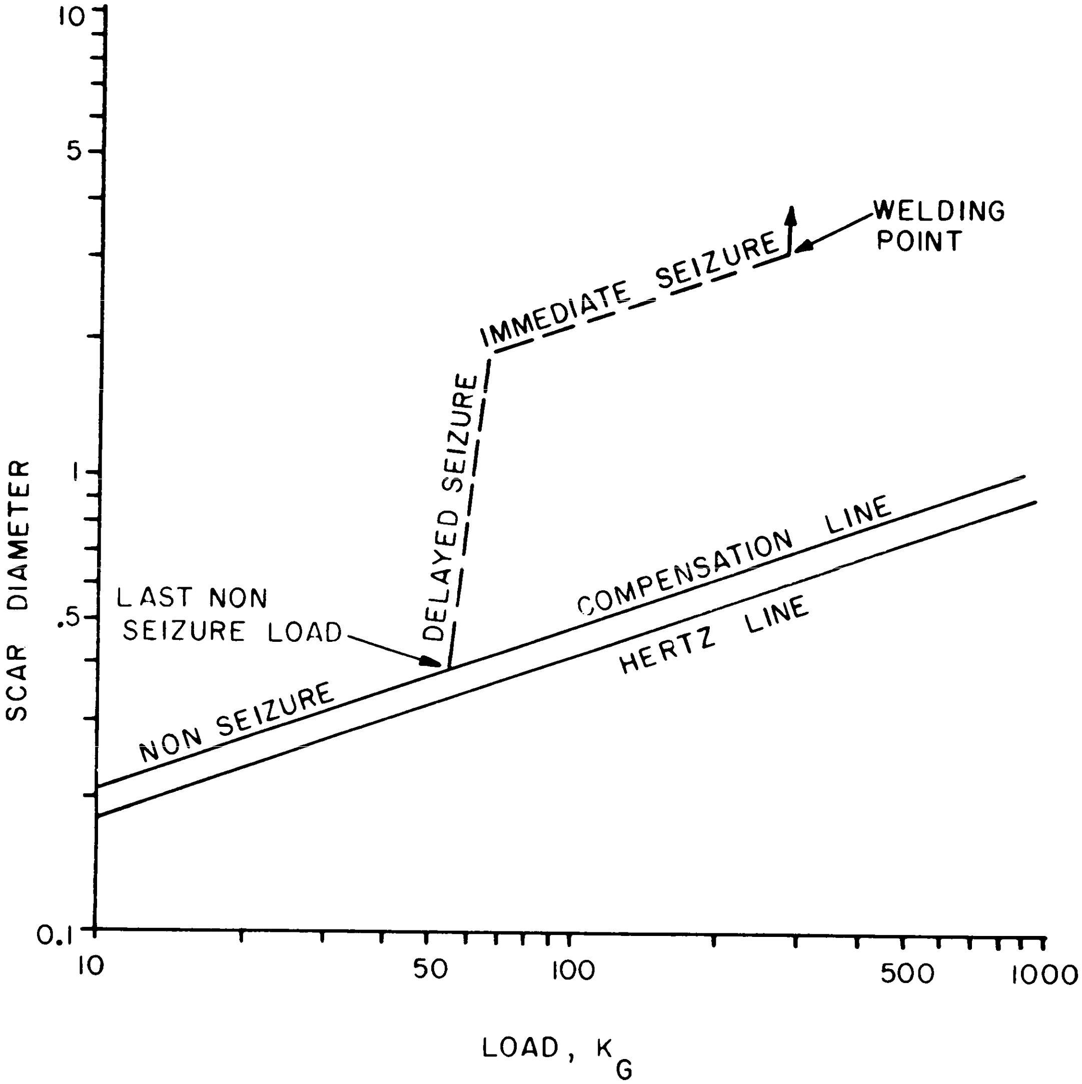

FIGURE I. Wear-load curve.

X-4429

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INSPECTION REQUIREMENTS

1. SCOPE

1.1 The inspection requirements herein are applicable to all petroleum products and are incumbent upon all suppliers of such products.

2. CONTRACTOR RESPONSIBILITIES

2.1 The contractor shall provide and maintain, and be responsible that subcontractors provide and maintain, an inspection system acceptable to the Government. Such system shall cover quality, quantity, packaging, marking, and loading.

2.2 The contractor shall insure that all inspection tests required by the specification are performed on each batch or blend of finished material furnished on the contract.

2.3 All inspection testing shall be the responsibility of the contractor and shall be performed at his expense in a laboratory acceptable to the Government inspector.

2.4 All bulk containers, such as storage tanks, of finished product shall be sufficiently protected to prevent contamination by other products during or subsequent to specification approval.

2.5 Contract material approved for shipment will be transferred from storage to shipping containers through an independent or properly protected system to prevent contamination. If not so moved, each loaded or filled shipping container shall be subject to complete specification tests prior to release for shipment.

2.6 The contractor shall maintain on file at the point of manufacture, test reports covering all material furnished on contract. These test reports will be signed by an authorized representative of the laboratory conducting the tests. These records shall be maintained on file for a period of one year following completion of the contract and then may be destroyed.

2.7 When material is shipped from an intermediate storage point, the contractor shall maintain on file, evidence of quality by such means as test reports or certificates acceptable to the Government inspector and covering the quality of the material received. These records shall be maintained on file for a period of one year following completion of the contract and then may be destroyed.

2.8 The contractor shall furnish at the request of, and in the manner specified by the Government inspector, a reasonable number of samples of contract material, without charge to the Government. Such samples shall be packed,

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marked, and shipped by the contractor, shipping expense prepaid, in containers and shipping boxes furnished by the contractor.

2.9 The Government reserves the right to inspect material at all times and places including during manufacture. If inspection is made by the Government on the premises of the contractor or a subcontractor, the contractor shall provide, and shall be responsible that subcontractors provide, all reasonable facilities and assistance for the safety and conveniences of the Government inspectors in the performance of their duties. The contractor shall, when requested by the Government inspector, make available such information as is necessary to permit the inspector to be familiar with the methods and procedures employed by the contractor to insure the quality of the material furnished under the contract.

Method Prepared By:

Army - ME - 1986

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METHOD 10000
September 30, 1986

MATERIAL HANDLING SAFETY PRECAUTIONS

1. SCOPE

1.1 This reference is used to list all toxic and hazardous material cited in Federal Test Method Standard (FTMS) 791. The relative hazard identification is listed in the material index (4.4). The synonyms, life hAzard, flammability, handling and storage precautions emergency treatment and measures, and spill practices of each chemical are explained in the material list (4.5).

2. SUMMARY

2.1 For each material cited in FTMS 791, the first three digits after the material's name 'indicate the relative hazard identification of health, flammability, and reactivity, respectively. The hazard classification is from the National Fire Protection Agency (NFPA). Refer to the material index (4.4) to locate the safety precautions of each material within this text.

3. SAMPLE

3.1 Acetone - 1, 3, 0 - 002.

3.2 Acetone has a health hazard identification of 1.
Acetone has a flammability hazard identification of 3.
Acetone has a reactivity hazard identification of O.
The Acetone index is 002.

4. RELATIVE HAZARD IDENTIFICATION

4.1 Health.

4 A few whiffs of the gas or vapor could cause death; or the gas, vapor, or liquid could be fatal on penetrating the fire fighters' normal full protective clothing which is designed for resistance to heat. For most chemicals having a Health 4 rating, the normal full protective clothing available to the average fire department will not provide adequate protection against skin contact with these materials. Only special protective clothing designed to protect against the specific hazard should be worn.

3 Materials extremely hazardous to health, but areas may be entered with extreme care. Full protective clothing, including self-contained breathing apparatus, impermeable rubber gloves, boots and bands around legs, arms and waist should be provided. No skin surface should be exposed.

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2 Materials hazardous to health, but areas may be entered freely with self–contained breathing apparatus.

1 Materials only slightly hazardous to health. It may be desirable to wear self-contained breathing apparatus.

0 Materials which on exposure under fire conditions would offer no health hazard beyond that of ordinary combustible material.

U Unknown.

4.2 Flammability.

4 Very flammdle gases, very volatile flammable liquids, and materials that in the form of dusts or mists readily form explosive mixtures when dispersed in dir. Shut off flow of gas or liquid and keep cooling water streams on exposed tanks or containers. Use water spray carefully in the vicinity of dusts so as not to create dust clouds.

3 Liquids which can be ignited under almost all normal temperature conditions. Water may be ineffective on these liquids because of their low flash points. Solids which form coarse dusts, solids in shreuded or fibrous form that create flash fires, solids that burn rapidly, usually because they contain their own oxygen, and any material that ignites spontaneously at normal temperatures in air.

2 Liquids which must be moderately heated before ignition will occur and solids that readily give off flammable vapors. Water spray may be used to extinguish the fire because the material can be cooled to below its flash point.

1 Materials that must be preheated before ignition can occur. Water may cause frothing of liquids with this flammability rating number if it gets below the surface of the liquid and turns to steam. However, water spray gently applied to the surface will cause a frothing which will extinguish the fire. Most combustible solids have d flammability rating of 1.

0 Materials that will not burn.

U Unknown.

4.3 Reactivity.

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4 Materials which in themselves are readily capable of detonation or of explosive decomposition or explosive reaction at normal temperatures and pressures. Includes materials which are sensitive to mechanical or localized thermal shock. If a chemical with this hazard rating is in an advanced or massive fire, the area should be evacuated.

3 Materials which in themselves are capable of detonation or of explosive decomposition or of explosive reaction but wnich require a strong initiating source or which must be heated under confinement before initiation. Includes materials which are sensitive to thermal or mechanical shock at elevated temperatures and pressures or which react explosively with water without requiring heat or confinement. Fire fighting should be done from an explosion-resistant location.

2 Materials which in themselves are normally unstable and readily undergo violent chemical change but do not detonate. Includes materials which can undergo chemical change with rapid release of energy at normal temperatures and pressures or which can undergo violent chemical change at elevated temperatures and pressures, Also includes those materials which may react violently with water or which may form potentially explosive mixtures with water. In advanced or massive fires, fire fighting should be done from a protected location.

1 Materials which in themselves are normally stable but which may become unstable at elevated temperatures and pressures or which may react with water with some release of energy but not violently. Caution must be used in approaching the fire and applying water.

0 Materials which are normally stable even under fire exposure conditions and which are not reactive with water. Normal fire fighting procedures may be used.

u Unknown.

4.4 Material Index

Index Number	Compound's Name	Health Hazard	Flammability Hazard	Reactivity Hazard
001	Acetic Acid	2	2	1
002	Acetone	1	3	0
003	Ammonium Acetate		0	
004	Ammonium Hydroxide		0	

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Index Number	Compound's Name	Health Hazard	Flammability Hazard	Reactivity Hazard
005	Ammonium Nitrate	0	1	3
006	Barium chloride	0	0	2
007	Barium Hydroxide			
008	Benzoic Acid			
009	Bromine	4	0	0
010	n-Butyl Alcohol	1	3	0
011	Butyric Acid	2	2	0
012	Capric Acid			
013	Caproic Acid	2	1	0
014	Caprylic Acid			
015	Chloroform	2	2	0
016	Cleaning Compound Special			
	Cleaning solution, Glass	See Sulfuric Acid		
017	Detergent, Liquid, Water Soluble Comm. Grade			
018	Diesel Fuels	0	2	0
019	Diethylene Glycol	1	1	0
020	Diethylene Glycol Monomethyl Ether			
021	Diethylene Glycol Adipate			
022	Diphenylamine	3	1	0
023	Drycleaning Solvent	0	2	0
	Eschka's Mixture	See Magnesium Oxide, Sodium Carbonate		
024	Ethyl Alcohol	0	3	0
025	Ethyl Ether	2	4	1
026	Ethylene Glycol	0	0	0
027	Ethylene Glycol Monomethyl Ether			
028	Ferrous Ammonium Sulfate			
	Freon - 12	See 1,1,2 Trichlorotrifluoroethane		
029	Gasoline	1	3	0
	Glacial Acetic Acid	See Acetic Acid		
030	Glycerine	1	1	0
031	n–Heptane	1	3	0
032	HeptyLic Acid			
033	h–Hexane	i	3	0
034	Hydrochloric Acid	3	0	0
035	Isooctane	0	3	0
036	Isopropyl Alcohol	1	3	0
037	Kerosene			
038	Lead Acetate			
039	Magnesium Oxide			
040	Mercuric Iodide			
041	Methyl Alcohol	1	3	0
	Methyl-Alcohol-Glycerine	See Methyl Alcohol and Glycerine		

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Index Number	Compound's Name	Health Hazard	Flammability Hazard	Reactivity Hazard
042	Methyl Ethyl Ketone	1	3	0
043	Methyl Orange			
044	Naphtha	1	4	0
045	Neopentyl POlyol Ester			
046	Nitric Acid	2	0	0
	Nitric-sulfuric Acid Mixture	See Sulfuric Acid		
047	NO-Chromix Cleaning Solution			
048	Oleic Acid	0	1	0
049	Pelargonic Acid			
	Petroleum Ether	See Naphtha		
050	1, 10-phenanthroline			
051	Phenolphthalein			
052	phosphoric Acid	2	0	0
053	Potassium Carbonate			
054	Potassium Chlorate	1	0	0
055	Potassium Bichromate	1	0	0
056	Potassium Hydroxide	3	0	0
057	Potassium Hydrogen phthalate			
058	Potassium Iodide			
059	Sebabic	0	0	0
060	Silicon Sulfate			
061	Soda Lime			
062	Sodium Carbonate			
063	Sodium Chloride	0	0	2
064	Sodium Bichromate	1	0	1
065	Sodium Hydroxide	3	0	1
066	Sodium Sulfate			
067	Sodium Thiosulfate			
068	Sulfuric Acid	3	0	2
069	Sulfurous Acid			
070	Tannic Acid	0	1	0
071	Teflon			
072	Tetrachloroethylene	2	0	0
073	Tetra Ethyl Lead	3	2	3
074	Toluene	2	3	0
075	1,1,1-Trichloroethane	2	1	0
076	1,1,2-Trichloro-1,2,2-Trifluoroethane			
077	Valerie Acid			
078	Xylene	2	3	0
079	Barium Carbonate			
080	Chromium Trioxide			
081	Nickelous Chloride			
082	Silver Nitrate			

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4.5 Material List

001 Acetic acid CH_3COOH

Synonyms: Ethanoic acid, Vinegar acid, Methanecarboxylic acid.

Life Hazard: May produce severe acid burns to skin and eyes. Prolonged breathing of concentrated vapor may be harmful. Threshold limit value, 10 parts per million.

Flammability: Flash point 43° C (open cup), 40° C (closed cup); ignition temperature 427° C; flammable limits 4 - 16 percent. Vapors form explosive mixtures with air. Dangerous in contact with chromic acid, sodium peroxide, nitric acid, or other oxidizing materials.

Handling: Separate from oxidizing materials and avoid storage near combustible materials. Expands upon freezing. Wear chemical goggles, chemical cartridge respirator, rubber protective clothing.

Emergency Treatment and Measures:

a. Hygienic Precautions: Adequate ventilation.

b. First Aid: Irrigate eyes with water. Wash contaminated areas of body with soap and water. Call a physician.

c. Fire Precautions (In case of outbreak): Use water spray, dry chemical, alcohol foam or carbon dioxide. Use water to keep fire-exposed containers cool.

Spills: Cover with soda ash or sodium bicarbonate. Mix and add water. Neutralize and drain into the sewer with sufficient water.

002 Acetone CH_3COCH_3

Synonyms: Dimethylketone, Beta-Ketopropane, 2-Propanone, Pyroacetic ether.

Life Hazard: Acetone is narcotic in high concentrations. Dangerous, due to fire and explosion hazard; can react vigorously with oxidizing materials.

Flammability: Flammable; flash point -9.4 (open cup), –20° C; ignition temperature 537.8° C; flammable limits 2.6 - 12.8 volume percent.

Handling: Keep away from plastic eyeglass frames, jewelry, pens, pencils, and rayon garments. Wear rubber gloves, rubber aprons, chemical goggles, and self-contained breathing apparatus.

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Emergency Treatment and Measures:

a. Hygienic Precautions: Adequate ventilation.
b. First Aid: Irrigate eyes with water. Wash contaminated skin with soap and water. call a physician if swallowed.
c. Fire Precautions (In case of outbreak): Use dry chemical, carbon dioxide, or alcohol foam. Water spray may be ineffective, but water should be used to keep fire-exposed containers cool.

Spills: Absorb on paper. Evaporate on a glass or iron dish. Burn the paper.

003 Ammonium acetate $(CH_3COO)NH_3$

Synonyms: N/A

Life Hazard: Ammonium acetate tends to lose ammonia upon standing.

Flammability: Not flammable. Irritating gases may be produced when heated.

Handling: N/A

Emergency Treatment and Measures:

a. Hygienic Precautions: Avoid inhalation of dust.
b. First Aid: If swallowed and victim is conscious, have victim drink water or milk. If swallowed and victim is unconscious or having convulsions, keep victim warm and nothing else. In both cases call a physician.

Spills: Wash down the drain with excess water.

004 Ammonium hydroxide NH_40H

Synonyms: Water of ammonia, Ammonium hydrate, Aqua ammonis, Aqua ammonium.

Life Hazard: Dangerous; emits irritating fumes and liquid can inflict burns. Hazardous reactions with inorganic acids immediately boil and are dangerous.

Flammability: Not flammdble.

Handling: Bottles with glass, plastic or rubber plug must not be filled completely to the brim and must be stored in cool place. Wear rubber gloves, large face shield and general purpose gas mask.

Emergency Treatment and Measures:

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a. Hygienic Precautions: Adequate ventilation. Preclude from exposure those individuals with eye and pulmonary diseases.

b. First Aid: Irrigate eyes with water.
Wash contaminated areas of body with soap and water. supply oxygen, with use of intermittent positive pressure breathing apparatus. Call a physician.

Spills: Neutralize with dilute sulfuric acid. Wipe with mop or use water aspirator. Drain into the sewer with sufficient water.

005 Ammonium nitrate NH_4NO_3

Synonyms: Nitric acid, Ammonium salt, Nitram.

Life Hazard: The oxides-of-nitrogen gases (except nitrous oxide - N_20) emitted on decomposition of ammonium nitrate are extremely toxic. Any person exposed to such fumes should receive immediate medical attention. Hazardous reactions: ignites by heating its mixture with combustible materials; ignites in the presence of zinc powder and water; explodes by impacting its mixture with ammonium sulfate.

Flammability: Oxidizing agent; supports combustion and is capable of undergoing detonation if heated under confinement or if subjected to strong shocks. Melts at about 150° C with slow decomposition; near 300° C, the decomposition accelerates with sudden rushes of light-brown to orange-copper fumes, indicating that the decomposition may become explosive. Self-ignition of mixtures of ammonium nitrate with easily oxidizable organic materials or easily oxidizable, finely divided metals may take place at moderately elevated temperatures.

Handling: Separate from all organic materials or other contaminating substances such as flammable liquids, acids, corrosive liquids, organic chemicals, chlorates, sulfur and finely divided metals or charcoal, coke, and sawdust. Wear rubber gloves and chemical goggles.

Emergency Treatment and Measures:

a. First Aid: When exposed to nitrogen oxides due to decomposition at high temperatures, individuals should be promptly given treatment by physician.

b. Fire Precautions (In case of outbreak): Flood with sufficient amount of water. Exercise extreme caution in application of water on fused or molten material to avoid eruptive scattering and spread of fire.

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Spills: Sweep into a beaker. Dilute with sufficient water. Acid soda ash. Mix and neutralize with dilute acid. Drain into the sewer with abundant water.

006 Barium chloride $BaCl_2 \cdot 2H_2O$

Synonyms: Barium chloride dihydrate.

Life Hazard: Highly toxic. yields toxic fumes when involved in fire. Threshold limit value of dust, 0.5 milligrams per cubic meter.

Flammability: N/A

Handling: Wear rubber gloves.

Emergency Treatment and Measures:

a. Hygenic Precautions: N/A
b. First Aid: If swallowed, call a physician.
c. Fire Precautions (In case of outbreak): N/A

Spills: Cover any spills with sufficient amount of sodium bicarbonate. Remove the mixture into a container such as a fiber drum, plastic bag or carton box for easy disposal in an incinerator.

007 Barium Hydroxide $Ba(OH)_2$

Synonyms: Barium hydrate, caustic baryta.

Life Hazards: Highly toxic by ingestion.

Flammability: N/A

Handling: Keep containers closed and store. Wear rubber gloves, safety glasses, and working clothes.

Emergency Treatment and Measures:

a. Hygienic Precautions: Adequate ventilation, protectors. preclude from exposure those individuals with pulmonary diseases
b. First Aid: Irrigate eyes with water: wash skin with soap and water. If swallowed, call a physician.
c. Fire Precautions (In case of outbreak):

Spills: To a solution of the product in water, add an excess of dilute sulfuric acid. Let stand overnight. Filter to separate the precipitate and filtrate. Add the precipitate slowly to excess ice Located in the

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hood behind a safety shield. The resulting mixture should then be neutralized and washed down the drain with excess water. The filtrate should be washed down the drain with excess water.

008 Benzoic Acid C_6H_5COOH

Synonyms: Phenylformic acid, benzenecarboxylic acid, carboxylbenzene.

Life Hazard: Low toxicity. Dust may be irritating to nose and eyes. At elevated temperatures, fumes may cause irritation of eyes, respiratory system, and skin.

Flammability: Flashpoint (121° C), autoignition temperature (574° C).

Handling: Wear rubber gloves, a mask, coveralls, a body shield, and self-contained breathing apparatus.

Emergency Treatment and Measure:

a. Hygienic Precautions: N/A
b. First Aid: Flush affected areas with plenty of water. If in eyes, hold open and flush with plenty of water. If swallowed, call a physician.
c. Fire Precautions (In case of outbreak): Use water, carbon dioxide, or dry chemical fire extinguisher.

Spills: Carefully mix the acidic compound with dry sodium bicarbonate. Dilute slowly with water and wash down the drain with excess water.

009 Bromine Br_2

Synonyms: N/A

Life Hazard: Highly dangerous; when heated, it emits highly toxic fumes; it. will react with water or steam to produce toxic and corrosive fumes; and it can react vigorously with reducing materials. Hazardous reactions with:

a. Hydrogen, methane, ethylene, sulfur, antimony, arsenic phosphor, sodium, potassium and other metallic powder: ignition and explosion.
b. Combustible materials and metallic powder: explosion by contact.

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Flammability: Nonflammable, but a strong oxidizing material and reactive with many substances. Heat of reacton may cause ignition of combustible materials.

Handling: Store in cool and dry areas out of direct sunlight. Separate from combustible, organic or other readily oxidizable materials. Keep above –6.7° C to prevent freezing but avoid heating above atmospheric temperatures as vapor pressure increase could rupture the containers. Wear rubber gloves, face shield, coveralls and self-contained breathing apparatus.

Emergency Treatment and Measures:

a. Hygienic Precautions: Adequate ventilation. Preclude from exposure those individuals with pulmonary diseases.
b. First Aid: Irrigate eyes with water. Wash contaminated areas of body with soap and water. Burns may be treated with a sodium bicarbonate paste. If swallowed, call a physician.
c. Fire Precautions (In case of outbreak): Use large amounts of water to cool containers and wash away spills.

Spills: Cover with weak reducing agents such as hype, bisulfites or ferrous salts. Bisulfites or ferrous salts need additional promoter of some 3M-H_2S0_4 to accelerate reaction. Transfer the slurry (or sludge) into a large container of water and neutralize with soda ash. Drain into a sewer with abundant water.

010 <u>n-Butyl Alcohol</u> $CH_3(CH_2)_2CH_20H$

Synonyms: l-Butanol; n-Butanol.

Life Hazard: Moderately dangerous because of its low volatility; when heated to decomposition it emits toxic fumes; it can react with oxidizing materials.

Flammability: Moderate fire risk. Flash point (open cup) 45.5” C, (closed cup) 28.9° C; ignition temp 365° C; flammable limits 1.4 - 11.2 percent. Less reactive; no adverse reaction takes place on fire.

Handling & Storage: Store in cool, unlighted place away from sources of ignition, and from explosives, oxidizing materials, organic peroxides, poisons and radioactive materials. Preferably provide electrical equipment with spark-resistant construction. Wear safety glasses and rubber protective clothing.

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Emergency Treatment and Measures:

a. Hygienic Precautions: Adequate ventilations.
b. First Aid: Flush eyes thoroughly with water. Wash out contaminated skin with soap and water. If swallowed, call a physician.
c. Fire Precautions (In case of outbreak): Use dry chemical, or carbon dioxide: alcohol foam may be ineffective. Water spray may help to keep containers cool, to dilute leaked butanol, and to diffuse vapors.

Spills: Absorb on paper. Evaporate on a glass or iron dish in hood. Burn the paper. Large quantities should be burned in a solvent burner.

011 Butyric Acid $CH_3(CH_2)_2COOH$

Synonyms: Butanic Acid, Butanoil Acid, Ethylacetic Acid, Propanecarbonic Acid.

Life Hazard: Inhalation causes irritation of mucous membranes and respiratory track; may cause nausea and vomiting. Ingestion causes irritation of mouth and stomach. Contact with eyes can cause serious injury. Contact with skin may cause burns; chemical is readily absorbed through the skin and may cause damage by this route.

Flammability: Flash point (76° C) Autoignition temperature (450° C), flammability limits in air (2.19 - 13.9 percent).

Handling: May attack aluminum or other light metals with the formation of flammable hydrogen gas. Protect containers against physical damage. Store in a cool, dry, well-ventilated place away from sources of ignition and heat.

Emergency Treatment and Measure:

a. Hygienic precautions: N/A
b. First Aid: If inhaled: remove victim to fresh air, give oxygen if breathing is difficult; call a physician. If ingested, give large amounts of water and induce vomiting, call a physician. If eye contact: irrigate with water for 15 minutes and seek medical attention. Skin contact: flush affected area immediately and throughly with water.
c. Fire Precautions: (In case of outbreak): Use dry chemical, "alcohol" foam, or carbon dioxide fire extinguisher. Water may not be effective.

Spills: Carefully mix the acidic compound with dry sodium bicarbonate. Dilute slowly with water and wash down the drain with excess water.

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012 Capric Acid $CH_3(CH_2)_8COOH$

Synonyms: Decanoic Acid, Decoic Acid, Decylic Acid.

Life Hazard: Moderately toxic.

Flammability: Flashpoint (112° C)

Emergency Treatment and Measures:

a. Hygienic Precautions: N/A
b. First Aid: N/A
c. Fire Precautions (In case of outbreak): N/A

Spills: Carefully mix the acidic compound with dry sodium bicarbonate. Dilute slowly with water and wash down the drain with excess water.

013 Caproic Acid $C_6H_{12}0_2$

Synonyms: Hexanoic Acid.

Life Hazard: N/A

Flammability: Flash point (104° C).

Handling: A corrosive material.

Emergency Treatment and Measures:

a. Hygienic Precautions: N/A
b. First Aid: N/A
c. Fire Precautions (In case of outbreak): Use foam, carbon dioxide, or dry chemical fire extinguisher.

Spills: Carefully mix the acidic compound with dry sodium bicarbonate. Dilute slowly with water and wash down the drain with excess water.

014 Caprylic Acid $CH_3(CH_2)$ CH=CH COOH

Synonyms: Octanoic Acid.

Life Hazard: Low toxicity, yieids irritability vapors which could cause coughing.

Flammability: Flash point 270° F, open cup.

Handling: N/A

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Emergency Treatment and Measures:

a. Hygienic Precaution: N/A
b. First Aid: N/A
c. Fire Precautions (in case of outbreak): N/A

Spills: Absorb on paper. Evaporate on a glass or iron dish in hood. Burn the paper. Large qualities should be burned in a solvent burner.

015 Chloroform $CHCl_3$

Synonyms: Trichloromethane

Life Hazard: prolonged exposure will induce anesthesia. poisonous and irritating gases are produced when heated. Suspected carcinogen.

Flammability: Not flammable, but will burn on prolonged exposure to flame or high temperature.

Handling: Protect containers against physical damage. Keep containers closed and store in a dark place away from direct sunlight and moisture. Wear safety glasses, self-contained breathing apparatus, protective clothing and rubber gloves.

Emergency Treatment and Measures:

a. Precaution: Adequate ventilation. Physical examination annually to study liver and kidney functions. preclude from exposure individuals with diseases of liver, kidney and central nervous system.
b. First Aid: If it has been ingested, or there has been great over-exposure, call a physician.
c. Fire Precaution (in case of outbreak): N/A.

Spills: Compound should be redistilled or otherwise repurified and reused.

016 Cleaning Compound, Special

Synonyms: Penetone ECS.

Life Hazard: N/A

Flammability: N/A

Handling: N/A

Emergency Treatment and Measures: N/A

Spills: N/A

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017 Detergent, Liquid, Water Soluble, Commercial Grade

Synonyms: N/A

Life Hazard: N/A

Handling: N/A

Emergency Treatment and Measures: N/A

Spills: Wash down the drain with excess water.

018 Diesel Fuels

Synonyms: Fuel Oil, Diesel Oil.

Life Hazard: Vapors are considered to be moderately poisonous. Dangerous: when exposed to heat or flame; can react vigorously with oxidizing materials.

Flammability: Flash point (greater than 38° C). Keep away from open flame.

Handling: Keep bottles, cans and drums closed and avoid direct sunlight. No fire. Outdoor or detached storage is preferred. For indoor storage, use standard combustible liquid storage rooms or cabinets. Wear goggles, rubber gloves, a chemical cartridge respirator and coveralls.

Emergency Treatment and Measures:

a. First Aid: Irrigate eyes with running water. Wash contaminated areas of body with soap and water. Administer oxygen, if indicated. If swallowed, call a physician.
b. Fire Precautions (In case of outbreak): Use carbon dioxide, dry chemical, or "alcohol" foam. Water spray is not effective for extinguishing, but effective to keep fire-exposed containers cool. If a leak or spill has not ignited, use water to disperse the vapor and to protect workers attempting to stop the leakage.

Spills: Absorb on paper. Evaporate on a glass or iron dish in hood. Burn the paper. Large quantities should be burned in solvent.

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019 Diethylene Glycol $(CHOCH_2)_2O$

Synonyms: Diglycol, DEG, 2,2 - oxybiethanol, 2-Hydroxyethyl ether.

Life Hazard: Suspected carcinogen of bladder.

Flammability: Flashpoint (143°C), autoignition temperature (229° C) flammable limits in air (1.6-10.8%).

Handling: N/A

Emergency Treatment and Measures:

a. Hygienic precautions: No eating in work areas. Preclude from exposure those individuals with diseases of liver, kidneys or nervous system.
b. First Aid: Ingestion: Induce vomiting, no known antidote - treat symptomatically. Eye and skin contact: flush with water. Call a physician.
c. Fire precautions (in case of outbreak): Use “alcohol” foam carbon dioxide, or dry chemical fire extinguisher. Water and foam may be ineffective.

Spills: Wash down the drain with excess water or dissolve in benzene, napiltha or higher alcohol such as butanol, then dispose by burning the solution in a hood.

020 Diethylene Glycol Monomethyl Ethane

Synonyms:

Life Hazards:

Flammability:

Handling:

Emergency Treatment and Measures:

a. Hygienic Precautions.
b. First Aid:
c. Fire Precaution (in case of outbreak):

spills:

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021 Diethyl glycol adipate

Synonyms: N/A

Life Hazards: N/A

Flammability: N/A

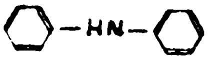
Handling: N/A

Emergency Treatment and Measures:

a. Hygienic Precautions: N/A
b. First Aid: N/A
c. Fire Precautions (In case of outbreak): N/A

Spills : N/A

022 Diphenylamine



Synonyms: phenylaniline, DPA, anilinobenzene, N-phenylaniline.

Life Hazard: Dangerous: When heated to decomposition, it emits toxic fumes; can react with oxidizing materials.

Flammability: Flash point 153° C; ignition temperature 635° C,

Handling: Store in a cool and dark place. Wear safety glasses, rubber gloves, rubber clothing.

Emergency Treatment and Measures:

a. Hygienic Precautions: Adequate ventilation.
b. First Aid: Flush eyes with water. Wash body with soap and water. Remove and dry clothing, then wash with soap or scrap. Burn shoes in an incinerator. If swallowed, call a physician.
c. Fire precautions (in case of outbreak): Use foam, dry chemical, or carbon dioxide fire extinguishers.

Spills: Spread over with the 9:1 mixture of sand and soda ash. After mixing, transfer into a paper carton, stuffed with ruffled paper. Burn in an open furnace with the utmost care or in the furnace with afterburner and scrubber.

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023 Dry cleaning Solvent

Synonyms: Stoddard Solvent, Drycleaner Naptha, Spotting, Naphtha petroleum Solvent.

Life Hazard: High concentration of vapors may cause intoxication. If liquid is swallowed, it may get into lungs by aspiration, not very irritating to skin or eyes.

Flammability: Flash point (43° C), Autoignition temperature (3820), flammable limits in air (0.8 - 5.0%).

Emergency Treatments and Measures:

a. Hygienic Precautions: Adequate ventilation.
b. First Aid: Inhalation: remove patient from exposure, treat symptoms. Ingestion: do not induce vomiting, call a physician. Eyes : flush with water for 15 minutes. Skin: wipe off and wash with soap and water.
c. Fire Precautions (In case of outbreak): Use foam, dry chemical, or carbon dioxide fire extinguisher.

Spills: N/A

024 Ethyl alcohol C_2H_5OH

Synonym: Ethanol, Grain Alcohol.

Life Hazard: Dangerous, when exposed to heat or flame.

Flammability: Flash point 12.2° C (closed cup), 15.8° C (open cup); ignition temperature 426° C; flammable limits 3.3 - 19 percent.

handling: Store away from all possible ignition sources. All precautions for the elimination of static electricity should be taken. Should not be stored with perchlcrates, peroxides, chromic acid and nitric acid. Protect containers against physical damage. Store indoors in a cool and well ventilated room, limiting the quantity of sealed drums or containers at any one time.

Emergency Treatment and Measures:

a. Hygienic Precautions: Physical examinations of exposed patient periodically including signs of chronic irritation of mucous membranes and chronic alcoholism.
b. First Aid: Irrigate eyes with water. If swallowed, call a physician.

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c. Fire Precautions (In case of outbreak): Use dry chemical, alcohol foam or carbon dioxide. Water spray may be ineffective as an extinguishing agent, but water should be used to keep fire–exposed containers cool.

Spills: Absorb on paper. Evaporate on a glass or iron dish in hood. Burn the paper.

025 Ethyl Ether $C_2H_50C_2H_5$

Synonyms: Sulfuric ether, Anesthesia Ether, Ethyl Oxide.

Life Hazard: A depressant of the central nervous system and is capable of producing intoxication, drowsiness, stupor, and unconsciousness.

Flammability: Flash point (C-40°C), autoignition temperature (180° C), flammable limits in air (1.85 - 36.5%).

Handling: N/A

Emergency Treatment and Measures:

a. Hygienic Precautions: Adequate Ventilation.
b. First Aid: Inhalation: remove victim to fresh air; if breathing has stopped, apply artifical respiration, call a physician. Eye contact: flush immediately with water for 15 minutes.
c. Fire precautions (In case of outbreak): Use alcohol foam, carbon dioxide, or dry chemical fire extinguisher.

Spills: Absorb on paper. Burn, but exert extra care in ignition as this material highly flammable.

026 Ethylene Glycol

Synonyms:

Life Hazard:

Flammability:

Handling:

Emergency Treatment and Measures:

a. Hygienic Precautions:
b. First Aid:
c. Fire Precautions (in case of outbreak):

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Spills:

027 Ethylene Glycol Monomethyl Ether $CH_3O(CH_2)_2OH$

Synonyms: 2-Methoxyethanol, Methyl cellosolve, Glycolmethyl ether, Dowanol em, Poly-solv em.

Life Hazard: Little health hazard if application doesn't require heating.

Flammability: Flash point (49°C), Autoignition temperature (288°C) Flammable limits in air (2.5 - 19.8%).

Handling: N/A

Emergency Treatment and Measures:

a. Hygienic precautions: N/A
b. First Aid: Contact with skin or eyes: flush with water. If swallowed, call a physician.
c. Fire Precautions (In case of outbreak): Use alcohol foam, carbon dioxide, or dry chemical fire extinguisher. Cool exposed containers with water.

Spills: Absorb on paper and burn in hood.

028 Ferrous ammonium sulfate $(NH_3)_2Fe(SO_4)2 \cdot 6H_2O$

Synonyms: Ammonium ferrous sulfate hexahydate, Iron ammonium sulfate, Mohr's salt.

Life Hazard: Toxicity will be that of iron ion. Irritating and toxic ammonia and oxides of nitrogen may form in fires.

Flammability: Not Flammable

Handling: Do not expose to light for extended periods of time.

Emergency Treatments and Measures:

a. Hygienic Precautions.
b. First Aid: Ingestion: Give large amount of water, induce vomiting, call a physician. Eye and skin contact: Flush with water.
c. Fire Precautions (in case of outbreak): N/A

Spills: Wash down the drain with excess water.

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029 Gasoline

Synonym: Petrol, Motor Spirit, Benzin.

Life Hazard: Vapors are considered to be moderately poisonous. Dangerous: When exposed to heat or flame; can react vigorously with oxidizing materials.

Flammability: Flash point about -45° C; ignition temperature about 250° C; explosive range about 1.3 - 6.0 percent.

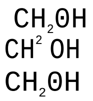
Handling: Keep bottles, cans and drums closed and avoid direct sunlight. No fire. Outdoor or detached storage is preferred. For indoor storage, use combustible liquid storage rooms or cabinets. Wear goggles, rubber gloves, a chemical cartridge respirator and coveralls.

Emergency Treatment and Measures:

a. First Aid: Irrigate eyes with running water. Wash contaminated areas of body with soap and water. If swallowed, call a physician. Do not induce vomiting. Administer oxygen, if indicated.
b. Fire Precautions (In case of outbreak): Use carbon dioxide, dry chemical, or "alcohol" foam. Water spray is not effective for extinguishing, but effective to keep fire-exposed “containers cool. If a leak or spill has not ignited, use water to disperse the vapor and to protect men attempting to stop the leakage.

Spills: Absorb on paper. Evaporate on a glass or iron dish in hood. Burn the paper.

030 Glycerine



$$\begin{matrix} CH_2OH \\ CH^{2}OH \\ CH_2OH \end{matrix}$$

Synonyms: Glycerol, 1,2,3-Propanetriol,Trihydroxypropane.

Life Hazard: Relatively nontoxic.

Flammability: Flash point 160° C; ignition temperature 429° C. May be explosive in contact with such strong oxidizer as bichromate, potassium chlorate, potassium permanganate.

Handling & Storage: Keep containers well closed.

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Emergency Treatment and Measures:

a. First Aid: Irrigate eyes with water. Wash contaminated areas of body with soap and water. If swallowed, call a physician.
b. Fire Precautions (In case of outbreak): Use water, dry chemical, alcohol foam, or carbon dioxide. Water or foam may cause frothing. Use water to keep fire-exposed containers cool, to flush spills away from exposures and to dilute spills to noncombustible mixtures.

Spills: Absorb on paper. Evaporate on a glass or iron dish in hood. Burn the paper.

031 n-Heptane $CH_3(CH_2)_5CH_3$

Synonym: Dimethyl pentene, Diethyl propane.

Life Hazard: Narcotic in high concentrations. A central nervous system irritant. Dangerous, upon exposure to heat or flame; can react vigorously, with oxidizing materials.

Flammability: Flash point -4° C (open cup), -22° C (close cup); ignition temperature 223° C; flammable limits 1.25 - 6.90 percent.

Handling: Keep containers such as can or bottle closed. Store in cool, dark, well-ventilated place. Avoid every source of ignition. Protect containers against physical damage. Wear rubber gloves, face protecting board , overalls.

Emergency Treatment and Measures:

a. First Aid: Flush eyes with water. Wash contaminated areas of body with soap and water. If swallowed, call a physician.
b. Fire Precautions (In case of outbreak): Use carbon dioxide, dry chemical or “alcohol” foam extinguisher. Water spray may be ineffective as an extinguishing agent, but water should be used to keep fire-exposed containers cool.

Spills: Absorb on paper. Evaporate on glass or iron dish in hood. Burn the paper.

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032 Heptylic Acid $CH_3(CH_2)_5COOH$

Synonyms: Heptanoic Acid

Life Hazard: N/A

Flammability: Flash point (112°C)

Handling: A corrosive material.

Emergency Treatment and Measures:

a. Hygienic Precautions: N/A
b. First Aid: N/A
c. Fire Precautions (In case of outbreak): N/A

Spills: Carefully mix the acidic compound with dry sodium bicarbonate. Dilute slowly with water and wash down the drain with excess water.

033 n-Hexane $CH_3(CH_2)_4CH_3$

synonym: Hexane.

Life Hazard: Dangerous: When heated or exposed to flame; can react vigorously with oxidizing materials. Vapors may explode.

Flammability: Flash point -30° C (close cup); ignition temperature 260° C; flammable limits 1.25 - 6.90 percent. Severe fire risk.

Handling: Keep containers closed; store in well-ventilated, cool and dark place. Away from sources of ignition. Inspect frequently existence of leak. Wear rubber gloves, and overalls.

Emergency Treatment and Measures:

a. Hygienic Precaution: Adequate ventilation.
b. First Aid: Skin contact: Wipe off, wash with soap and water. Eye contact: Flush with water. If swallowed, call a physician.
c. Fire Precautions (In case of outbreak): Use carbon dioxide, dry chemical or “alcohol” foam extinguisher. Water is ineffective to fight fire, but is effective to keep fire-exposed containers cool.

spills: Absorb on paper. Evaporate on a glass or iron dish in hood. Burn paper.

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034 Hydrochloric Acid HC1

Synonym: N/A

Life Hazard: Toxic. Eye, skin and respiratory irritant. Inhalation of concentrations of about 1500 parts per million in air are fatal in a few minutes. Hazardous reaction with ethylene.

Flammability: Not flammable.

Handling: Protect containers against physical damage. Store in a cool, well-ventilated place separated from oxidizing substances: Wear rubber gloves, rubber apron.

Emergency Treatment and Measures:

a. First Aid: Irrigate eyes with water. Wash contaminated areas of the body with soap and water. Treat burns as usual. If swallowed; provide oxygen. Do not induce vomiting; call a physician.
b. Fire Precautions (In case of outbreak): Use water. Neutralize chemically with basic substances such as soda ash or slaked lime.

Spills: Cover with sodium carbonate or an equal mixture of soda ash and slaked lime. After mixing, add water if necessary to form a slurry. Dispose by slowly adding soda ash and slaked lime. Discharge the solution with large amount of water into a sink lined with protective matting and filled with dripped marble.

035 Isooctane $(CH_3)_2CH(CH_2)_4CH_3$

Synonyms: 2,2,4-trimethylpentane, 2-methylheptane.

Life Hazard: High concentrations can cause narcosis.

Flammability: Flash point (-7° C), autoignition temperature (784° F)

Handling: Keep away from heat and open flame: can react viorously with reducing materials.

Emergency Treatment and Measures:

a. Hygienic Precautions: Adequate Ventilation.
b. First Aid: If swallowed, call a physician.
c. Fire Precautions (First Aid): Use foam, carbon dioxide, or dry chemical fire extinguisher.

Spills: Absorb on paper. Burn the paper in a hood.

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036 Isopropyl Alcohol $(CH_3)_2CHOH$

Synonyms: Isopropanol, Dimethylcarbinol, Sec-propyl alcohol.

Life Hazard: Acts as a local irritant and in high concentrations as a narcotic. Can cause eye burns. Dangerous! Keep away from heat and open flame; can react vigorously with oxidizing materials.

Flammability: Flash point 12° C (closed cup), 21° C (open cup); auto ignition temperature 399° C; explosive range 2 – 12 percent.

Handling & Storage: Wear safety glasses, rubber gloves, a face shield and coveralls.

Emergency Treatment and Measures:

a. Hygienic Precautions: Adequate ventilation.
b. First Aid: Irrigate eyes with water. If swallowed, call a physician.
c* Fire Precautions (In case of outbreak): Use “alcohol” foam or trichloroethane fire extinguisher. Water spray is not effective to extinguish a fire but is effective to cool containers facing fire or to disperse spills before igniting.

Spills: Absorb on paper. Evaporate on a glass or iron dish in hood. Burn the paper.

037 Kerosene

Synonyms: Kerosine

Life Hazard:

Flammability:

Handling:

Emergency Treatment and Measurements:

a. Hygienic Precautions.
b. First aid.
c. Fire precautions (in case of outbreak).

Spills: Absorb on paper. Burn the paper in a hood.

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038 Lead acetate $PD(CH_3COO)2 \cdot 3H_20$

Synonyms: Lead diacetate.

Life Hazard: A suspected carcinogen. Moderate fire and explosion hazard. When heated it emits highly toxic fumes; can react Vigorously with oxidizing materidls.

Flammability: Not flammable.

Handling: Keep containers closed. Wear rubber gloves, safety goggles. Separate from feed and foodstuff.

Emergency Treatment and Measurements:

Hygienic Precautions: protect against dust inhalation. Wash hands and fingers carefully before taking food and drink or smoking.

Spills: Dissolve in a beaker with plentiful water. Add soda ash and mix. Neutralize with dilute acid. Drain into the sewer with abundant water.

039 Magnesium oxide MgO

Synonyms: Magnesia, Calcined magnesia.

Life Hazard: Avoid inhalation of fumes. Dangerous when heated, it burns violently in air and emits fumes; will react with water or steam to produce hydrogen; on contact with oxidizing materials, it can react vigorously.

Flammability: May ignite and explode when heated with sublimed sulfur, magnesium powder or aluminum powder.

Handling: Keep containers well closed. Compound is moisture-sensitive. Wear thick gloves, safety glasses and a self-contained breathing apparatus.

Emergency Treatment and Measures:

First Aid: Irrigate eyes with water. Wash contaminated areas with soap and water.

Spills: Bury in a landfill, well away from streams, rivers or wells.

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040 Mercuric Iodide HgI_2

Synonym:

Life Hazards: A central nervous system toxin. Dangerous: When heated to vaporization, they emit highly toxic fumes of mercury.

Flammability:

Handling & Storage: Keep containers closed. (Small quantities are preferably stored in polyethylene bottle.) Maintain good ventilation. Close attention should be paid to maintenance and cleaning of apparatus. Wear rubber gloves, self-contained breathing apparatus.

Emergency Treatment and Measures:

a. Hygienic Precautions: Adequate ventilation. Housekeeping in plant must be meticulous and all spills must be cleaned up promptly. Air must be sampled frequently. No eating or smoking in work areas. Protective clothing with special lockers and bathing facilities. Physical examinations of exposed personnel at intervals determined by the degree of exposure, including determinations of mercury in urine as well as necrologic evaluations. Preclude from exposure those individuals with diseases of liver, kidneys, lungs and nerves.

b. First Aid: If swallowed, call a physician.

Spills: N/A

041 Methyl Alcohol CH_3OH

Synonyms: Methanol, Wood Spirits, Wood Alcohol.

Life Hazard: Narcotic in high concentrations and vapors act as an anesthetic. Dangerous, upon exposure to heat or flame; can react vigorously with oxidizing materials. Is poisonous.

Flammability: Flash point 15.5° C (open cup), 10° C (closed cup), autoignition temperature 464° C; flammable limits 6.0 - 36.5 percent.

Handling & Storage: Store containers in well-ventilated place. Large volume storage should be remote from inhabited buildings or structures. Keep away from all sources of ignition. Wear chemical goggles or face shield, rubber gloves, aprons and boots.

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Emergency Treatment and Measures:

a. Hygienic Precautions: Adequate ventilation. Physical examinations of exposed personnel every six months including tests of visual function, . careful necrologic evaluation, and studies of kidney and liver function. Preclude from exposure those individuals with diseases of eyes, liver, kidneys and lungs.
b. First Aid: Irrigate eyes with water. Wash contaminated areas of body with soap and water. Hospitalize, and call a physician.
c. Fire Precautions (In case of outbreak): Use dry chemical, alcohol foam, or carbon dioxide, water spray may be ineffective as an extinguishing agent, but water should be used to keep fire-exposed containers cool.

Spills: Absorb on paper. Evaporate on glass or iron dish in hood. Burn the paper.

042 Methyl ethyl ketone $CH_3COC_2H_5$

Synonyms: Methyl Ethyl Ketone; 2-Butanone, MEK.

Life Hazard: Strongly anesthetic. Threshold limit value probably similar to that of ethyl ether, 400 ppm. Wear self-contained breathing apparatus. Highly dangerous upon exposure to heat or flame.

Flammability: Flammable; dangerous fire and explosion risk. Flash point (open cup) -4° C; ignition temperature 516° C; flammable limits 2 - 10 percent.

Handling & Storage: Close tightly, store in cool place, and check intermittently for leakage. Avoid fire. Preferably provide electrical equipment with spark-resistant construction. Wear rubber gloves, protective clothing, and face shield. Provide with general-purpose breathing apparatus.

Emergency Treatment and Measures:

a. Hygienic Precautions: Adequate ventilation. Enforce adequate protective clothing. Make annually physical examinations, including blood cell count l Preclude from exposure those individuals with diseases of skin, blood, and central nervous system.
b. First Aid: Flush eyes with water. Wash out contaminated areas of body with soap and water. If swallowed, call a physician.

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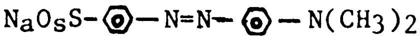
c. Fire Precautions (In case of outbreak): Use alcohol foam, powder, and carbon dioxide extinguisher. Water spray is ineffective for extinguishing, but may help to keep fire-exposed containers cool, and to guard fighters who attempt to stop leakage by diffusing vapor of the leaked ketone if not flushed yet.

Spills: Absorb on paper. Evaporate on a glass or iron dish in hood. Burn the paper.

043 Methyl orange



Synonyms: Helianthine B, Orange III, Bayer 22555, Dimethylaminobenzenediazosulfonic acid sodium, p-dimethaminoazobenzesulfonate.

Life Hazard: Dangerous: When heated to decomposition, it emits highly toxic fumes of SO_x.

Flammability: N/A

Handling: N/A

Emergency Treatment and Pleasures: N/A

Spills: The compound should be burned. Ideally, all hydrocarbons and related solvents should be burned in a solvent “burner. Bury in a land fill, well away from streams, rivers, or wells.

044 Naphtha

Synonym: Petroleum ether.

Life Hazard: A recognized carcinogen. Moderate, when exposed to heat or flame; can react with oxidizing materials. Keep containers tightly closed.

Flammability: Flash point -48.3° C; ignition temperature 287.8° C; flammable limits 0.9 - 6 percent.

Handling: Keep containers closed, and store in a cool, well-ventilated place. Wear rubber gloves, face shield, overalls and all-purpose canister mask.

Emergency Treatment and Measures:

a. Hygienic Precautions: Adequate ventilation.

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b. First Aid: Inhalation; remove to fresh air, treat symptoms. Ingestion: do not induce vomiting, call a doctor. Eyes : flush with water for 15 minutes. Skin: wipe off and wash with soap and water.
c. Fire Precautions (In case of outbreak): Use foam, dry chemical, or carbon dioxide fire extinguisher.

Spills: Absorb on paper. Evaporate on a glass or iron dish in hood. Burn the paper.

045 Neopentyl Polyol Ester

Synonyms: N/A

Life Hazard: N/A

Flammability: N/A

Handling: N/A

Emergency Treatment and Measures:

a. Hygienic Precautions: N/A
b. First Aid: N/A
c. Fire Precautions (In case of outbreak): N/A

Spills: N/A

046 Nitric acid HNO_3

Synonyms: Aqua Fortis, Engraver's Acid, Azotic Acid.

Life Hazard: Dangerous when heated to decomposition, it emits highly toxic fumes of NO_x and hydrogen nitrate; will react with water and steam to produce heat and toxic and corrosive fumes. Liquid causes severe tissue burns.

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Risks by Contacts under Mixed Conditions

Hazardous substances if contacts are made	Items	Conditions	Phenomenon	Remarks	
Nitric acid	Alcohol	Contacts under normal temperature	Ignition	Forms ester of nitric acid	The use of nitric acid is hazardous when selenium is oxidized into selenic acid as it forms an explosive coagulate during the drying-up. Phosphorus may explode by heating if it does not dissolve completely during the preparation of phosphor. ic acid.
	Inflammables		“		
	Copper chloride of β-diketone		Decomposition explosion		
Conc nitric acid	Acetylene	"	Ignition or Explosion	Forms tetranitromethane	
	Organics	"			
	Conc ammonia water	"		Ammonium nitrate	
	Conc amines	"	"	Amine nitrate	
	Nitrogen dioxide	"	"		
	Carbohydrates	"	"	Forms nitrocellulose, nitrostarch & acetyl nitrate	
	Organic acid	“	"		
	Strong oxidizing agent	"	"		
Fuming thick nitric acid	Turpentine oil, paper, wood, cloth & other organics	"	Ignition		
Fuming nitric acid	Thiophene	"	Explosion		
	Hydrogen iodide gas	"	Ignition		
	Hydrogen selenide	"	"		
	Hydrogen phosphide	"	"		
	Hydrogen sulfide	"	"		

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Flammability: Noncombustible but dangerously reactive with many materials. Reacts explosively with metallic powders, carbides, hydrogen sulfide and turpentine. Increases flammability of combustible, organic and readily oxidizable materials; can cause spontaneous ignition of some materials.

Emergency Treatment and Measures:

a. Hygienic Precautions: Requires proper ventilation and clothings for protection. Those suffering from diseases of lungs and kidney should avoid contact.
b. First Aid: Fully rinse eyes with water. Bodily polluted portions should be fully washed by 5 percent solution of sodium bicarbonate, or soap and water. Burns should be treated with a cloth immersed in a saturated solution of potassium thiosulfate. If swallowed, call a physician.
c. Fire Precautions (In case of outbreak): N/A.

Spills: Cover with sodium carbonate or an equal mixture of soda ash and slaked lime. After mixing, add water if necessary to form a slurry.

047 NO-Chromix Cleaning Solution

Synonyms: N/A

Life Hazard: This solution is a strong oxidizing agent and very corrosive.

Flammability: N/A

Handling: Safety equipment must be worn when preparing and using this solution.

Emergency Treatment and Measures: N/A

Spills: N/A

048 Oleic acid $CH_3(CH_2)CH = CH(CH_2)_7COOH$

Synonyms: cis-Octadecenoic acid, Red oil.

Life Hazard: Slight, when exposed to heat or flame.

Flammability: Flash point 200° C; Autoignition temperature 363° C; combustible.

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Handling & Storage: Keep containers closed and store in cool and dark places. Wear rubber gloves, face shield, coveralls, full body shields and self-contained breathing apparatuses should be equipped.

Emergency Treatment and Measures:

a. First Aid: Ingestion: give large amount of water, call a physician. Eyes: flush with water, get medical attention. Skin: wash with soap and water.
b. Fire precautions (In case of outbreak): Use dry chemical, or carbon dioxide. Water or foam may cause frothing. Water spray may be used to flush spills away from exposures.

spills : Cover with soda ash or sodium bicarbonate. Mix and add water. Neutralize and drain into a drain with sufficient water.

049 Pelargonic Acid $CH_3(CH_2)_7$, COOH

Synonyms: Ethyl Heptanoic Acid, Nonanoil Acid, Nonic Acid.

Life Hazard: Limited data suggests low systemic toxicity but high irritation of skin.

Flammability: Flash point (100° C).

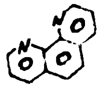
Handling: N/A

Emergency Treatment and Measures:

a. Hygienic Precautions: N/A
b. First Aid: N/A
c. Fire Precautions (In case of outbreak): N/A

spills: Bury in a land fill, well away from streams, rivers, or wells.

050 1,10-Phenanthroline



Synonyms: 4,5-Diazaphenanthrene, Orthophenanthroline, Beta-Phenanthroline, 4,5-Phenanthroline.

Life Hazard: A toxic material

Flammability: N/A

Handling: A hydroscopic material.

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Emergency Treatment and Measures: N/A

Spills: Absorb on paper. Burn in a hood.

051 Phenolphthalein $C_{20}H_4O_4$

Synonyms: 3-3-bis (p-hydroxyphenyl) phthalide.

Life Hazard: N/A

Flammability: N/A

Handling: N/A

Emergency Treatment and Measures:

a. Hygienic Precautions: N/A
b. First Aid: N/A
c. Fire Precautions (In case of outbreak): N/A

Spills: Absorb on paper, burn in solvent burner. Bury the ashes in a landfill well away from streams, rivers, or wells.

052 Phosphoric Acid H_3PO_4

Synonyms: Orthophosphoric Acid.

Life hazards: When heated to decomposition, it emits toxic fumes of POX.

Flammability: Not flammable. Reacts with metals to liberate flammable hydrogen gas.

Handling: A corrosive material. Wear rubber gloves.

Emergency Treatment and Measures:

a. Hygienic Precautions: Proper ventilation and protector: preclude from exposure those individuals with pulmonary diseases.
b. First Aid: Ingestion: do not induce vomiting, give water, milk or vegetable oil, call a physician. Skin or eye contact: flush with water for at least 15 minutes.
c. Fire precautions (In case of outbreak): N/A

Spills: Neutralize with lime or sodium bicarbonate. Dilute slowly with water and wash down the drain with excess water.

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053 Potassium carbonate K_2CO_3

Synonyms: Potash, Pearl ash.

Life Hazard: Toxic. Yields toxic fumes when involved in fire. A strong caustic.

Flammability: N/A

Handling: Wear rubber gloves, safety glasses and coveralls. A hydroscopic material.

Emergency Treatment and Measures: N/A

Spills:

a. For solid:
Sweep into a beaker. Dilute with sufficient water. Add soda ash. Mix and neutralize with dilute acid. Drain into the sewer with abundant water.

b. For solution:
Cover with soda ash. After mixing, transfer into a beaker containing water. Neutralize with dilute acid. Drain into a sewer with abundant water.

054 Potassium chlorate $KC10_3$

Synonym: Potcrate.

Life Hazard: Dangerous; shock will induce explosion; when heated to decomposition, it can emit toxic fumes and explode; can react with reducing materials. Hazardous reactions with:

Substance	Condition	Reaction
Sulfur	friction, impact, heating	explosion
Carbon disulfide	-same-	same
Organic sulfur, sulfides	-same-	same
Phosphorus red	-same-	same
Ammonium rhodanate	impact	ignition
Ammonium rhodanate+ copper+alcohol	friction, impact	explosion

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Hydrazine, hydroxylamine	contact	same
Zinc chloride	letting stand at atmospheric	heat generation
Sugar + ferryicyanides	impact	explosion
Sodium hyposulfite	impact, friction	same
Powder of combustible materials	same	same
Amines (org, inorg)	same	same

Flammability: Powerful oxidizing material. Forms explosive mixtures with combustible, organic or other easily oxidizable materials. These mixtures are easily ignited by friction or heat.

Handling: Protect containers against physical damage. Separate from combustible, organic or other readily oxidizable materials, acids, ammonium salts, sulfur and flammable vapors. Avoid storage on wood floors. Immediately remove and dispose of any spilled chlorate. Wear rubber gloves, face shield and coverall.

Emergency Treatment and Measures:

a. Hygienic Precautions: Encourage personal cleanliness. Provide instructions to exposed personnel.
b. First Aid: If swallowed, call a physician.
c* Fire Precautions (In case of outbreak): Flood with water.

Spills: Cover with weak reducing agents such as hype, bisulfites or ferrous salts. Bisulfites or ferrous salts need additional promoter of some 3M-H_2S0_4 to accelerate reaction. Transfer the slurry (or sludge) into a large container of water and neutralize with soda ash. Drain into a sewer with abundant water.

055 Potassium bichromate $K_2Cr_20_7$

Synonyms: Potassium bichromate, Red chromate of potash.

Life Hazard: Highly toxic. A recognized carcinogen. A moderate fire hazard by chemical reaction. A powerful oxidizer. Dust may cause skin and nasal irritation. Strong solutions can irritate the skin. Hazardous reaction with:

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	Condition	Reaction
Mercury cyanides	Friction	Burning
Flammable materials	Heating	Ignition
Hydrazines, their hydrates	Contact	Ignition, explosion
Hydroxylamines, their salts	Contact	Ignition, explosion
Slaked lime	Mixing	Explosion

Flammability: N/A

Handling: Store in cool, dry place away from easily oxidizable substances, inflammables and organic substances. Avoid storing on wooden floor. Keep away from mercury cyanide, hydrazine and its hydrates, hydroxylamine and the salts, slaked lime. Wear rubber gloves face shield, work clothing, and entire bodily shield if prevails strong reactions.

Emergency Treatment and Measures:

a. First Aid: Irrigate eyes with water. Wash contaminated areas of body with soap and water. Call a physician.
b. Fire Precautions (In case of outbreak): In case of a fire use a flooding amount of water.

Spills: Cover with weak reducing agents such as hype, bisulfites or ferrous salts. Bisulfites or ferrous salts need additional promoter of some 3M-H_2S04 to accelerate reaction. Transfer the slurry (or sludge) into a large container of water and neutralize with soda ash. Drain into a sewer with abundant water.

056 Potassium hydroxide KOH

Synonyms: Caustic potash, Potassium hydrate, lye.

Life Hazard: Toxic . A severe eye hazard; solid or concentrated solution destroys tissue on contact. Dangerous; will react with water or steam to produce caustic solution and heat.

Flammability: Not flammable.

Handling: Store in dry place to prevent corrosion of the surface of the drum, absorption of moisture, freezing, etc. For outdoor storage in liquid state, it is advised to protect with some insulation and heating systems. Wear rubber gloves, big face shield and working clothes.

Emergency Treatment and Measures:

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a. First Aid: Irrigate eyes with water. Wash contaminated areas of body with soap and water. Treat skin burns as usual. If swallowed, tail a physician.
b. Fire Precautions (In case of outbreak): Use large volume of water, but do not splash its solution.

Spills: a. For solid:
Collect and remove with a broom in a large bucket. Dilute with water and neutralize with dilute acid. Drain into a sewer with sufficient water.
b. For solution:
Neutralize with dilute acid. Wipe with mop or use water aspirator. Drain into a sewer with sufficient water.

057 Potassium Hydrogen Phthalate $HOOCC_6H_4COOK$

Synonyms:

Life Hazards:

Flammability:

Handling:

Emergency Treatment and Measures:

a. Hygienic Precautions:
b. First Aid:
c. Fire Precautions (In case of outbreak):

spills :

058 Potassium Iodide KI

Synonyms:

Life Hazard: Low toxicity; dietary supplement (up to 0.01 percent in table salt) .

Flammability:

Handling:

Emergency Precautions and Measures:

a. Hygienic Precautions:
b. First Aid:
c. Fire Precautions (In case of outbreak):

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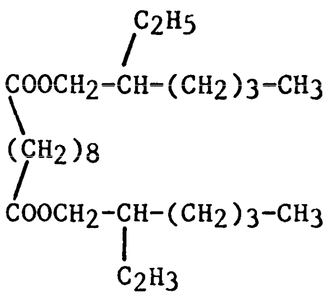
Spills:

059 Sebacic



Synonyms: Bisoflex DOS, Decanedioic Acid Bis (2-Ethylhexyl) ester, Di (2-ethylhexyl) sebacate, Dioctyl sebacate, DOS, 2-ethylhexyl sebacate, 1-Hexanol 2-ethyl-sebacate, Monoplex DOS, Octoiis octyl sebacate, PX 438, Staflex DOS Bisoflex DOS.

Life Hazard: Highly volatile and can act as asphyxiants or narcotic.

Flammability: N/A

Fire Precautions: Use foam, carbon dioxide, or dry chemical fire extinguisher.

Spills: Absorb on paper and evaporate on glass dish in hood. Burn the paper.

060 Silicon Sulfate

Synonyms:

Life Hazards:

Flammability:

Handling:

Emergency Treatment and Measures:

a. Hygienic Precautions:
b. First Aid:
c. Fire Precautions (In case of outbreak):

spills:

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061 Soda Lime

Synonyms: N/A

Life Hazard: N/A

Flammability: N/A

Handling: N/A

Emergency Treatment and Measures:

a. Hygienic Precautions: N/A
b. First Aid: N/A
c. Fire Precautions (In case of outbreak): N/A

SpillS: N/A

062 Sodium carbonate Na_2CO_3

Synonyms: Soda ash, Crystal carbonate.

Life Hazard: Low health hazard, is an irritant.

Flammability: N/A

Handling: Keep containers closed to store. A hydroscopic material. Wear rubber gloves, safety glass and coveralls.

Emergency Treatment and Measures:

First Aid: Flush eyes with water. Wash skin with soap and water. If swallowed, call a physician.

Spills: a. For solid:
Sweep into a beaker. Dilute with sufficient water. Add soda ash. Mix and neutralize with 6M-HC1. Drain into the sewer with abundant water.
b. For solution:
Cover with soda ash. After mixing, transfer into a beaker containing water. Neutralize with 6M-HCl. Drain into a sewer with abundant water.

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063 Sodium chloride NaCl

Synonyms: Salt, Common salt, Halite, Sea salt.

Life Hazard: Low health hazard.

Flammability: N/A

Handling: Store in dry area, is a hydroscopic material.

Spills and Leakage:

a. For solid:
collect, dilute with water, and drain into the sewer with sufficient water.

b. For solution:
Wipe with mop or use water aspiration. Drain into the sewer with sufficient water.

064 Sodium bichromate $Na_2Cr_2O_7 \cdot 2H_2O$

Synonyms: Sodium bichromate, Sodium acid chromate.

Life Hazard: A recognized carcinogen. Dust may cause skin and nasal irritation. Strong solutions can irritate the skin. Hazardous reaction with:

Carbide	Mixing	Ignition & explosion
Amines such as hydrazine, hydroxylamine, anilin		"
Slaked lime	"	"
Mercury cyanides	Friction	Heat evolution & decomposition
Oxidizable materials	Contact	Ignition

Flammability: Decomposes by heating and discharging oxygen, thus promotes the combustion.

Handling: Keep away from inflammables and easily oxidizable substances; tightly close and store in dry place. Wooden floor is not recommendable.

Emergency Treatment and Measures:

a. Hygienic Precautions: Adequate ventilation. Chest X-rays every six months up to five years exposure and every three months in excess thereof. Papanicolaou studies of sputum every three months.

b. First Aid: If swallowed, call a physician.

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c. Fire Precautions (In case of outbreak): Put out fire by flooding water.

Spills: Cover with weak reducing agents such as hype, bisulfites or ferrous Salts. Bisulfites or ferrous salts need additional promoter of some 3M-H_2S0_4 for radid reaction. Transfer the slurry (or sludge) into a large container of water and neutralize with soda ash. Drain into the sewer with abundant water.

065 Sodium hydroxide NaOH

Synonyms: Caustic soda, Sodium hydrate, White caustic, Soda lye.

Life Hazard: Toxic . A severe eye hazard; solid or concentrated solution destroys tissue on contact.

Flammability: Not combustible but solid form in contact with moisture or water may generate sufficient heat to ignite combustible materials. Contact with some metals can generate hydrogen gas.

Handling: Protect against physical damage of container. Store in dry place. Protect against moisture and water. Separate from acids, metals, explosives, organic peroxides and easily ignitible materials. Wear chemical goggles or full face shield, mechanical filter respirator, rubber gloves, aprons and boots.

Emergency Treatment and Measures:

a. Hygienic Precautions: Personal cleanliness.
b. First Aid: Irrigate eyes with water. Wash contaminated areas of body with soap and water. Treat skin burns as usual. If swallowed, call a physician.
c. Fire Precautions (In case of outbreak): Flood with water, using care not to splatter or splash this material.

Spills: a. For solid:
Collect and remove with a broom in a large bucket. Dilute with water and neutralize with dilute acid. Drain into a sewer with sufficient water.

b. For solution:
Neutralize with HC1. Wipe with mop or use water vacuum. Drain into the sewer with sufficient water.

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066 Sodium Sulfate Na_2SO_4

Synonyms:

Life Hazards: Is an irritant. Can emit highly toxic SO_x when heated to decomposition.

Flammability: Not Flammable.

Handling: IS a hydroscopic material.

Emergency Treatments and Measures:

a. Hygienic Precautions: N/A
b. First Aid: Ingestion, treatment is symptomatic and supportive, call a physician.
c. Fire Precautions (In case of outbreak): N/A

spills : Wash down the drain with excess water ,

067 Sodium Thiosulfate $Na_2S_2O_3 \cdot 5H_2O$

Synonyms: Hyposodium subsulfite.

Life Hazards: Low toxicity; used as food additive up to 0.19.

Flammability:

Handling:

Emergency Treatment and Measures:

a. Hygienic Precautions.
b. First Aid.
c. Fire Precautions (In case of outbreak).

spills:

068 Sulfuric acid H_2SO_4

Synonyms: Oil Of Vitriol, Dipping acid, Battery Acid, Fertilizer *Acid.*

Life Hazard: Contact with the body tissue results in rapid tissue destruction, causing severe burns. Threshold limit value of fumes or mist, 1 mg/m^3 moderate fire hazard, by chemical reaction; a powerful oxidizer; can ignite upon contact with combustibles. When heated, it emits highly toxic fumes.

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Flammability: Not flammable but highly reactive and capable of igniting finely divided combustible materials on contact. Reacts violently with water and organic materials with evolution of heat. Extremely hazardous in contact with many materials. Attacks and corrodes many metals by releasing hydrogen.

Handling: Protect containers against physical damage and prevent contacts with water. Separate from carbides, chlorates, fulminates, nitrates, picrates, powdered metals and combustible materials. Wear rubber gloves, chemical goggles, rubber boots and chemical cartridge respirator.

Emergency Treatment and Measures:

a. Hygienic Precautions: Adequate ventilation. Preclude from exposure those individuals with pulmonary diseases.
b. First Aid: Irrigate eyes with water. Wash contaminated areas of body with soap and water. If swallowed, call a physician. Do not induce vomiting.
c. Fire Precautions (In case of outbreak): Fire involving small amount of combustibles may be smothered with suitable dry chemical. Use water on combustibles burning in vicinity of this material but use care as water applied directly to this acid results in evolution of heat and causes splattering.

Spills: Cover with sodium carbonate or an equal mixture of soda ash and slaked lime. After mixing, add water if necessary to form a slurry.

069 Sulfurous Acid H_2SO_3

Synonyms: N/A

Life Hazard: Highly toxic by ingestion and inhalation; strong irritant to tissue.

Flammability: N/A

Handling: Wear self-contained breathing apparatus, eye goggles, rubber gloves, and rubber apron.

Emergency Treatment and Measures:

First Aid: If swallowed, call a physician.

Spills: N/A

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070 Tannic acid $C_{76}H_{52}O_{46}$

Synonyms: Gallotannic acid, Tannin, Glycerite.

Life Hazard: Moderately toxic by ingestion and inhalation. Combustible. Suspected carcinogen.

Flammability: Flash point 200° C, autoignition temperature 200° C.

Handling: Avoid skin contact and inhalation.

Emergency Treatment and Measures: N/A

First Aid: If swallowed, call a physician.

spills: Absorb on paper. Burn in a hood.

071 Teflon

Synonyms: Polytetra fluoroethylene.

Life Hazards: When heated to above 400° C, it decomposes to yield highly toxic fumes of fluorides.

Flammability: N/A

Handling: N/A

Emergency Treatment and Measures:

a. Hygienic Precautions: N/A
b. First Aid: N/A
c. Fire Precautions (In case of outbreak): N/A

Spills: Bury in a landfill well away from streams, rivers, or wells.

072 Tetrachloroethylene $C1_2C=CC12$

Synonyms: perchloroethylene. Ethylene tetrachloride, Nema, Carbon dichloride, Tetracap, Perclene.

Life Hazard: Incoordination and impaired judgement may occur at vapor exposures from 300 ppm to 1000 ppm. Dizziness, drowsiness, loss of consciousness and even death can occur at increasing levels of exposure. When involved in fire, tetrachloroethylene emits highly toxic and irritating fumes of chlorides, a suspected carcinogen.

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Flammability: The compound has no flash point. Vapor may decompose at high temperature such as open flame, red–heated materials, with evolution of poisonous gases such as chlorine, carbon monoxide, phosgene.

Handling: Store in a closed container in a cool place. Protect against direct sunlight. Do not store in ill–ventilated cellars and hollow places owing to high vapor density. Wear safety goggles, gas mask, rubber gloves. Adequate ventilation.

Emergency Treatment and Measures:

a. Hygienic Precautions: Examine liver and kidneys periodically. Preclude from exposure those individuals with diseases of heart, liver, kidneys and lungs.
b. First Aid: Irrigate eyes with water. Wash contaminated areas of body with soap and water. If swallowed, call a physician. Administer oxygen for oxygen-shortage.

Spills: Absorb on paper and evaporate on a glass dish in hood. Burn the paper. The compound should be redistilled and reused.

073 Tetra Ethyl Lead $Pb(C_2H_5)_4$

Synonyms: Lead tetraethyl, TEL.

Life Hazards: Powerful poison and a solvent for fatty materials. Suspected carcinogen.

Flammability: Flash point (85° C), Decomposes above 110° C. Violently explodes when heated to more than 170° C.

Handling: Decomposes when exposed to sunlight or allowed to evaporate. Separate from halogenated compounds or oxidzing agents.

Emergency Treatments and Measures:

a. Hygienic Precautions: Avoid skin contact.
b. First Aid: Ingestion: induce vomiting, call a physician Skin: wash immediately with kerosene or similar petroleum distillate followed by soap and water.
co Fire Precautions (in case of outbreak): Use water, foam, dry chemicals, or carbon dioxide fire extinguisher.

Spills: Absorb the spills with paper towels or like materials. Place in a hood to evaporate. Dispose by burning the towel.

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074 Toluene

Synonyms: Toluol, Methylbenzene, Phenylmethane, Methacide.

Life Hazard: A recognized carcinogen. Eye and respiratory irritant. Extreme inhalation of vapors may cause death by paralysis of the respiratory center. Threshold limit value, 200 parts per million. Dangerous, when heated, it emits highly toxic fumes; can react with oxidizing materials.

Flammability: Flash point 4.4° C (closed cup); ignition temperature 536° C; flammable limits 1.4 - 6.7 percent. Vapors may travel considerable distance to a source of ignition and flash back.

Handling: Protect containers against physical damage. Outdoors or detached or isolated storage is preferable. Indoor storage should be in a standard flammable liquid storage room. Wear chemical goggles, chemical cartridge respirator or self-contained breathing apparatus and impermeable rubber gloves.

Emergency Treatment and Measures:

a. Hygienic Precautions: Physical examinations of exposed personnel annually with special attention to eyes and nervous system, and including complete blood count and studies of liver function. Preclude from exposure those individuals with diseases of central nervous system and liver.

b. First Aid: Irrigate eyes with water. Wash contaminated areas of body with soap and water. An exposed person should be removed immediately to fresh air and kept warm and quiet. If breathing has stopped, artificial respiration should be commenced. Ingestion: do not induce vomiting, call a physician. Eyes; flush with water. Skin: wash with soap and water.

c. Fire Precautions (In case of outbreak): Use water spray, carbon dioxide, dry chemical or foam fire extinguishers.

Spills: Spills are absorbed on paper which is then placed in an iron pan to evaporate it in a hood. Then burn the paper down.

075 1,1,1-Trichloroethane $CH_3C\ Cl_3$

Synonyms: Methylchloroform, Chlorothene, Ethylidyne-chloride.

Life Hazard: Incoordination and impaired judgement may occur at vapor exposures from 500 ppm - 1000 ppm. Dizziness, drowsiness, loss of consciousness and even death can occur at increasing levels of exposure. When involved in fire, 1,1,1-trichloroethane emits highly toxic and irritating fumes.

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Flammability: Autoignition temperature 500° C, flammable limits in air 7-18 percent.

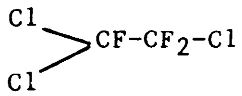
Handling & Storage: Do not store in aluminum containers. Wear safety goggles and rubber gloves.

Emergency Treatment and Measures:

a. Hygienic Precautions: Physical examinations of exposed personnel annually, including studies of liver and kidney function. Preclude from exposure those individuals with diseases of liver and kidneys.
b. First Aid: Irrigate eyes with water. Wash contaminated areas of body with soap and water. Inhalation: oxygen, if necessary. No Adrenaline. Ingestion: have victim drink water and induce vomiting, call a physician.
c. Fire Precautions (in case of outbreak): Use dry chemical, foam, or carbon dioxide fire extinguisher.

Spills: Absorb on paper. Evaporate on a glass dish in hood. Burn the paper in hood.

076 <u>1,1,2-Trichloro-1,2,2-trifluoroethane</u>



Cl_2CF-CF_2-Cl

Synonyms: Trifluorotrichloroethane, Freon-113, Freon TF.

Life Hazard: Tolerance, 1000 ppm in air, poisonous gases may be produced in fire.

‘ amiability: Not flammable.

Endling: Wear safety glasses, working gloves.

Emergency Treatment and Measures:

a. Hygienic Precautions: Wear rubber gloves and apron. Adequate ventilation.
b. First Aid: Skin contact: if frostbite has occured, flush area with warm water. If swallowed, call a physician.

Spills: The compound should be redistilled and reused.

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077 Valerie Acid $CH_3(CH_2)_3COOH$

Synonyms: Pentanic acid.

Life Hazard: A toxic material.

Flammability: Flashpoint (88° C)

Handling: A corrosive material.

Emergency Treatment and Measures:

a. Hygienic Precaution: N/A
b. First Aid: N/A
c. Fire precaution (In case of outbreak): Use alcohol foam, carbon dioxide or dry chemical fire extinguishers.

Spills: Absorb on paper, then burn in a hood.

078 Xylene $C_6H_4(CH_3)_2$

Synonyms: Xylol

Life Hazards: Vapors cause headache and dizziness. Liquid irritates eyes and skin. If taken into lungs, causes severe coughing, distress and rapidly developing pulmonary edema. If ingested, causes nausea, vomiting, cramps, headache, and coma; can be fatal. Kidney and liver damage can occur.

Flammability: Flash point (29-46° C), autoignition temperature (469-528° C).

Handling: Keep vapors away from open flames.

Emergency Treatments and Measures:
a. Hygienic Precautions: Adequate ventilation, rubber gloves.
b. First Aid: Inhalation: remove to fresh air, administer artifical respiration and oxygen if necessary, call a doctor. Ingestion: Do not induce vomiting, call a doctor, Eyes contact: flush with water for 15 minutes. Skin contact: wipe off and wash with soap and water.
c. Fire Precaution (In case of outbreak): Use foam, carbon dioxide, or dry chemical fire extinguisher.

Spills: Absorb on paper, then burn in a hood.

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079 Barium Carbonate

Synonyms: N/A

Life Hazard: N/A

Flammability: N/A

Handling: N/A

Emergency Treatment and Measures:

a. Hygienic Precautions: N/A
b. First Aid: N/A
c. Fire precautions (In case of outbreak): N/A

spills: N/A

080 Chromium Trioxide

Synonyms: N/A

Life Hazard: N/A

Flammability: N/A

Handling: N/A

Emergency Treatment and Measures:

a. Hygienic Precautions: N/A
b. First Aid: N/A
c. Fire Precautions (In case of outbreak): N/A

spills: N/A

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081 Nickelous Chloride

Synonyms: N/A

Life Hazard: N/A

Flammability: N/A

Handling: N/A

Emergency Treatment and Measures:

a. Hygienic Precautions: N/A
b. First Aid: N/A
c. Fire Precautions (In case of outbreak): N/A

Spills: N/A

082 Silver Nitrate

Synonyms: N/A

Life Hazard: N/A

Flammability: N/A

Handling: N/A

Emergency Treatment and Measures:

a. Hygienic Precautions: N/A
b. First Aid: N/A
c. Fire Precautions (In case of outbreak): N/A

Spills: N/A

Method Prepared by:

Army - ME - 1986

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LIST OF MATERIALS CITED IN EACH TEST METHOD

Method	Name and Materials
103.6	Color of gasoline. 1. Reference gasoline.
202.1	Cloud intensity at low temperature. 1. Methanol - glycerol. 2. Barium chloride. 3. Sulfuric acid. 4. Sodium hydroxide. 5. Distilled water.
203.1	Pour stability of lubricating oils. 1. Engine crankcase oil.
204.1	Diluted pour point. 1. Naphtha. 2. Xylene.
313.3	Penetration of lubricating greases after prolonged working. 1. Grease to be tested.
321.3	Oil separation from lubricating grease (static technique). 1. None.
335.3	Gear wear. 1. Dry cleaning solvent (ASTM D 484, type I). 2. Petroleum ether (O-E-751). 3. Di-2-ethylhexyl sebacate, commercial grade. 4. Test gear set, brass and steel.
339.6	Performance of diesel engine lubricating oil under severe operating conditions. 1. Fuel; marine diesel. 2. New engine parts.

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Method	Name and Materials
347.3	Performance of aviation piston engine oils in CLR engine (low temperature dispersancy and detergency). 1. Reference oil 2. Gasoline, referee grade. 3. Nonaddictive engine oil. 4. Solvent, dry cleaning, (ASTM D 484, type I). 5. Pentone ECS, special cleaning compound.
350.2	Evaporation loss of lubricating greases and oils (high temperature). 1. 1,1,1-trichloroethane (0-T-620). 2. Tissue, facial (UU-T-450).
352.1	Effect of evaporation on flammability. 1. Pipe cleaners.
353.1	Evaporation. 1. None.
354.1	Performance of arctic lubricating oils in a two-cycle diesel engine under cyclic, turbo-supercharged conditions. 1. Diesel fuel. 2. Dry cleaning solvent, ASTM D 484, type I, Exxon “Varsol” or “D-carb”. 3. Engine coolant, ethylene glycol and water. . 4. Reference engine oil.
355	Performance of lubricating oils in a two-cycle diesel engine under cyclic, turbo-supercharged conditions. 1. Diesel fuel. 2. Dry cleaning solvent. ASTM D 484, type I, Exxon “Varsol” or “D-carb”. 3. Engine coolant, ethylene glycol and water. 4. Reference engine oil.

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Method	Name and Materials
361.4	Stroking properties of hydraulic brake fluids. 1. Ethyl alcohol (ACS). 2. Crocus cloth. 3. Wheel cylinder assemblies. 4. Master cylinder assembly. 5. Rubber cups. 6. Wheel cylinder pistons. 7. Master cylinder pistons.
500.1	Induction system deposit (ISD) tendencies of motor gasoline. 1. n-Hexane, ACS reagent grade. 2. Toluene, ACS reagent grade. 3* Acetone, ACS reagent grade.
550.1	Emulsification tendencies of petroleum fuels by multiple contact extractions. 1. Cleaning solution, concentrated sulfuric acid saturated with technical grade potassium bichromate. 2. Distilled or deionized water.
1110.2	Quenching speed. 1. Steel test bars, QQ-S-631. 2. Abrasive paper, 280 grit (P-P-121). 3. 1,1,1-trichloroethane (0-T-620). 4. Facial tissue (UU-T-450).
1151.2	Explosive vapors in boiler fuel oil. 1. Hydrocarbon gas.
1303.2	Flock point (refrigerant compressor oil). 1. Refrigerant, freon-12 or equivalent.
2508,1	Thermal stability of lubricating and hydraulic fluids. 1. Cleaning solution, concentrated sulfuric acid saturated with potassium bichromate. 2. Detergent for cleaning glassware.

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Method	Name and Materials
3005.4	Dirt content of grease. 1. None.
3006.3	Contamination in engine oil. 1. Naphtha (TT-N-95). 2. Unleaded gasoline. 3. Iso-octane (technical grade).
3007.2	Water displacement and water stability. 1. Steel test panels, FS 1009, QQ-S-698. 2. Naphtha, aliphatic (TT-N-95). 3. Methanol (O-M-232). 4. Distilled water. 5. Silica sand, white, dry, sharp. 6. Surgical gauze. 7. Absorbent tissue. 8. Emulsion, water and oil.
3009.3	Solid-particle contamination in hydraulic fluids. 1. Distilled water. 2. Alcohol, isopropyl (TT-I-735). 3. Petroleum ether (O-E-751). 4. Detergent, water-soluble, commercial. 5. Cleaning solution, glass (concentrated sulfuric acid with saturated potassium or sodium bichromate, technical grade). 6. Tape, transparent, pressure-sensitive. 7. Filters, cellulose membrane.
3010.9	Solid particle contamination in aircraft turbine engine lubricants (gravimetric procedure). 1. Isopropyl alcohol, reagent grade. 2. petroleum ether, reagent grade, boiling point range 30° to 60° C.
3011.1	particulate contamination in aerospace hydraulic fluids using the HIAC counter. 1. Detergent, liquid, water soluble, commercial grade. 2. Isopropyl alcohol (TT-I-735). 3. Trichlorofluoroethane (MIL-C-81302). 4. Petroleum ether 100/120 degree celsius.

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Method	Name and Materials
3012	Determination of particulate matter in aerospace hydraulic fluids. 1. AC fine test dust. 2. Primary calibration standard. 3. Detergent, liquid, water soluble, commercial grade. 4. Isopropyl alcohol. 5. Trichlorotrifluoroethane (MIL-C-81302). 6. H-515 hydraulic fluid.
3013	Determination of particulate contamination in synthetic turbine engine lubricants. 1. Isopropyl alcohol, reagent grade. 2. Petroleum ether, 30 to 60° boiling range, reagent grade.
3110.1	Fatty oil in cutting fluids by infared spectrophotometry. 1. Fatty oil, MIL-F-46148. 2. Mineral oil, VV-O-241.
3180.2	Sulfur in cutting fluids (active and total). 1. Copper powder, ACS. 2. Nitric acid, 5 percent. 3. Acetone, ACS. 4. Isooctane, knock test grade. 5. Filter paper. Whatman No. 4 and No. 42 or equivalent. 6. Firing wire, iron approximately 26 B and S gage. 7. Blue litmus paper. 8. Materials required for ASTM D 129.
3201.7	Emulsion (petroleum and petroleum-like products). 1. Emulsifying agent (distilled water, sodium-chloride solution or synthetic seawater) as required by the specification.
3205.3	Emulsion (soluble cutting oils). 1. Distilled water.
3213.1	Foaming characteristics of aircraft turbine lubricating oils (static foam test). 1. Solvents, cleaning; dry cleaning solvent (ASTM D 484, type 1) or petroleum distillate. 2. Toluene conforming to ASTM D 892 specifications. 3. Petroleum ether (boiling range 30 to 60° C), ACS.

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Method	Name and Materials
3214.1	Foaming characteristics of aircraft turbine lubricating oils, (dynamic foam test). 1. Desicant, indicating Drierite ® or equivalent for air purifiers. 2. Trichlorotrifluoroethane cleaning solvent, in accordance with MIL-C-81302 type I or II.
3289.1	Total solids in water for aircraft injection systems. 1. Distilled water. 2. Demineralized water. 3. Cleaning solution, glass (concentrated sulfuric acid saturated with potassium or sodium bichromate, technical grade). 4. Sulfuric acid, concentrated, tech grade. 5. Detergent concentrate. 6. Steel wool, grade 1. 7. Indicating desiccant.
3403.2	Compatibility of turbine lubricating oils. 1. Referee lubricant. 2. 1,1,1-tricholoroethane. 3. Cleaning solution, glass (concentrated sulfuric acid saturated with potassium or sodium bichromate, technical grade).
3407.2	Oxidation and thermal stability of aircraft engine lubricating oils (CLR engine). 1. Reference oil. 2. Test fuel (MIL-G-55720), grade 115, 145 commercial aviation gasoline with 12 to 15 percent aromatic content containing 4.6 mL TEL as aviation mix. 3. Oil, SAE 20 noncompounded, having a minimum viscosity index of 75. 4. Solvent, dry-cleaning (ASTM D 484, type II). 5. Cleaning compound, special (Penetone ECS; Penetone Corporation, 74 Hudson Avenue, Tenafly, New Jersey, 07670, (201) 567-3000 or equivalent). 6. Diethylene glycol as coolant.

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Method	Name and Materials
3410.1	High temperature deposit and oil degradation characteristics of aviation turbine oils. 1. Lubricating oil, qualified under MIL-L-23699. 2. Dry cleaning solvent, (ASTM D 484, type I). 3. No. 400 emery paper. 4. No. 30 grit aluminum oxide. 5. Bisolvent; Isopropyl alcohol: Acetone.
3411.1	Thermal stability and corrosivity of aircraft turbine engine lubricants. 1. Toluene, reagent-grade. 2. Actone, reagent-grade. 3. Nitric-sulfuric acid mixture, approximately 1.10. 4. Abrasive paper, silicon carbide, 240 grit. 5. Steel specimens, QQ-S-698 mild steel.
3430.2	Compatibility characteristics of universal gear lubricants. 1. Naphtha, TT-N-95, type II. 2. Reference oils.
3432.1	Compatibility of elastomers with aircraft turbine lubricants. 1. Standard test rubber sheets, type F-A, conforming to US Air Force Specification bulletin 539. 2. Standard test rubber sheets type F’S, conforming to US Air Force specification bulletin 539. 3. Cleaning solution, turco alkaline rust remover or equivalent. 4. Dry cleaning solvent (ASTM D 484, type II). 5. Alcohol, ethyl, ACS grade. 6. Acetone, ACS grade. 7. Distilled water. 8. Filter paper.
3433	Compatibility of synthetic aircraft turbine lubricants with silicone rubber. 1. Standard silicone test rubber sheets, as per US Air Force specification bulletin 539, standard elastomer stocks. 2. Cleaning solution, glass (concentrated sulfuric acid saturated with potassium or sodium bichromate). 3. Methyl alcohol, ACS, particle free. 4. Solvent-naphtha or toluene, ACS. 5. Acetone, ACS, particle free.

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Method	Name and Materials
3440.1	Storage volubility characteristics of universal gear lubricants. 1. Naphtha, (TT-N-95, type II).
3450	Bearing deposition of aviation turbine engine lubricants. 1. Dry cleaning solvent (ASTM D 484, type I). 2. Carbon remover [penetone ECS]. 3. n-Heptone. 4. Acetone. 5. Lubricating oil, MIL-L-6082, grade 1100. 6. Polytetrafluroethylene tape/gasket. 7. Fiberfrax insulation. 8. Raxbestos - manhattan A-50 gasket materials. 9. Metal specimens. - Aluminum; QQ-S-250/4. - Titanium; AMS 4908. - Silver; MTL-S-13282, grade A. - Steel; AMS 5040. - Stainless steel; MIL-S-5059, grade 301, half-hard. 10. Glass wool fiber, coming cat. no. 3950. 11. 400 grit silicon carbide paper. 12. 30 grit aluminum oxide.
34.51.4	Stability of lubricating oils (work factor). 1. Naphtha, precipitation, ASTM D 91.
3452.2	Bearing comparability of turbine oils. 1. Naphtha; aliphatic (TT-N-95), type II.
3456.2	Channeling characteristics of lubricants. 1. None.
3457.2	Hydrolytic stability. 1. Emery paper, 00 or finer. 2. Litmus paper. 3. Petroleum ether (O-E-751). 4. 1,1,1-trichloroethane (methyl chloroform), stabilized (MIL-T-81533). 5. n-Hexane, technical grade. 6. Sodium sulfate, anhydrous (ACS). 7. Copper strip (QQ-C-502).

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Method	Name and Materials
3458.1	Low temperature stability test for oil. 1. None.
3459.1	Low temperature stability. 1. Methyl-alcohol-glycerine (technical grade), 1:1 solution by volume. 2. Turbidity standard prepared with barium chloride, sulfuric acid, sodium hydroxide, and distilled water. 3. Red dye (National Erie Bordeaux B or equivalent).
3463.1	Stability of grease in hot water (water immersion). 1. Distilled water.
3465.1	Storage stability test of fluids and lubricants. 1. Aluminum foil, commercial grade. 2. Scouring powder, commercial grade. 3. Distilled water.
3467.1	Storage stability of lubricating grease. 1. None.
3470.1	Homogeneity and miscibility of oils. 1. Six reference oils.
3480.1	Volatity of blended oils. 1. Test oil.
3500.1	Monobasic acid components of synthetic ester lubricants by gas chronography. 1. Potassium hydroxide, reagent grade. 2. Ethyl alcohol, 95 percent. 3. Distilled water. 4. Hydrochloric acid, dilute. 5. Ethyl ether, reagent grade. 6. Sodium sulfate, anhydrous, reagent grade. 7. Diethyleneglycol adipate polyester. 8. Gas chrom P, 60 to 80 mesh, acid-based washed or equivalent.

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Method	Name and Materials
	9. Chloroform, reagent grade. 10. Phosphoric acid, reagent grade, 85 percent. 11. Helium oil free. 12. Butyric acid, reagent grade. 13. Isovaleric acid, reagent grade. 14. Valerie acid, reagent grade. 15. Caproic acid, reagent grade. 16. Heptylic acid, reagent grade. 17. Caprylic acid, reagent grade. 18. Pelargonic acid, reagent grade. 19. Capric acid, reagent grade.
3603.5	Swelling of synthetic rubbers.
	1. Standard rubber test sheets, as required by the specification. 2. Alcohol, ethyl or methyl, anhydrous. 3. Filter paper. 4. Distilled water.
3604.2	Swelling of synthetic rubber by aircraft.
	1. Standard test rubber sheets, type H or FA. 2. Cleaning solution, glass (concentrated sulfuric acid saturated with potassium or sodium bichromate, technical grade). 3. Naphtha, technical grade. 4. Toluene, technical grade. 5. Alcohol, ethyl. 6. Emery cloth No. 60.
3710.1	Molybdenum disulfide purity.
	1. Potassium chlorate. 2. Nitric acid, concentrated. 3. Hydrochloric acid, concentrated. 4. Ammonium hydroxide, concentrated. 5. Methyl orange indicator solution. 6. Ammonium acetate solution. 7. Glacial acetic acid. 8. Lead acetate solution. 20 g lead acetate, 20 mL glacial acetic acid, and distilled water. 9. Tannic acid indicator. 0.05 g tannic acid, 2 mL glacial acetic acid, and 48 mL distilled water. 10. Ammonium nitrate solution. 30 g ammonium nitrate and distilled water.

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Method	Name and Materials
3720.2	Molybdenum disulfide content of lubricating grease. 1. n-Hexane, ACS grade. 2. Oleic acid, USP grade. 3. Petroleum ether (O-E-751).
3722.2	Molybdenum disulfide content of nonsoap thickened lubricating greases. 1. Hexane, normal, ACS. 2. Extraction thimble (double thickness 3.3 X 8.0 cm). 3. Filter paper (Whatman No. 1 or equivalent). 4. Filter paper (Whatman No. 40 or equivalent). 5. Eschka’s mixture - 2 parts calcined (“light”) magnesia thoroughly mixed with one part of sodium carbonate. 6. Bromine water, saturated. 7. Barium chloride 10 percent. 8. Sodium carbonate CP. 9. Potassium carbonate, CP.
3816.1	Film thickness of dry solid film lubricants. 1. Aluminum alloy test panel (QQ-A-250/5) anodized in accordance with MIL-A-8625, type 1. 2. 1,1,1-trichloroethane (MIL-T-81533).
400103	Corrosion protection by coating: salt-spray (fog) test. 1. Sodium chloride (O-C-265). 2. Hydrochloric acid (O-C-265). 3. Sodium hydroxide (O-C-265). 4. Bromthymol blue (MIL-B-11845) solution, indicator, 6.0 to 7.6 pH range. 5. Distilled water ACS. 6. 1,1,1-trichloroethane (0-T-620). 7. Cleaning tissue, facial (UU-T-450). 8. Low-carbon, open-hearth, cold-finished 1010 steel.
5003.2	Deposit-forming tendencies of aircraft turbine lubricants. 1. Silicon-carbide paper, No. 400. 2. Solvent, dry-cleaning (ASTM D 484, type II). 3. Cleaning solution, glass (concentrated sulfuric acid saturated with potassium or sodium bichromate, technical grade). 4. n-Hexane, thiophene-free (ACS).

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Method Name and Materials

5. Isopropyl alcohol (ACS).
6. Petroleum ether (ACS).
7. Acetic acid, 25 percent solution.
8. Distilled water.
9. Scouring powder, commercial grade.
10. Steel wool.
11. Pipe cleaners.
12. Cleaning compounds, special (penetone ECS; Penetone Corporation, 74 Hudson Avenue, Tenafly, New Jersey 07670 or equivalent).

5101.7 Neutrality (Qualitative).

1. Methyl orange indicator solution, 0.1 percent.
2. Distilled water.
3. Phenophthalein indicator solution.

5102.1 Acid and base number by extraction (color-indicator titration).

1. Potassium hydroxide, 0.1 N aqueous solution, standardized to within 0.005 N against potassium hydrogen phthalate (ACS), or benzoic acid (AC3), using phenolphthalein indicator.
2. Sulfuric acid, 0.1 N aqueous solution, standardized to within 0.01 N against the potassium hydroxide solution, using phenolphthalein indicator.
3. Alcohol solution, consisting of 1 part (by volume) absolute methyl alcohol (ACS), 10 parts 95 percent ethyl alcohol (ACS), and 11 parts distilled water (for neutralization number).
4. Phenolphthalein, 1 percent alcoholic solution.
5. Methyl/orgarge, 0.1 percent aqueous solution.

5304.5 Corrosiveness of greases or semi-solid products at 25” C.

1. Copper strips (QQ-C-576).
2. n-Hexane (ACS).
3. Actone (0-A-51), technical grade.
4. Abrasive paper (silicon-carbide or alumina), various grade of grit.
5. Abrasive paper, silicon-carbide, 240 grit.
6. Silicon-carbide, 150 mesh.
7. Cotton, absorbent (JJJ-C-561).

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Method	Name and Materials
5305.1	Corrosiveness of lubricants at 232° C (450° F). 1. Solvent, dry cleaning (ASTM D 484, type I). 2. 1,1,1-trichloroethane (reagent grade). 3. Acetone (ACS). 4. Nitric acid solution (3 parts concentrated nitric acid and 7 parts distilled water). 5. Pumice, FFF grade. 6. Eraser (Eberhard Faber “Pink Pearl” No. 100, or equivalent). 7. Cleaning solution, glass (concentrated sulfuric acid saturated with potassium or sodium bichromate, technical grade). 8. Distilled water.
5306.5	Corrosiveness of emulsifiable cutting fluids. 1. Sodium hydoxide solution, containing approximately 25 percent NaOH by weight. 2. Normal hexane, commercial. 3. 1,1,1-trichloroethane (0-T-620). 4. Distilled water. 5. Cleaning tissue (UU-T-450). 6. Two copper strips (QQ-C-576, electrolytic tough pitch, cold-rolled, half-hard temper). 7. Two brass strips (QQ-B-613, cartridge brass composition 2 half-hard temper). 8. Two cast iron strips (QQ-I-652, class 20, strip only). 9. Two steel strips (QQ-S-698), physical quality, cold-rolled, half-hard temper - CR half-hard No. 2 tempers).
5307.2	Corrosiveness and oxidation stability of aircraft turbine engine lubricants. 1. Metal specimens, washer type. 2. Titanium (AMS 4908). 3* Magnesium (QQ-M-44, Az31B, condition H24). 4. Steel, M-50 (AMS6490). 5. Steel, carbon, mild (QQ-S-698, grade 1009, cold rolled, condition No. 4 or 5). 6. Bronze, silicon (AMS 4616). 7. Silver (MIL-S-13282 [oral], grade A). 8. Aluminum (QQ-A-250/4, T-3 or T-4). 9. Abrasive paper, silicon carbide, 240 and 400 grit. 10. Cotton absorbent 11. n-Hexane, reagent grade.

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Method Name and Materials

12. Acetone, reagent grade.
13. Cleaning solution, glassware, consisting of 1000 mL cone. sulfuric acid and 35 mL saturated sodium bichromate solution (aqueous).
14. Nitric acid, cone, reagent grade.
15. Solvent, de-greasing, trichlorotrifluoroethane (“Freon”-TF or Genesolv–D).
16. Carbon remover, glassware (carb-N-kleen or equivalent).
17. Solution, metal speciman electrocleaning, aqueous solution of 15 g/L sodium hydroxide and 15 g/L trisodium phosphate.
18. Detergent, (alconox or equivalent).

5308.7 Corrosiveness and oxidation stability of light oils (metal squares).

1. Copper, electrolytic (QQ-C-576).
2. Steel, carbon, mild (ASTM A 366, class 1, commercial bright finish).
3. Aluminum alloy (QQ-A-250/4, temper T-3 or T-4).
4. Magnesium alloy (QQ-M-44, AZ 31B), condition H24 or H26.
5. Anodes, cadmium (QQ-A-671).
6. Cord (cotton, nylon or linen), light-weight, clean (for tying metal squares together).
7. Abrasive paper (silicon-carbide or alumina), various grades of grit.
8. Abrasive paper, silicon-carbide, 240 grit.
9. Silicon-carbide grains, 150 mesh.
10. Cotton, absorbent (JJJ-C–561).
11. 1,1,1-trichloroethane (0-T-620).
12. Filter paper (NNN-T-1475).
13. Naphtha, aromatic (TT-N-97).

5309.5 Corrosiveness of greases (copper strip, 100° C).

1. Copper strip, soft tempered, annealed.
2. n-Hexane (ACS grade).
3. Acetone (ACS grade).
4. Fine silicon-carbide or alumina grit paper.
5. 240 grit silicon-carbide paper.
6. 150 mesh silicon-carbide grains.

5321.2 Corrosion of lead by lubricating oils.

1. Test panel, chemical-lead (ASTM B29-55 or equal).
2. Test panel, copper, electrolytic (QQ-C-576).
3. Naphtha, petroleum (MIL-N-15178).

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Method	Name and Materials
	4. Acetone (O-A-51). 5. Steel wool, No 00 (FF-W-556). 6. Pads, absorbent-cotton (JJJ-P-141).
5322.2	Corrosiveness of oil on a bimetallic couple. 1. Steel disks (ASTM A 322, composition G52986). 2. Clips, brass (QQ–B-613, composition 2) spring temper. 3. Abrasive papers, silicon-carbide or aluminum oxide, 150, 240, 400, and 600 grit.
5327.4	Fuel system icing inhibitor in hydrocarbon fuels (Iodometric Method). 1. Crushed ice. 2. FSII standard solution. 3. Potassium bichromate solution, standard 0.2000 N. 4. Sodium thiosulfate solution, standard 0.100 N. A solution of sodium thiosulfate, sodium carbonate, potassium bichromate, sulfuric acid, water, and potassium iodide. 5. Starch indicator solution. A solution of soluble starch mercuric iodide preservative, and water. 6. Sulfuric acid, concentrated.
5329.2	Corrosion-protection (humidity cabinet). 1. Naphtha, aliphatic (TT-N-95). 2. Methyl alcohol (O-M-232). 3. Silica sand, white, dry, sharp (size IAW RR-S-366). 4. Test panels, FS 1009 steel, fabricated from open-hearth, “killed” type low carbon, No. 4 soft-temper, cold–rolled sheet or strip conforming to QQ-S-698. 5. Surgical gauze.
5330.2	Fuel-system icing-inhibitor in hydrocarbon fuel (calorimetric method). 1. Potassium bichromate, ASC grade. 2. Sulfuric acid, concentrated, ASC grade. 3. Distilled or deionized water.
5331.1	Corrosion protection of steel against sulfurous acid-salt spray by solid film lubricants. 1. Steel specimen, carbon steel conforming to FS 1010. 2. Synthetic see water-sulfurous acid test solution (formula ASTM D 1141).

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Method	Name and Materials
	3. Aluminum oxide cloth 240 grit. 4. 1,1,1-trichloroethalle (MIL-T-81533). 5. Distilled water (ASTM D 1193, type III). 6. Sulfurous acid, ACS.
5333.1	Fuel system icing inhibitor by freezing point depression method. 1. Sodium chloride (table salt). 2. Crushed ice.
5340.2	Fuel system icing inhibitor in hydrocarbon fuels (refractometer method). 1. Ethylene glycol monomethyl etherglycerin, ACS grade. 2. Commercial liquid dishwashing detergent. 3. Distilled water.
5341	Fuel system icing inhibitor in hydrocarbon fuels (redox method). 1. Crushed ice. 2. Ethylene glycol monomethyl ether (EGME) standard solution. 3. Potassium bichromate solution, standard 0.2000 N. 4. Ferroin indicator (1,10 phenanthroline ferrous complex). 5. Ferrous ammonium sulfate solution, 1.1000 N. A solution of ferrous ammonium sulfate, concentrated sulfuric acid, potassium bichromate, ferroin indicator, and water. 6. Sulfuric acid, concentrated.
53.2	Fuel system icing inhibitor in hydrocarbon fuel (hand refractometer method). 1. Commercial liquid dishwashing detergent. 2. Distilled water. 3. Lens tissue.
5350.1	Silting index of hydrocarbon fuels. 1. Precipitation naphtha, ASTM D 91. 2. Filters, 0.8 micrometer membrane.
5414.4	Resistance of grease to fuel. 1. Standard test fluid (TT-S-735, type III). 2. Aluminum strip (QQ-A-250/4, tempers T-3 or T-4).

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Method	Name and Materials
5415.1	Resistance of grease to water and a 1:1 water-ethanol solution. 1. Alcohol, ethyl, specially denatured, aircraft (MIL-A-6091). 2. Distilled water.
6050.1	Nitrate-type ignition improves in diesel fuel. 1. Saponification mixture (1 N). A solution of potassium hydroxide and n-butyl alcohol. 2. Diphenylamine (1 percent) solution. A solution of diphenylamine (ACS indicator grade) and sulfuric acid. 3. Toluene (ACS reagent grade).
6052.1	High-temperature - high-pressure spray ignition. 1. Nitrogen gas.
6053.1	Manifold ignition test. 1. Steel wool (FF-S-740).
6505.2	Load–carrying capacity of universal gear. Lubricants by the Timken machine. 1. Kerosene (VV-K-211). 2. Naphtha (TT-N-95, types I or II).
6508.2	Load carrying capacity of lubricating oils (Ryder Gear machine). 1. Lubricating oil, MIL-L-6082, grade 1100. 2. Flushing solvents. Stoddard solvent (ASTM'D 484, type I) and petroleum ether (O-E-751). 3. Test gear, Fafnir WO-6. 4. O-rings, National No. 622710. 5. Shaft seals.
6509.2	Gear-fatigue characteristics of aircraft gas turbine lubricants at 204° C. 1. Lubricating oil, MIL-L-7808. 2. Lubricating oil, MIL-L-9236. 3. Dry cleaning solvent, ASTM D 484, type I. 4. Cleaning compounds, special (penetone ECS; Penetone Corporation, 74 Hudson Avenue, Tenafly, New Jersey 07670 or equivalent). 5. Household cleaner.

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Method Name and Materials

6511.2 Load carrying capacity of lubricating oils at 204° C.

1. Lubricating oil, MIL-L-7808.
2. Lubricating oil, MIL-L-9236.
3. Dry cleaning solvent (ASTM D 484, type I).
4. Cleaning compounds, special (Penetone ECS or equivalent).
5. Household cleaner.

6516.2 Oscillation test of grease in helicopter bearings.

1. Dry cleaning solvent, ASTM D 484, type I.
2. Test bearings (1) timken cone No. 2687 and (2) timken cup No. 2631.
3. Hydraulic fluid, MIL–H-5606.

6517 High–temperature gear load–carrying capacity of lubricating oils.

1. Lubricating oil, MIL-L-7808 or MIL-L-6082, grade 1100.
2. Dry cleaning solvent (ASTM D 484, type I).
3. Petroleum ether (60° - 900).
4. Platers wax.
5. No. 30 grit aluminum oxide.
6. Purified crystalline nickelous chloride (NiC1$_2$).
7. Hydrochloric acid (HC1), reagent grade.
8. Crystalline chrominum trioxide, reagent grade (Cr0$_3$).
9. Crystalline silver nitrate, reagent grade (AgN0$_3$).
10. Barium carbonate, reagent grade (BaC0$_3$).
11. Nickel bar stock.
12. Lead sheet.
13. Reference oil.

6520.1 Extreme pressure properties of lubricants (four ball tester).

1. Dry cleaning solvent (ASTM D 484, type I or type II).
2. Hexane, technical grade.
3. Test balls, AISI-C-52100 steel, AFBMA grade 2.5 EP, extra polish.

9601.1 Inspection requirements.

None.

10000 Material handling safety precautions.

None.

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CROSS REFERENCE LIST BETWEEN INDEX NUMBER (i.e., MATERIAL NAME) AND TEST METHOD NUMBER WHERE THE MATERIAL IS CITED

Index Number	Test Method Number
1	5003
2	500, 3180, 3410, 3411, 3432, 3433, 3450, 5304, 5305, 5307, 5308, 5309, 5321, 5322
3	3710
4	3710
5	3710
6	202, 3459, 3722
7	5102
8	5102
9	3722
10	6050
11	3500
12	3500
13	3500
14	3500
15	3500
16	347, 3407, 3450, 5003, 6509, 6511
Cleaning solution, glass	550, 2508, 3009, 3289, 3403, 3433, 3604, 5003, 5305, 5307
17	2508, 3011, 3012, 5340
18	339
19	3407
20	5327
21	3500
22	6050
23	335, 347, 354, 355, 3213, 3407, 3410, 3432, 3450, 5003, 5305, 6508, 6509, 6511, 6516, 6517, 6520
Eslka's mixture	3722
24	361, 3432, 3500, 3603, 3604, 5102, 5415
25	3500
26	354, 355
27	5327, 5340, 5341
28	5341T
Freon-12	1303
29	103, 347, 3006, 3407

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Index Number	Test Method Number
Glacial acetic acid	3710
30	
31	3450
32	3500
33	500, 3457, 3720, 3722, 5003, 5304, 5306, 5307, 5309, 6520
34	3500, 3710, 4001, 5322, 6517
35	3006, 3180
36	3009, 3010, 3011, 3012, 3013, 3410, 5003
37	6505
38	3710
39	
40	5327
41	202, 3007, 3433, 3603, 5102, 5322, 5329
Methyl alcohol - glycerine	3459
42	
43	3710, 5101, 5102
44	204, 3006, 3007, 3013, 3430, 3433, 3440, 3451, 3452, 3604, 5308, 5321, 5329, 5350, 6505, 6517
45	
46	3180, 3710, 5305, 5307, 5322
Nitric-sulfuric acid mixture	3411
47	
48	3720
49	3500
Petroleum ether	335, 3009, 3010, 3011, 3213, 3457, 3720, 5003, 6508
50	5341
51	5101, 5102
52	3500
53	3500, 3722
54	3710
55	5327, 5330, 5341
56	5102, 6050
57	5102
58	5327
59	335
60	

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Index Number	Test Method Number
61	5102
62	3722, 5327
63	3201, 4001, 5333
64	
65	202, 3459, 4001, 5305
66	3457, 3500
67	5327
68	202, 3289, 3459, 5102, 5322, 5327, 5330, 5341, 6050
69	5331
70	3710
71	
72	
73	
74	500, 3213, 3411, 3433, 3604, 6050
75	350, 1110, 3403, 3457, 3816, 4001, 5305, 5306, 5308, 5331
76	3011, 3012, 3214, 5307
77	3500 (2)
78	204
79	6517
80	6517
81	6517
82	6517

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FED-STD-791C

2. DOCUMENT TITLE LUBRICANTS, LIQUID FUELS, AND RELATED PRODUCTS; METHODS OF TESTING

3a. NAME OF SUBMITTING ORGANIZATION

b. ADDRESS *(Street, City, State, ZIP Code)*

4. TYPE OF ORGANIZATION *(Mark one)*
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