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MILITARY SPECIFICATION

LUBRICATING OIL, AIRCRAFT TURBINE ENGINE, ESTER BASE

This specification is mandatory for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 This specification covers the requirements for one grade of aircraft gas turbine engine lubricating oil.

2. APPLICABLE DOCUMENTS

2.1 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.

SPECIFICATIONS

Federal

QQ-A-250/4	Aluminum Alloy 2024, Plate and Sheet
QQ-M-44	Magnesium Alloy Plate and Sheet
QQ-S-698	Steel, Sheet and Strip, Low Carbon

Military

MIL-S-13282	Silver and Silver Alloy

STANDARDS

Federal

Fed. Test Method Std. No. 791	Lubricants, Liquid Fuels, and Related Products: Methods of Testing

Military

MIL-STD-290	Packaging, Packing, and Marking of Petroleum and Related Products

FSC 9150

PUBLICATIONS

USAF Specification Bulletin

539	Standard Elastomer Stocks

(Copies of specifications, standards, drawings, and publications required by suppliers in conjunction with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 Other publications. The following documents form a part of this specification 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 4616	Silicon Bronze, 92 Cu - 3.2Si - 2.8Zn - 1.5 Fe
AMS 4908	Titanium Alloy Sheet and Strip, 8Mn Annealed
AMS 5544	Alloy Sheet, Strip, and Plate, Corrosion and Heat Resistant, Nickel Base - 19.5Cr - 13.5Co - 4.3Mo - 3.0Ti - 14Al, Consumable Electrode or Vacuum Induction Melted, Annealed
AMS 6260	Steel Bars, Forgings, and Tubing, 1.2Cr - 3.25Ni - 0.12Mo (0.07 - 0.13) (SAE 9310)
AMS 6475	Steel Bars, Forgings, and Tubing, Nitriding 1.1Cr - 3.5Ni - 0.25Mo - 1.25Al (0.21 - 0.26C)
AMS 6490	Steel Bars, Forgings, and Tubing, 4.-Cr - 4.25Mo - 1.0V (0.77 - 0.85C), Premium Bearing Quality, Consumable Electrode Vacuum Melted

(Application for copies should be addressed to the Society of Automotive Engineers, Incorporated, Two Pennsylvania Plaza, New York, New York 10001.)

American Society for Testing and Materials

ASTM D92	Flash and Fire Points by Cleveland Open Cup
ASTM D97	Pour Point
ASTM D270	Sampling Petroleum and Petroleum Products
ASTM D412	Tension Testing of Vulcanized Rubber
ASTM D445	Viscosity of Transparent and Opaque Liquids (Kinematic and Dynamic Viscosities)
ASTM D471	Test for Change in Properties of Elastomeric Vulcanizates Resulting from Immersion in Liquids
ASTM D664	Neutralization Number by Potentiometric Titration
ASTM D892	Foaming Characteristics of Lubricating Oils
ASTM D972	Evaporation Loss of Lubricating Greases and Oils

ASTM D1298	Test for Density, Specific Gravity, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method
ASTM D1744	Water in Liquid Petroleum Products by Karl Fischer Reagent
ASTM D1947	Load-Carrying Capcity of Steam Turbine Oils
ASTM D2155	Autoignition Temperature of Liquid Petroleum Products
ASTM D2240	Test for Indentation Hardness of Rubber and Plastics by Means of a Durometer
ASTM D2273	Trace Sediment in Lubricating Oils
ASTM D2532	Viscosity and Viscosity Change after Standing at -65°F (-53.9°C) of Aircraft Turbine Lubricants
ASTM D2603	Test for Sonic Shear Stability of Polymer-Containing Oils
ASTM D2766	Test for Specific Heat of Liquids and Solids

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.)

3. REQUIREMENTS

3.1 Qualification. The lubricating oil furnished under this specification shall be a product which is qualified for listing on the applicable qualified products list at the time set for opening of bids.

3.1.1 Requalification. Before any change is made in the quality, composition, or source of ingredients of the lubricating oil, or in the site of manufacturing, blending, or rebranding, the supplier must request the qualifying activity (see 6.3) to determine if requalification is required.

3.2 Composition. The composition of this lubricating oil is not limited except that organometallic compounds of titanium are prohibited, and the basestock shall be an ester. If the lubricating oil contains a tricresyl phosphate additive, the oil manufacturer shall certify that not more than one percent of the tricresyl phosphate is orthoisomer.

3.3 Performance characteristics. The performance of the lubricating oil shall conform to the requirements listed in section 3 when tested in accordance with the applicable test method.

3.4 Trace element content. The trace element content of the lubricating oil shall be determined in accordance with 4.8.2. The trace element content shall not exceed the content limit.

Element		Content limit (ppm, max)
Aluminum	(Al)	2
Iron	(Fe)	2
Chromium	(Cr)	2
Silver	(Ag)	1
Copper	(Cu)	1
Magnesium	(Mg)	2
Nickel	(Ni)	2
Titanium	(Ti)	2

3.5 Physical and chemical properties. The physical and chemical properties of the lubricating oil shall conform to the requirements listed in table I when tested in accordance with the applicable test method specified therein.

3.6 Elastomer compatibility characteristics. The elastomer compatibility characteristics of the lubricating oil shall be determined in accordance with 4.8.3. Deterioration of standard synthetic stocks shall not exceed the following limits:

Standard Rubber Stock	Percent Swell, Min/Max		Tensile Strength, Per-Cent Chg, Max	Elongation, Percent Change Max	Hardness, Shore Durometer Change, Max
NBR-H	12	35	--	--	--
F-A	5	25	50	50	25
FS	5	25	50	50	25

3.7 Corrosion characteristics

3.7.1 Corrosion and oxidation stability. The lubricating oil shall be tested in accordance with 4.8.4 and shall meet the requirements of table II.

Table 1 Performance Characteristics

Properties	Requirements		Test Methods ASTM
Water Content, PPM	500 max		D-1744
Trace Sediment, ml/200 ml of Oil	0 005 max		D-2273 1/
Neutralization Number	0 5 max		D-664 2/
Specific Gravity at 60°F/60°F	Report		D-1298
Viscosity at 500 F (260°C), cs	1 0 min		D-445
Viscosity at 210°F (98 9°C), cs	Report		D-445 3/
Viscosity at 100°F (37 8°C), cs	Report		D-445 3/
Viscosity at -40°F (-40°C), cs			
at 35 minutes	15,000 max		D-2532
at 3 hours	15,900 max		D-2532
at 72 hours	17,000 max		D-2532
Pour Point, °F	-65 max		D-97
Shear Stability, Percent Viscosity Loss	4 0 max		D-2603 4/
Flash Point, °F	475 min		D-92
Autoignition Temperature, °F	770 min		D-2155
Evaporation Loss, Percent, @			
400°F (204°C)	5 0 max		D-972 5/
500°F (260°C)	50 max		D-972 5/
Specific Heat, @			D-2766 6/
500°F (260°C)	.48 min		
320°F (160 C)	.44 min		
140°F (60°C)	40 min		
Foaming Characteristics At	Foam Volume, ml, at the end of		D-892 7/
	5 min aeration	60 sec settling period	
75°F (24°C)	25 max	None	
200°F (93°C)	25 max	None	
75°F (after test at 200°F)	25 max	None	

NOTES

1/ Sediment shall be centrifuged from 200 ml of oil sample without the use of solvent

2/ Titrate to a pH11 end point.

3/ The viscosity of subsequent individual production lots reported at 210 F (98 9 C) and 100°F (37 8°C) shall be within ±1.0% and ±1 0%, respectively, of the corresponding viscosity submitted with the original qualification test sample

4/ Use an irradiation period of 30 minutes on a 30 ml oil sample at a power setting which causes 11 5 ±0.5 percent viscosity loss to a 30 ml sample of reference fluid A when irradiated for 5 minutes.

5/ Use a 6-1/2-hour test period and a bath temperature within ±2°F (±1 C) at 400°F and ±4°F (±2°C) at 500°F. Air temperature shall be maintained within ±4°F (±2°C) of bath temperature, using a preheater if necessary

6/ Values may be calculated from an equation of specific heat vs temperature derived from a minimum of five determinations of enthalpy change made over the specified temperature range These shall include determinations of enthalpy change made at elevated temperatures within ±20°C (±36°F) of each of the three required test temperatures.

7/ Report foam collapse period in seconds Complete foam collapse is adjudged to be that point at which no more than a single row of bubbles remain around the cylinder wall and the air inlet tube If this ring of bubbles around the cylinder wall contains segments having two or more layers of bubbles and the difference in height of the foam in the ring is not greater than 10 ml, complete foam collapse is adjudged to be that point at which a break occurs in the ring of bubbles without subsequent reforming of the ring

Table II. Corrosion and Oxidation Stability

Post Test Oil Properties			Post Test Metal Specimen Weight Change, Mg/Cm^2, max.								
Test Temperature	Change in Viscosity at 100°F	Change in Neutralization Number	Al	Ag	Br_1	Br_2	Fe	M-50	Mg	WSP	Ti
428°F (220°C)	25	2.0	±.2	±.2	±.4	-	±.2	±.2	±.2	-	±.2
464°F (240°C)	100	8.0	±.2	±.2	-	±.4	±.2	±.2	-	±.2	±.2

3.8 Deposition characteristics

3.8.1 Bearing deposition. The lubricating oil shall be tested in accordance with 4.8.5 at a test-oil sump temperature of 464°F (240°C) and a test bearing temperature of 572°F (300°C). The test-oil in temperature should be approximately 455°F (235°C) and the test-oil return temperature should be approximately 428°F (220°C). Test results must include reporting data on all determinations conducted. The average overall deposit demerit ratings shall not exceed 80. The weight of filter deposits shall not exceed 2.5 grams and the total oil consumption shall not exceed 3600 ml. The viscosity of the lubricating oil shall not have changed more than 100 percent from the original viscosity at 100°F (37.8°C), and the change in neutralization number shall not be greater than 2.0 during test and at the end of the test period. The metal specimen weight change at the end of the test period shall be not greater than ±0.2 mg/cm^2 from the before test weight for each metal specimen. In addition the following shall be reported:

a. Bearing stabilization temperature
b. Major item deposit demerits
c. Major item colored photographs.

3.9 Lubrication characteristics

3.9.1 Gear load carrying ability at 165°F. The gear load carrying ability of the lubricating oil shall be determined in accordance with 4.8.6.1 and shall meet the below listed requirements.

a. Qualification test requirement: The lubricating oil shall be subjected to six determinations. The average percentage of the six relative rating determinations shall be multiplied by the reference oil specified average value of 2900 ppi and the resulting load carrying ability shall be equal to or greater than 2400 ppi.

b. Quality conformance test requirement: The lubricating oil shall be subjected to a minimum of two and a maximum of six determinations. Test results must include reporting data on all determinations conducted. The average percentage of the relative rating determinations shall be multiplied by the reference oil specified average value of 2900 ppi and the resulting load carrying ability shall be equal to or greater than the following values:

Number of Determinations	Load Carrying Ability (Avg % Relative Rating x 2900 ppi)
2	2550 min
4	2450 min
6	2400 min

3.9.2 Gear load carrying ability at 428°F. The gear load carrying ability of the lubricating oil shall be determined in accordance with 4.8.6.2 and shall meet the below listed requirements:

a. Qualification test requirement: The lubricating oil shall be subjected to six determinations. The average percentage of the six relative rating determinations shall be multiplied by the reference oil specified average value of 2900 ppi and the resulting load carrying ability shall be equal to or greater than 1000 ppi.

b. Quality conformance test requirement: The lubricating oil shall be subjected to a minimum of two and a maximum of six determinations. Test results must include reporting data on all determinations conducted. The average percentage of the relative rating determinations shall be multiplied by the reference oil specified average value of 2900 ppi and the resulting load carrying ability shall be equal to or greater than the following values:

Number of Determinations	Load Carrying Ability (Avg % Relative Rating x 2900 ppi)
2	1150 min
4	1050 min
6	1000 min

3.10 Compatibility

3.10.1 Compatibility, turbidity. The lubricating oil shall be tested in accordance with 4.8.7 and shall be compatible with each of the lubricating oils currently approved under this specification. At the end of the test period, mixtures shall not be turbid and the volume of sediment shall not exceed 0.005 ml per 200 ml of oil.

3.10.2 Compatibility, intermixing. When the lubricating oil is mixed with equal parts of each of the lubricating oils currently approved under this specification the resulting oil intermixture shall be evaluated and pass all of the requirements specified herein except the following:

a. Trace element content (3.4)
b. 100-Hour engine endurance (3.11)
c. Extended storage stability (3.12).

3.11 100-Hour engine endurance. The lubricating oil shall be engine tested in accordance with 4.8.8 to determine its acceptability for turbine engine use. The post test condition of the engine shall indicate no excessive deposits, wear, corrosion, etc. which are attributed to the test oil. The condition of the periodically sampled used oil shall indicate no excessive changes in performance characteristics.

3.12 Extended storage stability. After storage in accordance with 4.8.9, the lubricating oil shall be evaluated to determine conformance with all the requirements specified herein except the specific heat test, compatibility, intermixing, and the 100-hour engine endurance test. Tentative approval shall be given to products meeting all specification qualification tests and final approval shall be awarded upon successful completion of this test. Failure to pass this test shall be cause for withdrawal of approval.

3.13 Workmanship. The finished lubricating oil shall be transparent, uniform in appearance, and shall be free from cloudiness, suspended matter or other adulterations, when examined visually be transmitted light.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or order, the supplier may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Classification of tests. The inspection and testing of lubricating oil shall be classified as:

a. Qualification tests (4.6)
b. Quality conformance tests (4.7)

4.3 Sampling lots

4.3.1 Bulk lot. A bulk lot is defined as an indefinite quantity of a homogeneous mixture of material offered for acceptance in a single isolated container or manufactured by a single plant run (not exceeding 24 hours) through the same processing equipment, with no change in ingredient material.

4.3.2 Packaged lot. A packaged lot is defined as an indefinite number of 55-gallon drums or small unit packages of identical size and type offered for acceptance and filled with homogeneous mixture of material from one isolated container, or filled with a homogeneous mixture of material manufactured by a single plant run (not exceeding 24 hours) through the same processing equipment, with no change in ingredient material.

4.4 Sampling. Each bulk lot of material shall be sampled for verification of product quality in accordance with ASTM D270. Each packaged lot of material shall be sampled for verification of product quality and compliance with MIL-STD-290 in accordance with the applicable provisions of 4.7. An additional 50-ml minimum sample representing each bulk lot of material shall be submitted to the Aerospace Fuels Laboratory, SFQLA, Wright-Patterson Air Force Base, Ohio 45433 for determining compliance to the trace element content requirement of 3.4.

4.4.1 Storage stability sampling. A sample consisting of 5 cases of quart containers (120 cans) from the first production lot of each tentatively qualified product shall be forwarded to the qualifying activity (see 6.3).

4.5 Inspection of material. Inspections shall be in accordance with method 9601 of Federal Test Method Standard No. 791.

4.6 Qualification tests

4.6.1 Original formulation lubricating oil.

4.6.1.1 Qualification letter of request. The manufacturer shall forward a letter to the activity responsible for qualification (see 6.3) before the test sample is supplied. The letter shall contain the following:

a. Request for authorization to submit test sample for qualification.

b. Identification of the manufacturing site of the specific batch of test sample to be submitted.

c. Certified test report containing data on the specific batch of test sample to be submitted showing results of the tests specified herein, except trace element content, compatibility, 100-hour engine endurance, and extended storage stability which shall be conducted by the activity responsible for qualification (6.3).

d. Verification that the composition of the test sample complies with the requirements of 3.2.

4.6.1.2 Qualification test sample. The qualification test sample, selected from a single lot, shall consist of 200 gallons packaged in 55-gallon drum containers. Samples shall be identified as required and forwarded to the activity responsible for qualification (see 6.3).

4.6.1.3 Tests. Original formulation qualification tests shall consist of all the tests specified under 4.8.

4.6.2 Reblend lubricating oil. A reblend lubricating oil is a qualified original formulation, as defined by 4.6.1 in which one or more ingredients have been blended by a manufacturer other than the manufacturer of the original formulation.

4.6.2.1 Qualification letter of request. The manufacturer shall forward a letter to the activity responsible for qualification before the test sample is supplied (see 6.3). The letter shall contain the following:

a. Request for authorization to submit test sample for qualification.

b. Identification of the product (by QPL reference number) for which reblend approval is requested.

c. Proof that authorization to blend the product has been granted by the manufacturer of the original formulation lubricating oil.

d. Identification of the blending site of the specific batch of test sample to be submitted and the source and percentage of each ingredient blended.

e. Certified test report containing data on the specific batch of test samples to be submitted showing results of the tests specified herein except trace element content, compatibility, 100-hour engine endurance, and extended storage stability which shall be conducted by the activity responsible for qualification (see 6.3).

f. Suggested manufacturer's designation for the reblend product.

4.6.2.2 Qualification test sample. The qualification test sample, selected from a single lot, shall consist of 200 gallons packaged in 55-gallon drum containers. Samples shall be identified as required and forwarded to the activity responsible for qualification (see 6.3).

4.6.2.3 Tests. Reblend qualification tests shall consist of all the tests specified under 4.8. The 100-hour engine endurance test requirement may be waived if test results demonstrate equivalence of reblend oil to original formulation oil.

4.6.3 Rebrand lubricating oil. A rebrand lubricating oil is a qualified fully formulated oil as defined by 4.6.1 or 4.6.2, which is packaged by a supplier other than the manufacturer of the fully formulated oil.

4.6.3.1 Qualification letter of request. The supplier shall forward a letter to the activity responsible for qualification (see 6.3). The letter shall contain the following:

a. Request for authorization to submit test sample for qualification.

b. Identification of the product (by QPL reference number) for which rebrand approval is requested.

c. Proof that authorization to rebrand the product has been granted by the supplier of the product.

d. Identification of the rebranding site in which the product is to be packaged.

e. Suggested supplier's designation for the rebrand product.

4.6.3.2 Tests. Rebrand qualification tests shall consist of the extended storage stability test (4.8.9).

4.6.4 Additional tests. The right is reserved to subject the oil to any such additional tests as are considered necessary to assure the serviceability of the material.

4.6.5 Qualification priority. Tests conducted by the qualifying agency will be accomplished in order of technical priority.

4.7 Quality conformance tests. Tests of individual lots which will serve as a basis for Government acceptance shall consist of all requirements specified in section 3 except the viscosity test at 500°F (260°C), the -40°F (-40°C) viscosity stability test at 72 hours, the 500°F evaporating test, the autoignition temperature test, the specific heat test, the compatibility tests, the 100 hour engine endurance test, and the extended storage stability test. In addition, a representative sample of oil obtained from a filled, sealed and thoroughly shaken container, taken at the end of each 2-hour run, must conform to the workmanship and trace sediment requirements. Also, a representative sample of oil obtained from a filled, sealed, and thoroughly shaken container (1 quart and 1 gallon only), taken from the packaging line every half-hour, must conform to the workmanship requirement.

4.7.1 Rejection and retest. Lubricating oils which have been rejected may be reworked to correct the defects, and resubmitted for acceptance. Before resubmitting, full particulars concerning previous rejection and the action taken to correct the defects found in the original sample shall be furnished the inspector. Lubricating oil rejected after retest shall not be resubmitted without the specific approval of the procuring activity. Failure of production lots to pass the quality conformance tests shall be cause for removal from the qualified products list.

4.7.2 Reporting. A copy of the quality conformance test report on each lot shall be forwarded to the qualifying agency (see 6.3).

4.8 Test Methods

4.8.1 Qualification and quality conformance tests required by section 3 shall be conducted in accordance with the applicable tests in table 1 and in 4.8.2 through 4.8.9.

4.8.2 Trace element content. The trace element content of the material shall be determined by the Aerospace Fuels Laboratory by emission spectrographic analysis.

4.8.3 Elastomer compatibility test

4.8.3.1 Swelling of standard rubber stock NBR-H shall be determined in accordance with Federal Test Method Standard No. 791, method 3604.

4.8.3.2 The percent volume swell, percent tensile strength change, percent elongation change, and durometer number change shall be determined on "F-A" standard stock elastomeric specimens after exposure to the test lubricant for a period of 72 hours at 347°±2°F (175°±1°C) and on "FS" standard stock elastomeric specimens after exposure to the test lubricant for a period of 72 hours at 302°±2°F (150°±1°C). These determinations will be accomplished as follows:

a. The sheets of standard stock elastomer shall be inspected for flaws in the material. Sections of an elastomeric sheet having a flaw shall not be used for specimens. Four specimens shall be cut from sheets of standard stock, all sheets being from a single production batch, for each synthetic lubricant to be tested. The specimens shall be cut using ASTM Die C as described in ASTM D412. A hole shall be punched into both ends of each elastomeric specimen. The hole shall be made using a 1/16 inch diameter leather punch and shall be centered and 1/4 inch from the end of the specimen.

b. The elastomeric specimens will be immersed 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 test specimen to be hung from each hook. The two specimens should hang parallel and 1/2 inch apart. The wire specimen hanger is attached to a standard size number 19 cork that is fitted with two lengths of 8-mm pyrex glass tubing (chimneys), one being 3 inches in length, the other 5 inches in length. The 3-inch chimney shall extend through the cork and 1/2 inch above the top of the cork. The 5-inch chimney shall extend through the cork and 3-1/2 inches above the top of the cork. The cork and specimen hanger with the specimens shall be placed into a 300-mm length test tube having a 39-mm outside diameter. The elastomeric test specimens should not contact the sides of the test tube. The test tube should be made from heat resistive glass. The length of the specimen hanger shall be such 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. Only two elastomeric specimens shall be hung in one test tube.

c. An aluminum block or oil bath shall be used to heat the test tube containing the elastomeric test specimens and 140 ml of test lubricant. Aluminum block baths shall have insulation on top of the heating medium 50 mm ±10 mm in thickness. Oil baths shall have a cover with openings for immersion of the test tubes. The block or oil bath is preheated to a temperature that will maintain the test lubricant at required test temperature. 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 1-5/8 inches above the heating medium of the bath. This distance shall be measured from the heating medium and not from the top of the insulation of bath covering. The bath shall be maintained at a temperature such that the test lubricant surrounding the small section of the elastomeric specimens is at required test temperature. A suggested method of controlling this temperature 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 elastomeric specimens in the test lubricant tube. By use of this thermocouple, correct bath temperature can be maintained.

d. The test time starts when the test tubes are inserted into the bath. The test duration shall be 72 hours. After the 72-hour heating period, the elastomeric test specimens are removed from the test tube and placed in a beaker of fresh test lubricant which is at room temperature and allowed to cool for a minimum of 30 minutes. The specimens are then removed from the cooling oil and placed into a beaker of acetone to remove excess oil. The specimens are removed from the acetone within 14 to 20 seconds and are blotted dry with filter paper. Volume swell, durometer, elongation and tensile strength measurements are then made on each of the four elastomeric specimens.

e. A baseline for elongation and tensile strength measurements shall be made for each batch of standard stock elastomer. Eight specimens shall be cut from a single production batch of the stock elastomer with no more than two specimens from any one sheet. Elongation and tensile strength shall be determined on the specimens in an untreated condition and the mean of these values shall be used as the baseline for determining elongation change and tensile strength change on oil treated specimens.

f. The percent volume swell for "F-A" stock and "F-S" stock elastomeric specimens shall be determined by ASTM D471. The average of the four volume swell determinations shall be reported as the percent volume change.

g. Durometer readings shall be determined on the elastomeric test specimens using a type A Shore durometer as described in ASTM D2240. Four readings (two on each large end) shall be made of the four elastomeric test specimens before and after oil aging. Durometer change shall be calculated for each elastomeric test specimen by taking the average mean of the four readings obtained before oil aging and subtracting this value from the average of the four readings obtained after oil aging. The Durometer number change shall then be determined by averaging the durometer change of all four elastomeric specimens.

h. Elongation measurements shall be determined as outlined in ASTM D412. The 1-inch bench marker shall be used. Percent elongation change shall be calculated using the following formula:

$$\text{Percent elongation change} = \frac{(E_4 - E_3) - (E_2 - E_1) \times 100}{(E_2 - E_1)}$$

Where E_1 = 1 inch.

E_2 = distance between bench marks at rupture on baseline specimens. (Average of eight baseline determinations.)

E_3 = 1 inch.

E_4 = distance between bench marks at rupture of oil aged specimens.

The percent elongation change of the test lubricant shall be obtained by averaging the percent elongation change of the four test specimens.

i. Tensile strength measurements shall be determined in accordance with ASTM D412. The percent tensile strength change shall be calculated by the following formula:

$$\text{Percent tensile strength change} = \frac{T_A - T_B \times 100}{T_B}$$

Where T_B = the average of the tensile strength of the eight baseline specimens. The tensile strength of each of the eight specimens is determined by dividing the breaking load, measured in pounds, by the cross sectional area expressed in square inches.

T_A = the average tensile strength of the four specimens after oil aging. The tensile strength of each specimen is determined by dividing the breaking load, measured in pounds, by the cross sectional area expressed in square inches.

4.8.3.3 Standard elastomer stocks shall conform to the formulation data and physical property requirements provided in USAF Specification Bulletin 539. Additional information relative to standard elastomer stocks may be obtained from Air Force Materials Laboratory: Attn: LAE, Wright-Patterson AFB, Ohio 45433.

4.8.4 Corrosion and oxidation stability test. The oil shall be evaluated in the 48-hour corrosion and oxidation stability test in accordance with procedure I, method 5307 of Federal Test Method Std. 791, at the conditions specified below:

a. At a test temperature of 428°F (220°C) the metal specimens shall be:

Bottom	Aluminum (QQ-A-250/4, T3 or T4)
	Silver (MIL-S-13282 grade A)
	Silicon Bronze (AMS 4616)
	MILD Steel (QQ-S-698, grade 1009, cold rolled, condition No. 4 or 5)
	M-50 Steel (AMS 6490)
	Magnesium (QQ-M-44, AZ31B, H24)
Top	Titanium (AMS 4908)

b. At a test temperature of 464°F (240°C) the metal specimens shall be:

Bottom	Aluminum (QQ-A-250/4, T3 or T4)
	Silver (MIL-S-13282, grade A)
	Bronze Alloy (SAE-CA674)
	Mild Steel (QQ-S-698, grade 1009, cold rolled, condition No. 4 or 5)
	M-50 Steel (AMS 6490)
	Waspaloy (AMS 5544)
Top	Titanium (AMS 4908)

4.8.5 Bearing deposition test. The oil shall be evaluated in the bearing deposition test in accordance with the test method defined in appendix 1A, except that the metal specimens shall be as follows:

Aluminum (QQ-A-250/4, T3 or T4)
Silver (MIL-S-13282, grade A)
Bronze Alloy (SAE-CA674)
Mild Steel (QQ-S-698, grade 1009, cold rolled, condition No. 4 or 5)
M-50 Steel (AMS 6490)
Waspaloy (AMS 5544)
Titanium (AMS 4908)

Suitable insulation should be appropriately applied to achieve the required test-oil in temperature and the test-oil return temperature.

4.8.6 Gear load carrying tests

4.8.6.1 Load carrying capacity at 165°F shall be determined in accordance with ASTM D-1947 using AMS 6260 test gears. Only those gear machines having a reference oil "C" average (six determinations) rating within the range of 2,500 to 3,300 ppi are acceptable.

4.8.6.2 Load-carrying capacity at 428°±5°F (220° ±3°C) shall be determined under the test conditions listed using the WADD high temperature gear machine conducted in accordance with the test procedure described in appendix 1B.

Gear material: AMS 6475* (nitralloy N)
Gear temperature: 428° ±5°F (220° ±3°C)
Test oil-in temperature: 401° ±5°F (205° ±3°C)
Support oil-in temperature: 165°±5°F (74° ±3°C)
Atmosphere: Ambient air

Only those gear machines having a reference oil "C" average (six determinations at 165°F using AMS 6260 test gears) rating within the range of 2500 to 3300 ppi are acceptable.

*Gears shall be finish-machined including gear tooth profile grinding after nitriding.

4.8.7 Compatibility. The compatibility test shall be conducted in accordance with method 3403 of Federal Test Method Standard No. 791 with the following additional procedure. Upon completion of the 168-hour oven period, the test flasks shall be stored in the dark and room temperature, 77° ±9°F, for 21 days before visual inspection for turbidity and centrifuging. Centrifuge tubes having a small scale division of 0.005 ml or less shall be used. (DeLaval centrifuge tube, part No. 14209, or equivalent, is acceptable).

4.8.8 100-Hour engine endurance test. A J-57 turbine engine, modified to control and number 6 sump cover at 572°F (300°C), shall be operated using test oil for 100 hours at a bulk oil temperature of 428°F (220°C). Periodic oil samples shall be withdrawn and tested during and upon completion of the test. A post test inspection shall be conducted on the disassembled engine.

4.8.9 Extended storage stability. Five cases of quart containers (120 cans) from the first production lot of the tentatively qualified oil shall be stored at ambient temperatures not lower than -40°F (-40°C) and not greater than 140°F (60°C), for periods up to 3 years. After storage for the specified time, the lubricating oil shall be tested for conformance to the specified tests.

4.9 Inspection of the preservation, packaging, packing and marking for shipment and storage. Sample items or packs and the inspection of the preservation, packaging, packing and marking for shipment and storage shall be in accordance with the requirements of section 5, or the documents specified therein.

5. PREPARATION FOR DELIVERY

5.1 Packaging, packing, and marking. Packaging, packing and marking shall be in accordance with MIL-STD-290.

6. NOTES

6.1 Intended use. This lubricating oil is intended for use in special aircraft turbine engine applications requiring a synthetic ester base oil with an approximate temperature range capability of -40° to +220°C (-40° to +428°F).

6.2 Ordering data. Procurement documents should specify the following:

a. Title, number, and date of this specification

b. Type and size of containers required (see 5.1)

c. Level of packaging and packing required (see 5.1)

d. Quantity desired.

6.3 Qualification. With respect to products requiring qualification, awards will be made only for products which are at the time set for opening of bids, qualified for inclusion in the applicable Qualified Products List whether or not such products have actually been so listed by that date. The attention of the suppliers is called to this requirement, and manufacturers are urged to arrange to have the products that they propose to offer to the Federal Government tested for qualification in order that they may be eligible to be awarded contracts or orders for the products covered by this specification. The activity responsible for the Qualified Products List is the Air Force Aero Propulsion Laboratory, Attn: SFL, Wright-Patterson Air Force Base, Ohio 45433, and information pertaining to qualification of products may be obtained from that activity.

6.4 Supplemental information concerning qualification and procurement of this material are contained in the Defense Standardization Program Document, SD-6 entitled Provisions Governing Qualification (Qualified Products List) dated 1 March 1967.

Custodians:
Army - MR
Navy - AS
Air Force - 11

Review Activities:
Army - AV, MI
Air Force - 68

Preparing Activity:
Air Force - 11

Project No. 9150-0323

APPENDIX 1A

BEARING DEPOSITION TEST METHOD

10. SCOPE

10.1 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.

20. APPLICABLE DOCUMENTS

20.1 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.

SPECIFICATIONS

Military

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, drawings, and publications required by suppliers in conjunction with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

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-6-69002	Test-oil Pump Standoff Gasket, Bearing Test Rig
A-6-69008	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: SFL, Wright-Patterson Air Force Base, Ohio 45433.)

20.2 Other publications. The following documents form a part of this specification 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, Two Pennsylvania Plaza, New York, New York 10001.)

American Society for Testing and Materials

ASTM D445	Viscosity of Transparent and Opaque Liquids (Kinematic and Dynamic Viscosities)
ASTM D664	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.)

30. OUTLINE OF METHOD

30.1 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.

40. APPARATUS AND MATERIALS

40.1 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.

40.1.1 100-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 transformer. 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.

40.1.1.1 Test-oil jet. The test-oil jet, F, is a nominal 0.040-inch-diameter jet located at the 12 o'clock position on a 2.625-inch radius from

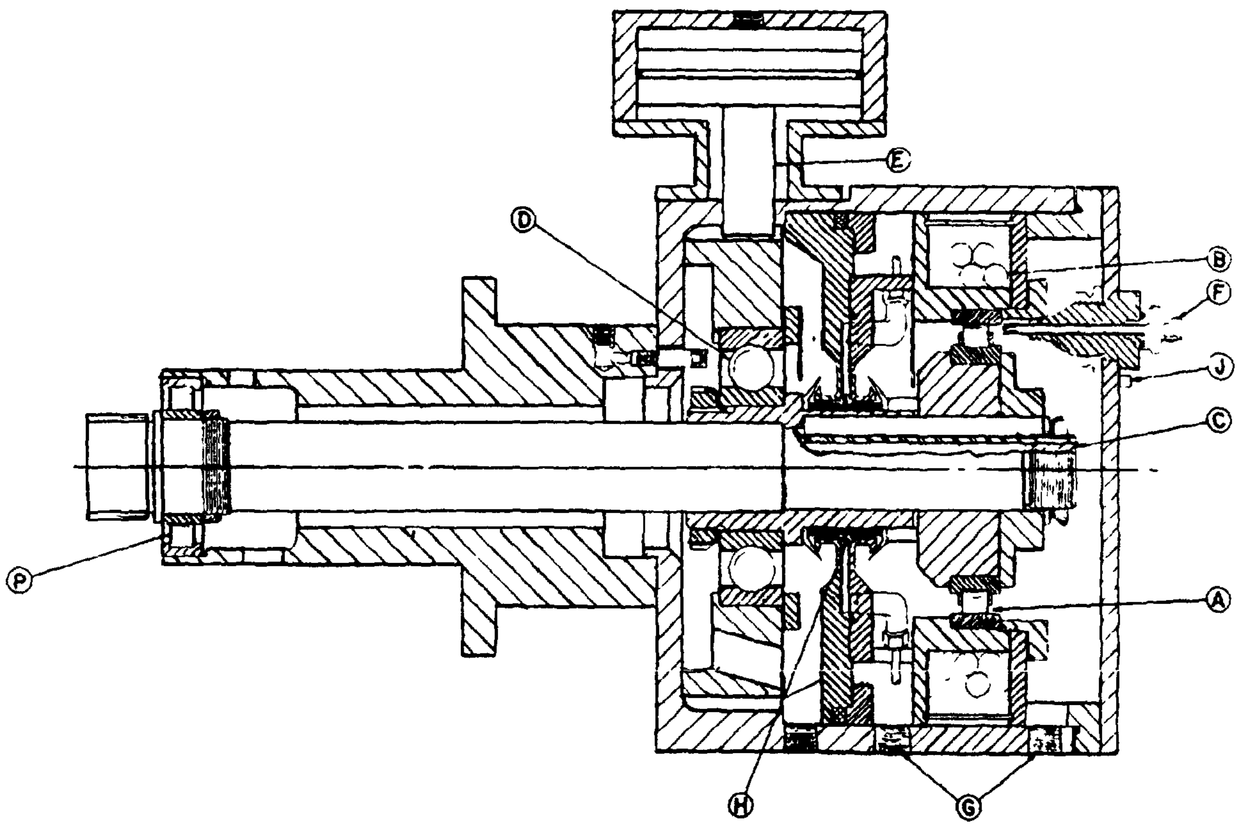


Figure 1. Cross Section of 100-mm Roller Bearing Machine

the center of the bearing machine end cover. Prior to test, the size of the jet is checked with standard plug pin gages, 0.039-inch-diameter gage go, and 0.041-inch-diameter gage no-go. In addition, the condition of the jet is observed under flow conditions by connection to a pressurized water-line. Water flow through the jet is maintained by a 15-psig pressure. The jet should deliver an essentially solid stream in axial alignment with the jet orifice. Corrections for size and axial straightness of jet flow are made by replacing the jet plug or the entire test-oil jet as required.

40.1.2 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.

40.1.3 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. Three spot-type thermocouples are located 120° 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.

40.1.3.1 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 a spherical bead on the junction about 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° intervals.

40.1.3.2 Thermocouple packing. Asbestos string 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.

40.1.4 Test-oil system. A schematic of the test-oil system is shown on figure 2. Table I identifies each numbered part 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 upper most 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 controller to monitor total power input. The test oil is pumped from the sump by the variable-speed pressure pump to the 100-mesh filter housing. 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 5 psig and one at a maximum pressure of 35 psig. In the event of a test-oil pressure excursion outside this range, the 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 located beneath the bearing head. The test oil exits the 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.

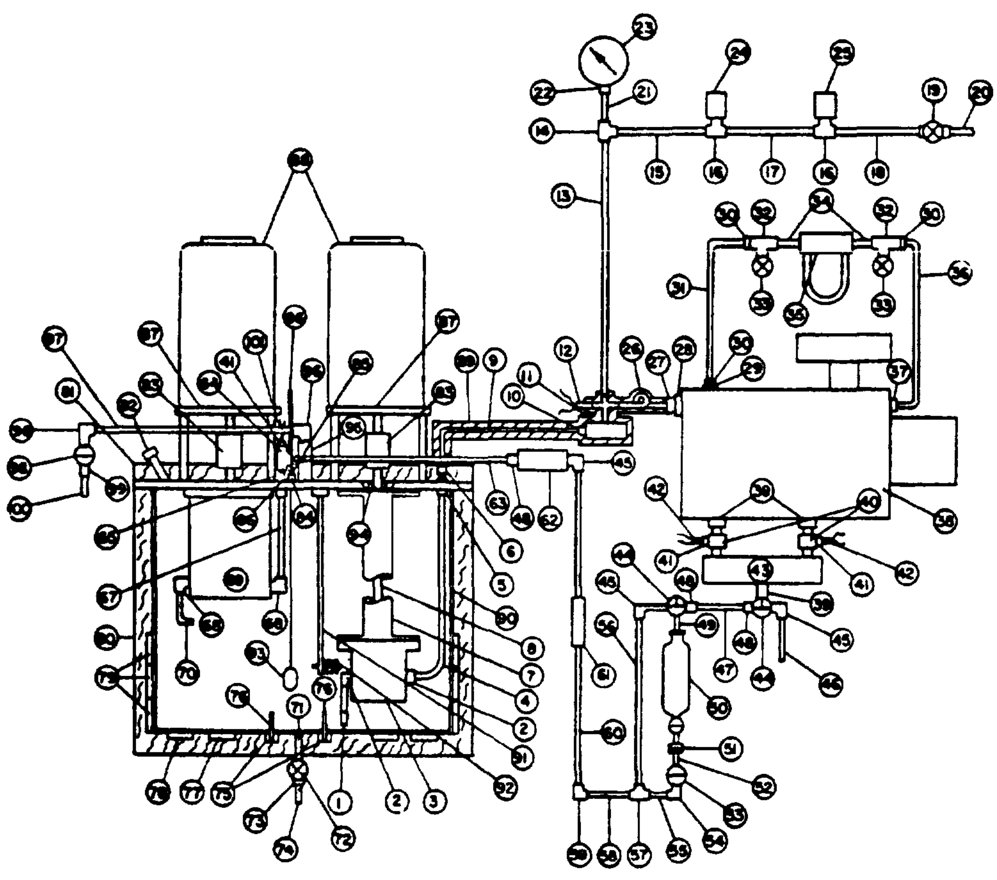


Figure 2. Schematic of Test-Oil System

40.1.4.1 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.

40.1.4.2 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 asbestos tape to maintain the desired oil temperature entering the sump.

40.1.4.3 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.

40.1.4.4 Test-oil sump

40.1.4.4.1 The overall configuration and construction details of the test-oil sump conform to the detailed drawings specified in (see 20.1 and table I).

40.1.4.4.2 Sump cover seal. A 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.

40.1.4.4.3 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 3/8-inch rod mounted on the sump lid and extending 8 inches into the sump (or approximately 2 inches below the cold oil level). The specimens are secured to the rod by a 10-32 size screw, 1-1/2 inch in length. The specimens are individually placed on the screw and separated by spacers of 1/8-inch thickness and 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. The metal specimens are 0.032-inch thick, 3/4-inch diameter disks with 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, grade 301, half-hard

TABLE I 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 & Sharpe, 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	0 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-oil jet 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
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

TABLE I IDENTIFICATION OF TEST OIL SYSTEM PARTS (Cont'd)

Item No	Description	No Required
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 B-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 tube 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
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 A 70, 660 watts, 240 volts	1
78	Ring heater Edwin L Wiegand Co, Chromalox** No A 90, 1000 watts, 240 volts	1

TABLE I IDENTIFICATION OF TEST-OIL SYSTEM PARTS (Cont'd)

Item No	Description	No Required
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 3)	
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.

A sketch of the metal specimen assembly, indicating the metal specimen order, is shown on figure 3.

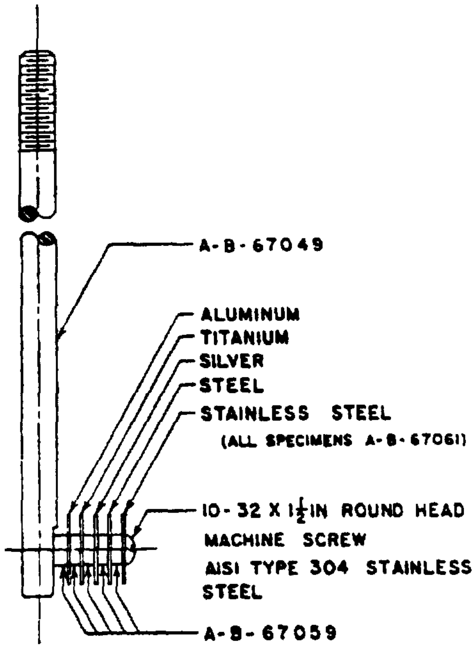


Figure 3. Metal Specimen Assembly

40.1.5 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 1/4-inch X 1/8-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 1-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 24-inch length of 2-inch Pyrex, 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.

40.1.5.1 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 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 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.

40.1.5.2 Screw seal. The screw type seal is vented to atmosphere at both the top and bottom seal housing connections.

40.1.5.3 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, 1 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 0.3 inch to 0.5 inch of test-oil column relative to the support-oil compartment pressure.

40.1.5.4 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 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.

40.1.5.4.1 The procedure for the sump-air venting discussed above is modified for bearing tests employing sump bulk-oil temperature above 350°F. The valve is closed to the atmosphere and a vent pipe-blower assembly is connected to the sump oil-fill port, as shown on figure 4 and in table II, 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.

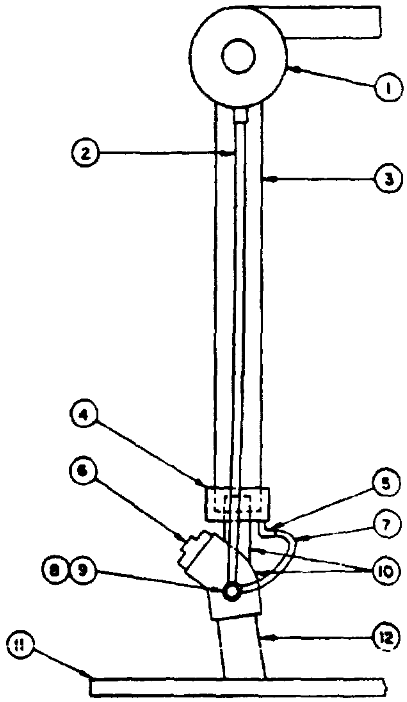


Figure 4. Schematic of Vent Pipe Blower Assembly

TABLE II 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.

50. PREPARATION FOR TEST

50.1 Cleaning procedure

50.1.1 Test-oil sump. The test-oil sump assembly is completely dismantled for cleaning of all internal components 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 pump shaft seal is installed prior to each test.

50.1.2 Test-oil pressure and scavenge pumps. The test-oil pressure and scavenge pumps are completely disassembled and cleaned to remove all deposits from the previous test.

50.1.3 Test-oil accumulator. The test-oil accumulator located directly below the bearing head is diassembled and then cleaned with a stainless steel brush in Stoddard solvent, or equivalent.

50.1.4 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 Stoddard solvent, or equivalent.

50.1.5 Oil filter assemblies. All oil filter housings in the test-oil system are removed and cleaned with a stainless steel brush in Stoddard solvent, or equivalent. A soft fiber brush is usually adequate in scrubbing the filter elements after a short soaking in a solvent bath.

50.1.6 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.

50.1.7 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.

50.1.8 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.

50.1.9 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 benzene 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 benzene 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 a 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.

50.2 Bearing head assembly

50.2.1 Main shaft. If the main shaft is not solid, its front end should be plugged with an aluminum plug.

50.2.2 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.

50.2.3 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 -0.0002 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.

50.2.3.1 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 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 1/8 inch of either front or rear inner faces are marked. During final assembly, Transite spacers, or equivalent,(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 50.2.5 is accomplished.

50.2.3.2 <u>Test-bearing heater mount positioning</u>. 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.

50.2.4 <u>Test bearing.</u> 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 0.0008 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 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 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.

50.2.5 <u>End cover</u>. Before installing the end cover on the rig, the test-oil jet tube alignment is verified. The jet position is midway between the outer race ID and the cage OD. Alignment is verified by assembling (outside the machine housing) the heater mount with the outer race installed, the pinch plate, and the end cover. The heater mount is fixed by installing the heater terminal nuts and making certain 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.

50.2.6 Check of seal operation. After assembly of the bearing head, the screw-thread seal operation is checked under a 500-pound radial load to the load bearing by applying 51-psi 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.

50.2.7 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.

50.3 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.

50.4 Critical test items. Before starting a test, care should be taken that critical test items conform to the tolerances listed in table III.

TABLE III CRITICAL TEST ITEMS

Item	Dimensional Tolerances, in	
	Minimum	Maximum
Test-bearing outer race fit in heater mount	-0 0002	+0 0007
Test-bearing inner race fit on hub	-0 0008	-0 0014
Screw seal diametral clearance	0 018	0 022
Test-oil jet	0.039	0 041

60. OPERATING CONDITIONS

60.1 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.

60.2 Initial test-oil flow setting. The test-oil sump is charged with 2 gallons of the test lubricant at room temperature and heated to a temperature of 260°F. Air to the end cover is set at 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 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 0.3 to 0.5 inch of test oil by making fine adjustments to the gearbox vent valve. As soon as a 250°F oil temperature at the jet has stabilized, a minimum of two separate flow checks of 1-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 cc/min. Once the flow rate of 600 cc/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.

60.2.1 After the oil flow is set, the following conditions are allowed to stabilize:

Oil-in temperature	250 ±2°F
Oil flow rate	600 ±20 cc/min
Bearing speed	10,000 rpm ±200
Radial load	51 psig(500 lb)
Support-oil-in- temperature	160° to 180°F
Support-oil pressure	80 to 100 psig
Gearbox-oil pressure	25 to 30 psig
Airflow to end cover	0.35 ±0.02 cfm
Pressure drop across seal	0.3 to 0.5 inch of test oil (test compartment higher)

60.2.1.1 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 250°F oil-in temperature to the jet indicate that a temperature range of 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.

60.2.1.2 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 the 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 450°F, or above, is employed. The heater is not actuated until a sump temperature of 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.

60.2.1.3 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 cc/min. The sump vent-gas flow is also measured at this time. The scavenge pump motor speed is adjusted to obtain a flow of 0.5 ±0.02 cfm.

60.3 <u>Test cycle</u>. 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.

60.4 <u>Used oil analysis</u>. The following laboratory tests are run on the new and used oil samples:

Test	ASTM Method
Viscosity at 100°F, cs	D445
210°F, cs	D445
Neutralization No., mg KOH/g	D664, using a pH 11 endpoint

60.5 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-wave valve which connects to the scavenge line.

60.5.1 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 min, 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 separatory funnel.

60.5.2 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 pint of the test oil should be poured into a clean container and saved for laboratory analyses.

60.6 Rig photographs. As soon as practical, the rig is disassembled and 4-X 5-inch color photographs 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° angle, 0° position

f. Test bearing - inner race, rollers and cage assembly close-up, 45° angle, 180° position

g. Test bearing - outer race close-up, inside diameter, 0° position (adjacent to test-oil jet)

h. Test bearing - outer race close-up, inside diameter, 180° position

A typical set of photographs, reduced and in black and white, is shown on figure 5.

60.6.1 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.

70. TEST PROCEDURE

70.1 Preparation for test

Step 1. Turn on rig power switches.

Step 2. Turn on support-oil tank heaters and set at 180°F.

Step 3. Turn on multipoint temperature recorder.

Step 4. Charge the test-oil sump with 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.

Step 5. Turn on test-oil heaters and adjust controller to obtain 260°F.

Step 6. Open air bleeds on both sides of the differential manometer which is filled with test oil.

Step 7. Check loading valve on console. It should be in the open or zero-load position.

Step 8. When the bulk-oil temperature in the test tank reaches 260°F, turn on the air supply to end cover and adjust to 0.35 cfm.

Step 9. Start the test-oil pressure and scavenge pumps. Test-oil pressure should be at least 10 psig at test-oil jet.

Step 10. Start the support-oil pumps.

Step 11. Set and maintain support-oil pressure at 80 to 100 psig.

Step 12. Adjust the load pressure to 10 psig and start the drive motor.

Step 13. Increase rig speed immediately to 10,000 rpm.

Step 14. Close loading valve on console until 51 psig is obtained on gage.

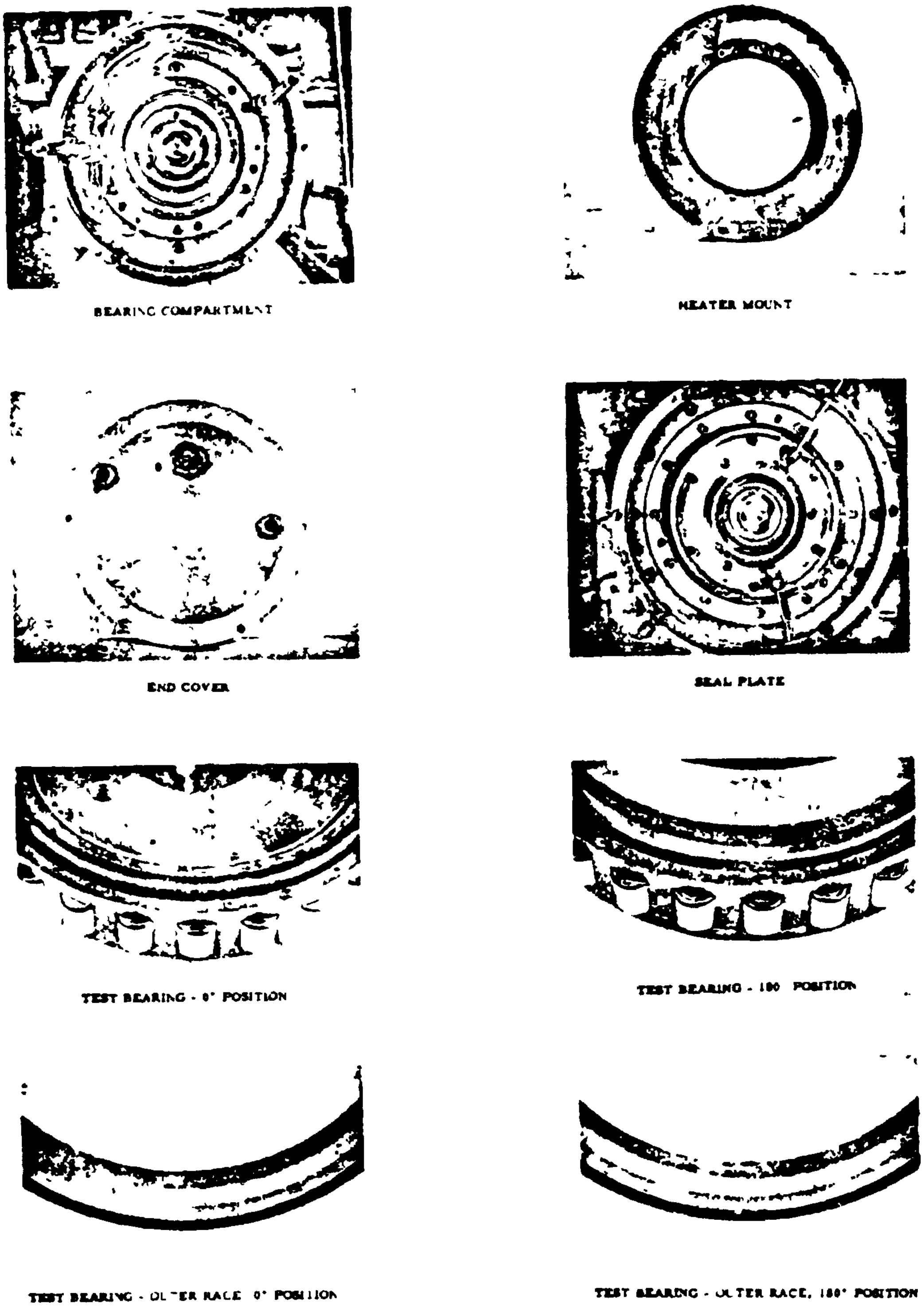


Figure 5. Typical Photographs of Disassembled Rig after Test

Step 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 0.3 inch to 0.5 inch of test-oil column relative to the support-oil compartment pressure.

Step 16. Continue running until the following conditions are stabilized:

Test-oil-in temp	250° ±2°F
Test-tank bulk-oil temp	260° ±5°F
Airflow to end cover	0.35 ±0.02 cfm

Step 17. Make at least two separate flow checks of 1-minute duration each at the test oil flow measuring system. The measured volume flow rate should be 600 ±20 cc/min.

Step 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 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 350°F during this period, proceed with the next step.

Step 19. Turn on test bearing heater and adjust controller to obtain the required bearing operating temperature. Adjust bearing heater voltage to achieve a 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.

Step 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.

Step 21. Adjust the test-oil heater controller to obtain the required bulk-oil temperature.

Step 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.

Step 23. Mark the level indicator tube to show the full position. All subsequent oil level checks are made in reference to this point.

Step 24. Take at least two separate flow checks of 1-minute duration, each at the test-oil flow measuring system. Flow rate should be 600 ±20 cc/min.

Step 25. Measure the sump vent-gas flow at the exhaust valve and adjust the scavenge pump motor speed to obtain 0.5 ±0.02 cfm vent-gas flow.

Step 26. Adjust airflow to air cooler to maintain specified test-oil return temperature.

Step 27. Continue running to complete the 16-hour operating period, shut down the rig in accordance with 70.3, and observe a shutdown period.

70.2 Operating procedure

70.2.1 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

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

70.2.2 Take 40-ml samples of test oil from three-way valve in scavenge line every 4 hours (including warmup time along with endurance time).

70.2.3 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.

70.2.4 Test-oil-in and test-oil-out filters are replaced with clean, pre-weighed elements during each 4-hour down period. The used filter elements are allowed to drain for 1 hour at 185°F, weighed, and the weight gain recorded.

70.3 <u>Shutdown sequence</u>

a. Shut off test-bearing and sump heaters.

b. Adjust loading valve on console and reduce load pressure to 25 psig.

c. Continue running at these conditions until test-bearing temperature (maximum) drops to 400°F.

d. Reduce load to 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.

70.4 <u>Startup sequence</u>

a. Turn on rig power switches and support-oil heaters in sufficient time to attain the 180°F temperature prior to startup.

b. Turn on multipoint temperature recorder.

c. Follow step Nos. 5 through 17 of 70.1

d. Continue running until the maximum bearing temperature stabilizes within 5°F between successive readings taken at 2-minute intervals. This stabilization normally occurs within 20 to 30 minutes after starting the drive motor.

e. Follow step Nos. 19 through 22 of 70.1.

f. Add sufficient new oil to bring the sump level indicator to the full mark.

g. Follow step Nos. 24 through 27 of 70.1.

80. DEPOSIT RATING SYSTEM

80.1 Outline of method

80.1.1 Deposit demerits. Bearing machine cleanliness is reported in this deposit demerit system by the assignment of values of 0 to 20 to identify the different types and thicknesses of deposits as follows: 0 shall designate a new or clean condition; 20 shall represent the worst condition that could be expected.

80.1.2 Table IV shows the numerical demerits to be assigned to different types and degreees of deposits.

TABLE IV DEMERIT RATING NUMBERS USED FOR NUMERICALLY DESCRIBING DEPOSITS

Deposit Type	Demerit 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

80.1.3 Table V defines deposit types and severities.

80.1.4 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)

TABLE V 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, opaque
Sludge	-	Shiny, oily emulsion of carbon and oil usually light brown in color Removable by wiping with a rag
	Light Medium Heavy	Less than 1/64-in thickness 1/64 to 3/64 in thickness 3/64 in thickness or more
Smooth carbon	-	Carbonaceous coating not removable by wiping with a rag
	Light* Medium Heavy	Less than 1/64 in thickness 1/64 to 3/64-in thickness 3/64-in thickness or more
Crinkled carbon		Same as for smooth carbon, ridged or uneven surface, not smooth
	Light Medium Heavy	Less than 1/64 in thickness 1/64 to 3/64 in thickness 3/64-in thickness or more
Blistered carbon		Same as for smooth carbon blistered bubbled
	Light Medium Heavy	Less than 1/64-in thickness 1/64 to 3/64 in thickness 3/64-in thickness or more
Flaked carbon		Same as for smooth carbon flaked or broken blisters, peeling
	Light Medium Heavy	Less than 1/64-in thickness 1/64 to 3/64 in thickness 3/64-in thickness or more

*Some difficulty may be encountered in distinquishing 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

c. Heater-mount front

d. Heater-mount rear

e. Seal plate

f. Test bearing

80.1.5 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 section 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

80.2 Computation of overall deposit rating

80.2.1 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.

80.2.2 A rating for each inspected item is obtained by multiplying the area demerit rating by the demerit value assigned in table IV 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 cover	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	$5X_6$

80.2.3 The overall deposit rating is the sum of the major item demerits divided by six.

80.2.4 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.

90. METAL SPECIMEN PREPARATION

90.1 After test, the metal corrosion specimens are disassembled from the holder and solvent-rinsed to remove residual test oil. (The specimens are stored in benzene if final processing is delayed.) The individual specimens are benzene swabbed using a series of cotton swabs or pads until clean pads are noted. The coupons are then rinsed in clean benzene and acetone, air-dried, and weighed to the nearest 0.1 mg.

90.2 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.

APPENDIX 1B

TEST METHOD FOR THE DETERMINATION OF THE HIGH-TEMPERATURE GEAR LOAD-CARRYING CAPACITY OF LUBRICATING OILS

10. SCOPE

10.1 This method describes a procedure for determining the gear load-carrying capacity of lubricating oils at controlled test gear temperatures of 428°F through 700°F.

20. OUTLINE OF METHOD

20.1 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.

30. APPARATUS AND MATERIALS

30.1 Test unit. The apparatus used in this method is the WADD gear machine, or equivalent, available from Erdco Engineering Corp., Addison, Ill. 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.

30.1.1 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 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

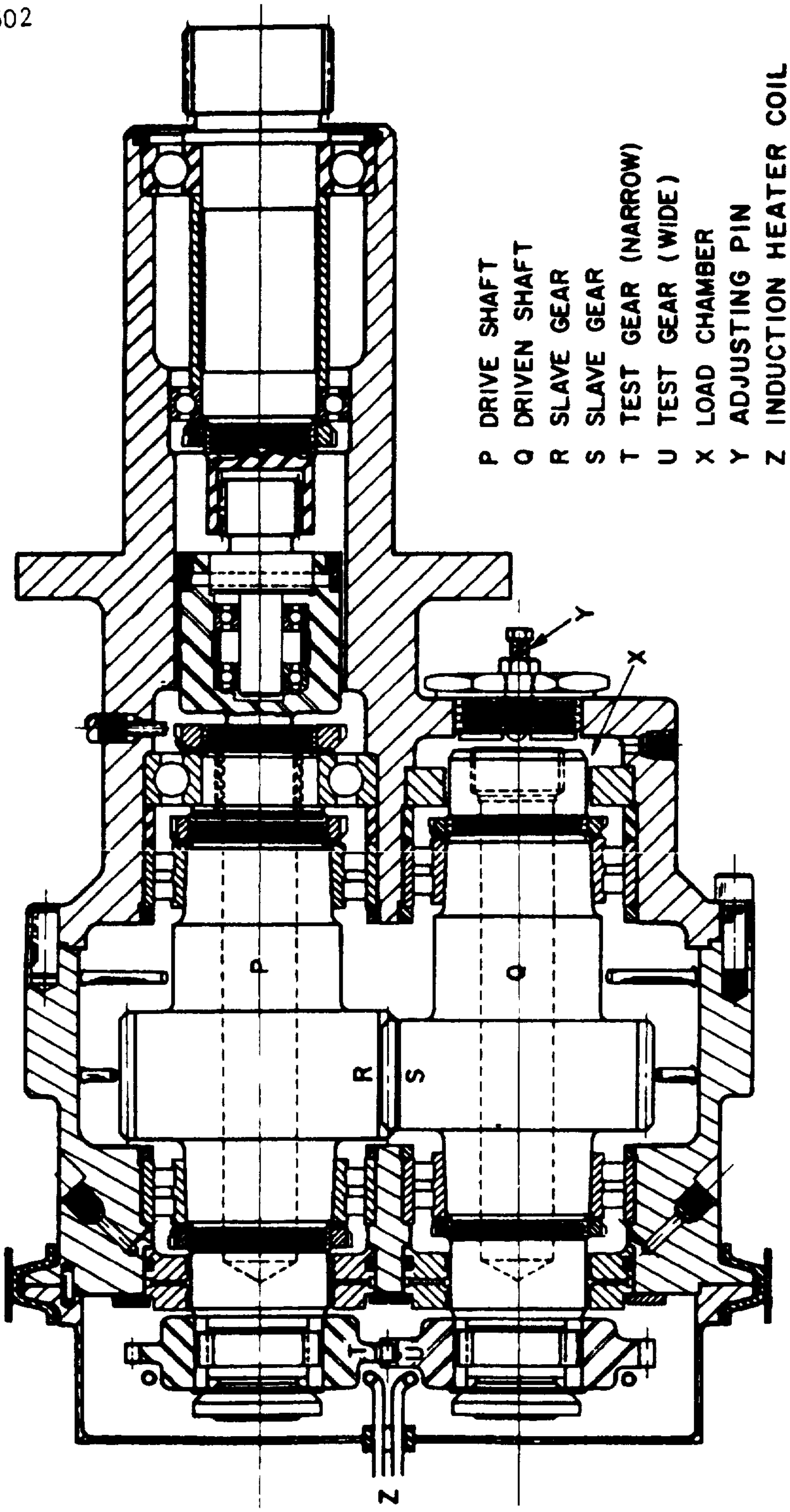


Figure 1. Cross Section of WADD Gear Machine

load-oil pressure can be obtained by arithmetic calculation, calibration, or both. Arithmetic calculation is used herein.

30.1.2 Test gears. The test gears are special spur gears, made of AMS 6475 steel, nitrided and ground, having 28 teeth, 3.5-inch pitch diameter, 8 diametral pitch, 22.5 degree pressure angle, 0.0000-to 0.0001-inch tip relief, and 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: 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.

Each set of test gears comprises gears of two different widths. The narrow test gear (0.25-inch wide gear teeth) is used for rating purposes. The mating gear is wider (0.375-inch wide gear teeth) 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.

30.1.2.1 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 1/4-inch toward the center of the gear, provides a continuous black body radiation surface for accurate test gear temperature measurement during test.

30.1.3 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.

30.1.4 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.

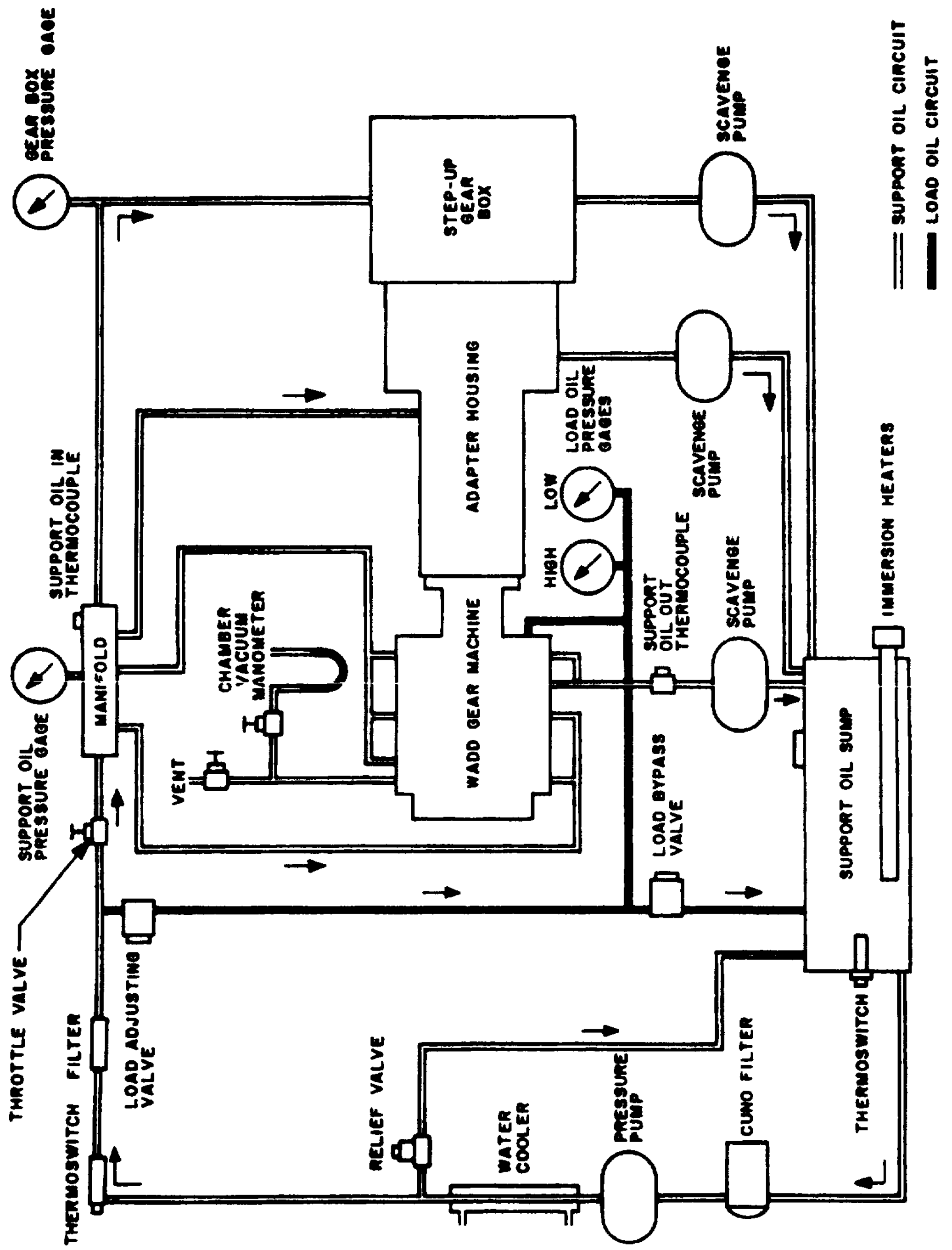


Figure 2. Support and Load Oil System

3.1.4.1 The system is charged with approximately 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 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. 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.

30.1.4.2 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.

30.1.5 Test-oil system. A test-oil system capable of maintaining a test-oil temperature of 401°F is used with the WADD gear machine for high-temperature gear load-carrying capacity evaluations. A schematic diagram of the 401°F 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 401° ±5°F by means of two electrical band heaters located on the outside of the test-oil sump.

30.1.6 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 54 inches 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.

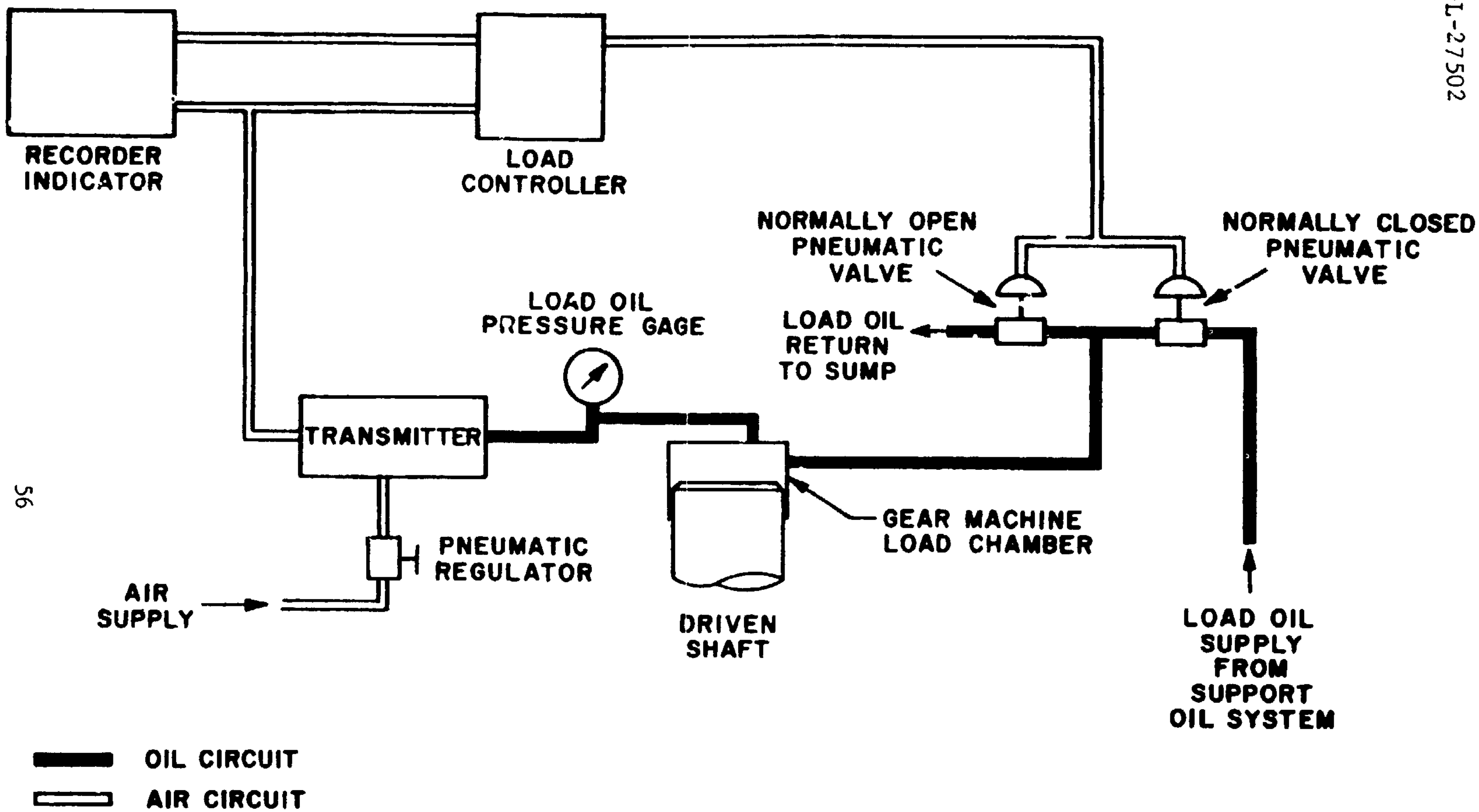


Figure 3. Optional Automatic-Recording Load Oil System

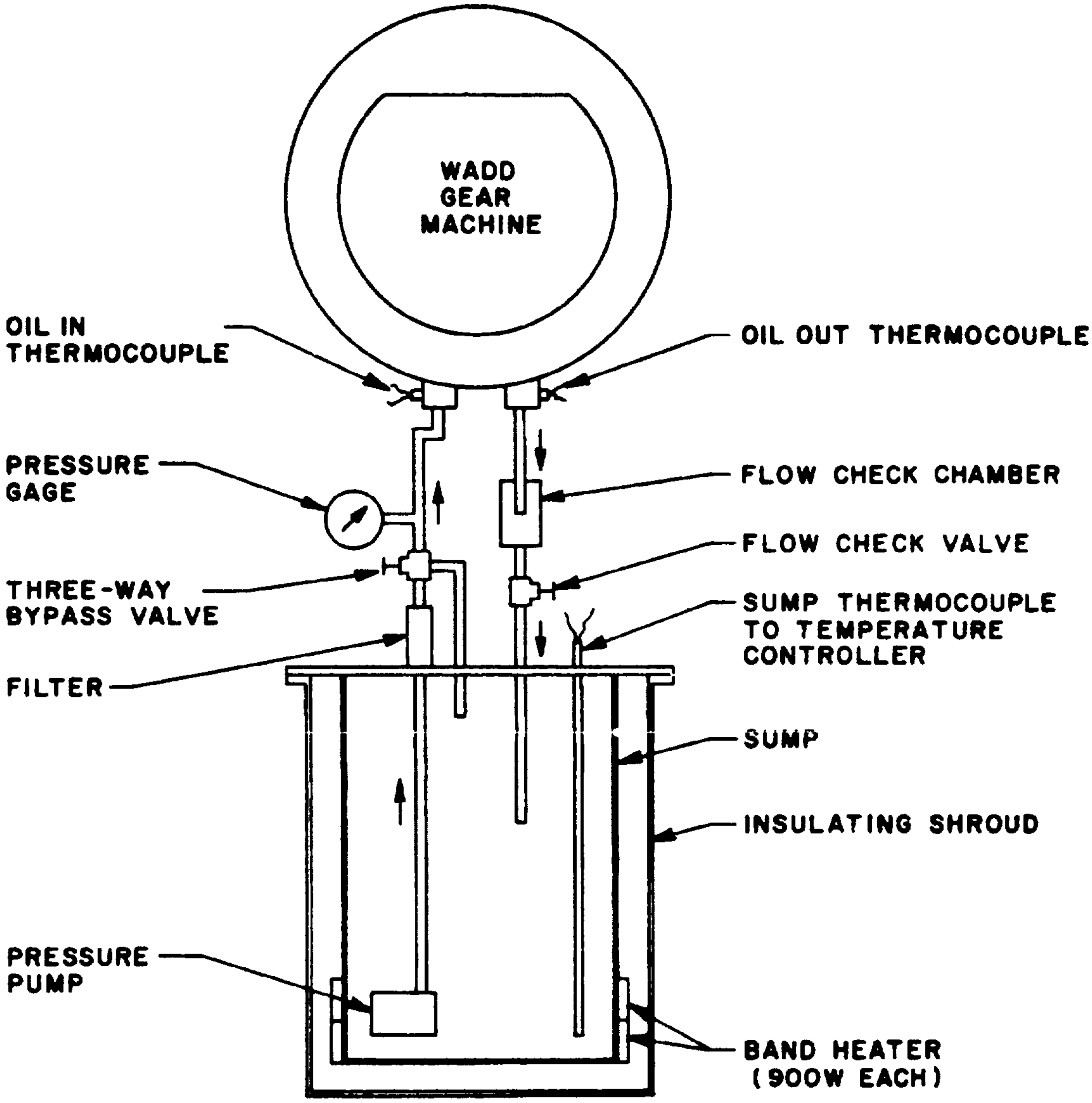


Figure 4 Test Oil System

30.1.7 Induction heater. A Lepel T-5N-3, or equivalent, induction heater having a 5kW output at 450kHz with a wide range continuous grid control is used to heat the test gears to the desired test temperature.

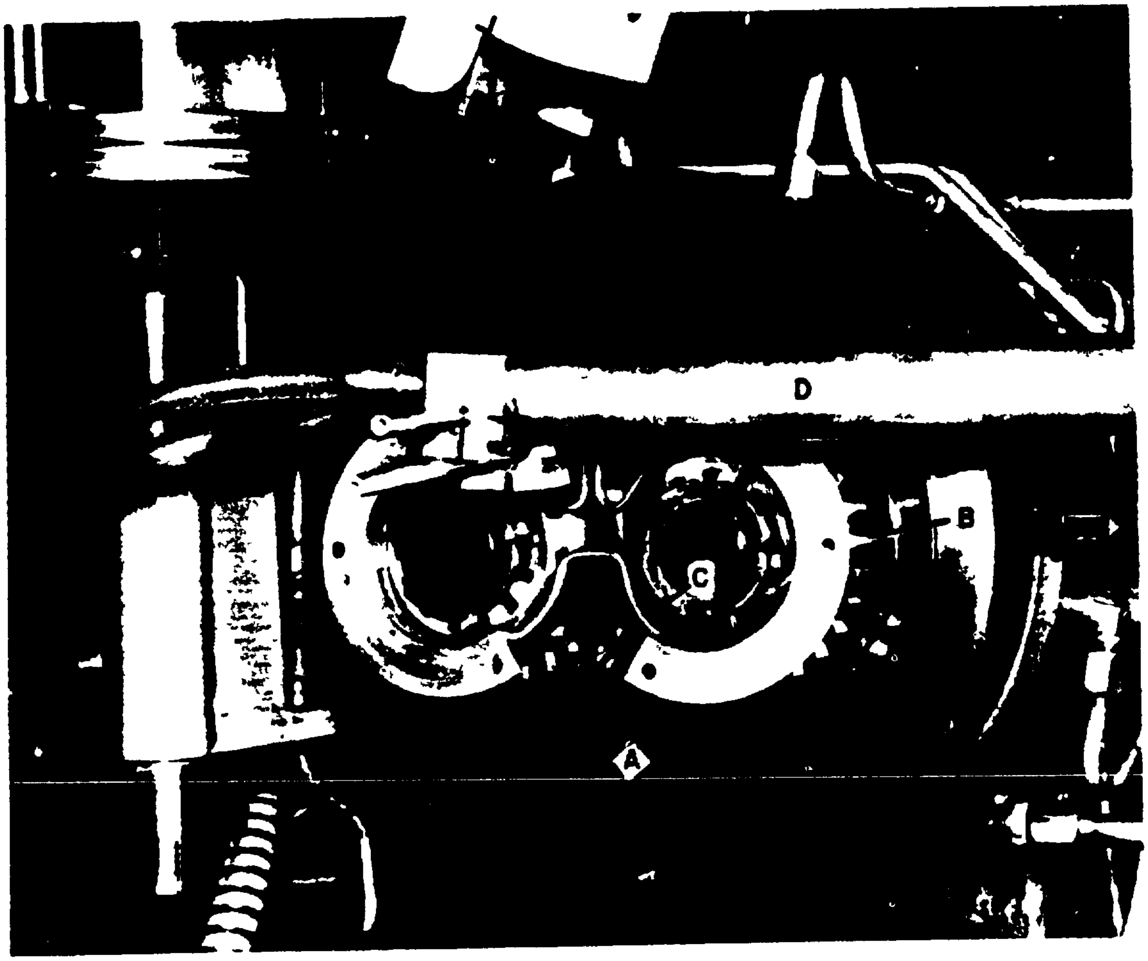
30.1.7.1 A load coil transformer is used in conjunction with the induction heater to minimize power loss from the induction heater. The load coil transformer is mounted inside the test cell approximately 15 inches to one side of the WADD gear machine. The test gear heating coil, shown in figure 5 without the end cover, is mounted inside the end cover of the WADD gear machine and is connected directly to the load coil transformer output terminals by removable, silver-plated connectors.

30.1.8 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.

30.1.8.1 Speed measurement and control. An elctronic 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.

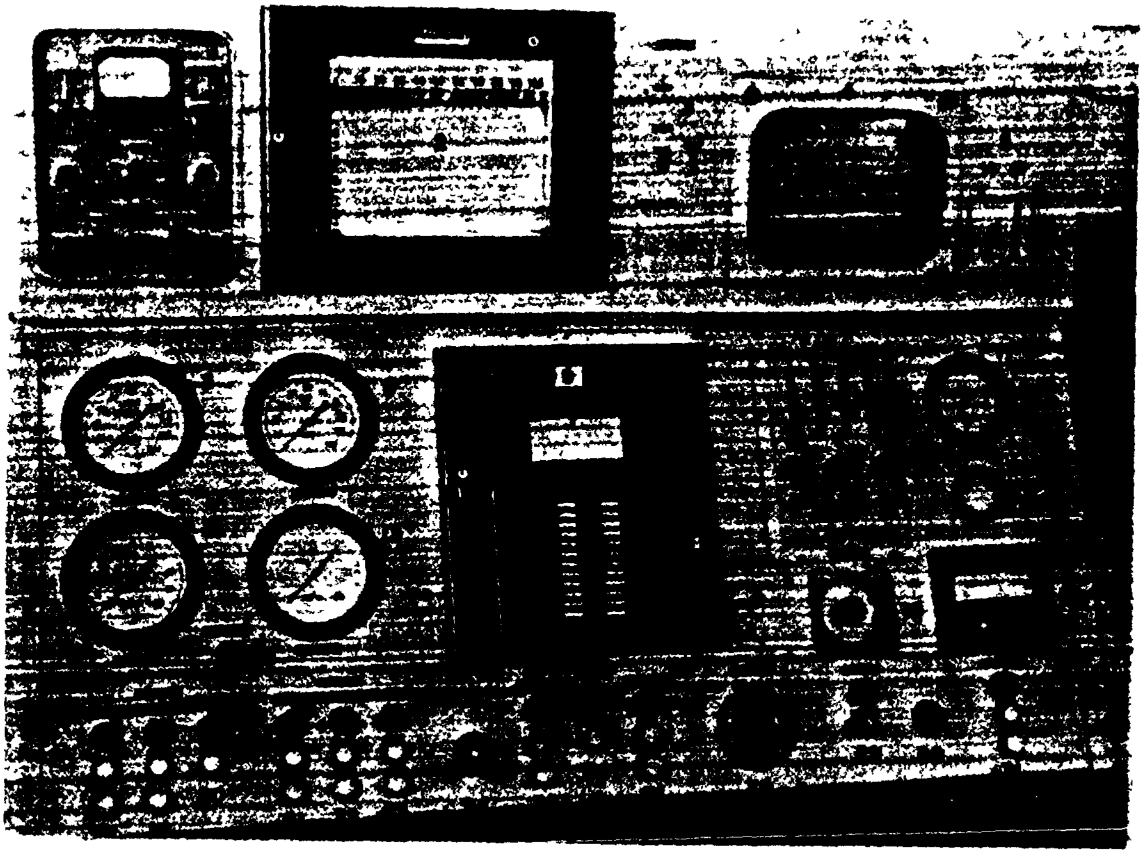
30.1.8.2 Control of test-run duration. An electric timer (figure 6, item 16), located on the console, is used to control the duration of each test run. As soon as the desired test load and test gear temperature has been reached, the timer is started. After the 10-minute run is over, the timer automatically turns off the drive motor and opens the load-bypass valve. The timer switch must be turned to the "stop" position immediately following coast down of the machine.

30.1.8.3 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 1 inch of water under normal test conditions.



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



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

30.1.8.4 Control of load-oil pressure. The control of load-oil pressure has been explained in 30.1.4.2. 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 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 must be turned to the "open" position prior to the next run.

30.1.8.5 Emergency stop. The emergency stop button (figure 6, item 26) 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.

30.1.8.6 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.

30.1.8.7 Inspection equipment. The standard 18-power microscope furnished with the Erdco Ryder gear machine, or equivalent, 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.

30.1.8.8 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.

30.1.8.9 The following additional instruments are required:

a. Stop watch for oil flow-rate check.

b. Micrometer (0 to 1 inch) for the measurement of the gross tooth width of the narrow gear.

c. Scale with divisions of 1/64 inch.

d. Set of conventional mechanical tools as necessary for assembly, disassembly, maintenance, and repair.

40. TEST GEAR PLATING PROCEDURE

40.1 The following procedure is used to plate the black chromium rings on the web of the narrow test gears:

Step 1. Clean the gear with Stoddard solvent and rinse with petroleum ether.

Step 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.)

Step 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 1/8-inch thick on all gear surfaces.

Step 4. Allow the wax coating to cool and harden. Cut a groove in the wax coating with a knife to expose the masking tape.

Step 5. Remove the masking tape to expose the area to be plated.

Step 6. Lightly sand blast the exposed portion of the test gear using No. 30 grit aluminum oxide.

Step 7. Immediately following the sand blast, the gear must be rinsed thoroughly with distilled water and placed in the nickel strike for 2 minutes.

Step 8. Rinse the gear again with distilled water and place in the nickel plate bath. The nickel is plated to a thickness of approximately 0.001 inch (approximately 6 minutes).

Step 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.

Step 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).

Step 11. Rinse the gear thoroughly with distilled water. Remove the platers wax from the gear.

Step 12. Clean the gear with Stoddard solvent and rinse with petroleum ether.

Step 13. Dip the cleaned test gear in standard reference oil and store in suitable container until required for test.

NOTE: 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.

40.2 Test gear nickel strike and plating solution. Approximately one gallon of nickel strike and plating solution is required, as follows:

a. Prepare the nickel strike and plating solution in a clean Pyrex glass beaker.

b. Add 3 liters distilled water to 896 g purified crystalline nickelous chloride ($NiCl_2$) and dissolve the crystals.

c. Add 308 g reagent grade hydrochloric acid (HCl) to the solution.

d. Add additional distilled water to make approximately 3.785 liters of solution.

40.3 Black chromium plating solution. Approximately one gallon of black plating solution is required, as follows·

a. Prepare the chromium plating solution in a clean Pyrex glass beaker.

b. Dissolve 1 kg reagent grade crystalline chromium trioxide (CrO_3) in 3.785 liters distilled water.

c. Add 1/4 g reagent grade crystalline silver nitrate ($AgNO_3$). Stir solution, cover and place in a dark area for 4 hours.

d. Decant and discard precipitate.

e. Add 1 g reagent grade barium carbonate ($BaCO_3$). Stir solution, cover and place in dark area for 4 hours.

f. Decant and discard precipitate.

g. Add 1 g hydrofluoric acid. Stir solution, cover and store in dark area until bath solution is required for plating.

40.4. 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 2 inches x 6 inches x 1/4 inch, is used for elctrodes in the nickel strike and nickel plate bath.

d. Sheet lead, approximately 6 inches x 8 inches x 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.

40.5 Plating conditions. The following conditions are used for the strike and plating baths:

	Solution Temp, °F	Plating Time, min	Power, amp	Gear Polarity
Nickel strike	155 ±5	2	0.5	Positive
Nickel plate	155 ±5	6	0.5	Negative
Black chrome plate	85 ±5	20	13.0	Negative

50. OPERATING CONDITIONS

50.1 Throughout the entire test, the test gear temperature is controlled at 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 5 psig load oil pressure (nominal 230 lb/in tooth load), and then at successive increments of 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.

Table 1. Operating Conditions

Condition	Value
Test gear temperature, °F	428 ±5
Test gear speed, rpm	10,000 ±10
Test-oil inlet temperature, °F	401 ±5
Test-oil flow rate, ml/min	270 ±5
Test-oil pressure, psig	15 ±5
Support-oil inlet temperature, °F	165 ±5
Support-oil pressure, psig	
To load-oil system	120 ±10
To stepup gearbox	35 ±5
To WADD gear machine	35 ±5
Airflow to seals, cfm	0.70 ±0.10

60. TEST PROCEDURES

60.1 Preparation for test

Step 1. Turn on main electric switch and main water valve to test cell.

Step 2. Push instrument button to "ON" position.

Step 3. Push support oil sump heater button to "ON" position.

Step 4. Turn radiometer function switch to "READY" position.

Step 5. Turn on power supply to induction heater and place induction heater filament switch in "ON" position.

Step 6. Inspect test-oil system to see that it was thoroughly cleaned and dried after previous test.

Step 7. Remove gear-case end cover.

Step 8. Clean a set of new plated test gears with petroleum ether, and dry with air.

Step 9. Measure gross tooth width of the narrow test gear with a micrometer, and record.

Step 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.

Step 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 having divisions of 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.

Step 12. Reinstall gear-case end cover with induction heating coil.

Step 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: 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.

Step 14. Turn on water supply to induction heater load coil transformer and induction heating coil.

Step 15. Turn on ventilating blower in load coil transformer.

Step 16. Turn on ventilating blower connected to gear-case end cover.

Step 17. Turn on air to nonrubbing seals. Adjust to approximately 1 psig.

NOTE: Approximately 0.7 cfm of air (total for both air seals) is required for the nonrubbing air seals to function correctly.

Step 18. Fill test-oil sump with approximately 1 liter of test oil.

Step 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.

Step 20. Push test-oil heater button to "ON" position.

Step 21. Allow approximately 20 minutes to elapse after turning support oil sump heaters on (step 3). Then start support oil pumps.

Step 22. Turn timer switch to "STOP" position.

Step 23. Check electric timer to insure it is set to 10 minutes and 0 seconds, then lock timer dial.

Step 24. Turn rpm-adjust control to "ZERO" position.

Step 25. When the support-oil temperature is up to the specified value of 165° ±5°F, adjust the support oil supply pressure to the required values.

Step 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.

Step 27. When the test-oil temperature is up to the specified value of 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: The test-oil in pressure is maintained at 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 0.026- and 0.032-inch diameter, depending upon the test oil viscosity.

Step 28. Turn radiometer function switch to "NORMAL RANGE" position.

Step 29. Check radiometer temperature detector spot position on narrow test gear. Refocus temperature detector if necessary.

NOTE: 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.

60.2 Test on "A" side of test gears

NOTE: 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.

Step 1. Turn radiometer function switch to "READY" position.

Step 2. Recheck test-oil flow rate as in step 27 of 60.1.

Step 3. Determine radiometer reference temperature using null meter on radiometer.

NOTE: 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.

Step 4. Set radiometer scale selector to appropriate scale for test temperature desired.

Step 5. Turn radiometer function switch to "NORMAL RANGE" position.

Step 6. Turn on air supply to automatic load-control unit.

Step 7. Check to see that the rotating device of the gear-tooth inspection equipment is in the disengaged position.

Step 8. Check automatic load-control set point to see that load set point is on "0."

Step 9. Start drive motor.

Step 10. Increase gear speed by turning rpm-adjust control clockwise until the specified 10,000 ±100 rpm is obtained.

Step 11. Turn on power to induction heater plate and slowly adjust plate control until the radiometer reading determined in step 3 is obtained.

Step 12. Set automatic load-control set point to 5-psi load-oil pressure.

Step 13. Check gear speed, and adjust if necessary.

Step 14. Check gear temperature, and adjust plate control if necessary.

Step 15. Turn timer switch to "START" position. The 10-minute run now begins.

Step 16. Maintain the test gear temperature and speed at the predetermined specified values.

Step 17. Record all pertinent data about midway of the test run.

Step 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" position.

Step 19. Turn induction heater plate power off.

Step 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.

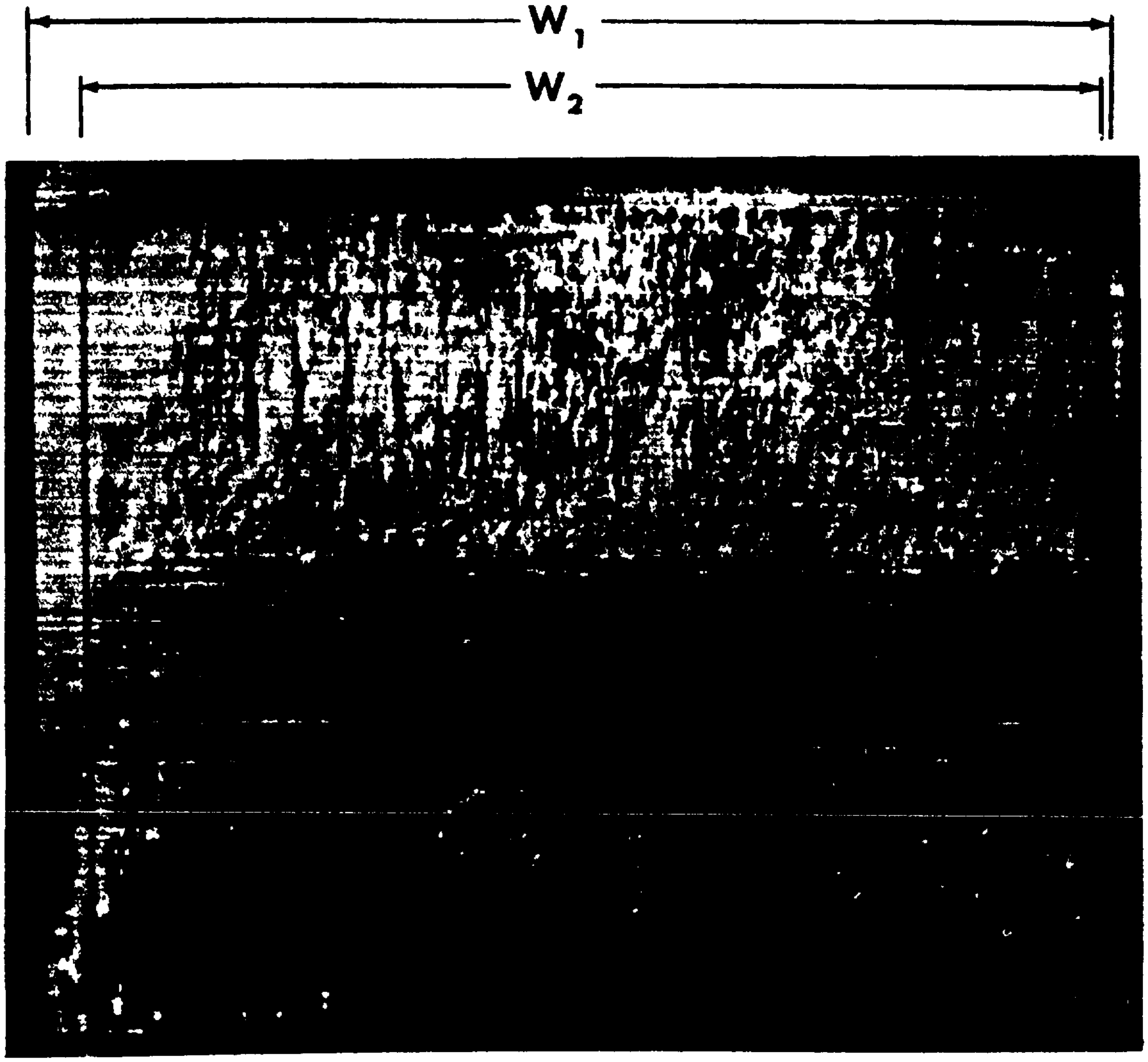
e. Set indexing-ratchet wheel to "No. 1" position.

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.



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)

j. Turn 3-way valve to running position.

Step 21. Repeat step 3 of 60.2.

Step 22. Repeat steps 7 through 20 at the next test load of 10 psig load-oil pressure.

Step 23. Continue the test at 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.

Step 24. Further continue the test at 5-psi load-oil pressure increments, until an approximate average scuffed area of 30 percent or more is obtained.

Step 25. Push test-oil heater button to "OFF" position.

Step 26. Push support-oil heater button to "OFF" position.

Step 27. Push support-oil pressure button to "OFF" position.

Step 28. Turn radiometer function switch to "READY" position.

Step 29. Switch induction heater power supply to "OFF" position.

Step 30. Turn off water supply to induction heater load coil transformer and induction heating coil.

Step 31. Turn off ventilating blower connected to gear-case end cover.

Step 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.

Step 33. Disconnect induction heating coil from load coil transformer.

Step 34. Disconnect ventilating blower from gear-case end cover.

Step 35. Remove gear-case end cover.

Step 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.

Step 37. Adjust driven shaft in accordance with 60.1, step 11.

Step 38. Rinse face of gear case and test gears with petroleum ether and blow off with compressed air.

Step 39. Rinse inside of gear-case end cover, including the test-oil jet, with petroleum ether and blow off with compressed air.

Step 40. Blow out test-oil jet with compressed air.

Step 41. Reinstall gear-case end cover and connect induction heating coil to load coil transformer.

Step 42. Reinstall ventilating blower to gear-case end cover.

Step 43. Clean test-oil line screen filter with petroleum ether. Blow out line screen filter with compressed air.

Step 44. Rinse test-oil sump, lines, pump, and inlet filter with petroleum ether and blow off with compressed air.

Step 45. Reassemble test-oil system.

60.3 <u>Test on "B" side of test gears</u>

Step 1. Turn on water supply to induction heater load coil transformer and induction heating coil.

Step 2. Turn on ventilating blower connected to gear-case end cover.

Step 3. Proceed on "B" side of the test gears by following the procedure outlined in 60.1, steps 18 through 29, and 60.2, steps 1 through 35.

Step 4. Remove used test gears.

Step 5. Rinse gear-case face and shaft ends with petroleum ether.

Step 6. Rinse gear-case end cover and test-oil jet with petroleum ether.

Step 7. Reinstall gear-case end cover (without test gears).

Step 8. Turn radiometer function switch to "OFF" position.

Step 9. Place induction heater filament switch in "OFF" position.

Step 10. Turn off power supply to induction heater.

Step 11. Turn rpm counter to "OFF" position.

Step 12. Push instruments button "OFF".

Step 13. Turn off main electric switch to test cell.

Step 14. Turn off main water valve to test cell.

60.4 Emergency stop

Step 1. Push emergency stop button.

Step 2. Push instruments button "OFF".

Step 3. Turn off induction heater power supply.

Step 4. Turn off main water valve to test cell.

70. INSPECTION AND RATING

70.1 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, 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.

70.2 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,

$$\text{Percent tooth area scuffed} = \frac{\text{scuffed area X 100}}{\text{working area}}$$

$$= \frac{A + B}{A + B + C} \text{ X } 100$$

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.

70.3 Data sheets. 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.

HIGH-TEMPERATURE LOAD-CARRYING CAPACITY TEST
OPERATING CONDITIONS DATA SHEET

Rig No ______ Machine No ______ Time Meter at Start of Test __________ Gear Side ______ Test No ______

RECORD THE FOLLOWING AFTER 5 MINUTES AT EACH LOAD

Load, psig	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120
Time																								
S. O. Press., psig																								
T. O. Press., psig																								
T. O. "In" Temp., °F																								
S O. "In" Temp., °F																								
S O "Out" Temp., °F																								
T. O. Sump Temp., °F																								
S. O Sump Temp, °F																								
Test Gear Temp, °F																								
Operator's Initials																								

TEST OIL FLOW, TIME FOR 270 ML __________ SECONDS

REMARKS ______________________________

Figure 8 Operating Conditions Data Sheet

HIGH-TEMPERATURE LOAD-CARRYING CAPACITY TEST
GEAR TEETH INSPECTION DATA SHEET

Test Oil Code ________ Date ________ Wide Gear No ________ Narrow Gear No ________ Test No. ________

Gross Tooth Width ________ Effective Tooth Width ________ % Gear Temp. ________ °F Gear Side ________

Tooth No.	PERCENT 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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25																								
26																								
27																								
28																								
Total %																								
Avg. %																								

Figure 9. Gear Teeth Inspection Data Sheet

70.4 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.

70.5 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. To determine the effective tooth width, measure the gross tooth width by means of a micrometer. The effective tooth width is taken as:

$$W_2 = 0.98W_1$$

W_2 = effective tooth width in inches.

W_1 = measured gross tooth width in inches.

70.6 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.

70.6.1 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 from the following equation:

$$P = \frac{KL}{W_2}$$

P = load-carrying capacity of the lubricant in pounds per inch of tooth-face width.

K = WADD gear machine constant (11.5 by definition).

L = load-oil pressure, psig.

W_2 = effective tooth-face width in inches.

70.7 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:

HIGH-TEMPERATURE LOAD-CARRYING CAPACITY TEST
PLOT AND CALCULATIONS SHEET

Test No ________ Date ______________ Oil Code ________________
Test Gear Temp, °F __________ Engineer ________________________

	"A" Side	"B" Side
Effective Tooth Width, in	______	______
Load Oil Pressure at 22 5% scuffing	______	______
Load-Carrying Capacity, lb/in	______	______
Mean Load-Carrying Capacity, lb/in	______	
Reference Oil C Rating, lb/in	______	
Relative Rating, %	______	

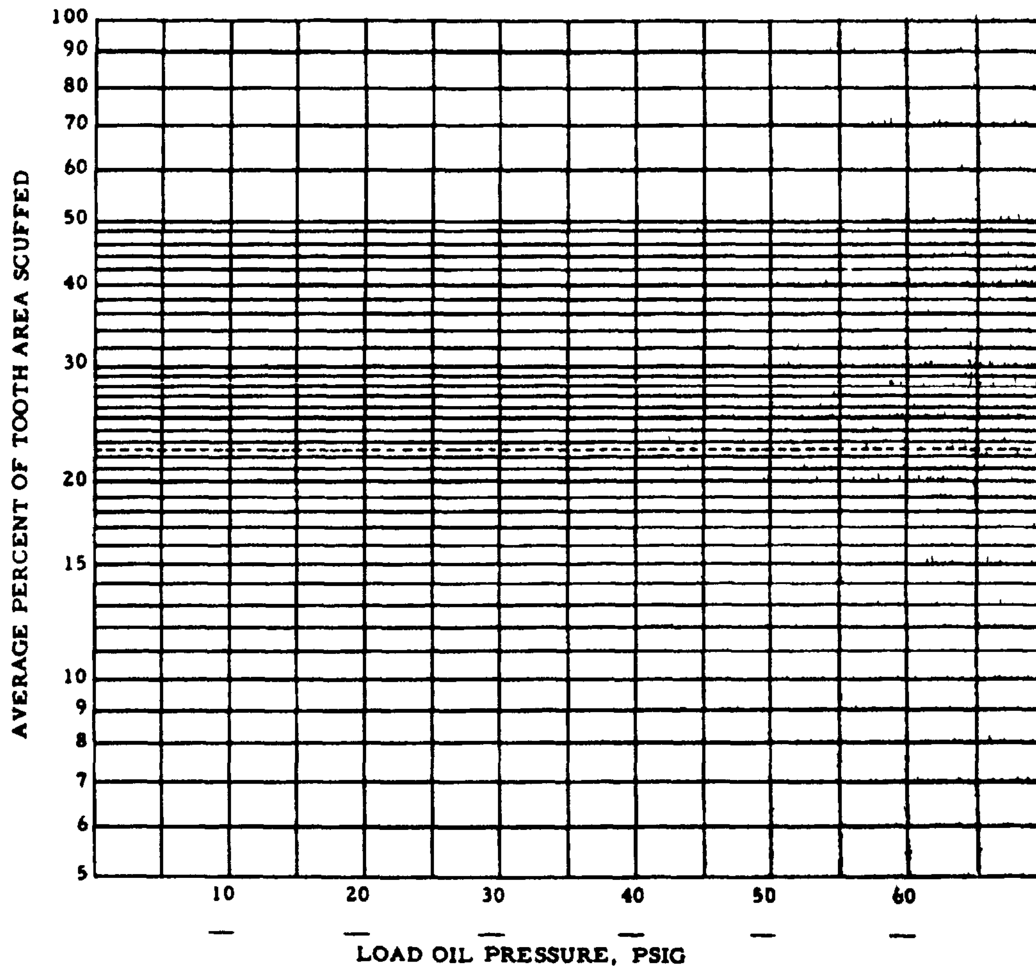

Figure 10 Plot and Calculations Sheet

NOTE: Standard reference oil can be obtained from Southwest Research Institute, 8500 Culebra Road, San Antonio, Texas 78284.

70.8 Determination of reference oil average rating

NOTE: All load-carrying capacity tests on the standard reference oil are conducted in accordance with ASTM D1947 using AMS 6260 steel test gears at 165°F test temperature conditions.

70.8.1 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 800 lb/in, the average is taken as the reference oil rating. If the high and low values differ by more than 800 lb/in, four additional determinations (two gears) shall be conducted and the average of the 12 determinations taken as the reference oil rating.

70.8.2 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 300 lb/in, and the high and low values obtained do not differ by more than 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.

70.8.3 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 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 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 70.8.1.)

NOTE: Maximum and minimum acceptable average ratings for the reference oil are 3300 lb/in and 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.

8. REPORT

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 pounds per inch of the tooth-face width (70.6.1).

b. The average rating of the test oil in pounds per inch of tooth-face width.

c. The standard reference oil average rating in pounds per inch of tooth-face width (70.8).

d. The relative rating of the test oil in percent

$$= \frac{\text{test oil average rating}}{\text{reference oil average rating}} \times 100.$$

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SPECIFICATION ANALYSIS SHEET	Form Approved Budget Bureau No. 22-R255

INSTRUCTIONS: This sheet is to be filled out by personnel, either Government or contractor, involved in the use of the specification in procurement of products for ultimate use by the Department of Defense. This sheet is provided for obtaining information on the use of this specification which will insure that suitable products can be procured with a minimum amount of delay and at the least cost. Comments and the return of this form will be appreciated. Fold on lines on reverse side, staple in corner, and send to preparing activity. Comments and suggestions submitted on this form do not constitute or imply authorization to waive any portion of the referenced document(s) or serve to amend contractual requirements.

SPECIFICATION

ORGANIZATION

CITY AND STATE	CONTRACT NUMBER

MATERIAL PROCURED UNDER A

☐ DIRECT GOVERNMENT CONTRACT ☐ SUBCONTRACT

1. HAS ANY PART OF THE SPECIFICATION CREATED PROBLEMS OR REQUIRED INTERPRETATION IN PROCUREMENT USE?

   A. GIVE PARAGRAPH NUMBER AND WORDING.

   B. RECOMMENDATIONS FOR CORRECTING THE DEFICIENCIES

2. COMMENTS ON ANY SPECIFICATION REQUIREMENT CONSIDERED TOO RIGID

3. IS THE SPECIFICATION RESTRICTIVE?

   ☐ YES ☐ NO *(If "yes", in what way?)*

4. REMARKS *(Attach any pertinent data which may be of use in improving this specification. If there are additional papers, attach to form and place both in an envelope addressed to preparing activity)*

SUBMITTED BY *(Printed or typed name and activity - Optional)*	DATE

DD FORM 1 JAN 66 1426 REPLACES EDITION OF 1 OCT 64 WHICH MAY BE USED.

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