

MIL-HDBK-406

31 OCTOBER 1971

MILITARY STANDARDIZATION HANDBOOK
CONTAMINATION CONTROL
TECHNOLOGY

Cleaning Materials for Precision Precleaning
and
Use in Clean Rooms and Clean Work Stations



FSC 3694

MIL-HDBK-406
Contamination Control Technology
Cleaning Materials for Precision Precleaning
and Use in Clean Rooms and Clean Work Areas
31 October 1971

1. This standardization handbook was developed by the US Army Missile Command in accordance with established procedure.
2. This publication was approved on 31 October 1971 for printing and inclusion in the military standardization handbook series.
3. This document provides basic and fundamental information on cleaning materials for use in precision precleaning of material to be further processed in clean rooms or clean work areas. It provides valuable information to both design and logistics personnel who are concerned with material which requires precision cleaning techniques. The handbook is not intended to be referenced in its entirety for mandatory use in procurement specifications except for informational purposes. Specific materials may be specified. No criteria herein is intended to supersede any specification requirements.
4. Every effort has been made to reflect the latest information on materials suitable for use as delineated. It is the intent to review this handbook periodically to insure its completeness and currency. Users of this document for changes and inclusions to:

Commanding General
US Army Missile Command
Standardization Division
AMSMI-RCS
Redstone Arsenal, Alabama 35809

MIL - HDBK - 406
31 October 1971

FOREWORD

The purpose of this document is to focus the attention of designers, clean room personnel and those persons engaged in contamination control, on the importance of the proper selection of cleaning materials, and cleaning agents; and their compatibilities with the materials being cleaned. This report should serve as a guide for the proper selection of cleaning materials. It does not, however, recommend any given cleaning agent or process for specific hardware, as the types of materials used in various systems differ widely.

The purpose of this handbook was to present as much pertinent data as possible, in one volume, on most of the cleaning agents associated with precision cleaning of hardware.

It has been observed that most of the indepth studies to date, of materials compatibilities with cleaning agents, have been undertaken as the result of catastrophic failure or system malfunction. It should be pointed out that safety and compatibility testing must be performed prior to hardware production.

MIL - HDBK - 406

31 October 1971

SAFETY WARNING

Adequate safety precautions should be taken when handling any chemical (solvent, cleaning material, etc.). Inhalation or direct contact with the skin should be avoided. Appropriate protective clothing (suits, gloves, masks, etc.) should be utilized at all times, while handling chemicals or in their immediate proximity. Some chemicals present fire hazards others vary in toxicity and yet others are asphyxiants.

The THRESHOLD LIMIT VALUES (TLV) or MAXIMUM ALLOWABLE CONCENTRATION (MAC) is listed for most chemicals encountered in the clean room environment. These are recommended values only, and should be used as a guide, as some individuals are more sensitive to certain chemicals than others.

When combinations of chemicals are used together or in proximity to each other the effects of the different hazards should be considered as additive. That is the sum of the following fractions.

$$\frac{C_1}{T_1} + \frac{C_2}{T_2} + \dots + \frac{C_n}{T_n}$$

EXAMPLE:

General case; when the air is analyzed for each component; the air contains 15 ppm Carbontetrachloride (TLV=25), 100 ppm Trichloroethylene (TLV=200), and 200 ppm Methyl Ethyl Ketone (TLV=250).

$$\frac{15}{25} + \frac{100}{200} + \frac{200}{250} = \frac{475}{250} = 1.9$$

Thus the threshold limit is exceeded.

NOTE:

More detailed information may be obtained from the Governmental Industrial hygienists, 1014 Broadway, Cincinnati, Ohio 45202 Or the Handbook of Toxicology, Vol. 1, Acute Toxicities, prepared by The National Academy of Sciences, National Research Council.

MIL - HDBK - 406
31 October 1971

CONTENTS

FOREWORD	Page iii
SAFETY - WARNING	iv
Contents	v - xy

SECTION 1

Paragraph		Page
1.1	SCOPE	1
1.2	SELECTION OF CLEANING AGENTS	1
1.3	CONFLICTS	1
1.4	CLASSIFICATION	1

SECTION 2

2.	CONTAMINANTS	3
2.1	What are they?	3
2.1.1	Oxidation	3
2.1.2	Light	3
2.1.3	Microbial organisms	3
2.1.4	Lubricants	3
2.2	Sources and Forms	3
2.2.1	Petroleum Industry	4
2.2.1.1	Crude Oil Production	4
2.2.1.2	Refinery Operations	4
2.2.2	Metallurgical Industry	4
2.2.3	Organic Solvents	4
2.2.4	Mineral Processing	4
2.2.5	Motor Vehicles	5
2.2.6	Natural Environment	5
2.3	The Environment	5
2.4	Man in the Contaminant Generation Cycle	5
2.4.1	How much can Man Generate?	5
2.4.2	People Packaging	12
2.5	Contamination Migration	12
2.5.1	Fluid	12
2.5.2	Solids	12
2.5.3	Physical Contact Carriers	12
2.5.4	Waves	12
2.6	Contamination Retention	12
2.6.1	Gravity	13
2.6.2	Electrostatic Charges	13
2.6.3	Molecular Attraction	13
2.6.4	Viscous Surface Coatings	13
2.6.5	Physical Entrapment	13

MIL - HDBK - 406
31 October 1971

CONTENTS (CON'T)

Paragraph		Page
2.7	Contamination in Liquids, Solids and Gases	14
2.7.1	Liquids	14
2.7.1.1	Particles in Liquids	14
2.7.1.2	Dissolved Matter in Liquids	14
2.7.2	Solids	15
2.7.3	Gases	15
2.7.3.1	Particulates in Gases	15
2.7.3.2	Gases in Gases	15

SECTION 3

3.	CONTAMINATION CONTROL THROUGH PRODUCT DESIGN	17
3.1	How Clean is Clean?	17
3.2	Manufacturing and Processing Environments	17
3.2.1	Manufacturing Precautions	17
3.2.2	Fabrication as a Contamination Generator	18
3.2.3	Assembly Generates Contamination Also	18
3.3	Test Procedures	18
3.3.1	Gauges, Fixtures and Test Equipment	19
3.3.2	Chemical Tests	19
3.3.3	Operations	19
3.4	Storage	19
3.4.1	Wood	19
3.4.2	Cushioning	19
3.4.3	Vapors	19
3.4.4	Copper, Iron and Manganese	19
3.4.5	Organic Materials	19
3.5	The Designer in Contamination Control	19
3.5.1	The Systems Designer	20
3.5.2	Designers Must Define and Identify	21
3.5.3	Methods, Techniques and Considerations	21
3.5.3.1	Considerations	21
3.5.3.2	Control Techniques	22
3.5.3.3	Control Methods	22

SECTION 4

4.	CONTROL OF SURFACE CONTAMINANTS	23
4.1	Cleaning of Surfaces	23
4.1.1	Physical Cleanliness	23
4.1.2	Chemical Cleanliness	23
4.1.3	Metallurgical Cleanliness	23
4.2	Cleaning Forces	24
4.2.1	Fluid Dynamical	24
4.2.2	Inertial	24
4.2.3	Direct Mechanical Contact	24

MIL - HDBK - 406
31 October 1971

CONTENTS (CON'T)

Paragraph		Page
4.3	Liquid Cleaning	24
4.3.1	Wetting	24
4.3.2	Emulsification	25
4.3.3	Saponification	25
4.3.4	Deflocculation	25
4.3.5	Solvent Activity	26
4.3.6	pH	27
4.3.7	Buffer Activity	27
4.3.8	Alkalinity and Acidity	27
4.4	Corrosion	28
4.5	Corrosion Forms	29
4.5.1	Intergranular Corrosion	29
4.5.2	Crevice Corrosion	30
4.5.3.1	Sources of Stress	30
4.5.3.2	The Favorable Environment	30
4.5.4	Hydrogen Embrittlement	31
4.5.5	Galvanic Corrosion	31
4.5.6	Porous Castings	32
4.5.7	Fungi and Bacteria	32
4.5.8	Metal Whiskers	32
4.6	Corrosion Prevention	32
4.6.1	Intergranular Corrosion	32
4.6.2	Crevice Corrosion	32
4.6.3	Stress Corrosion	32
4.6.4	Hydrogen Embrittlement	33
4.6.4.1	Choose organic films or vacuum deposited films	33
4.6.4.2	Plating	33
4.6.4.3	Materials not subject to Hydrogen Embrittlement	33
4.6.5	Galvanic Corrosion	33
4.6.6	Fungi	34
4.6.7	The Environment	38
4.6.8	Metallic Coatings	41
4.6.9	Material Choices	41

SECTION 5

5	GROSS CLEANING	51
5.1	Barrel Cleaning	51
5.2	Mechanical Cleaning	52
5.3	Abrasive Blast	52
5.4	Washers	53
5.4.1	Single-Stage	54
5.4.2	Two-Stage	54
5.4.3	Multi-Stage	54
5.5	Agitation	54

MIL - HDBK - 406
31 October 1971

CONTENTS (CON'T)

Paragraph		Page
SECTION 6		
6	PRECISION CLEANING	57
6.1	Methods	57
6.1.1	Vapor Degreasers	57
6.1.1.1	Design	57
6.1.1.2	Types	58
6.1.1.3	Solvents	62
6.1.1.3.1	Characteristics	62
6.1.2	Ultrasonic Cleaning	65
6.1.2.1	Components	65
6.1.2.2	How does it Work?	68
6.1.2.3	Solvent Property Effects	68
6.1.2.4	How is the System Evaluated?	70
6.1.2.5	How is the Cleaning Monitored?	71
6.1.2.6	What must be Considered?	71
6.1.3	Drying Methods	78
6.2	The Environment	78
6.2.1	The Clean Room	78
6.2.1.1	Non-Laminar Airflow	78
6.2.1.2	Fume Hoods	80
6.2.1.3	Laminar Airflow	81
6.2.1.4	Vertical Laminar Airflow	81
6.2.1.5	Horizontal Laminar Airflow	83
6.2.1.6	Horizontal Airflow Tunnels	84
6.2.1.7	Horizontal Airflow Work Bench	84
6.3	Packaging	85
6.3.1	Packaging Elements	85
6.3.2	Packaging Films	86
6.3.3	Attack by Packaging	87
SECTION 7		
7	DETAIL REQUIREMENTS	89
7.1	Properties	89
7.1.1	Solvency	89
7.1.2	Toxicity	89
7.1.2.1	TLV	90
7.1.3	Non Volatile Residue (NVR)	90
7.1.4	Flammability	90
7.1.5	Boiling Point	91
7.1.6	Freezing Point	91
7.1.7	Particulate Content	91
7.1.8	Stability	92
7.1.9	Vapor Pressure	92
7.1.10	Surface Tension	92
7.1.11	Viscosity	92
7.1.12	Density	93

CONTENTS (CON'T)

Paragraph		Page
7.2	Compatibility Considerations	93
7.3	Bulk Handling and Storage	93
7.3.1	The Tank	93
7.3.2	Pipes, Fittings, Gaskets and Hoses	93
7.3.3	Pumps, Meters, Valves and Gages	94
7.3.4	Tank Cleaning	94
7.4	<u>Acetone</u>	129
7.4.1	Physical Properties	129
7.4.2	Specifications	129
7.4.3	General Information	129
7.4.4	Solubility Data	129
7.4.5	Materials Compatibility	131
7.5	<u>Benzene</u>	132
7.5.1	Physical Properties	132
7.5.2	Specifications	132
7.5.3	General Information	132
7.6	<u>Carbon Tetrachloride</u>	132
7.6.1	Physical Properties	132
7.6.2	Specifications	133
7.6.3	General Information	133
7.6.4	Decomposition	133
7.6.5	Materials Compatibility	134
7.7	<u>Chloroform</u>	134
7.7.1	Physical Properties	134
7.7.2	Specifications	134
7.7.3	General Information	134
7.8	<u>Ethyl Alcohol</u>	135
7.8.1	Physical Properties	135
7.8.2	Specifications	135
7.8.3	General Information	135
7.8.4	Materials Compatibility	136
7.9	<u>Ethylene Chloride</u>	136
7.9.1	Physical Properties	136
7.9.2	Specifications	136
7.9.3	General Information	136
7.10	<u>Isopropyl Alcohol</u>	137
7.10.1	Physical Properties	137
7.10.2	Specifications	137
7.10.3	General Information	137
7.10.4	Materials Compatibility	137
7.11	<u>Methyl Alcohol</u>	138
7.11.1	Physical Properties	138
7.11.2	Specifications	138
7.11.3	General Information	138
7.11.4	Materials Compatibility	139

MIL - HDBK - 406
31 October 1971

CONTENTS (CON'T)

Paragraph		page
7.12	<u>METHYLENE CHLORIDE</u>	139
7.12.1	Physical Properties	139
7.12.2	Specifications	140
7.12.3	Typical Commercial Specifications	140
7.12.4	General Information	140
7.12.5	Solubility Data	140
7.12.6	Decomposition	141
7.12.6.1	Effects of Temperature on Decomposition	142
7.12.6.2	Effects of Water on Decomposition	142
7.12.6.3	Effects of Oxygen on Decomposition	142
7.12.6.4	Effects of Metals on Decomposition	142
7.12.6.5	Effects of Water and Metals on Decomposition	142
7.12.6.6	Decomposition under Varied Conditions	142
7.12.7	Materials Compatibility	143
7.13	<u>METHYL ETHYL KETONE</u>	144
7.13.1	Physical Properties	144
7.13.2	Specifications	145
7.13.3	General Information	145
7.13.4	Solubility Data	145
7.14	<u>PERCHLOROETHYLENE</u>	147
7.14.1	Physical Properties	147
7.14.2	Specifications	147
7.14.3	Typical Commercial Analysis	147
7.14.4	General Information	148
7.14.5	Materials Compatibility	148
7.15	<u>TOLUENE</u>	149
7.15.1	Physical Properties	149
7.15.2	Specifications	150
7.15.3	General Information	150
7.16	<u>1,1,1-TRICHLOROETHANE</u>	150
7.16.1	Physical Properties	150
7.16.1.1	Specific Properties	151
7.16.2	Typical Commercial Properties	151
7.16.3	Specifications	151
7.16.4	General Information	152
7.16.5	Solubility Data	152
7.16.6	Materials Compatibility	154
7.16.6.1	Effects on Plastics	154
7.16.6.2	Effects on Elastomers	155
7.16.6.3	Effects on Various Materials	155
7.16.6.4	Effects on Wire Coatings	156
7.16.6.5	Effects on Aluminum Alloys	156
7.16.6.6	Effects on Various Metals	157
7.16.6.7	Compatibility With Missile Fuels	157

MIL - HDBK - 406
31 October 1971

CONTENTS (CON'T)

Paragraph		page
7.17	<u>TRICHLOROETHYLENE</u>	158
7.17.1	Physical Properties	158
7.17.2	Specifications	158
7.17.3	Solubility Data	158
7.17.4	Materials Compatibility	159
7.17.4.1	Effect on Materials of Construction	159
7.17.4.2	Effect on Plastics, Elastomers and Rubbers	159
7.17.4.3	Effect on Aluminum Alloys	160
7.17.4.4	Effect on Various Metals	160
7.17.4.5	LOX & NTO Sensitivity	160
7.18	<u>TRICHLOROFLUOROETHANE</u>	161
7.18.1	Physical Properties	161
7.18.1.1	Liquid Density	162
7.18.2	General Information	162
7.18.3	Solubility Data	162
7.18.4	Materials Compatibility	163
7.18.4.1	Effects on Plastics	163
7.18.4.2	Effects on Elastomers	164
7.18.4.3	Effects on Machinery Enamel	164
7.18.4.4	Effect on Wire Insulation	165
7.18.4.5	NTO Sensitivity	165
7.19	<u>TRICHLOROTRIFLUOROETHANE</u>	165
7.19.1	Physical Properties	165
7.19.1.1	Commercial Solvent Grade Specification	166
7.19.1.2	Commercial White Room Grade Specification	166
7.19.2	Specifications	166
7.19.2.1	Commercial Specification and Test	167
7.19.3	Solubility Data	168
7.19.3.2	Solubility of Various Materials	168
7.19.3.3	Various Oils Totally Miscible with Trichlorotrifluoroethane	169
7.19.4	Materials Compatibility	169
7.19.4.1	Effect on Plastics	169
7.19.4.2	Effect on Plastics and Rubber	170
7.19.4.3	Effect on Wire Coatings	170
7.19.4.4	Effect on Wire Insulation	170
7.19.4.5	Effect on Various Metals	171
7.19.4.6	Effect on Aluminum Alloys	171
7.19.4.7	Effect on Various Metals	171
7.19.4.8	Effect on Aircraft Materials	172
7.19.4.9	Impact Sensitivity	172
7.19.4.10	Impact Sensitivity Height	173

MIL - HDBK - 406
31 October 1971

CONTENTS (CON'T)

Paragraph		Page
7.20	<u>TRICHLOROTRIFLUOROETHANE AND SDA-30 ETHYL</u> <u>ALCOHOL BLEND</u>	173
7.20.1	Physical Properties	173
7.20.2	Solubility Data	174
7.20.3	Materials Compatibility	174
7.20.3.1	Effect on Plastics	174
7.20.3.2	Effect on Elastomers	175
7.20.3.3	Effect on Wire Coatings	175
7.21	<u>TRICHLOROTRIFLUOROETHANE AND ISOPROPYL ALCOHOL BLEND</u>	
7.21.1	Physical Properties	175
7.21.2	Solubility Data	175
7.21.3	Materials Compatibility	176
7.21.3.1	Effect on Plastics	176
7.21.3.2	Effect on Elastomers	176
7.21.3.3	Effect on Wire Coatings	176
7.22	<u>TRICHLOROTRIFLUOROETHANE/WATER/SURFACTANT</u>	177
7.22.1	Physical Properties	177
7.22.2	Solubility Data	177
7.22.3	Materials Compatibility	177
7.22.3.1	Effect on Metals	177
7.22.3.2	Effect on Plastics	178
7.22.3.3	Effect on Elastomers	178
7.23	<u>TRICHLOROTRIFLUOROETHANE AND SDA-30 ETHYL</u> <u>ALCOHOL AZEOTROPE</u>	178
7.23.1	Physical Properties	178
7.23.2	Solubility Data	179
7.23.3	Materials Compatibility	179
7.23.3.1	Effect on Plastics	179
7.23.3.2	Effect on Wire Coatings	179
7.23.3.3	Effect on Elastomers	180
7.24	<u>TRICHLOROTRIFLUOROETHANE AND CHLOROFORM AZEOTROPE</u>	180
7.24.1	Physical Properties	180
7.24.2	Solubility Data	180
7.24.3	Materials Compatibility	181
7.24.3.1	Effect on Metals	181
7.24.3.2	Effect on Plastics	181
7.24.3.3	Effect on Elastomers	181
7.25	<u>TRICHLOROTRIFLUOROETHANE AND ACETONE AZEOTROPE</u>	182
7.25.1	Physical Properties	182
7.25.2	Solubility Data	182
7.25.3	Materials Compatibility	182
7.25.3.1	Effect on Plastics	182
7.25.3.2	Effect on Elastomers	182

MIL - HDBK - 406
31 October 1971

CONTENTS (CON'T)

Paragraph	SECTION 8	Page
8	VERIFICATION OF CLEANLINESS	190
8.1	Direct Cleanliness Measurement	190
8.2	Indirect Cleanliness Measurement	190
8.3	Cleanliness Tests	190
8.3.1	Visual	190
8.3.2	Tissue Paper or White Cloth	191
8.3.3	Water Break	191
8.3.4	Atomizer	191
8.3.5	Contact Angle	191
8.3.6	Ring Test	191
8.3.7	Radioactive Tracer	191
8.3.8	Radiochemical	192
8.3.9	Gravimetric	192
8.3.10	Ferrocyanide Paper	192
8.3.11	Copper Dip	192
8.3.12	Solvent Ring	192
8.3.13	Solvent Monitoring	192
8.3.14	Indium Adhesion	193
8.4	ASTM Test Methods	193
	SECTION 9	
9	MICROBIOLOGICAL CONTAMINATION	194
9.1	Bacteria, What Are They? How Many Are There?	194
9.1.1	Algae	194
9.1.2	Protozoa	194
9.1.3	Fungi	194
9.1.4	Slime Molds	197
9.1.5	Bacteria	197
9.1.6	Rickettsiae	197
9.1.7	Viruses	197
9.2	How are the Bacteria Classified?	197
9.3	What is the Bacteria Life Cycle?	198
9.4	How can Microorganisms be Seen?	198
9.5	How are Bacteria Counted?	198
9.6	What are Spores?	199
9.7	What is Staining?	199
9.8	Gram Staining	199
9.9	Chromosomes	199
9.9.1	Mutation	199
9.10	Does Bacteria Effect Cleaning Materials?	200
9.11	Do Microorganisms Effect Hardware?	202
9.12	Sources of Microbial Contamination	202
9.13	Detection and Prevention	202
	SECTION 10	
10	CONCLUSION & RECOMMENDATIONS	204
11	GLOSSARY	206
12	BIBLIOGRAPHY	210-224

MIL - HDBK - 406
31 October 1971

CONTENTS (CON'T)

Figure #	FIGURES & ILLUSTRATIONS	Page
6 - 1	The Vapor Degreaser	59
6 - 2	Spray-Vapor	60
6 - 3	Vapor-Spray-Vapor	60
6 - 4	Vapor-Immersion-Vapor	61
6 - 5	Boiling Solvent-Cool Solvent-Vapor	61
6 - 6	The Ultrasonic Frequencies	67
9 - 1	Bacteria - Primary Classification	195
9 - 2	Typical Bacterial Cell	196
9 - 3	Relationship of a Machined Surface and Organisms	203
Table	TABLES	Page
2 - 1	Sources of Contaminants & the Affected Environments	6-8
2 - 2	Classification of Airborne Contaminants	9
2 - 3	Particle Size Range of Various Materials in Microns	10
2 - 4	Sources of Contaminants	11
4 - 1	Effects of Moisture on Non-Metallic Materials	29
4 - 2	Favorable Environments for Stress-Corrosion-Cracking	30-31
4 - 3	Compatible Metal Groups	33-34
4 - 4	Galvanic Couples	34-35
4 - 5	Preventing Galvanic Corrosion	36
4 - 6	Fungi-Inert Materials	37
4 - 7	Organics as a Source of Corrosive Vapors	38
4 - 8	Man-made Corrosive Conditions	39
4 - 9	Selection of Coatings for Minimum Corrosion	40
4 - 10	Incompatible Materials	41
4 - 11	Examples of Incompatible Materials	42
4 - 12	Plastic Resistance Toward Various Corrosive Media	43-49
5 - 1	Abrasive Blasting Methods	53
6 - 1	Vapor Degreaser Limitations	63
6 - 2	Properties of Vapor Degreasing Solvents	66
6 - 3	Comparison of the Standard Cleaning Frequencies	72
6 - 4	Monitoring Ultrasonic Cleaning	73-74
6 - 5	Considerations for Ultrasonic Cleaning	75
6 - 6	Considerations for Cleaning Electronic Components	76
6 - 7	Laminar Flow Advantages and Disadvantages	77
6 - 8	Vertical Laminar Flow Room Requirements	82

CONTENTS (CON'T)

Table	TABLES (CON'T)	Page
7 - 1	Non Volatile Residue Detection Techniques	95
7 - 2	Danger Points of the Common Solvents	96-99
7 - 3	Effect of solution composition on corrosion of Type 304 and Mild Steel exposed to Uninhibited Trichloroethylene.	100
7 - 4	Corrosion of Type 304 Steel Exposed to Boiling Methylene Chloride and 1,1,2 Trichloroethane.	100-101
7 - 5	Corrosion of Materials Exposed to degraded Trichloroethylene	101
7 - 6	Condensate corrosion of Type 304 Steel Exposed to Degraded Trichloroethylene	101
7 - 7	Effect of soluble water and Acid Content on Corrosion of Type 304 Steel Exposed to Solutions of Chlorinated Solvents	102
7 - 8	Stress-Corrosion Cracking of Titanium in Methanol and Other Solutions	103
7 - 9	Smooth Specimen Tests in Organic Liquids	104
7 - 10	Expected Time to Failure in Hours	105
7 - 11	Results Obtained with Unalloyed (A55) U-Bend Specimens	106
7 - 12	Results Obtained with Unalloyed (A55) U-Bend Specimens	107
7 - 13	Influence of Environments on Titanium Alloy Stress Intensities Required for Cracking	108
7 - 14	Effects of Organic Solvents and Sodium Chloride on Stressed Titanium U-Bends	109
7 - 15	Chemical Resistance of Plastics & Metals	110-113
7 - 16	Corrosion Resistance of Various Metals	114-115
7 - 17	Titanium Corrosion Resistance	116-118
7 - 18	Corrosion Resistance of Stainless Steel Types 430, 302 & 316	119-121
7 - 19	Corrosion Resistance of Types 316, 304 & 430 Stainless Steels in Various Media	122-123
7 - 20	The Corrosion Resistance of 430, 302 & 316 Steel	124-125
7 - 21	Corrosion Resistance of Type 316, 304 & 430 Steel	126-128
7 - 22	Solvent Properties Comparison Chart	185-188
9 - 1	Environmental Extremes of Microorganisms	201
9 - 2	Quantitative Distribution of Microorganisms	203

MIL - HDBK -406
31 October 1971

1. SCOPE

1.1. Scope

This Handbook serves as a guide and establishes the minimum requirements for selection, storage and compatibility considerations of cleaning agents for use in Clean Rooms and Clean Work Stations and Controlled Environmental Facilities.

1.2. Selection of Cleaning Agents

Unless otherwise specified, the responsibility for cleaning agent selection and cleaning method selection shall rest with the activity responsible for the end item.

1.3. Conflicts.

In the event of conflict between the requirements of this handbook and those of specifications or drawings, the conflict shall be resolved by the procuring agency or activity.

1.4. Classification

For the purpose of this document, the term "Cleaning Agent" and the term "Solvent" will be considered to be synonymous, and shall refer to two basic types of agents, aqueous and non aqueous. Aqueous refers to water, deionized water and distilled water and those cleaning solutions which are, in part composed of water. Non Aqueous solutions shall refer to organic solvents such as alcohols, ketones, chlorinated hydrocarbons and chlorofluorinated hydrocarbons. Purity levels of these agents shall be determined in accordance with MIL. STD 1246 () and all applicable Handbooks and Specifications for the agents involved.

MIL - HDBK - 406
31 October 1971

2. CONTAMINANTS

2.1. What are they?

A contaminant is any material, substance or energy that is undersirable or adversely affects any part, component or assembly.

Any given material or energy may be a contaminant in a given situation, this is not necessarily true in all cases:

- 2.1.1. Oxidation - oxidation products are normally considered contaminants. The controlled oxidation of aluminum and its alloys is vital to the protection of the metal.
- 2.1.2. Light - light is essential to the normal human functions; yet even minute amounts of light in a photographic dark room where there is exposed, undeveloped film can prove disastrous.
- 2.1.3. Microbial organisms - there is no doubt that microorganisms perform many useful functions; the byproducts of microbial metabolism, however, can etch the surface of a piece of fine optical glass. The growth microorganisms can bridge todays micro-circuits, delaminate a printed circuit board and in general, lessen the performance of an electrical component through increased resistance, poor contact, etc. Their growth can also cause paints and sealing compounds to blister and peel.
- 2.1.4. Lubricants- although lubrication of many mechanical systems is essential to the smooth, friction-free operation of the system, the presence of oils or greases (even in minute quantities) will result in lower conductivity of electrical contacts. The contamination of a liquid oxygen system with lubricants can result in a highly explosive situation.

2.2. Sources and Forms

Contaminants are the products of activity. The activity, or expenditure of energy, may be mechanical, chemical, electrical, thermal or radiological in nature. All activities of man contribute to the generation of contaminants. TABLE 2-1 illustrates the sources and affected environments of various contaminants.

MIL - HDBK - 406
31 October 1971

The nature of contamination is varied. A contaminant only becomes such when the environment, component configuration or situation prohibits its presence.

Airborne contaminants are classified by their physical state as either gaseous or non-gaseous. The gaseous contaminants are further broken down as organic and inorganic gases. The non-gaseous contaminants are also known as aerosols which take in all solid and liquid particulate matter. TABLE 2-2 shows a breakdown of these contaminants by class, subclass and typical members of each.

Many end items are cleaned of particulate matter according to the maximum allowable size of any given contaminant the end item can tolerate. To ensure that the particles normally found in ambient air are prevented from coming into contact with an item, ultra-filtration is required. This will be discussed in detail in the section on precision cleaning. Note TABLE 2-3 illustrates the comparative sizes of particulates normally found in ambient air.

Many of the particulate and gaseous contaminants found in our air are generated by the activities of both man and nature:

2.2.1. Petroleum Industry

2.2.1.1. Crude Oil Production - contaminants consist of escaping natural gases and evaporated hydrocarbons (ethane and methane) some carbon monoxide, oxides of sulfur and nitrogen.

2.2.1.2. Refinery Operations - contaminants include all classes and subclasses (see TABLE 2-1). The majority includes hydrocarbons, oxides of sulfur and nitrogen and carbon monoxide.

2.2.2. Metallurgical Industry - contaminants are primarily in the aerosol category (smoke, dusts and metallic fumes).

2.2.3. Organic Solvents - the evaporation of solvents results in the emission of all organic gas contaminants.

2.2.4. Mineral Processing - this primarily contributes to the aerosol contaminant category.

MIL - HDBK - 406
31 October 1971

2.2.5. Motor Vehicles

these are the principal contributors of hydrocarbon gases, carbon monoxide, nitrogen oxides and lead.

2.2.6. Natural Environment

these are primarily due to the generation of aerosols (pollens, spores, plant fibers, insect and animal parts, bacteria and viruses and dust).

TABLE 2-4 gives a breakdown of these contaminants and their sources.

2.3. The Environment

Second only to man in the generation of contaminants during the precision cleaning stage, is the environment. While environments can be listed as air, gas, liquid, solid and surface, the factors which most often contribute contaminants to these environments are people, tools, fixtures, equipment, control devices etc.

Much of the contamination control effort is directed at the removal of contaminants from the environment before a cleaned item comes in contact with the environment. The precision cleaning section will go into greater detail on the methods of contaminant removal from the manufacturing and processing environment and from the clean room environment.

2.4. Man in the Contaminant Generation Cycle

The principal offender in the generation of contaminants is man. His presence near a product or in the products environment practically assures that the product can easily become contaminated.

2.4.1. How much can Man Generate?

Interestingly enough, a man sitting still generates particulate contamination despite the fact that he is not moving. Even the least amount of movement possible will increase the amount of particulate contamination generated. One index gives the following example of the rate and amount of particles that a man will generate:

Sitting or standing, wearing cleanroom garments with no movement, an individual will shed approximately 100,000 particles per minute of 0.3 microns and larger. The same person, with only simple arm movement will generate 500,000 particles. Average arm and body movement with some slight leg movement, will produce over 1,000,000 particles per minute.

Walking: Slowly - 5,000,000; average - 7,500,000; fast - 10,000,000 particles per minute. Boisterous activity in the clean room can result in the release of as much as 15 to 30,000,000 particles per minute into the environment.

MIL - HDBK - 406
31 October 1971

TABLE 2-1

Sources of Contaminants and the Affected Environments

Sources and Contaminant	Contaminant Type	Affected Environments	
		General	Specific Examples
Sun X-ray Ultraviolet Visible light Electro-magnetic Radioactive Materials Alpha particles Beta particles Gamma rays Electrons Neutrons Production Processes Welding (light and heat) Soldering (heat) Machining (vibration, sound, heat) Product Heat (electrical, mechanical, chemical) Vibration	Radiation	Air.....	Laboratories Fabrication areas Assembly areas Inert gases Fluid systems Fuels Hydraulic fluids
		Gases.....	
		Liquids.....	
		Solids.....	Plastics Magnetic memory core Explosives Solid state devices Transistors, etc.
		Surfaces.....	Photographic film Magnetic tape Electrical contacts
People and Animals Bacteria (spores and vegetative cells) Rickettsiae Viruses Soil Bacteria Fungi Protozoa Plants Pollen Fungi	Microbial (viable)	Air.....	Laboratories Fabrication areas Assembly areas Operating rooms Fluid systems Inert gases Fill gases Fuels Solvents Hydraulic fluids Coolants Lubricants
		Gases.....	
		Liquids.....	
		Solids.....	Plastics Fuels Explosives Parts Tubes Assemblies
		Surfaces.....	
		Living combinations...	People and animals Plants Food
		Inert combinations...	Animal waste products Soil

TABLE 2-1 (CON'T)

MIL - HDBK - 406
31 October 1971

Sources and Contaminant	Contaminant Type	Affected Environment	
		General	Specific
People: Skin oils Production Processes: Cleaning solvents Plating baths Machining oils Coolants Lubricants Atmosphere: Condensates	Liquid	Air(droplets).. Gases(droplets) Liquids..... Solids..... Surfaces.....	Laboratories Fabrication areas Assembly areas Fluid systems Inert gases Fill gases Fuels Solvents Hydraulic fluids Coolants Lubricants Explosives Propellants Plastics Metals Inside tubes Functional parts and assemblies
Production Processes: Condenses flux vapors Chemical films (oxides, etc.) Cleaning residues Product: Condenses flux vapors Condenses out-gassing products from plastics chemical films, oxides	Solid	Adsorbed on Surfaces.....	Electrical contacts Bearings Protective covers Inside tubes
People: Skin oils Production Processes: Fluxes Plastic ships etc. Atmosphere: Dust particles	Dissolved	Liquids..... Solids.....	Fuels Hydraulic fluids Coolants Cleaning solvents Metals Plastics

MIL - HDBK - 406

31 October 1971

TABLE 2-1 (CON'T)

Sources and Contaminant	Contaminant Type	Affected Environment	
		General	Specific
People: Bacteria and virus Epidermal scale Hair Cosmetics Cigarette smoke Clothing: Fibers and lint Industrial Processes: Smoke fumes Flue dust Solder and weld splatter Machining chips and burrs Sand, etc. Product: Wear particles Material shedding Corrosion products Earth: Dirt Sand Plants: Pollen	Particulate	Air..... Gases..... Liquids.... Solids..... Surfaces...	Laboratories Fabrication areas Assembly areas Fluid systems Inert gases Fill gases Fuels Solvents Hydraulic fluids Coolants Lubricants Metals Plastics Glass Explosives Fuels Electrical contacts Filters Fabrics Mechanical parts Tubing
People: Body vapors Production Processes: Chemical vapors from cleaning, encapsulating Combustion gases sublimated flux Product: Sublimated materials from flux, plastic etc.	Gaseous	Air..... Gases..... Absorbed in Liquids... Solids..... Adsorbed on Surfaces..	Laboratories Fabrication areas Assembly areas Fluid systems Inert gases Fill gases Fuels Solvents Hydraulic fluids Coolants Lubricants Explosives Fuels Plastics Fuels Explosives Metals Plastics

MIL - HDBK - 406
31 October 1971

TABLE 2 - 2

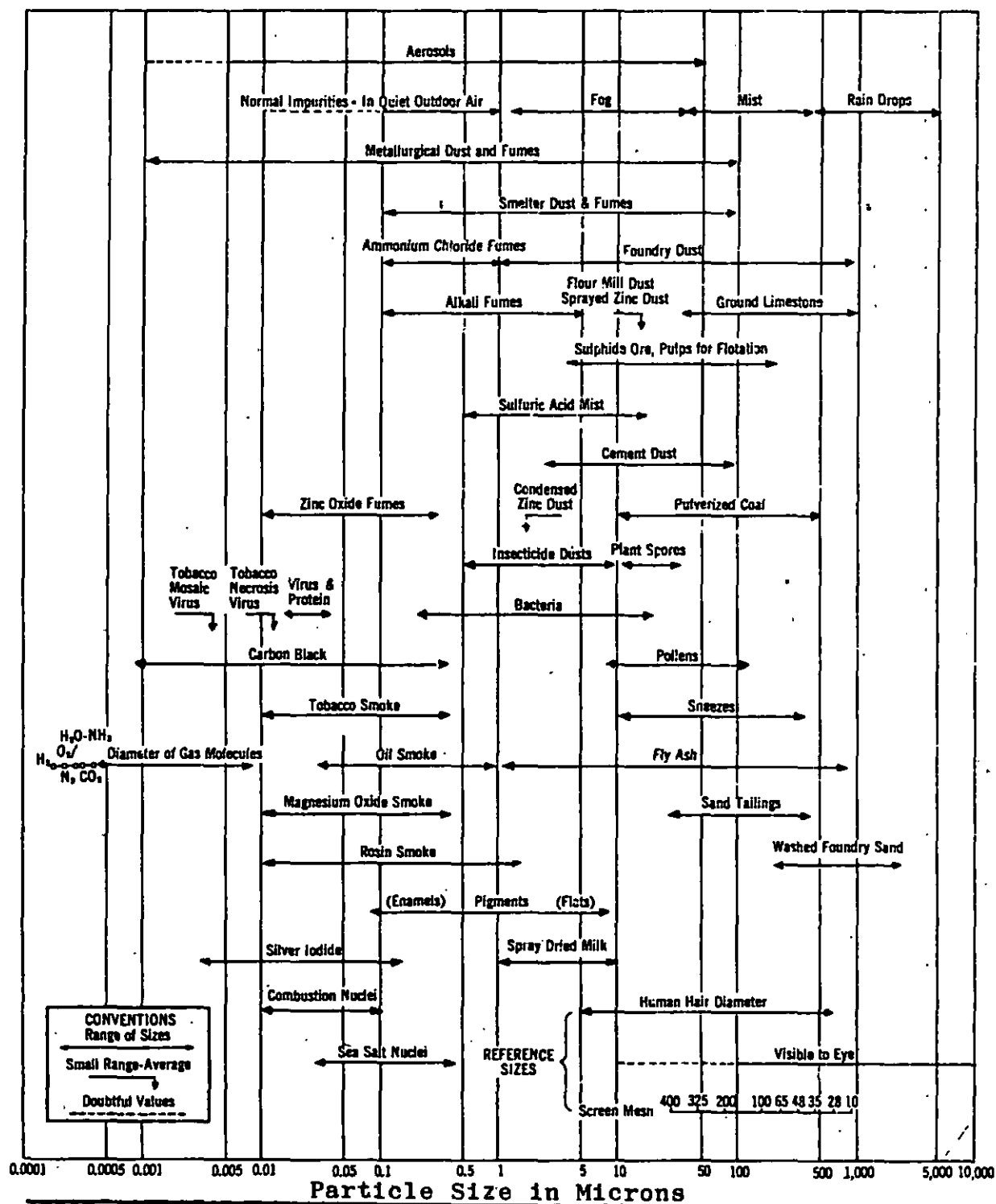
Classification of Air-borne Contaminants

Major Classes	Subclasses	Typical Members
	Hydrocarbons	Hexane, Xylene, Ethylene, Pentane, Butane, Butadiene, Methane.
Organic Gases	Aldehydes and Ketones	Formaldehyde, Acetone
	Other Organics	Chlorinated hydrocarbons, Alcohols.
	Oxides of Sulfur Oxides of Nitrogen	Sulfur dioxide, Sulfur Trioxide. Nitrogen dioxide, Nitric oxide.
Inorganic Gases	Carbon Monoxide	Carbon monoxide.
	Other Organics	Hydrogen sulfide, Ammonia, Chlorine.
Aerosols	Solid Particulate Matter	Dusts, Smoke, Fumes, Ash, Soot.
	Liquid Particulate Matter	Oil mists, Entrained liquid droplets.

MIL - HDBK - 406
31 October 1971

TABLE 2-3

PARTICLE SIZE RANGE OF VARIOUS MATERIALS- IN MICRONS



1 Micron = $\frac{1}{1000}$ mm or $\frac{1}{25,400}$ in.

TABLE 2-4

MIL - HDBK - 406
31 October 1971

Sources of Contaminants

	Organic Gases			Inorganic Gases			Aerosols		
	Hydrocarbons	Aldehydes and Ketones	Others	Oxides of Nitrogen	Oxides of Sulfur	Carbon Monoxide	Others	Liquid and Solids	
Petroleum									
Refining	S	S	N	S	S	S	S	S	
Marketing	S	N	N	S	N	N	N	N	
Production	S	N	N	S	N	N	N	N	
Metallurgical									
Nonferrous	N	N	N	N	N	N	S	S	
Ferrous									
Grey iron	N	N	N	N	N	N	S	S	
Electric steel									
Open Hearth	N	N	N	N	N	N	N	S	
Organic solvent									
Surface coat	S	S	S	N	N	N	N	S	
Dry cleaning	S	S	S	N	N	N	N	N	
Degreasing	S	S	S	N	N	N	N	N	
Mineral									
Asphalt									
batching	N	N	N	N	S	S	N	S	
Concrete									
batching	N	N	N	N	N	N	N	N	
Glass and									
ceramic	N	N	N	N	S	S	N	S	
Insulation	N	N	N	N	N	S	N	S	
Motor Vehicle									
Exhaust	S	N	N	S	S	S	N	S	
Blowby	S	N	N	N	N	S	N	N	
Evaporation	S	N	N	N	N	N	N	N	
Combustion									
Heaters and									
boilers	S	N	N	S	S	N	N	S	
Incineration	S	N	N	S	S	S	N	S	
Other industry	S	N	N	S	S	S	N	S	
Natural environment		N	N	N	N	N	N	S	

S - Significant contribution

N - Negligible contribution

MIL - HDBK - 406
31 October 1971

2.4.2. People Packaging

To control and contain these particles, much is being done in the area of "People Packaging", or the containment of man's contaminants with garments. The American Association for Contamination Control offers the following criteria for clean room garment construction:

Garments shall give body coverage as required. Hoods, collars and cuffs shall be adjustable to give snug fit. As required, garments may be fastened by snaps, ties, elastic or zippers. Garments must exhibit limited linting characteristics. The fabric of the garments and accessories will be of a synthetic type which is nonflammable, exhibits limited linting properties, has a weave and fiber which does not exhibit electrostatic generating property and has the ability to discharge electrostatic build-up.

2.5. Contamination Migration

To understand what must be done to either contain or control a contaminant, the mechanism by which they move or migrate must first be understood.

2.5.1. Fluid contaminants are suspended, adsorbed, absorbed or dissolved in the liquid. Particles are dropped out at the velocity of the fluid decreases, or as they become attached to surfaces.

2.5.2. Solids Contaminants can be entrapped, adsorbed, absorbed, or moved as the solid is moved from place to place.

2.5.3. Physical Contact Carriers can be the result of migration which occurs by means of an operator's hands, tools, working surfaces, fixtures, etc.

2.5.4. Waves are generally produced as the result of the propagation mechanism as an inherent characteristic of the contaminating energy as with light, sound, heat, etc.

2.6. Contamination Retention

Generally, the more common mechanisms of contamination retention on a surface are:

MIL - HDBK - 406
31 October 1971

- 2.6.1. Gravity - the amount of contamination retained by gravitational force depends on the angle of the surface and the mass of the particle.
- 2.6.2. Electrostatic Charges - these charges not only hold contamination but they also attract it from the surrounding environment. If possible, the polar characteristics of a cleaning agent should match those of the soil to be removed.
- 2.6.3. Molecular Attraction - this involves adhesion and adsorption and the affects of van der Waal's forces. It is directly affected by particle size, shape, composition and contact area, as well as the surface roughness of the part.
- 2.6.4. Viscous Surface Coatings - these are common cause of retention, particularly where machining, lubricating and shin oils are present.
- 2.6.5. Physical Entrapment - this should be a definite consideration for rough surface finishes or porous surfaces and materials.

Listed above are general types of forces resulting in contaminant retention. More specifically, the mechanism of retention may be described as follows:

When a liquid capillary layer exists between a particle and a surface, the surface tension of the liquid acting on the particle produces a component of force normal to the surface, provided that both the particle and the surface are wetted by the liquid For a given surface and environmental conditions, the force is proportional to the radius of the particle.

Electrical forces can affect both deposition and adhesion of particles to surfaces When a charged conductive particle approaches a grounded conductive surface, there is initially an attractive force due to image charges before the particle comes into contact with the surface; however, after contact is made, the charge is grounded leaving no net affect on adhesion.

A third class of adhesive force is that due to molecular interactions Examples of molecular forces include the interaction of dipoles with other dipoles or with polarizable molecules, hydrogen bonds, metallic bonds and image bond.

MIL - HDBK - 406
31 October 1971

Another type of resistance to the removal of a particle is offered by a time dependent force which is especially important in liquid systems. In a liquid system, including the case of a liquid capillary layer, as a particle is pulled away from the surface there is resistance to the flow of the liquid into the gap. This tends to retard the movement of the particle away from the surface. Thus a given force must be applied for a finite time in order to separate the particle a given distance from the surface.

2.7. Contamination in Liquids, Solids and Gases

2.7.1. Liquids

Liquids may be contaminated by suspended particles, dissolved matter (combinations, gases solids) or other liquids. Since the liquids used as a part of a system may be continuously reused or recycled, a level of cleanliness must be specified for the liquid.

2.7.1.1. Particles in Liquids - particles can be removed from liquids by filtration, centrifugal separation or settling. Filtration is the most common method.

The filters employed can be of several types: screen membrane, fritted glass, sintered metal or simply, a slit opening. The choice of filtration depends upon a number of factors:

- Filter/Liquid compatibility
- Liquid quantity
- Contaminant quantity
- Permanence and replacement accessibility
- Liquid pressure
- Flow restrictions imposed by the filter
- Pressure variations

2.7.1.2. Dissolved Matter in Liquids - the removal of dissolved matter from liquids may be accomplished by chemical separation, ion exchange, distillation or heating of vacuum.

The removal of dissolved matter may be difficult when the liquid and dissolved matter possess nearly identical physical properties. Physical property similarity also makes the detection of contaminants difficult.

MIL - HDBK - 406
31 October 1971

2.7.2. Solids

The contamination of solids may be in the form of particles, dissolved matter, gases or droplets. Generally, the contaminants are acquired while the solid is in a liquid state. Contaminants may also be absorbed directly into the solid, especially if the solid is porous as in the case of plastics and some metals. Exposure to some liquids or gases may also result in the absorption of contaminants.

Contaminants in solids frequently result in the alteration of the properties of the solid:

Mechanical Properties - changes in strength, hardness, brittleness.

Optical Properties - changes in the light transmission and absorption.

Electrical Properties - changes in the dielectric constant and the conductivity of the solid.

Contaminants in solids are generally controlled through the use of raw materials which meet a verifiable purity level. The close adherence to contamination control principles in the processing stages will also limit the level of contaminants. Porous materials may have to be protected at all times.

2.7.3. Gases

Contaminants in gases are generally in the form of particulates but can also be present in the form of gaseous contamination.

2.7.3.1. Particulates in Gases - these are generally removed by filtration when small particles are concerned, centrifugal separation or sedimentation may be the more practical removal methods. Filtration considerations include:

- Removal efficiency for specific size particles
- Quantity of Gas
- Gas/filter compatibility
- Pressure requirements
- Gas temperature
- Prefilter requirements

2.7.3.2. Gases in Gases - The elimination of gaseous contaminants from gases is primarily a process of maintaining the purity/integrity of the gas. Several considerations are necessary:

MIL - HDBK - 406
31 October 1971

Separation and removal of contaminants
may be difficult and expensive when
the two gases possess identical or
very similar properties and characteristics.

Isolation of the gas From contaminants
requires caution to ensure that the
system does not impart any contamination
in the form of surface absorbed gases.

Condensation of gases may result when the
gas is converted from its natural
state to a liquid or solid. Water
vapor may condense during this
process.

Control of chemical reactions within the
system can result in the generation
of contamination.

MIL - HDBK - 406
31 October 1971

3. CONTAMINATION CONTROL THROUGH PRODUCT DESIGN

3.1. How Clean is Clean?

This is at best, an academic question equal to "How high is up?"; but it does point to the fact that there is a need for cleanliness requirements.

The first phase of contamination control through product design is the determination of cleanliness levels for the end item. Since there is no established or industry-wide accepted standard, the selection of a cleanliness requirement or level frequently becomes, at best, a random affair. Ref. MIL-STA - 1246 ().

The imposition of unnecessarily stringent cleanliness requirements is actually damaging to the component. The prime consideration is to control the level of contamination only to the point where it will not constitute a hazard or degrade the function of the product concerned.

The selection of a cleanliness level can be a rational choice if the total end assembly is considered. How will the degree of cleanliness of this component affect the total system function? What is an actual, realistic, allowable amount of contamination a product can tolerate and still function properly? Obviously, a system containing an orifice one micron in diameter cannot tolerate a cleanliness level which permits particles 5 microns in diameter to remain on the part after cleaning. Conversely, a truck engine could conceivably tolerate contaminants many times that size.

3.2. Manufacturing and Processing Environments

The more closely attention is paid to detail during the manufacturing of components, the less contamination it will be necessary to remove from the completed assembly.

3.2.1. Manufacturing Precautions

Some of the precautions which can be taken during manufacture to reduce the built-in generation of contaminants are:

- Deburr each detail part.
- Clean with ultrasonics or degreasers to remove cutting oils, lapping compounds and other handling and manufacturing contaminants.

MIL - HDBK - 406
31 October 1971

Prohibit or limit the use of glass balls as a grinding or lapping compound.
Locate all cleaning and clean room areas away from manufacturing areas.
Employ plastic packaging and avoid the use of preservatives.
Keep all final cleaning operations in-house where possible.
Avoid joinings which prevent adequate future cleaning.
Monitor ultrasonic cleaning energy levels to avoid possible damage to the product.
Package in heat-sealed double plastic bags after final cleaning.

3.2.2. Fabrication as a Contamination Generator

Many fabrication steps are generators of contamination by their very nature:

Casting - Sand and cores, residues, blind holes, capillary traps, entrapped gases.
Moulding - Flash, mold release residue, mold wear particles.
Forging - Scale.
Machining - Blind holes, burrs and sharp edges, capillary traps, coolants, cutting oils.
Plating - Flaking and scaling.
Heat Treatment - Scale.
Cleaning - Residue, effect on material.

3.2.3. Assembly Generates Contamination Also

Assembly procedures are also a major contributor to the built-in manufacturing contaminants:

Rivets - Galvanic corrosion, fragments.
Nuts, Bolts, Screws - Plating, shedding, chips, burrs, abrasives.
Product Flow - Contaminants from surfaces of tools, work surfaces and fixtures.
Welding, Brazing, Soldering - Fragments, residues, fumes, oxides.
Marking - Etch residue, particles, shedding.
Gaskets - Flaking, shedding.
Personnel - Scale, hair, lint, fibers, finger prints, cosmetics.

3.3. Test Procedures

While it is necessary to test assemblies and components at

MIL - HDBK - 406
31 October 1971

various stages of manufacture, caution must be taken to ensure that during such testing and inspection, the equipment and operations employed do not impart contaminants to the components or assemblies. When performing testing, the operator must watch for:

3.3.1. Gages, Fixtures and Test Equipment - Flaking, shedding, oil, dirt, abrasion products.

3.3.2. Chemical Tests - Residues, dyes, corrosion.

3.3.3. Operations - Burrs, chips, plating, scale, released fluids, wear, personnel contaminants.

3.4. Storage

Storage and packaging should fall hand-in-hand here; however, a greater amount of space is devoted later to the packaging of cleaned products.

Storage requirements must be rigidly stated with regard to the facilities. Limitations must be established for environmental extremes of humidity, temperature and pressure. Insect and rodent infestation precautions must be considered as well as statements on the proper storage and shelving receptacles. This last requirement (shelving and storage receptacle), may be the most critical because:

3.4.1. Wood - emits harmful gases

3.4.2. Cushioning - often emits sulfurous or acidic vapors which will attack silver, cadmium and other metals.

3.4.3. Vapors - organic, acidic and ammonia vapors attack cadmium. The vapors from papers and cardboards which are not specifically designed for packaging electronic hardware, may tarnish silver and copper.

3.4.4. Copper, Iron and Manganese - promote cracking of rubbers.

3.4.5. Organic Materials - partially cured or uncured organic materials will outgas, thereby corroding nearby surfaces.

3.5. The Designer in Contamination Control

Last in the list, but obviously the most important, is the role

MIL -HDBK - 406
31 October 1971

of the designer in the control of contamination. It is the designer who establishes the criteria for all of the other factors. It is also the designer's responsibility to understand fully the nature of his materials of construction, their interrelationships and limitations and the environments which they can reasonably expect to see during their service life.

3.5.1. The Systems Designer

The systems designer must, to as great a degree as possible, ensure:

- ... that the system has as few deadend legs as possible, allowing system recirculation or purge capability.
- ... that recommended filtration for hydraulic systems includes adequate coarse and fine filtration, and in recirculating systems, return-line filtration is provided.
- ... that accessible drains are provided at the low point of a liquid system to facilitate the removal of contaminated fluids and improve system flushing.
- ... that plumbing is done as simply as possible, avoiding the use of adaptors and reducers, loops, bends and unnecessary discontinuities.
- ... that pipe threads and thread lubricants are avoided and teflon tape is employed instead.
- ... that shock and vibration is minimized, especially around filters, lessening the chance of migration of particles from contaminant traps.
- ... that hydraulic systems are designed with closed reservoirs.
- ... that filtration is employed downstream of hoses and disconnects.
- ... that air is eliminated from liquid systems, lessening the chance of high velocities across valve seats, which promotes erosion of the seats.
- ... that provisions are made for draining of cylinders and reservoirs which are contaminant traps.

MIL - HDBK - 406
31 October 1971

... that critical components are protected by upstream or integral filters.

3.5.2. Designers Must Define and Identify

To ensure exactness and a continuation of the contamination control program he establishes, the designer must define and identify:

- ... contaminant sensitive parts.
- ... the level of cleanliness necessary.
- ... those contaminants which cannot be tolerated by the system.
- ... the purity levels for the materials of construction.
- ... sequences of assembly.
- ... cleaning methods.
- ... cleanliness levels for process and assembly areas.
- ... purity requirements for materials used in production and cleaning.
- ... methods for measuring cleanliness.
- ... methods to be employed for excluding contaminants from the cleaned item.
- ... methods of servicing and maintenance operations.

3.5.3. Methods, Techniques and Considerations

The designer must make the following considerations, and determine what techniques and specific methods can be employed in the contamination control program:

3.5.3.1. Considerations -

- ... what contamination level and quantities can be tolerated.
- ... what are the contaminants.
- ... where the contaminants originate, how they affect the item and how can they best be removed.

MIL - HDBK - 406
31 October 1971

- ... what cleaning methods are suitable or compatible with the materials of construction and the total assembly.

- ... what cleaning solutions are suitable and compatible with the materials of construction.

3.5.3.2. Control Techniques -

- ... eliminate the contaminant and its source.

- ... exclude the contaminants from the item.

- ... reduce the quantity of contaminants from the environment to which the end item is exposed.

- ... eliminate contaminant gathering materials.

- ... lessen the effects of the contaminants.

3.5.3.3. Control Methods -

- ... choose materials which are compatible, non-corrosive and do not generate contaminants.

- ... design with an end item configuration in mind, and ensure that there are the least possible number of entrapment areas.

- ... specify maximum tolerances and surface finishes.

- ... specify processes most compatible with the desired cleanliness levels.

- ... define methods of monitoring for each type of contaminant.

- ... specify storage and packaging requirements.

MIL - HDBK - 406
31 October 1971

4. CONTROL OF SURFACE CONTAMINANTS

4.1. Cleaning of Surfaces

The contamination of surfaces is a major cause of failure of electrical and menhanical components.

While there are numerous cleaning methods, agents and equipment types, none represents a panacea for the removal of all contaminants from all possible surfaces. One of the potential problems is that any given cleaning process or solvent may be ideal at a given point in the manufacturing process, but may adversely affect later stages of processing or cleaning. It becomes necessary, therefore, to examine the entire cleaning process in relation to all subsequent processes.

Surface cleanliness is defined by degrees of physical, chemical or metallurgical cleanliness when describing metal cleaning.

- 4.1.1. Physical Cleanliness - the state of cleanliness which feels "clean to the touch." The piece of oily steel which has been wiped clean meets this degree.
- 4.1.2. Chemical Cleanliness - the state in which all residual organic contaminants have been removed. Generally, this state is achieved by immersion in an alkali solution.
- 4.1.3. Metallurgical Cleanliness - that state in which the surface is not only free of surface dirt and organic residues, but is also free of any oxide film. This is generally achieved by the immersion of a "chemically clean" part in an acid solution.

The difference in the degree of cleanliness achieved depends upon the soils removed, the metal activity and the applied finish. In some instances, it may be desirable to remove one type of film and replace it with another type which is more desirable or more readily controlled. For example:

- ... removing the oxide film on a aluminum and replacing it with a controlled oxide (anodizing etc.).
- ... removing the chromate from stainless steel and replacing it with chrome plating.

MIL - HDBK - 406
31 October 1971

... removing the oxide from aluminum and replacing it with zincate prior to plating.

4.2. Cleaning Forces

To accomplish any cleaning of a surface, any one or any combination of cleaning methods can be employed: Acid, alkali, solvent, emulsion, electrolytic, pickling, descaling and mechanical. Regardless which of these methods is employed, there are three basic forces at work in the removal of surface contamination:

- 4.2.1. Fluid Dynamical - liquid or airstream.
- 4.2.2. Inertial - centrifugal, vibrational or gravitational.
- 4.2.3. Direct Mechanical Contact - brushing, sanding, grinding, etc.

4.3 Liquid Cleaning

Primarily, we shall be concerned here with the first of the forces: Fluid Dynamical, or liquid cleaning. Liquid cleaning involves wetting, emulsification, saponification, deflocculation, colloidal activity, ph, buffers, solvent power, alkalinity and acidity, each of which is discussed briefly below.

4.3.1. Wetting

For a surface to be cleaned, it must first be wetted by a cleaning solution. Wetting action brings the detergent or cleaner in contact with the soil, which results in penetration so that the detergent or solvent can act where it is most needed. A metal surface that is wetted completely by a detergent is separated from the contaminant by a cleaning film. Although wetting power is a property of all liquids, the ability to wet a surface varies from liquid to liquid. Water, for example, possesses less wetting power than acetone, ammonia and most oils.

The wetting ability can be improved by reducing the surface and interfacial tension of a liquid. Pure water has a higher surface tension than most oils; as a result, if water is poured on top of oil, it will bead on the surface of the oil as the two surface tensions resist one another. The water is unable to wet the oil film. If the surface tension of the water is lowered below that of the oil film, the water will penetrate and displace the oil.

MIL - HDBK - 406
31 October 1971

4.3.2. Emulsification

The forces of cohesion which hold an oily film to a surface are very strong. It is almost impossible to remove a film by wiping or scrubbing alone. As long as water will bead on a surface which at one time was contaminated with an oily film, the film persists. While the surface may be physically clean, it may not be considered chemically clean until water refuses to break on the surface.

It can be said that in order to perform a cleaning operation, emulsification must follow wetting. The wetting of the oil film results in the formation of beads of oil on the surface of the water; if an emulsifying agent is present in the solution, the oily beads will be dispersed disrupted, and once so scattered, the oil cannot be redeposited on the surface again.

When part of a film has been removed from a surface, a new layer of oil is exposed to the cleaning solution, and the wetting of the film takes place again; and an additional layer of oil again comes into play. Thus, it can be seen that wetting and emulsification are contingent upon one another, and that the action of the two factors results in the loosening, breaking up and dispersion of the oily film.

4.3.3. Saponification

Saponification is the process of chemically uniting certain alkaline substances and the fatty acids in animal and vegetable oils to form soap. The resultant soap is very much like household soap in properties, behavior and appearance. Many greases consist of a mixture of animal fats and petroleum oils. Petroleum oils or mineral oils cannot be saponified and must be removed through the process of wetting and emulsification. The animal or fatty acid components of the lubricants do react with certain alkaline detergents, forming water soluble soap.

4.3.4. Deflocculation

Deflocculation is the process of breaking up a solid or semi-solid mass into small particles and dispersing them throughout a liquid medium.

MIL - HDBK - 406
31 October 1971

The mechanism of deflocculation is thought to be a neutralization of those forces of surface tension which are responsible for the attraction between solid particles. Complete wetting of the solid is absolutely necessary for deflocculation to take place.

4.3.5. Solvent Activity

Solvents may be broken down into two basic categories; water base (aqueous) and organic base (non-aqueous).

In aqueous cleaning solution, water acts as the solvent medium for the detergent compounds, liberating the energies resulting in wetting, emulsification, saponification and deflocculation. The water also acts as a dispersal medium for oils and particles which it will not dissolve, but will carry in suspension. It also acts as a medium for the application of heat energy, mechanical agitation, both of which play roles in the detergency of the solution.

The primary limitation of the aqueous solutions is that they have little or no effect on oils and greases. As such, they are described as lipophobes or fat haters.

Their counterparts are described as lipophiles or fat lovers; these are the organic or non-aqueous solvents. The organic solvents are derived basically from petroleum, coal and wood. While they are unable to dissolve many substances which are readily soluble in water, they do possess the ability to dissolve not only oils and greases, but many resins, rubber, bitumens, paraffin, waxes and plastics.

One of the major advantages of the organic solvents is that they can be formulated in chemically neutral solutions, making them safe for the cleaning of the more reactive metals such as aluminum, magnesium, copper and zinc.

The organic solvents are often employed to remove the carbon deposits from engines. While the solvent does not remove the carbon itself because none of the solvents will dissolve the carbon, the organics will dissolve the resins which bond the carbon particles together.

MIL - HDBK - 406
31 October 1971

4.3.6. pH

pH is the yardstick used to determine or measure the degree of acidity or alkalinity of a solution. The pH is a measure of energy, not quantity.

All acids share in common the ability to yield hydrogen (H^+) ions in a water solution. All alkalis will yield hydroxyl (OH^-) ions in a water solution. An acid which entering into chemical unions with other substances and is said to be strong acid. The same holds true for alkalis; however, the release is hydroxyl ions. It may be concluded that the concentration of hydrogen and hydroxyl ions determines the relative degree of acidity or alkalinity of a water solution. To simplify the expression of these values, a scale has been determined based on the logarithm of the reciprocal of hydrogen (or hydroxyl) ion concentration.

The value assigned for this scale is known as the pH value of the solution. The scale is arranged with values from 0 to 14, with 7 being the neutral point. Values above 7 indicate the degree of alkalinity, with 14 being the most alkaline solution possible. Values below the neutral 7 are degrees of acidity, with 0 being the strongest acid solution possible. Each increment of pH indicates a tenfold increase or decrease in acidity or alkalinity.

Since pH is a method of stating the concentration of electrically charged groups of molecules, the most accurate method of measuring pH involves the use of a sensitive voltmeter (a pH meter) which measures the electrical potential across the charged ions and registers this in terms of pH values.

4.3.7. Buffer Activity

The degree of acidity and alkalinity of a cleaning solution plays an important part in rust and scale removal, etching and pickling, saponification and emulsification. Buffering is the means by which a solution resists changes in pH.

Since the stripping of paint from reactive metals requires a solution which does not ionize, buffers play an important role in the control of the solution.

4.3.8. Alkalinity and Acidity

The active alkalinity or acidity of a cleaning solution is

MIL - HDBK - 406
31 October 1971

a factor in cleaning to the extent to which the detergent ionizes to yield hydrogen or hydroxly ions. If the detergent disassociates completely during the course of cleaning, the total amount of acid or alkali is made available for useful cleaning. On the other hand, if all of the solution is not made available, it merely represents so much inert material which does not play any part in the cleaning, and represents a rinsing problem.

In the selection of a cleaning compound, the value to consider is not the total volume of alkali or acid present in the compound but rather, the total amount available for cleaning.

In the form of a scientifically balanced detergent, the choice of each component can be justified in terms of the function assigned to that component in the clean process. Additionally, the components will not only perform their own functions, but will reinforce each other so that the entire compound will be more active and still more stable than each of its individual components.

4.4. Corrosion

Many people consider corrosion to be the rust on a steel girder or that reddish-brown scale on the garden tool that was left out in the rain. These are in fact, forms of corrosion; but the specific definition in reference to electronic components would be:

... corrosion is more likely to be a film of an organic contaminant on a relay contact causing failure... or moisture leading to malfunction of stripline assembly... or fungal growth causing fogging of a lens... or "whiskers" ruining sealed capacitors. Deterioration refers to any unwanted change in properties, size or function, caused by environmental or service conditions... Corrosion proceeds slowly and is often invisible, but nearly always degrades performance.

MIL STD 1250 (MI) 31 March 67, defines corrosion as:

A specific type of deterioration resulting in damage or impairment of metals or metallic parts as the result of attack by moisture, air, acid, alkali, chemicals or electrochemical action. Although mechanical stress is a factor in certain types of corrosion, damage or breakage as the result of purely mechanical load or shock is not included.

MIL - HDBK - 406
31 October 1971

Non-Metallics are often affected by exposure to adverse environmental conditions. TABLE 4-1 shows the effects of moisture on non-metallic materials.

TABLE 4-1

Effects of Moisture on Non-Metallic Materials

Electrical Properties

- Increases Surface Conductivity
- Increases Loss Angle
- Increases Capacitance
- Increases Dissipation Factor
- Reduces Volume Resistivity
- Reduces Dielectric Strength

Physical and Mechanical Properties

- Swelling
- Distortion
- Decomposition
- Change in Strength
- Wicking and Moisture Retention

Fungal Resistance

- Encourages Fungal Growth

4.5. Corrosion Forms

There are several forms of metal corrosion. Intergranular, crevice, stress-corrosion-cracking, hydrogen embrittlement and galvanic corrosion, are discussed briefly below.

4.5.1. Intergranular Corrosion

Because metals are not completely homogenous, some areas (often the grain boundaries) are more susceptible to corrosion than others. In aluminum alloys, the grain boundaries are anodic to the grain centers. In a damp corrosive environment, pitting may occur in a preferential pattern, clearly outlining the grain boundaries. Brasses

MIL - HDBK - 406
31 October 1971

with more than 15 percent zinc are subject to a form of intergranular corrosion called "dezincification" in which the zinc is removed, leaving only a porous copper part.

4.5.2. Crevice Corrosion

This kind of attack occurs in crevices, or at threaded fasteners, or under washers where there is a lack of oxygen. It is also called "oxygen starvation", or "concentration cell" corrosion, or differential aeration. It is usually found on corrosion-resistant steel, Inconel, nickel, aluminum and other metals which may be either "passive" (protected by a thin oxide film) or "active." The passive film does not persist in the presence of electrolyte, and in the absence of oxygen; thus, the metal in the joint where oxygen cannot penetrate will become "active", and therefore, anodic to the rest of the part. Residues from soldering flux can cause crevice corrosion.

4.5.3.1. Sources of Stress

The residual stress which causes stress corrosion originates in the fabrication of the part, not in service. Heat treatment, (especially rapid quenching), welding, grinding, joggling, swagging, bending and severe forming, excessive tightening of fasteners, pressfits and tapered bolts, all produce high levels of stress in parts.

4.5.3.2. The Favorable Environment

Many environments are favorable to the stress corrosion of specific metals and alloys. TABLE 4-2 gives a breakdown of these environments.

TABLE 4-2

Favorable Environments for Stress-Corrosion-Cracking

<u>Alloy</u>	<u>Environment</u>
Steel	Alkalis, nitrates, hydrogen cyanide Hydrogen sulfide, anhydrous liquid ammonia, sodium chloride solutions, marine atmospheres.
Chromium Stainless Steels (over 12% Cr)	Halides, hydrogen sulfide, steam.

MIL - HDBK - 406
31 October 1971

TABLE 4-2
(Con't)

Austenitic Stainless steel (18%Cr, 8%Ni, 300 series)	Chlorides, caustic.
PH Stainless Steel	Chloride Solutions, marine atmosphere
Copper alloys	Ammonia, mercurous nitrate, steam.
Gold alloys	Iron chlorides, potassium cyanide.
Magnesium alloys	Sodium chloride/potassium chromate, fluorides, moisture.
Aluminum alloys	Sodium chloride solutions, tropical environments.
Nickel alloys	Caustic, hydrofluorosilicic acid.
Monel, Inconel	Hydrogen fluoride vapors.
Titanium alloys	Red fuming nitric acid, hydrogen chloride, dry molten chloride, salts chlorinated hydrocarbons.

4.5.4. Hydrogen Embrittlement

Closely associated with stress corrosion is hydrogen embrittlement. This is primarily a problem in high strength iron base and nickel base alloys and titanium. When these high strength (or highly stressed) metals are acid cleaned, pickled, electroplated, welded or otherwise exposed to nascent hydrogen, they may pick up enough hydrogen to cause them to crack spontaneously, in what is known as a delayed failure or fracture.

4.5.5. Galvanic Corrosion

A frequent problem resulting in the failure or malfunction of many components is that of galvanic corrosion resulting from the contact of dissimilar metals. This occurs when two metals of different electromotive potential are placed in close contact in the presence of an electrolyte. This arrangement results in a flow of current from the anode to the cathode with the liberation of hydrogen at the cathode and the formation of alkali.

Several other conditions are favorable to the corrosion of metals:

MIL - HDBK - 406

31 October 1971

4.5.6. Porous Castings

Any surface which is porous offers an aid to corrosion since contaminants and moisture can collect in the openings and cause corrosion of not only the part, but the surrounding parts also.

4.5.7. Fungi and Bacteria

A detailed discussion of the problem of bacterial attack on metals is offered in a later section; however, it should be noted here that any condition which holds moisture can promote the growth of microorganisms. The metabolic by-products of their growth are acids which can etch and corrode metals and cause the separation of layers of materials.

4.5.8. Metal Whiskers

Many metals, including tin, zinc, cadmium copper and iron, will grow "whiskers" during storage even when they are hermetically sealed.

4.6. Corrosion Prevention

In each of the corrosion situations mentioned above, there are specific steps which can be taken to either prevent or lessen the possibility of the corrosion taking place.

4.6.1. Intergranular Corrosion

Selection of the proper grade and heat treatment condition of the metal and the provision of protective coatings where possible will lessen the possibility of intergranular corrosion.

4.6.2. Crevice Corrosion

Since the presence of water or other electrolytes is a key factor here, the sealing of joints will prevent this form of attack.

4.6.3. Stress Corrosion

The metal, the stress and the environment are the three key factors; therefore, the selection of metals which are not susceptible reduce the stress, both operating and residual, and protect the metal from the environment or remove the corrosive element.

31 October 1971

4.6.4. Hydrogen Embrittlement

Care should be taken, if possible, to avoid acid cleaning, pickling and electroplating. The designer should select materials and processes which minimize the danger of embrittlement:

4.6.4.1. Choose organic films or vacuum deposited films.

4.6.4.2. If plating is necessary, use alkaline baths or other processes designed for low hydrogen pick up; use cadmium instead of zinc or chromium; shot peen before plating; stress relieve before plating and immediately afterward.

4.6.4.3. Use materials not subject to Hydrogen Embrittlement such as, 300 series corrosion resistant steels and oxygen-free or deoxidized copper.

4.6.5. Galvanic Corrosion

Anything which reduces the potential difference between metals involved, or lessens the contact of the metals reduces the chance of galvanic corrosion. One may group metals by their compatibility (TABLE 4-3) or by their electromotive potential (TABLE 4-4). The former, represents groups of metals which are considered similar to one another and may be coupled with others in the same group, but not with those in other groups. The latter represents acceptable couples bases on the electromotive potential. Note also, TABLE 4-5 which offers problems, solutions and examples for the prevention of galvanic corrosion.

TABLE 4-3**Compatible Metal Groups**

Group 1	Group 2	Group 3	Group 4
Magnesium and alloys	Aluminum and Zinc alloys	Cadmium	Copper and alloys
Aluminum 5056 5052, 5356, 6061, 6063	Zinc Cadmium Tin	Steel Lead Tin	Nickel and alloys Chromium
Tin	Stainless Steel	Stainless Steel	Stainless Steel
	Tin-lead	Nickel and	Gold

MIL - HDBK - 406
31 October 1971

TABLE 4-3
(Con't)

Group 1	Group 2	Group 3	Group 4
	Solder	alloys Tin-lead Solder	Silver

4.6.6. Fungi

The damaging effects of fungi and bacteria can be limited or eliminated through several precautions: choose materials which are fungi-inert; keep equipment dry and use fungicides. See TABLE 4-6 for listing of some fungi-resistant materials.

TABLE 4-4
Galvanic Couples

Group	Metalurgical Category	EMF (volt)	Permissible Couples
1	Gold, gold-platinum, platinum	0.15	o
2	Rhodium, graphite	0.05	● o
3	Silver	0	● o
4	Nickel, monel, high nickel-copper alloys, titanium	-0.15	● o
5	Copper, low brass or bronze, silver solder, German silver, high copper-nickel alloys, nickel-chromium, austenitic (type 300) stainless steels	-.20	● o
6	Commercial yellow brass and bronze	-0.25	● o
7	High brass and bronze; naval brass, muntz metal	-0.30	● o
8	18% chromium type steels	-0.35	● o

NOTE: o = Cathodic ● = anodic

MIL - HDBK - 406
31 October 1971TABLE 4-4
(Con't)

Group	Metalurgical Category	EMF	Permissible Couples
8	18% chromium type steels	-0.35	○
9	Chromium, tin, 12% chromium type steels	-0.45	● ○
10	Tin-plate; tin-lead solders; terneplate	-0.50	● ○
11	Lead; high lead alloys	-0.55	● ○
12	Aluminum, wrought, 1000 series	-0.60	● ○
13	Iron, low alloy steels, armco iron	-0.70	● ○
14	Aluminum, 3000, 6000, and 7000 series; aluminum silicone castings	-0.75	○ ●
15	Aluminum castings (other than silicone); cadmium	-0.80	○ ●
16	Hot dip zinc, galvanized steel	-1.05	○
17	Zinc	-1.10	●
18	Magnesium		

NOTE: ○ = Cathodic ● = anodic

MIL - HDBK - 406
31 October 1971

TABLE 4-5

Preventing Galvanic Corrosion

Problem	Solution	Example
Dissimilar Metals	Select permissible couples.	Use nickel, not naval brass, next to silver.
Dissimilar Metals	Plate with compatible metal to reduce potential difference.	Tin coat steel and bronze used together.
Dissimilar Metals	Keep affected area of less noble metal (anode) as large as possible	Stainless steel hardware in aluminum may be satisfactory because of large area of aluminum.
Dissimilar Metals	Apply corrosion inhibitors such as zinc chromate paste.	Assemble dissimilar metal hardware with zinc chromate.
Contact	Interpose inert barrier or gasket to prevent the contact.	Vinyl tape, cadmium plated washer, rubber gasket.
Contact	Paint the cathode, or both of the metals.	
Electrolyte	Avoid design which allows moisture to be entrapped.	
Electrolyte	Use desiccant.	
Electrolyte	Seal joint with organic insulator, alkali resistant.	
Electrolyte	Seal faces of the metals against contact with the electrolyte.	Primer, paint or sealant.
General	Use cadmium in preference to zinc plating. Use tin or nickel plated hardware. Avoid the use of magnesium.	

MIL - HDBK - 406
31 October 1971TABLE 4-6
Fungi-inert Materials

Fungi-inert in all Conditions	Fungi-inert in some grades
Acrylonitrile-vinyl chloride copolymer	Acetal resins Cellulose acetate
Asbestos	Cellulose acetate butyrate
Ceramics	Epoxy glass fiber laminates
Chlorinated polyether	Epoxy resin
Glass	Melamine-formaldehyde
Metals	Natural rubbers
Mica	Phenol-formaldehyde
Plastic laminates: Silicone glass fiber Phenolic nylon fiber Diallyl phthalate and polyethylene terephthalate	Poly methyl methacrylate Poly vinyl chloride Poly vinyl chloride acetate
Polyacrylonitrile	Poly vinyl fluoride
Polyamide	Plastics laminates
Polycarbonate	
Polyethylene	
Polymonochlorotrifluoroethylene	Synthetic rubbers
Polypropylene	Urea-formaldehyde
Polystyrene	
Polytetrafluoroethylene	
Polyethylene terephthalate	
Poly vinylidene chloride	
Silicone resin	

MIL - HDBK - 406
31 October 1971

4.6.7. The Environment

As indicated in the section on the selection of materials and storage facilities, the environment is a serious factor to be reckoned with in the prevention of corrosion. Many organic substances of highly corrosive vapors as shown in TABLE 4-7. Man again comes into the picture as a prime contributor of corrosive conditions (TABLE 4-8).

TABLE 4-7

Material	Organics as a Source of Corrosive Vapors		
	Severely Corrosive	Somewhat Corrosive	Not Corrosive
Adhesive	Ureaformaldehyde	Phenol-formaldehyde	Epoxy
Gasket	Neoprene/asbestos resin/cork	Nitrile/asbestos glue/cellulose	-
Insulation (wire)	Vinyl Polyvinylchloride/vinylidene fluoride	Teflon Nylon Polyimide	Polyurethane Polycarbonate
Sealer	Polysulfide	Epoxy	Silicone
Sleeving	Vinyl Polyvinylchloride	Silicone	-
Tubing	Neoprene, shrinkable		
Plastics	Melamine ABS Phenolic	Polyester Diallyl Phtalate	Silicone Epoxy Polyurethane
Varnish	Vinyl	Alkyd	-

MIL - HDBK - 406
31 October 1971

TABLE 4-8

Man-made corrosive conditions

Environment	Produced by	During	Attacks
Corrosive Liquids	Cleaning	Fabrication	Insulation, Components
High Temperature	Exotherm, Encapsulant	Fabrication	Insulation, Components
High Temperature	Cure Encapsulant	Fabrication	Insulation, Components
High Temperature	Lack of cooling or short	Test or service	Insulation, Components
Ozone	Welding Machines	Fabrication or storage	Rubbers
Acid	Incomplete cleaning	Fabrication	Metals,
Air	Insufficient Packaging	Fabrication or storage	Conductor surfaces
Corrosive Gases	Sulfur in paper	Fabrication or storage	Silver
Corrosive Gases	Undercured organics	Storage	Metals, Plastics
Corrosive Gases	Packing Materials	Storage	Cadmium other metals
Corrosive Gases, acid	Overheated insulation	Test or service	Metals, conductors
Corrosive Gases	Propellant	Test or service	Plastics, metals
Oil or grease	Leakage	Storage or rework	Cadmium, paint
Pool of water	Sump area	Storage	Everything
Diester oils	Lubricants	Storage	Neoprenes, plastics

MIL - HDBK - 406
31 October 1971

TABLE 4-9
Selection of Coatings for Minimum Corrosion

<u>Purpose</u>	<u>Recommended</u>	<u>Not Recommended</u>
Contact with aluminum or magnesium	Cadmium or tin	Chromium, copper, silver, gold
Pre-paint coating	Cadmium or tin	Chromium, copper, nickel, gold, silver
Tarnish prevention	Rhodium over silver Gold over silver, copper or nickel Nickel between copper and silver	
Marine exposure	Heavy gold 0.00030 inch minimum	
Solderability	Tin, gold or tin-lead	Nickel, chromium, rhodium
Storage	Gold, rhodium, or reflowed heavy tin	Cadmium, silver, copper
Wear	Chromium, nickel, rhodium or hard gold	Cadmium, tin

MIL - HDBK - 406
31 October 1971

4.6.8. Metallic Coatings

Frequently, the designer may consider the use of coatings for the prevention or limitation of corrosion. TABLE 4-9 offers a guideline for the selection of a metallic coating for corrosion prevention.

4.6.9. Material choices

The designer has the option of choosing materials which can limit the dangers of corrosion and lessen the chance of product failure. TABLE 4-10 offers a partial listing of materials which cannot or should not be combined in a product. TABLE 4-11 proposes an additional selection of incompatible material combinations.

When the designer is aware of the environment his product will see, he can choose materials which can be used in that environment. TABLE 4-12 offers a choice of plastics which can be used in various corrosive environments at both room and elevated temperatures.

TABLE 4-10

Incompatible Materials

Do Not Use		
Copper/manganese	with	Rubber
Cyano-acrylate sealants	with	cellulosics, methacrylate polycarbonate styrene vinyl
Diester oils	with	Neoprene/plastics
Hydrocarbons/ketones	with	Acrylics, cellulosics vinylchloride
Ketones, esters, alcohol	with	Vinyl butyral
Paper	with	Copper or silver
Silicone oils and greases	with	Metals to be coated

MIL - HDBK - 406
31 October 1971

TABLE 4-11
Examples of Incompatible Materials

<u>Material</u>	<u>Is incompatible with</u>
Acid	Acrylic, alkyd, cellulosic, polyamide, polyester, polyethylene, urethane
Alkali	Acrylic, alkyd, cellulosic, polyester
Ammonia	Cadmium, copper, zinc, cobaltous chloride humidity indicators
Copper, iron, manganese	Rubber
Cyano-acrylate sealant	ABS, cellulosic, methylmethacrylate, polycarbonate, vinyl
Diester oil	Polychloroprene (neoprene), vinyl
Hydrocarbon solvents	Acrylic, cellulosic, polycarbonate, polystyrene, silicone
Organic vapors	Cadmium, zinc
Paper, cardboard	Brass, copper, silver
Polyvinyl chloride	Zinc, aluminum, magnesium, brass, copper, lead, tin, tin-lead, gold plate over brass
Silicone oil or grease	Most organic coatings

MIL - HDBK - 406
31 October 1971

TABLE 4-12

Plastic Resistance Toward Various Corrosive Media
at Room Temperature and 200°F

At Room Temperature:

Polyvinylchloride;

possesses excellent resistance to-
strong acids, strong bases, aliphatic solvents,
weak bases and salts.

good to excellent resistance to-
strong oxidants,

unacceptable to poor resistance to-
aromatic solvents, esters and ketones

unacceptable resistance to-
chlorinated solvents

Polyvinylidene chloride (saran);

possesses excellent resistance to-
strong acids, strong bases, aliphatic solvents,
weak bases and salts.

good resistance to-
chlorinated solvents, strong oxidants

fair to good resistance to-
aromatic solvents, esters and ketones

Polyethylene;

possesses excellent resistance to-
strong acids, strong bases, weak bases and salts
strong oxidants

unacceptable to poor resistance to-
aromatic solvents, esters and ketones, aliphatic
solvents

unacceptable resistance to-
chlorinated solvents

Polystyrene;

possesses excellent resistance to-
strong bases, weak bases and
salts

MIL - HDBK - 406.
31 October 1971

TABLE 4-12 (Con't)

unacceptable to poor resistance to-
strong acids, strong oxidants, aromatic solvents,
esters and ketones, aliphatic solvents

unacceptable resistance to-
chlorinated solvents

Polychlorotrifluoroethylene;
possesses excellent resistance to-
strong acids, aromatic solvents, esters and
ketones, aliphatic solvents, weak bases and
salts, strong oxidants, strong bases

poor to fair resistance to-
esters and ketones

unacceptable to poor resistance to-
strong bases, strong oxidants

Polyester;
possesses excellent resistance to-
aromatic solvents, chlorinated solvents, aliphatic solvents

good to excellent resistance to-
esters and ketones, weak bases and salts

poor to fair resistance to-
strong bases

unacceptable resistance to-
strong oxidants

Epoxy;
possesses excellent resistance to-
aromatic solvents, chlorinated solvents, aliphatic solvents,
weak bases and salts

good to excellent resistance to-
strong bases, esters and ketones

fair to good resistance to-
strong acids

unacceptable resistance to-
strong oxidants

MIL - HDBK - 406
31 October 1971

TABLE 4-12 (CON'T)

Polyvinylidene flouride;

possesses excellent resistance to - strong acids, aromatic solvents,
chlorinated solvents, aliphatic solvents, weak bases and salts,
strong bases

Good resistance to - esters and ketones

fair resistance to - strong oxidants

Chlorinated polyether;

possesses excellent resistance to - strong acids, aromatic solvents,
strong bases, chlorinated solvents, aliphatic solvents, weak bases
and salts

good to excellent resistance to - esters and ketones

unacceptable resistance to - strong oxidants

Furan;

possesses excellent resistance to - strong acids, aromatic solvents,
chlorinated solvents, esters and ketones, aliphatic solvents

good to excellent resistance to - weak bases and salts

good resistance to - strong bases

unacceptable resistance to - strong oxidants

Polymethyl methacrylate;

possesses excellent resistance to - weak bases and salts

fair resistance to - strong bases

unacceptable resistance to - strong acids, strong oxidants, aromatic
solvents, chlorinated solvents, esters and ketones, aliphatic
solvents

Polycarbonates;

possess excellent resistance to - aliphatic solvents

good resistance to - strong oxidants, weak bases and salts

fair resistance to - strong acids

poor resistance to - strong bases, esters and ketones

unacceptable resistance to - aromatic solvents, chlorinated solvents

MIL - HDBK - 406
31 October 1971

TABLE 4-12 (CON'T)

Polyamides;

possess excellent resistance to - aliphatic solvents, aromatic solvents, chlorinated solvents

good resistance to - esters and ketones, weak bases and salts, strong acids

poor resistance to - strong oxidants, strong bases

Polyphenylene oxides;

possess excellent resistance to - aliphatic solvents, weak bases and salts

good resistance to - strong acids, strong bases

fair resistance to - strong oxidants

poor resistance to - esters and ketones

unacceptable resistance to - aromatic solvents, chlorinated solvents

Polysulfides;

possess excellent resistance to - aliphatic solvents, strong acids, strong bases

good resistance to - strong oxidants

poor resistance to - aromatic solvents, esters and ketones, weak bases and salts

unacceptable resistance to - chlorinated solvents

Vinyl esters;

possess excellent resistance to - aliphatic solvents, weak bases and salts, strong bases

fair to good resistance to - strong acids, strong oxidants

unacceptable resistance to - aromatic solvents, chlorinated solvents, esters and ketones

At 200°F

Polyvinyl chlorides;

possess no resistance, above the operating temperature of the plastic.

TABLE 4-12 (CON'T)

Polyvinylidene chlorides (saran);

possess no resistance, above the operating temperature of the plastic.

Polychlorotrifluoroethylenes;

possess excellent resistance to - strong acids, strong oxidants, aromatic solvents, strong bases, esters and ketones, aliphatic solvents, weak bases and salts

Polystyrenes;

possess no resistance, above the operating temperature of the plastic.

Phenolic;

possesses excellent resistance to - strong acids, aromatic solvents, chlorinated solvents, aliphatic solvents

Polyesters;

possess good to excellent resistance to - aliphatic solvents

fair to good resistance to - chlorinated solvents, strong acids, aromatic solvents, weak bases and salts

fair resistance to - esters and ketones

unacceptable to fair resistance to - strong bases

unacceptable to poor resistance to - strong oxidants

Epoxies;

possess good to excellent resistance to - aliphatic solvents

fair to good resistance to - chlorinated solvents, aromatic solvents, strong bases

poor to fair resistance to - strong acids

poor resistance to - esters and ketones

unacceptable resistance to - strong oxidants

Polyvinylidene fluorides;

possess excellent resistance to - strong acids, aromatic solvents, strong bases, chlorinated solvents, aliphatic solvents, weak bases and salts

poor resistance to - esters and ketones, strong oxidants

MIL - HDBK - 406
31 October 1971

TABLE 4-12 (CON'T)

Chlorinated polyethers;

possess excellent resistance to - strong acids, strong bases, aliphatic solvents, weak bases and salts

fair to good resistance to - chlorinated solvents

poor resistance to - aromatic solvents

unacceptable to poor resistance to - esters and ketones

unacceptable resistance to - strong oxidants

Furan;

possesses excellent resistance to - strong acids, aromatic solvents, chlorinated solvents, esters and ketones, aliphatic solvents, weak bases and salts

good resistance to - strong bases,

unacceptable resistance to - strong oxidants

Polymethyl methacrylate;

possesses no resistance, above the operating temperature of the plastic.

Polycarbonates;

possess good resistance to - aliphatic solvents

fair resistance to - strong oxidants, weak bases and salts

unacceptable resistance to - aromatic solvents, strong bases, chlorinated solvents, esters and ketones

Polyamides;

possess excellent resistance to - aliphatic solvents

good resistance to - aromatic solvents, chlorinated solvents, esters and ketones, weak bases and salts

fair resistance to - strong acids

unacceptable resistance to - strong bases, strong oxidants

Polyphenylene oxides;

possess excellent resistance to - aliphatic solvents, strong bases, weak bases and salts

fair resistance to - strong acids

MIL - HDBK - 406
31 October 1971

TABLE 4-12 (CON'T)

poor resistance to - strong oxidants

unacceptable resistance to - aromatic solvents, esters and ketones,
chlorinated solvents

Polysulfides;

possess fair resistance to - strong acids, strong bases, aliphatic solvents

poor resistance to - strong oxidants

unacceptable resistance to - aromatic solvents, weak bases and salts,
esters and ketones, chlorinated solvents

Vinyl esters;

possess excellent resistance to - strong bases, weak bases and salts

good resistance to - aliphatic solvents

poor to fair resistance to - strong acids

poor resistance to - strong oxidants

unacceptable resistance to - aromatic solvents, chlorinated solvents,
esters and ketones

NOTE: Unacceptable: Severe attack, deteriorated
Poor: attacked, softened, swollen
Fair: mild attack
Good: slight attack
Excellent: inert

MIL - HDBK - 406
31 October 1971

5. GROSS CLEANING

Gross cleaning would not normally be considered a contamination control method in the aerospace industry; it is however, normally the first stage or step in the total cleaning environment that a part or component can expect to see. If the gross cleaning is inadequate, the final precision cleaning then becomes a monumental task and it is unlikely that all possible soils will ultimately be removed. A part or system failure may be the end result.

We shall discuss briefly, the nature of some of the gross cleaning operations and procedures.

5.1. Barrel Cleaning

As its name would imply, barrel cleaning is performed in a rotating enclosure and is accomplished by the action of parts tumbling in a medium. Generally the media and parts occupy 50 to 90 percent of the barrel volume.

Barrel cleaning may be used for the removal of oil and grease although other methods are generally more suited for that type of cleaning. Barrel cleaning is more commonly employed for descaling rather than cleaning. Acid compounds are the normal media preferred for their faster action. Wetting agents and abrasives may be used as supplements.

Dry tumbling is frequently employed for the removal of mill scale, sand and hardened mold release materials from castings and forgings.

To ensure the best possible results from barrel cleaning, one must consider:

Barrel Speed - proper speed avoids reaching sufficient centrifugal force to keep the parts on the barrel surface and not in the media.

Compound - correct choice must be made for application, non-corrosiveness and adequate concentration.

Water Level - the level should be sufficient to prevent excessive tumbling but not filling the barrel.

Medium - choice must be made considering material size, shape and quantity.

MIL - HDBK - 406
31 October 1971

Work Pieces - size, configuration and composition should be considered.

Flushing - parts and barrel must be flushed after tumbling to remove unwanted elements.

5.2. Mechanical Cleaning

Mechanical cleaning is employed only for the removal of gross soils by either abrasion or erosion. Several of the more common mechanical methods are discusses:

Grinding Wheels - portable or stationary grinders are employed to remove heavy weld splatter, flash and scale.

Wire Brush - manual or power brushes are uses for the removal of weld scale and light oxides.

Rasp Files - these are part of the manual process for the removal of heavy metal soils.

Steam - this process is very good for the removal of heavy oils, grease and sludge when pressurized.

Chipping - hammer and chisel can be used for weld bead removal, scale and heavy weld splatter.

Wiping - solvent saturated wipe cloths can be uses for the removal of oils, greases and dirt.

5.3. Abrasive Blast

Abrasive blast cleaning employs the forceful impingement of particles against a metal for soil removal. Some of the common abrasive blast cleaners are: Sand, grit and glass beads for strong abrasion. Crushed corn cobs, rice hulls and walnut shells may also be used when a milder abrasion is desired.

When abrasive blasting is employed, the personnel operating the equipment must be protected with suitable apparel, safety glasses, independent air supply etc.

The abrasive material is propelled by either compressed air or a rotating, bladed wheel. There is a major disadvantage to the bladed wheel in that the direction of the abrasive cannot be controlled to place the shot where it is most needed. While the compressed air propulsion can be more exactly controlled, it

MIL - HDBK - 406
31 October 1971

requires ten to fifteen times the horse power to operate as compared to the bladed wheel.

TABLE 5-1 gives a comparison of the wet and dry abrasive blasting methods.

TABLE 5-1		
Abrasive Blasting Methods		
	<u>Wet</u>	<u>Dry</u>
Type & Force Used	Compressed Air	Compressed Air High Speed Blower
Media	Aluminum Oxide Garnet Quartz Novaculite Silica Organics Glass beads	Metallic shot Metallic grit Aluminum oxide Garnet Quartz Novaculite Silica Organics Glass or plastic beads
Soils Removed	Light rust Surface oxides Light mill scale Welding scale	Rust Mold sand Mill and heat- treat scale Welding flux Paint Carbon Weld splatter

5.4. Washers

The possible combinations of types of washers and cleaning solutions is nearly unlimited. Most washing equipment is custom designed for specific processes. The equipment is characterized by the following features:

- Work size or volume capacity
- Type of washing action
- Number of stages
- Automation
- Part movement type
- Filtration system

MIL - HDBK - 406
31 October 1971

Parts washers are grouped by types: single-stage, two-stage and multi-stage.

5.4.1. Single-Stage

The single-stage washer employs immersion, spray or steam as the cleaning method. It may be operated manually or by automation, and it is generally used for low quantity operation.

5.4.2. Two-Stage

The two-stage washer is generally a spray or paddle wheel type. One of the stages may be rinse or dry operation.

5.4.3. Multi-Stage

The multi-stage washer employs automation. It is generally conveyORIZED, using rollers, endless belts, monorails or rotating spiral drums. The multi-stage washer generally includes several washes with both rinsing and drying. It is designed for high quantity production.

There are numerous cleaning agents available for washers. Among them are included: detergent, acid, alkaline and solvent solutions.

5.5. Agitation

Agitation of solvent solutions improves soil removal by physical action, carrying the soil away and replacing it with fresh solvent. There are two means of attaining cleaning agent agitation: movement of the part and movement of the solution.

The part can be moved by the use of an endless wire belt or, as in barrel cleaning, the use of rotating drums or barrels which provide additional tumbling action. Oscillation or off-center rotation may be used if the parts are racked or placed in baskets. The baskets may also be moved with the parts in them.

Solution agitation can be attained by boiling the solution, which sets up convection currents. The danger here is the possibility of fire, vapor, or decomposition hazard, resulting in a corrosive condition. Compressed air may be forced through the solution, but this can result in the excessive foaming of the solution when detergents are used. Paddles in the solution will provide a continuous large volume of solution moving against the parts. This is especially effective against fines and chips contamination the part.

MIL - HDBK 406
31 October 1971

Sprays are largely accepted and very effective for many kinds of soils. The spray nozzles must be arranged in such a manner as to ensure that the solution strikes the entire part.

Circulation pumps have found great favor where the part to be cleaned is compatible with that method. It is especially good when immersion cleaning is done and when the part configuration is such as to prohibit internal observation of cleanliness by normal visual means.

Some other methods of gross cleaning are:

Orbital Finishing - high centrifugal forces are concentrated in barrels attached to the periphery of a rapidly revolving turret. The two rotate in opposite directions.

Extrude Hone Process - hydraulic pressure forces a viscous paste loaded with a fine abrasive past the part areas being deburred.

Electrochemical Deburring - this method involves a selective electrolyte action which concentrates on the burrs only.

Vibratory Finishing - parts, media and compound are processed in a vibratory tub.

Chemical Surface Conditioning - acids are used to etch metal surfaces to several thousandths of an inch.

The last cleaning method we are including is cleaning by an Ionized Gas Jet:

This method is accomplished by one of the following methods:

Flaming the metal surface

Telsa discharge over the metal surface

Placing the metal in a glow discharge at reduced gas pressure.

A review of these methods will reveal that no one method and no given cleaning solution is going to be suitable in all instances. It should be noted that cleaning surfaces is a decision-making process based on the factors of economy, safety, solvency, availability and suitability.

MIL - HDBK 406
31 October 1971

6. PRECISION CLEANING

There is no exact definition of what actually constitutes precision cleaning. The nearest one can come to describing the process is to state that precision cleaning involves a degree of accuracy or level of cleanliness not found in the gross cleaning methods described in section 5. The degree of control or accuracy may vary from a visually clean surface to assurances that no more than X number of particles .5 microns in size remain within or on a component after final cleaning.

As the degree of cleanliness becomes more stringent, the need for high purity solvents, more sophisticated cleaning equipment, cleaner work environments and more sensitive test equipment increases to meet the new requirements.

6.1. Methods

6.1.1. Vapor Degreasers

Simply defined, vapor degreasing is the process of contaminant removal from a part by the condensation of chemical solvent vapors on the surface of the part.

6.1.1.1. Design

Although degreasers are generally designed by the manufacturer for specific uses, the general characteristics of the system are fairly universal. Figure 6-1 illustrates the basic parts of the degreaser.

Size - should be determined by the dimensions, production volume and racking methods employed by the manufacturer.

Freeboard - the space above the vapor level. The freeboard minimizes the escape of vapors and lessens the problems of vapor disturbance by movement in the surrounding environment.

Heat - should be sufficient to: heat the maximum work load; meet any internal distillation requirements; and, compensate for normal thermal losses.

MIL - HDBK 406
31 October 1971

Condenser - must be sufficient to condense all the vapors generated at maximum heat input.

Safety Thermostats - an automatic heat input shut-off located just above the normal vapor level to insure that the vapors will not rise above the condenser level in the event of unusual heat conditions or condenser failure.

Cleanout - provisions should be made for easy machine cleanout.

Water Separators - will minimize the formation of water/solvent vapor mixtures which are easily lost into the air.

Racks or Baskets - should be no larger or heavier than necessary, too large a basket will act as a piston, forcing the vapors into the surrounding air.

Hoists - should be set to operate at a maximum verticle speed of 12 feet per minute, minimizing vapor disturbance and solvent loss into the surrounding environment.

6.1.1.2 Types

Vapor degreasing units often combine several cleaning methods with the degreasing to increase the total efficiency of the cleaning cycle, frequently, the degreaser is arranged to repeat the vapor phase of the cleaning. The most common degreaser arrangements are: FIGURE 6 - 1

Spray-Vapor - used when the soil to be removed would have been baked onto the part when processes through the normal vapor phase, the spray is cold and used as the first step in the system. FIGURE 6 - 2

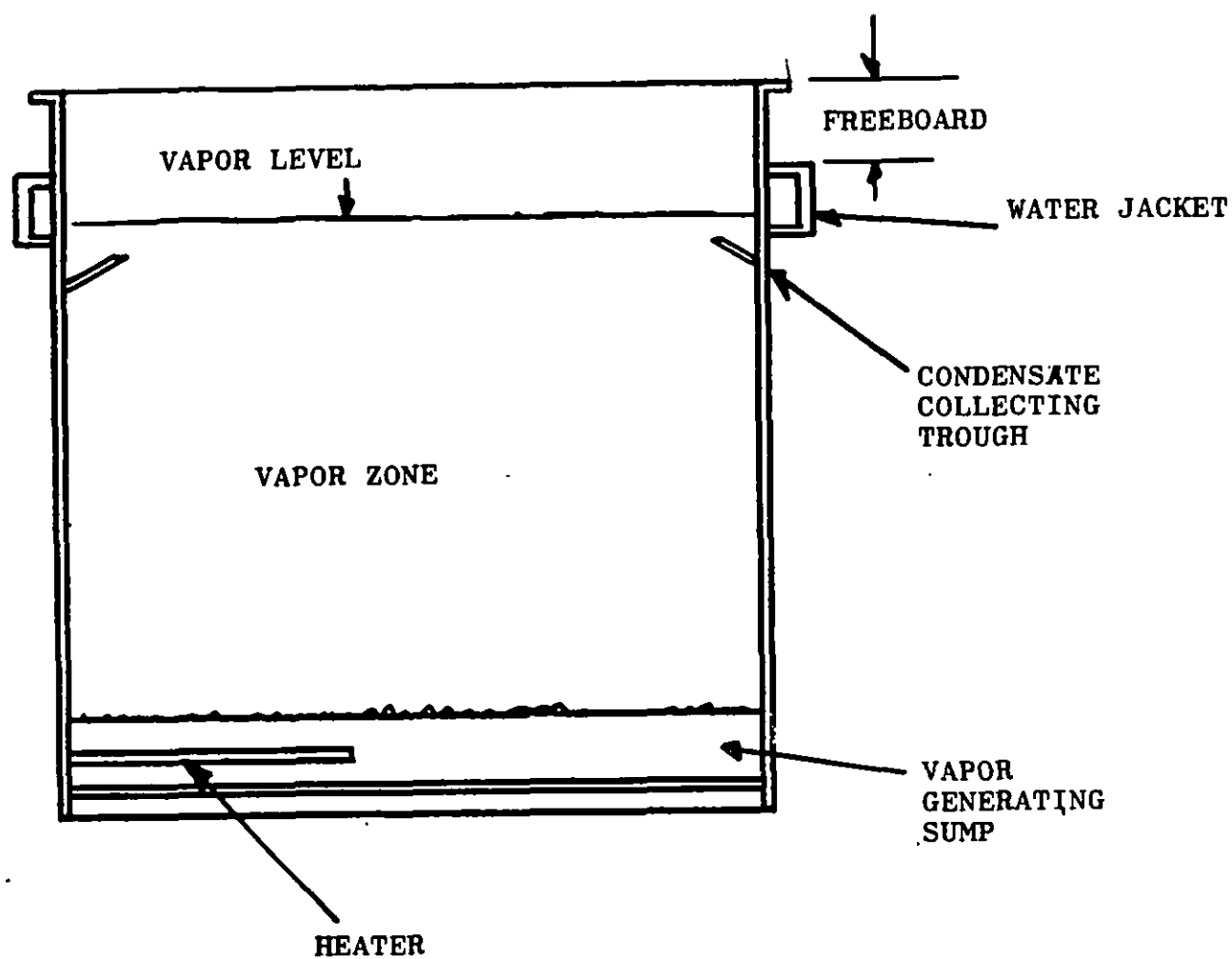
Vapor-Spray-Vapor - more effective in the removal of medium light soils from parts with complex configurations and blind holes. FIGURE 6 - 3

Vapor only - for the removal of light soils, soluble in the degreasing solvent. FIGURE 6 - 1

Vapor-Immersion-Vapor - for the removal of medium heavy soils from thin wall parts or small bulk parts loaded into baskets or other containers. FIGURE 6 - 4

MIL - HDBK - 406
31 October 1971

FIGURE 6 - 1
THE VAPOR DEGREASER



MIL - HDBK - 406
31 October 1971
FIGURE 6 - 2 SPRAY-VAPOR

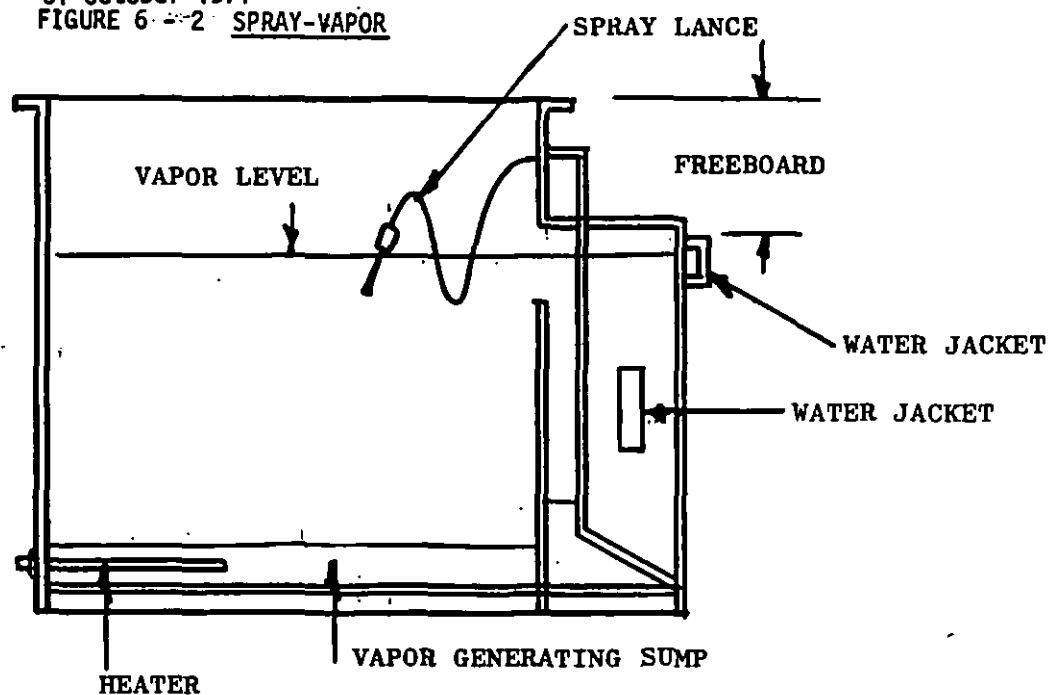
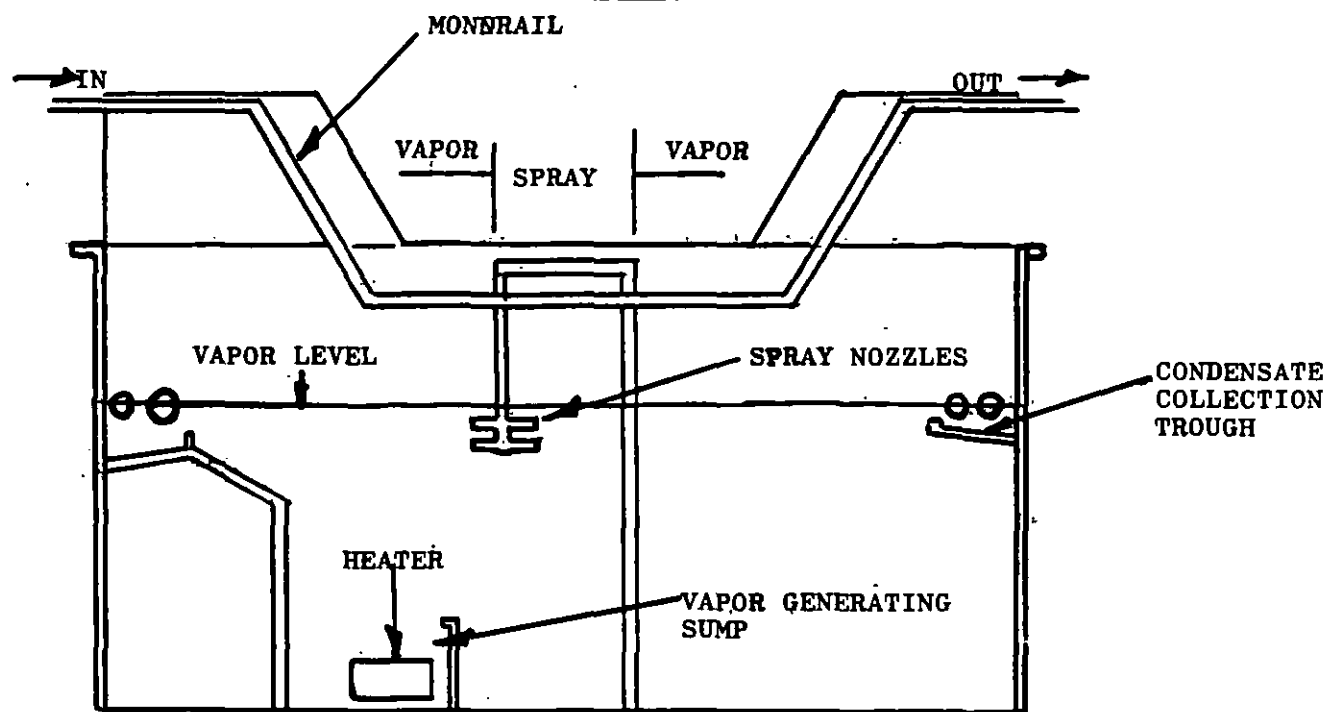


FIGURE 6 - 3 VAPOR-SPRAY-VAPOR



MIL - HDBK - 406
31 October 1971

FIGURE 6 - 4 VAPOR-IMMERSION-VAPOR

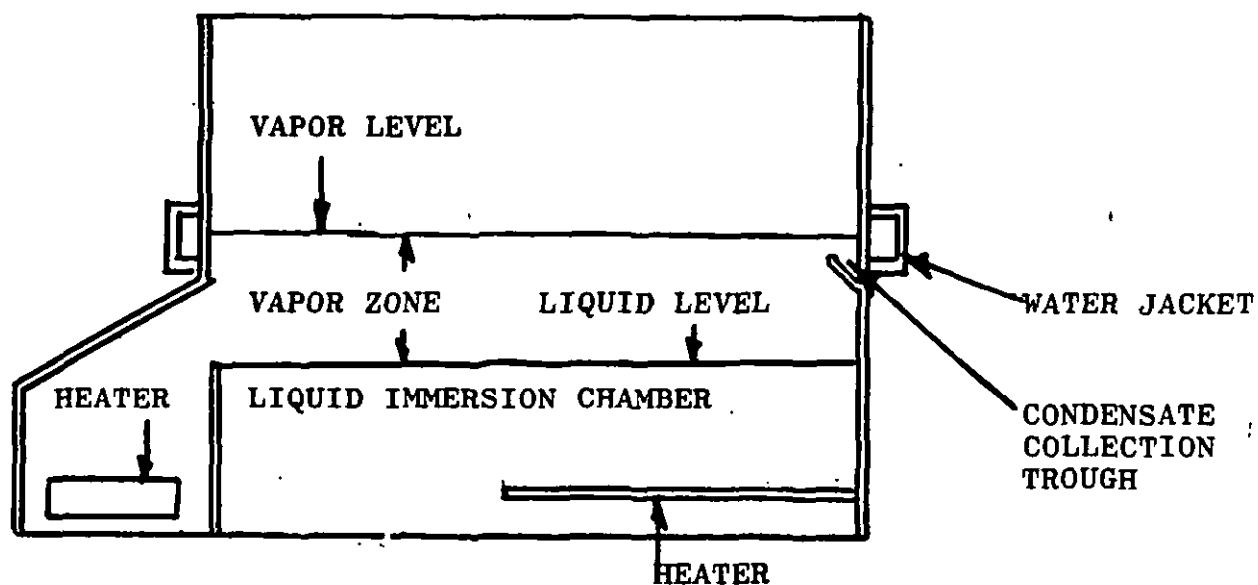
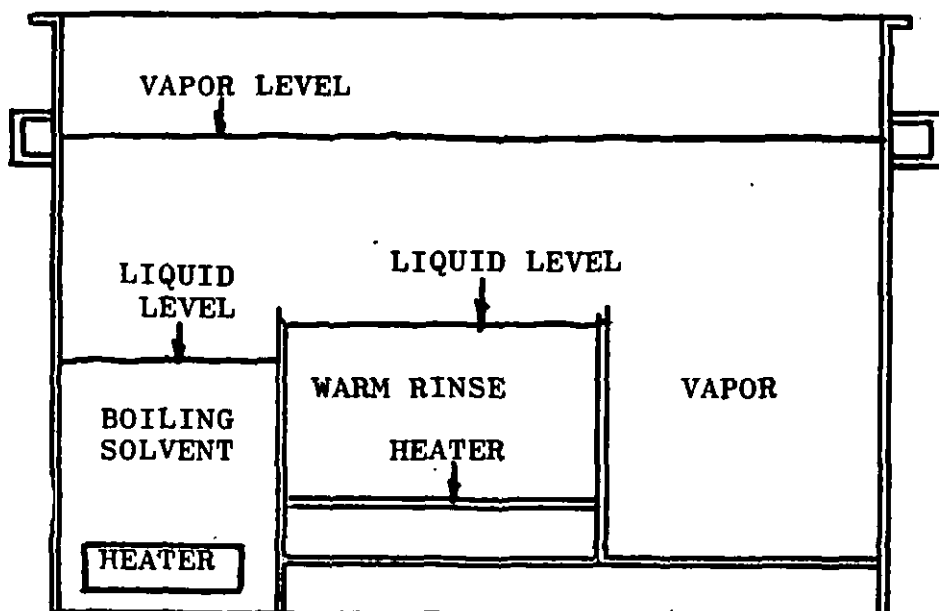


FIGURE 6 - 5 BOILING SOLVENT-COOL SOLVENT-VAPOR



MIL - HDBK - 406
31 October 1971

Boiling Solvent-Cool Solvent-Vapor - Very effective on heavy soils and where complex configurations are involved. Figure 6-5.

Ultrasonic - When combined with vapor degreasing, the end result is a very high degree of cleanliness. Generally followed by spray and vapor rinses.

These are by no means the total possible combinations but any special applications or requirements should be discussed with an equipment manufacturer, who can furnish designs to suit any needs.

There are also, of course, limitations to vapor degreasers, see Table 6-1 for a listing of some of these limitations.

6.1.1.3 Solvents

To choose the solvent best suited for an individual vapor degreasing operation, one must consider the materials being cleaned, the contaminant to be removed, the material configuration and the cost of reclamation of the solvent.

The most commonly used solvents in vapor degreasing are:

- Trichloroethylene
- Perchloroethylene
- Trichlorotrifluoroethane
- Methylene Chloride
- 1,1,1,-Methyl Chloroform (Trichloroethane)
- Specific Azeotropes

6.1.1.3.1 Characteristics

Generally, the suitable vapor degreasing solvents all possess the following characteristics:

High Solvent Power - the ability to dissolve all oils, greases, fats, waxes, resins, gums and tars generally encountered in manufacturing.

Inertness to Metals- the ability to clean without oxidizing, staining, pitting or in general, corroding the metal.

Non-Flammability - flammable solvents would not be suitable for use in a vapor degreaser where elevated temperatures are a requisite part of the system.

MIL - HDBK - 406
31 October 1971TABLE 6-1 Vapor Degreaser Limitations

Topic	Limitation	Recommendation
Acidity	Solvent decomposition, resulting in attack of the common metals and the more reactive metals.	Monitor solvent acidity. Clean degreaser at regular intervals.
Rust	Ferrous parts which have been degreased are subject to oxidation.	Apply rust proofing solutions.
Heat	High temperatures are dangerous for certain rubbers and plastics. High temperature may also bake on certain soils.	Check maximum safe operating temperatures.
Chlorides	The chlorides formed by the decomposition of solvents will attack some rubbers and metals as well as plastics	Monitor chloride content.
Thin-wall parts	Part may reach the vapor temperature, preventing proper cleaning by condensate formation.	Use vapor/spray/vapor cycle.
Blind Holes	May present draining problems and may not be properly cleaned.	Use vapor/spray/vapor cycle ultrasonic plus vapor, rotate part to drain.
Convolute parts	Solvent entrapment.	Rotate during degreasing.
Metal Castings	Due to porosity, all of the contaminants may not be removed. May weep oil.	Use ultrasonic-vapor degreasing cycle.
Oil impregnated metal parts	Bearings and bushings may be oil impregnated for part life, degreasing will remove lubricant.	Mild solvent surface wipe or brush, or degrease and relubricate.

MIL - HDBK - 406
31 October 1971

Low Toxicity - the safety and health of the operating personnel must be considered at all times.

Low Latent Heat - low latent heat reduces the heating costs of vaporizing the solvent to provide adequate condensing action.

High Vapor Density - this permits ease of solvent recovery and permits effective control of the solvent vapor level.

Chemical Stability - the solvent should remain stable in both the liquid and vapor phases after repeated cleaning cycles. Reactive metal fines and chips should not decompose the solvent. Solvents which hydrolyze easily should be used within limitations.

Boiling Point - the boiling point should be low enough to limit the heating requirements and allow easy separation from the dissolved soils by distillation. The boiling point must also be high enough to permit efficient condensation of the vapors without refrigeration.

See TABLE 6-2 for a comparison of the properties of the various vapor degreasing solvents.

Generally, the following characteristics can be attributed to each of the individual solvents:

Trichloroethylene

Efficiency and cost make this solvent the optimum one
Easily controlled stabilizers
Acceptable part temperature at the completion of cleaning
High solvency
Easy distillation
Moderate boiling temperature

Perchloroethylene

Removes the moisture content of aqueous solutions
Low tendency to hydrolyze
High boiling point resulting in:
better removal of tars and waxes with melting point in 190-250°F range complete drying of parts
reduced staining of light gage metal, costly heating requirements, baking-on of insoluble contaminants

MIL - HDBK - 406
31 October 1971

high solvent vapor temperature results in compatibility problems

Methylene Chloride

Lowest boiling point
Reduced heating requirements
Minimal cleaning time
Minimum part cooling time

1,1,1-Methyl Chloroform (Trichloroethane)

Special distillation equipment
Low vapor density
Not suitable for aluminum
Hydrolysis occurs readily

Trichlorotrifluoroethane

Highest vapor density
Low boiling point
Chemically stable
Easily reclaimed through simple distillation
Very low toxicity
Mild solvent

6.1.2. Ultrasonic Cleaning

The removal of surface soils by the scrubbing action from the implosion of vaporous bubbles or cavitation, is called ultrasonic cleaning.

"Ultrasonic" refers to those energy vibrations above 20,000 Hertz, which is above the range of audible sound (normally from 20 to 20,000 Hertz-with a general limit of 16,000 hertz for older persons). Figure 6-8 illustrates these ranges.

6.1.2.1. Components

An ultrasonic cleaning system is comprised of three basic components:

Ultrasonic Generator - which produces ultrasonic oscillations which are relayed to. . .

The Ultrasonic Transducer - which converts the electrical impulses into mechanical vibrations of the same frequency. The transducer is in turn attached to the. . .

MIL - HDBK - 406
31 October 1971

TABLE 6-2
Properties of Vapor Degreasing Solvents

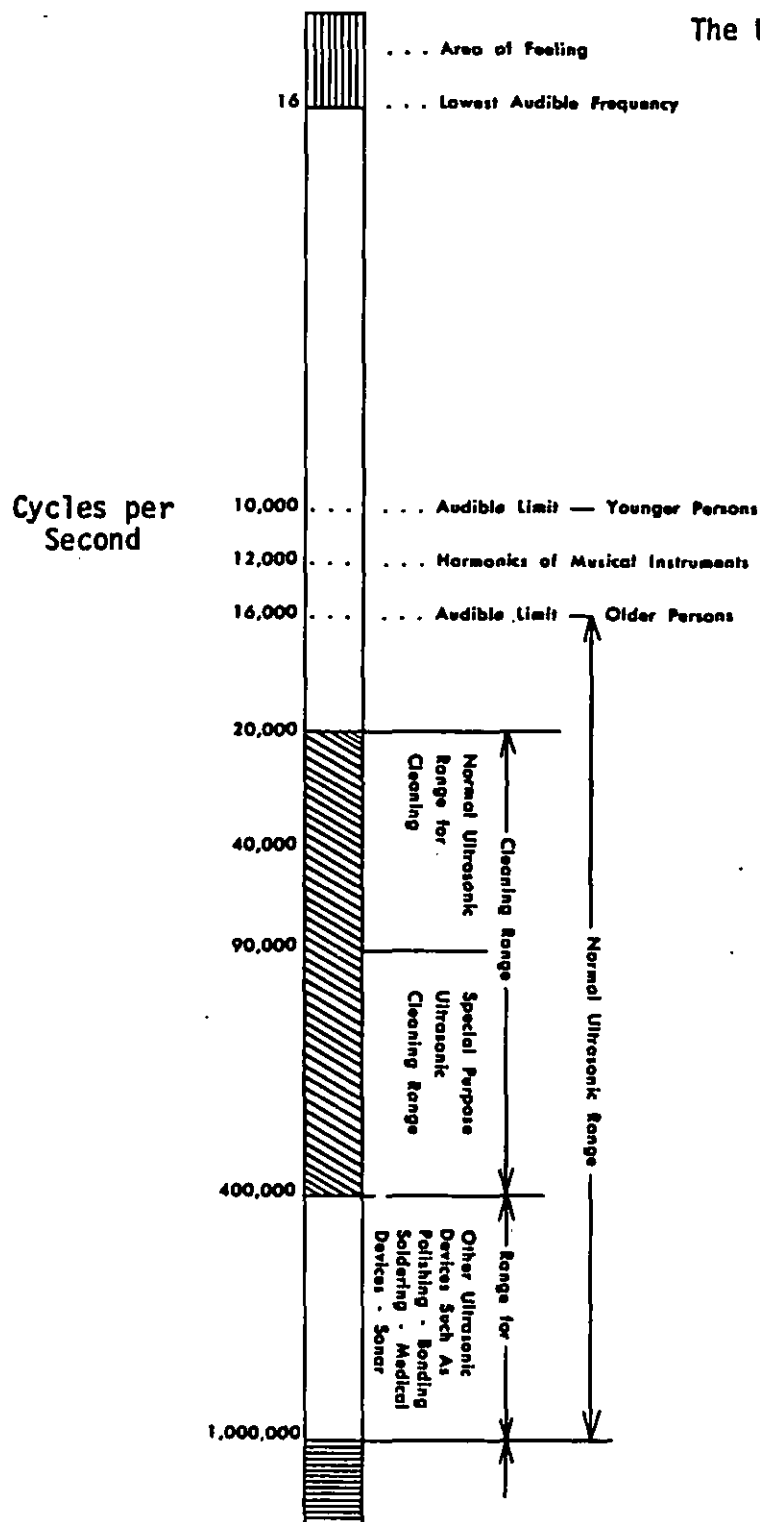
Solvent	Boiling Point (°F)	Surface Tension at 68°F (dynes/cm)	Latent Heat at the Boiling Point	TLV	Specific Gravity of vapor at $r=1000$	Kauri Butanol Value
Trichloroethylene	188	32.0	103	100	4.54	130
Perchloroethylene	250	32.3	90	100	5.73	90
Trichlorotrifluoroethane	117.6	19.6	1063.1	1000	6.75	31
Methylene Chloride	104	28.2	142	500	2.95	136
Methyl Chloroform (1,1,1-trichloroethane)	165	25.5	95	350	4.50	130

Threshold Limit Values (TLV) are 1965 American Conference of Governmental Industrial Hygienists.

MIL - HDBK - 406
31 October 1971

FIGURE 6 - 6

The Ultrasonic Frequencies



MIL - HDBK - 406
31 October 1971

The Transducerized Tank - or cleaning tank which has been designed to give the best cleaning possible

6.1.2.2. How does it Work?

Sound waves are the basis of ultrasonic cleaning, they travel through a material by the alternate compression and expansion of its molecules. When sound passes through an elastic medium such as metal, the medium and the sound energy vibrate at the same rate. When sonic energy travels through a liquid, the liquid ruptures (cavitates), . . . small pockets are created which immediately collapse or (implode). This phenomenon occurs only at or above the sonic intensity level of the threshold of cavitation. The rapid implosion of these ruptures in great quantity, creates a vigorous scrubbing action on any surface in contact with the area of cavitation.

The transducer attached to the cleaning tank vibrates at ultrasonic frequency. When it moves toward the liquid in the tank, a high pressure (compression) wave is formed; a low pressure (rarefaction) wave is produced as the transducer moves away from the liquid.

If the amplitude of the transducer is great enough, the low pressure wave will reduce the pressure of the liquid below its vapor pressure and thousands of minute bubbles will be formed. When the high pressure wave is created, the vapor bubbles recondense; as this implosion occurs, the scrubbing action is created.

6.1.2.3. Solvent Property Effects

The vapor pressure, surface tension, viscosity and density of the solution are the properties which have the most pronounced effects on the efficiency of ultrasonic cleaning.

Vapor Pressure - the vapor pressure of the liquid affects the threshold of cavitation. As the vapor pressure increases the threshold decreases. A liquid with low vapor pressure absorbs more of the ultrasonic energy in getting to the

MIL - HDBK - 406
31 October 1971

threshold and less energy remains to cause the formation of more cavitation bubbles.

The cavitation bubbles of a liquid with low vapor pressure will implode with greater force because of the higher internal-external pressure differential. While the more intense or "harder" implosion may be an aid to the scrubbing, the number of cavitation bubbles formed in a liquid with low vapor pressure may be too low to create sufficient scrubbing. The better value here is the middle range of vapor pressure.

Surface Tension - high surface tension would cause the vapor bubbles to collapse faster, creating greater scrubbing force but at the same time, the force required to expand the bubble increases with surface tension. A point may be reached where the surface tension is so great as to absorb all of the ultrasonic energy with the end result that the bubble would not grow to sufficient size to offer any effective scrubbing force whatsoever.

Low surface tension on the other hand does not require much energy to reach the point of cavitation but the bubbles may grow too large and implode too softly to scrub the surface sufficiently. The best value in surface tension will also be an intermediate one for the most effective cavitative.

Viscosity - high viscosity requires a greater force to cause cavitation. Higher viscosity results in a damping of the energy being transmitted through the liquid. In the case of viscosity, the lower the value, the better the cavitation.

Density - while it takes more energy to expand the vapor bubble in a high density liquid, the implosion force is greater than that of a low density liquid. Generally, the higher the density the better suited the liquid is for efficient cavitation.

It can be seen therefore that the "ideal" cleaning solution would be one of moderate vapor pressure and surface tension, low viscosity and high density.

Since temperature will affect all of these properties, (Low temperature will cause: higher density which is good and higher viscosity, lower vapor pressure, and higher surface tension which are undesirable. High temperature near the boiling point will cause: lower viscosity which is good and lower density, lower surface tension and higher vapor pressure which

MIL HDBK - 406
31 October 1971

are undesirable; the most intense cavitation will occur at a point well below the boiling point of the liquid.

Ultimately, the cleaning solution must perform specific functions in the cleaning tank for the cleaning to be effective:

- Lower interfacial tension providing better solution/part contact
- Lower surface tension, lessening energy losses
- Penetrate the soil rapidly allowing maximum scrubbing action at the part/contaminant contact point
- Chemically react with soils
- Disperse and prevent the redeposition of soils

6.1.2.4. How is the System Evaluated?

Generator - the function of the generator is to convert line voltage into high frequency electrical energy. A common method for the evaluation of the generator is by describing the power intensity delivered to the tank:

Watts per Gallon - obtained by dividing the average power of the generator by the volume of cleaning solution.

Watts per Square Inch of Transducer Face - divide the power of the generator by the transducer surface area.

Watts per Square Inch of Tank Cross Section - divide the average power of generator by the tank cross sectional area.

Each of these ratings can be used to interpret specific information about the system:

Watts per Gallon - indicates the needed tank heating or cooling requirements.

Watts per Square Inch of Transducer - indicates power intensity for sidemounted transducers.

Watts per Square Inch of Tank Cross Section - indicates power intensity for complete tank. Normal rating for bottom-mounted transducers.

MIL - HDBK - 406
31 October 1971

Transducer - the transducer converts electrical impulses from the generator into mechanical vibrations on the cleaning tank. Transducers are generally one of two types, magneto-strictive or piezoelectric.

Magneto-strictive - these transducers are not as popular as piezoelectric types but are still widely used. These devices use an arrangement of coils and a metallic core. Most of them operate at 20,000 Hz but some can be pushed to 50,000 Hz. The energy transfer is generally less than with the piezoelectric units.

Piezoelectric - these are generally ceramic type units; barium titanate for general use and lead zirconate for heavy duty and high temperature applications.

Frequency - while there is theoretically a full range of frequencies to choose from, not all of them are suitable for cleaning applications.

Those frequencies below 20,000 Hz, while they cover a wide angle in the tank, are inefficient because they lack the power of the high frequencies, in addition, the noise levels are offensive.

The higher frequencies are very directional in the area of cavitation, especially those above 100,000 Hz, where the cavitation is a straight and narrow path from the transducer. Frequencies in the 90,000 to 100,000 Hz range show only slight loss of cavitation area, penetration into deep crevices and hidden areas is excellent, cleaning speed and effectiveness is greatly improved over the lower frequencies and the noise level is very low. See TABLE 6-3 for a comparison of the cleaning frequencies.

6.1.2.5. How is the Cleaning Monitored?

A number of tests may be conducted to determine the efficiency of specific aspects of ultrasonic cleaning. TABLE 6-4 lists these methods.

6.1.2.6. What must be Considered?

Numerous considerations must be given for effective ultrasonic cleaning. TABLE 6-4 lists some of the general considerations to be given and TABLE 6-5 lists the considerations for electronic component cleaning.

MIL - HDBK - 406
31 October 1971

TABLE 6-3
Comparison of the Standard Cleaning Frequencies

Frequency Range in Kilo Hertz	Angle of Energy from Transducer	Noise Level	Size of Cavitation Bubbles	Pain Sensation	Cleaning
16 to 30	25 to 35°	High	Largest	Pricking sensation on tips of fingers or interiors of tanks ers upon immersion and tubes. Not generally recommended for confined areas because of high noise levels.	Most inexpensive for large flat surfaces
30 to 45	15 to 25°	Buzz	Medium	Sensation similar to electric shock surfaces. Good for on finger nails	Good for general cleaning of medium and large surfaces. Good for small castings.
80 to 90	11 to 15°	Little	Smallest	Intense pain in joints of fingers	Best range for cleaning of small tightly packed parts. Ability to penetrate pores.

MIL - HDBK - 406
31 October 1971TABLE 6-4
Monitoring Ultrasonic Cleaning

Device of Method	Measurement	Principle	Characteristics or Limitations
Foil Erosion	Cavitation intensity	Cavitation erodes the immersed foil strip	The effects are more apparent in water than in solvents. Easily performed, with fair reliability. No standards have been established. Evaluation is based on visual observation and comparison. Limited to before or after cleaning readings.
Bead or steel ball bounce	Tank vibration causes movement	Energy in the solution produces vibration of the test tube and in turn, makes the bead or ball bounce	Easily performed but not readily and meaningfully interpreted.
Heat rise	Solution Temperature	Ultrasonic energy causes a rise in solution temperature.	Plotted curve of temperature versus time should approximate a straight line. Degrades transducers can produce heat which gives a false reading. Not an accurate measurement of cavitation.
Cavitation meters	Cavitation intensity	Probes pick noise frequencies.	Direct readout and quick test. Some units do not have frequency range switches.

MIL - HDBK - 406
31 October 1971

TABLE 6-4 (CON'T)

Chlorine release	Correlation of cavitation and Chlorine	Cavitation energy releases chlorine from Carbon tet.	Frequency and temperature dependent in the 20 to 40 kHz range. Amount of liberated chlorine is determined by optical density measurements with spectrophotometer. Limited to low temperature.
Dispersion probe	Soil removed	Soil removal is known.	Measurement is made by determining the amount of soil removed from an etched glass probe.
Standard test piece	Surface Cleanliness of test	Amount of removal.	Surface cleanliness is generally evaluated by water break, coefficient of friction, electrical conductivity or oxide film tests.
Transducer amplitude	Amplitude of transducer surface	Correlation between the and cavitation.	Can continuously monitor or spot read, results vary with solution used.

MIL - HDBK - 406
31 October 1971TABLE 6-5
Considerations for Ultrasonic Cleaning

Factor	Remarks
Cleaning Solution	Selection must be made for the soils to be removed. Fluid level must be high enough to prevent damage to the ultrasonic tank.
Degassing	Cleaning solutions should be degassed before use. Shallow tanks, higher solution temperatures and higher power intensity with a pulsed wave allows faster degassing. Time depends on solution used.
Immersion of parts	Parts must be removed from and introduced into the tank slowly, while in operation. If there is any screeching, the parts are being introduced too rapidly and the generator is being strained.
Part loading	Neither parts or the parts basket should be on the tank bottom. High density parts should be each exposed to direct ultrasonic waves. Part cross-sectional area should not exceed 75% of the tank area.
Basket design	A basket with too high a mass can reduce the effectiveness of the cleaning.
Part position	Critical areas to be cleaned should face the transducer if possible. No air may be entrapped in blind holes. Racked parts should be placed vertically and no stacked. Should be covered by at least 3/4 in. of solution.
Noises	Buzzing or hissing noise is caused by the shock waves produced by cavitation. Screeches or squeals from beat notes must be avoided. Beat notes are caused by; (1) too rapid part immersion, (2) too violent agitation of the liquid, (3) resonant bubbles, or (4) two or more unsynchronized generators.
Filtering	Particulate matter must be removed from the cleaning solution. Those may be accomplished by using a continuously recirculating filtration system.

MIL - HDBK - 406
31 October 1971

TABLE 6-6 Considerations for Cleaning Electronic Components

Characteristic	Remarks
Physical makeup	Components produced by some manufacturers are not structurally sound enough to withstand the shock imposed by ultrasonic cleaning.
Power intensity	Any delicate component has an upper power intensity limit with reference to time.
Power uniformity	Non-uniform power intensity can expose components to higher intensities than those which can normally be tolerated and are recommended for safe operation on the components.
Mass of load	Electronic components, particularly circuit boards, should be ultrasonically cleaned in racked loads, not as individual parts.
Dwell time	The time the parts are immersed to the ultrasonic cavitation should be very closely controlled. 5 to 15 seconds is generally sufficient.
Cleaning solution	The type of solution has a direct effect on the type of cavitation produced (hard or soft). Solutions which produce fairly soft cavitation should be used, i.e., a solution with high vapor pressure and low surface tension be employed.

MIL - HDSK - 406
31 October 1971

TABLE 6-7
Laminar Flow Advantages and Disadvantages

<u>Advantage</u>	<u>Reason</u>
Clean-down capability	Air velocity is generally great enough to carry away contamination generated or carried into the facility.
Particles will see the item only once.	Any airborne particle will see the item only once because of the airflow pattern.
Reduced Maintenance	Since the facility exhaust itself continuously, the necessity to vacuum the area is eliminated.
Class 100	Vertical laminar flow facilities are capable of attaining a class 100 level and with good management, will even exceed that level.
Control of humidity and temperature	The volume of introduced air is so great that the maintenance of desired levels is greatly simplified. The air which is recirculated is easier to maintain at the specified conditions.
Garments	Garment restrictions may be reduced from those of a non-laminar facility. Continued high standard of garment use will lessen the chance of contamination however. The facility should not be relied upon to dissipate all generated particles.
Air locks, Airshowers	Except in microbial or sterile conditions, air showers, double door airlocks, and large dressing rooms are not usually necessary. Again, such precautions do lessen the danger of contamination and decreases the load the room or facility is expected to withstand.
<u>Disadvantages</u>	<u>Reason</u>
Increased volume of air required.	Higher velocity air requires larger fans, motors and ducts.
Vertical rooms require more clearance	The floor and ceiling plenums of vertical rooms occupy 4 to 6 feet of vertical height. This space must be added to the height of the room itself to determine total vertical space requirements.
Original cost	In terms of initial cost, the vertical facility costs more than other types of equipment, but it offers greater efficiency and reduced maintenance costs. A horizontal system will cost less than competitive facilities with improved efficiency.

MIL - HDBK - 406
31 October 1971

6.1.3. Drying Methods

Directly related to cleaning is the drying parts. There are several drying methods available and all must be monitored to insure the continuance of the established cleanliness level. Some of the methods displace the water from a part and others remove it by evaporation. There are three general types of drying systems, mechanical, chemical and thermal. Detailed information on the methods under each of these categories is presented in TABLE 6-7.

6.2. The Environment

6.2.1. The Clean Room

All of the precautions taken to insure maximum cleaning efficiency; solvent purity and material purity are valueless if the environment in which the product is handled and cleaned is not also as controlled as the rest of the factors.

Essentially, the clean room is a controlled environmental facility where every effort is made to insure the elimination of contaminants and their sources.

Based on the airflow characteristics of the room, the facility will fall into one of two broad categories, the laminar or non-laminar flow design.

6.2.1.1. Non-Laminar Airflow

Commonly referred to as a "conventional" clean room, these facilities are characterized by:

Airtight structure into which air is introduced at a predetermined rate.

Personnel are "packaged" completely.

The facility is constantly vacuumed or wiped.

The air in the room is changed at a rate of 15 to 20 changes per hour. The air movement patterns in non-laminar facilities are irregular and offer many opportunities for contaminants to settle on work pieces.

MIL - HDBK - 406
31 October 1971

TABLE 6-7 Drying Method Characteristics

Mechanical Methods

Wiping - absorption by wiping material -

Use lint free cloth; usually gross or a predry operation;
Not preferred because of sloughing problem.

Air Blowoff - Physical force of air stream displaces cleaning solution -
Air supply line must be filtered, possess water trap and
regulator. the air stream might agitate other contaminants
in the area.

Dry nitrogen blowoff - Same as air blowoff -
Final drying for precision cleaning.

Sonic - Gradient of moisture content near surface of the part
is modified by air agitation from sound waves -
Not widely employed with metals. Can be used with heat
sensitive parts and where high velocity air stream might
cause damage.

Chemical Methods -

Alcohol and Acetone - Combines cleaning and drying, water
absorption, rapid drying -
Highly flammable, effective in some cleaning.

Freon TDAD 352 - Water displacement -
Removes large or small quantities of water from metals,
plastics and material combinations.

Freon TWD 602 - Water emulsification, vapor evaporation -
Dries traces of residual water from surfaces, small holes,
and cracks, used in ultrasonic or vapor degreasing
equipment.

Trisec - Water displacement -
Chlorinated solvent, cationic surfactant. Vapor degreaser.

Thermal Methods -

Ovens - Evaporation by heat -
Not applicable for heat sensitive materials. Should
be recirculating, indirect gas-fired or electrically
heated, with high volume static exhaust.

Infrared and heat light bank - Evaporation by heat -
Not normally used in contamination control situation.
Conveyorized operation.

MIL - HDBK - 1971

31 October 1971

The non-laminar facility possesses poor self-cleaning ability and the time required to exhaust contaminants increases as the rate of generation increases. The best means of combatting contaminants is to employ garmented janitorial employees constantly vacuuming during the area working hours.

Since there is a lack of control in the non-laminar room, there is a need for smooth surfaces, and a total limitation of ledges, crevices and projections on which contaminants might lodge.

Stainless steel has long been an accepted material and all joints are covered to provide easy cleaning. A hard gloss, non caking surface is also satisfactory, it must be frequently cleaned with a vacuum brush. The room must also be sealed to preclude the entry of contaminants from the outside.

The personnel entry door should be the inner part of an air lock which will accomodate only one person at a time and both doors of which will not open simultaneously. An air shower should precede the air lock and must be capable of removing any particulates which might be shed or sloughed off by activity.

The most effective garment for use in the non-laminar flow room is the bunny suit which covers the entire body, including shoe covers which are made of non shedding material and head covering which entirely covers the head, hair and neck.

6.2.1.2. Fume Hoods

A fume hood is basically a ventilated enclosure designed to confine and discharge odors and toxic materials in the form of fumes, gaseous vapors, etc., into the atmosphere. Fume hoods are designed in several types or configurations:

Conventional - an enclosure vented through slots at the top and bottom of the rear wall.

Streamlined - incorporates a streamlined entrance to provide a reduced face velocity. The elimination of corner posts, off sets and irregular shapes promotes a uniform, slow movement of air through entrance.

Bypass - Provides an air bypass to the exhaust blowers to prevent a vacuum starved condition at the blowers when the entrance is closed.

Balanced - designed to introduce untempered air form the atmosphere into the entrance area so that it will mix with

MIL - HDBK - 406
31 October 1971

the tempered air from the room. This is especially good when the room is air conditioned since it lessens the load on the conditioners due to loss.

Since the hood generally exhausts air into the outside environment, precautions must be taken when the exhausted gases are toxic or corrosive, to prevent contamination of the atmosphere.

6.2.1.3 Laminar Airflow

A laminar air flow is one in which the entire body of air within an enclosure or room, moves at a uniform velocity along parallel lines. The Laminar Airflow may be in either a vertical or a horizontal direction and the rate of movement covers a wide range of velocities. The velocity for a vertical air flow is normally 90 + 5 lineal feet per minute, while the horizontal facility will range from 100 to as great a 140 feet per minute, depending upon the length of the facility.

Laminar flow facilities have several advantages and disadvantages (see TABLE 6-7); several characteristics differentiate the horizontal and vertical facilities.

6.2.1.4 Vertical Laminar Airflow

A Vertical Laminar Airflow (VLF) employs the Laminar flow principle with the air moving from a filter bank in the ceiling downward through a grating in the floor. The VLF room provides the following advantages over other types of clean rooms:

- Can operate well within the class 100 level.
- Operates well utilizing a wide range of air velocities.
- Offers rapid removal of generated contaminants from the room.
- Lessens the possibility of cross-contamination between adjacent operations in the room.
- Lower janitorial costs.
- Minimizes the effects of personnel emission.
- Long term operation and maintenance proves less costly than other facilities.

MIL - HDBK - 406
31 October 1971

TABLE 6-8
Vertical Laminar Flow Room Requirements

Ceiling	Composed entirely of supporting frame work and (certified-to-be-) leak-free HEPA Filters. The seal around the filters should be leak-free and any openings for wiring or sprinklers must also be leak-free.
Floor	The entire area should serve as an exhaust and should be made up of a grating or perforated metal with an open area of at least 60% of the floor space.
Walls	Normal materials are satisfactory if they are firmly fixed and all joints are sealed. The interior surface of the facility must be a hard gloss, non-shedding surface. Strips, ledges and wall irregularities must be eliminated because they will result in the creation of irregular flow characteristics.
Plenum	The plenum must be of sufficient depth to insure the proper flow of air in the room. A shallow plenum can cause a dead spot or turbulence in the air flow, reducing the overall efficiency of the room.
Air Velocity	To attain a class 100 level, the lineal air velocity measured 12 inches from the face of the HEPA filter must fall in the 90 ± 10 ft./min. range.
Construction	The general construction requirements should include a specification that the room be capable of maintaining a minimum of plus 0.05 in. WG pressure.
Shoe Cleaners	These are not generally needed because of the Floor grating. If the location is such that excessive amounts of contaminants are brought into the room, then a brush vacuum shoe cleaner should be considered.

MIL - HDBK - 406
31 October 1971

Some of the basic design requirements for vertical laminal flow rooms are listed in TABLE 6-8.

Portable VLF units are available which provide the capability of enclosing large cumbersome components in controlled environments. The portable facilities will provide a class 100 level of cleanliness. The portable units are curtained in plastic, have their own blowers and filter banks and illumination. They may even be used out-of-doors, providing the wind velocity is less than 20 mph.

One precaution with the portable unit: If the unit is not in constant use and has frequent shut-downs of more than a minute, the unit should be allowed to purge itself for about five minutes prior to use again. If the shut-down periods are in excess of 4 hours, the purge time is 30 minutes, accompanied by a vacuuming of the interior.

In addition to the portable unit, there are also vertical Laminar flow work stations or benches. The station employs a perforated metal work surface with the open area ranging from about 30 to 60 percent. Air velocities range from 65 to a top of 145 FPM. The vertical flow work station will operate well within the class 100 range.

6.2.1.5 Horizontal Laminar Air Flow

The horizontal facility differs from the vertical flow design in the direction of the air travel. In the horizontal design, the HEPA filter bank comprises one entire wall of the room or tunnel. The opposite wall of a room is an exhaust grating. Horizontal rooms are not characterized as being of one class, 100, 10,000 etc.; they are always "zoned". The class level being determined by the distance from the filter bank.

The ceiling height in the horizontal facility needs only to be adequate to contain the equipment being used.

The air velocities in a horizontal facility needs are higher than those of a vertical room because:

The air travels a greater distance and the higher velocities ensure that the particulates remain suspended in the air.

Obstructions above the work level become a problem when the air flow is horizontal.

MIL - HDBK - 406
31 October 1971

The minimum velocity for a short room would be 100 fpm with increases up to 140 fpm in a long facility.

The placement of equipment and work stations within a horizontal facility is critical because the operations of one station may effect all subsequent operation upstream of that operation. It is advisable that equipment and work stations be placed in a staggered configuration to lessen the dangers of contamination.

6.2.1.6 Horizontal Airflow Tunnels

The tunnel differs from the horizontal airflow room in the following:

The tunnel is always erected within another building.

The tunnel air supply is taken from the surrounding atmosphere.

The exhausted air is released into the surrounding atmosphere while the room air is recirculated.

No positive pressure is maintained in the tunnel.

Temperature and humidity is limited to that of the surrounding atmosphere.

The open-ended horizontal airflow tunnel offers these benefits;

Rapid clean down

Lowest cost per square foot

Although not portable, relocation is economical

Easily enlarged or reduced in length.

Very low maintenance costs

6.2.1.7 Horizontal Airflow Work Bench

The horizontal work bench provides the capability of establishing a localized clean zone. The horizontal bench can operate within the class 100 range when the air velocity is 90 ± 5 ft/min.

MIL - HDBK - 406
31 October 1971

The horizontal work bench offers several advantages:

Rapid self-clean-down

Ready access to work area through open front

Minimal personnel restrictions other than normal training.

6.3 Packaging

Packaging, in general, constitutes enclosing an item in some material to protect it from some environmental condition. The idea of clean packaging is really quite simple; the package must be able to maintain the cleanliness level of the item throughout handling, storage and transportation until further assembly or use. To achieve this goal, certain conditions must be met:

The packaging material must be cleanable and precision cleaned prior to use.

The cleanliness level of the cleaned packaging material must be maintained until a closure is made.

The packaging must be done in a clean environment.

Stringent clean packaging techniques must be observed.

The package must be constructed and sealed as to prevent the entrance of contaminants from outside the package.

The packaging material itself must not contribute to the contamination of the item, except within acceptable limits.

6.3.1 Packaging Elements

The basic elements or parts which comprise a complete clean package are;

Intimate Package - Requires same degree of cleanliness as part, since the material may contact the part or at least is environmentally adjacent to the part. Rigid materials of high density and hard finish can provide the highest degree of barrier protection but poses some problems in the formation and sealing. Flexible materials create problems because of their sloughing characteristics.

MIL - HDBK - 406
31 October 1971

They are heat sealable and good barriers to certain environments.

Environmental Package - Used to provide an additional barrier to specific environments which may not be provided by the intimate package. Rigid materials provide greater protection from shock and impact. The sloughing of flexible materials is not as significant a problem here.

Intimate cushion - When the packaged item contains sharp edges, protrusions or external threaded portions, protection is needed to prevent penetration of the intimate or environmental package. Cushions must be as clean as the item they protect.

6.3.2. Packaging Films

Polyethylene - Advantage: economical, available in many types, sizes and thicknesses. Disadvantage: lower strength than most films and higher degree of sloughing. Distorts when in contact with oils.

Polyamide (Nylon 6) - High in abrasion and flex resistance, least self-contaminating among all films now in use. Not a good moisture barrier. Because of poor moisture resistance, normally requires an environmental package such as polyethylene.

Fluorohalocarbon (Aclar) - This is the only packaging material which is compatible with LOX. While Aclar abrades more easily than nylon 6, the sloughed particles are LOX compatible while other materials constitute a potential explosive hazard on impact in LOX service.

Polyester (Mylar) - Excellent resistance to abrasion and grease and oil, low moisture permeability. Sloughing from flexing is somewhat higher than nylon and heat sealing is very difficult.

Aluminum foil - Not generally for use as clean intimate package; clean, oil-free sheets are LOX & LOX impact safe.

MIL - HDBK - 406
31 October 1971

High rate of sloughing produces aluminum particles which are not safe with LOX. Not heat sealable, opaque surface, the surface oxides may abrade precision surfaces and contact with dissimilar metals may promote corrosion. Environmental or intermediate packaging use is desirable because of high resistance to grease, oils, acids, heat, moisture permeability and its nonflammability.

Composite films - Comprised of two or more films in sandwich layer, offers the desirable properties of each film employed. A recent addition to the packaging area is a laminate called Nylo-Flur. Essentially, it is a nylon, Aclar 33C combination. Sandwiched between the layers, where the ink cannot slough off its' printing which identifies which side of the film should be IN or OUT for compatibility with LOX (Aclar IN) or simply particulate protection (Nylon IN). While the laminate may be heat sealed nylon to nylon or Aclar to Aclar, it is impossible to achieve an Aclar to Nylon seal.

6.3.3. Attack by Packaging

Special care must be taken to avoid storing incompatible materials within a compartment or package. Attention should be paid to the following:

Wood - (sometimes used for shelving and boxes) emits harmful gases. Oak, cedar and chestnut are especially bad.

Cushioning materials - often give off sulfurous or acidic vapors, attacking silver, cadmium and other materials.

Paper and cardboard - if not made especially for the packaging of electronic materials may tarnish silver and copper.

Copper, Iron and Manganese - promote the cracking of rubber.

Uncured or partially cured organic materials - outgas, corroding nearby surfaces.

7. DETAIL REQUIREMENTS

MIL - HDBK - 406
31 October 1971

The detail requirements for solvent or cleaning agent selection for specific applications shall be those stated in MIL SPEC ____, Section 5.

7.1. Properties

When selection of a solvent or cleaning agent is necessary, the physical properties of the solvent must be considered to determine applicability. The properties to be considered are: Solvency, toxicity, nonvolatile residue, flammability, boiling range and freezing point, particulate content and the thermal and chemical stability of the agent. Property listings will be taken from MIL-SPEC ____, and all applicable Federal and Military Specifications and Standards.

7.1.1. Solvency

Solvency may be measured by many means but for this handbook and MIL-SPEC ____, a single, known standard shall apply. Solvent manufacturers and users have adopted the Kauri-Butanol (K-B) value as the standard rating of solvency.

Solvency expressed in terms of K-B value is the amount of solvent or cleaning agent which when added to a standard kauri gum solution in butanol, produces a definite turbidity as compared to the amount of benzene used in a similar titration. It is the number of milliliters of solvent which must be added to 20 grams of standard kauri solution at 25° C to produce sufficient precipitate of the gum that a printed sheet of 10 point Century type will appear blurred or illegible when viewed through the flask containing the solution. Generally, 100.0 milliliters of benzene are needed to produce this effect, and the K-B value of benzene is therefore the accepted standard.

The K-B value serves as an index of the relative solvent power of a cleaning agent. The K-B value is not necessarily the best means of judgement, since the value does not indicate what solution will be most effective in all cases. Temperature, time, material and cleaning method must be considered.

7.1.2. Toxicity

A solvent which is ideal in all respects of soil removal, compatibility etc., is valueless if it is sufficiently toxic as to make it use hazardous to the operator.

Exposures to some halogenated hydrocarbons on a repeated basis can result in serious liver and kidney damage. Other halogenated hydrocarbons are capable of only anesthetic effects, but while such effects can result in death after sufficient time has elapsed, removing the person from the fumes will generally result in his complete and rapid recovery.

MIL - HDBK - 406
31 October 1971

The degree of hazard can be minimized by containing the cleaning in a closed system. Ventilation, gas masks, respirators and self contained or remote breathing apparatus may also be employed to limit exposure.

While inhalation of solvent vapors constitutes the major or most common hazard, contact with the solvent itself may result in dermatitis and in some cases, the solvent can be absorbed through the skin. In both cases, damage to the internal organs is possible.

Halogenated solvents cause dermatitis in several ways: They remove the natural skin oils by dissolving them, thus drying the skin; Chlorinated solvents will dissolve the superficial keratin layer and cause red blotches and blisters.

7.1.2.1. Threshold Limit Values (TLV)

The toxic effects of cleaning agents are of major concern to industry, and adherence to proven safety limits can appreciably reduce the dangers from inhalation, and skin contact. The American Conference of Governmental Industrial Hygienists has established threshold limit values (TLV) for determination for the blends. The TLV represents an exposure condition under which it is believed that nearly all workers may be repeatedly exposed from day to day for eight hours without adverse effects.

7.1.3. Non Volatile Residue (NVR).

Particulate and other non volatile residue are of great concern in contamination control. Gross particulates can be detected by visual observation, but smaller matter must be detected by filtration and microscopic examination. NVR is the soluble material and the insoluble particulates remaining after temperature controlled evaporation of a volatile liquid which has been filtered. NVR can be determined by any of the following, as they shall be applicable:

ASTM-NVR-66	MSFC-QUAL-AMC-5	MSFC-SPEC-164
MSFC-PROC-195	MSFC-DWG-10M0167	MSFC-DWG-A10419906
MSFC-PROC-245	ASTM-D-1025052	ASTM-D-1353165

7.1.4. Flammability

The halogenated hydrocarbons do not generally present a fire hazard. The commonly used solvents, trichloroethylene, perchloroethylene, 1,1,1-trichloroethane, trichlorotrifluoroethane, and methylene chloride, do not have flash or fire points.

MIL - HDBK - 406

31 October 1971

There are many other solvents, among them, the ketones, alcohols, esters and petroleum hydrocarbons which present serious fire hazards but are used because specific solvency characteristics or cost factors. Caution must be exercised at the point of use to prevent the ignition of flammable solvents. Exhaust systems help prevent the build-up of explosive vapor concentrations. Sources of flame or very high temperatures in the use area must be eliminated. Electrical equipment must be well grounded to prevent the build-up of static electricity, and adequate fire extinguisherequipment must be maintained and on hand.

The assumption cannot be made that because a solvent has no flash or fire point to begin with, that it will remain free of hazard during use. This is primarily a problem with the solvent blends. Usually, the halogenated solvent is more volatile than the petroleum hydrocarbons in the mixture. As the formulation evaporates during use, the more volatile, non flammable constituent leaves the mixture first and the flammable petroleum solvent increases in concentration. Ultimately, a condition is reached where the remaining solvent has developed a flash point and becomes a fire hazard. See MIL SPEC ____, for a listing of solvent danger points.

7.1.5. Boiling Point

Knowledge of the boiling point of the cleaning agent, allows the user to establish several things:

- The ability of the agent to clean those materials which are heat sensitive.

- The operating temperature of the solvent in a vapor degreasing application.

- The recovery range of the agent through distillation.

7.1.6 Freezing Point

In combination with the boiling point, knowledge of the freezing point permits the determination of the total operating range of the cleaning agent.

7.1.7. Particulate Content

When precision cleaning is performed, the agent must be as free of contaminants as possible. When used on ultra-pure assemblies, the allowable particulate content of the agent is often spelled out within exacting limits. Allowable particulate content shall be determined in accordance with MIL STD 1246 ().

MIL - HDBK - 406

31 October 1971

7.1.8. Stability

Cleaning systems must be monitored continually for contaminants within the system, since some contaminants, in combination with the solvents, can promote corrosion or solvent attack on the materials being cleaned. Some pure solvents will also, in some situations, react with some materials of construction. See MIL SPEC _____ for compatibility comparisons of cleaning agents. All solvents must be monitored carefully for acid and HCl build-up to avoid the problems encountered with solvent degradation. Caution must also be exercised to insure that solvent vapors are not drawn into the ventilation or supply ducts for boilers since the high heat encountered may decompose the solvent into acids which cause severe corrosion, or into toxic gases such as phosgene.

7.1.9. Vapor Pressure

The vapor pressure of the liquid affects the threshold of cavitation in an ultrasonic application as the vapor pressure increases, the threshold decreases. A liquid with low vapor pressure absorbs more of the ultrasonic energy in reaching the threshold and less energy remains to cause the formation of more cavitation bubbles. The cavitation bubbles of a liquid with low vapor pressure will implode with greater force because of the higher internal-external pressure differential. While the more intense implosion may be an aid to scrubbing, the number of cavitation bubbles formed in a liquid with low vapor pressure may be too low to create sufficient scrubbing. The better value here is the middle range of vapor pressure.

7.1.10. Surface Tension

High surface tension will cause cavitation bubbles to collapse faster, creating greater scrubbing force but at the same time, the force required to expand the bubble increases with surface tension. A point may be reached where the surface tension is so great as to absorb all of the ultrasonic energy with an end result being that the bubble would not grow to sufficient size to offer any effective scrubbing force at all. Low surface tension does not require much energy to reach the point of cavitation, but the bubbles may grow too large and implode too softly to scrub the surface sufficiently. The better value in surface tension is the intermediate one, offering maximum effective cavitation.

7.1.11. Viscosity

High viscosity requires a greater force to cause cavitation. Higher viscosity also results in a damping of

MIL - HDBK - 406
31 October 1971

the energy being transmitted through the liquid. Low viscosity is the better value for effective ultrasonic cavitation.

7.1.12. Density

Although more energy is required to expand the cavitation bubble in a liquid with high density, the greater implosion force is desirable. The higher density value is the better one in ultrasonic application.

7.2. Compatibility Considerations

Most conclusions drawn from corrosion research indicate that there are many factors involved in solvent corrosion and that there are means available for inhibiting or stopping the corrosion process. Compatibility testing prior to solvent usage is mandatory and the addition of inhibitors to a solvent must be carefully monitored to insure that the addition does not affect the NVR or particulate levels of the agent. The inhibitors must be monitored to insure that they are not lost through use or reclamation. See MIL SPEC _____, for listings of the corrosion resistance of various materials and the effects on various materials of construction by the solvents.

7.3. Bulk Handling And Storage

Since the properties of the halogenated hydrocarbons are generally very similar, one type of bulk storage facility will likely be satisfactory. The solvent manufacturer should be consulted for specific storage requirements.

7.3.1. The Tank

The generally non corrosive nature of the halogenated hydrocarbons permits the storage of those solvents in mild steel tanks which can be installed either vertically or horizontally. Common construction materials can also be used for storage containers with the exception of aluminum and galvanized materials which can form explosive mixtures with the solvents.

7.3.2. Pipes, Fittings, Gaskets And Hoses

The piping should also be constructed of mild steel with welded or flanged connections. If threaded connections are used, standard pipe dope cannot be employed because it is dissolved by the solvents. Fluorinated elastomer tapes, graphite or glycerin pastes are acceptable.

Since natural and synthetic elastomers are attacked by the solvents, they cannot be used as flexible hoses. Polyvinyl alcohol is resistant to the solvents but must be protected from water. Flexible monel, stainless or mild steel may also be used.

MIL - HDBK - 406
31 October 1971

If rigid piping and swivel joints are used, the seals in the joints must be fluorinated elastomers.

7.3.3. Pumps, Meters, Valves and Gages

Side suction, positive head centrifugal pumps are recommended for solvent use, a deep-well type jet pump may be substituted. The pumps must be closed, solvent type construction.

Meters should be designed for solvent use and be rotary gear type.

Mild steel gate or ball valves with or without nickel or Monel trim can be used for general service. If the application is a high pressure one, a cast steel valve is necessary.

Any standard steel pressure gage is suitable.

7.3.4. Tank Cleaning

Occasionally, it is necessary to clean the storage tank. After the tank has been drained, it may be cleaned with a wire brush, then followed by vacuuming or washing. The tank must be totally dry before replacing the solvent.

MIL - HDBK - 406
31 October 1971

TABLE 7-1
Non Volatile Residue Detection Techniques

Gravimetric - Principle of operation - Weigh a container and evaporate a known quantity of solvent, reweigh the container, the gain is the NVR.

Sensitivity - 0.01 ppm by weight

Time for determination - from .75 to 8 hours

Unit of measurement - Milligrams per volume,
converted to ppm by weight.

Nephelometer- Principle of operation - Solvent is made into an aerosol and sampled by light scattering photometer. When the NVR increases, the rate of evaporation is decreased resulting in larger aerosol droplets producing greater signal output.

Sensitivity - 1 ppm

Time for determination - 5 minutes

Unit of measurement - ppm by weight or volume.

Solvent purity meter- same as nephelometer

Sensitivity - 1 ppm

Time for determination - 1 minute

Unit of measurement - ppm by weight or volume.

Spectrophotometry - Principle of operation - Absorption of electromagnetic radiation.

Sensitivity - 1 ppm optimum

Time for determination - 5 minutes to 1 hour

Unit of measurement - percent transmittance
converted to ppm or actual weight.

Chromatography - Principle of operation - Multitheoretical plate/ Distillation/ Selective adsorption

Sensitivity - 1 ppm

Time for determination - 5 minutes to 1 hour

Unit of measurement - Retention volume and
direct readout are difficult.

MIL - HDBK - 406
31 October 1971

TABLE 7-2
DANGER POINTS OF THE COMMON SOLVENTS

Solvent	Flash Point (°F)	Explosive Upper (%V.V.)	Limits Lower (%V.V.)	Ignition Point (°F)	Threshold Limit Value (ppm)
Acetal	-5	10.4	1.6	446	
Acetaldehyde	-36	55.0	4.1	365	200
Acetone	0	12.8	2.6	1000	1000
Allyl alcohol	70	18.0	2.5	713	5
Amyl acetate	77		1.1	750	200
Amyl alcohol	100		1.2	700	
Amyl chloride	55	8.6	1.6	650	
Benzene	12	7.1	1.4	1000	25
Benzyl acetate	216			862	
Benzyl alcohol	213			817	
Benzyl cellosolve	265			665	
Butyl acetate	72	7.6	1.7	790	200
Iso-butyl acetate	64				
Butyl alcohol	84	11.2	1.4	650	100
Iso-butyl alcohol	82			800	
Sec-butyl alcohol	75			777	
Butyl benzene	160	5.8	0.8	774	
Butyl butyrate	128				
Butyl carbitol	172			442	
Butyl cellosolve	141	10.6	1.1	472	50
Butyl cellosolve acetate	180				
Butyl chloride	20	10.1	1.8	612	
Butyl lactate	160			720	
Butyl propionate	90			800	
Carbitol	201				
Carbitol acetate	225				
Carbon disulfide	-22	44.0	1.2	212	20
Carbon tetrachloride	none	none			25
Cellosolve	104	14.0	1.8	406	200

MIL - HDBK - 406
31 October 1971

TABLE 7-2 (CON'T)

Solvent	Flash Point (°F)	Explosive Upper (% V.V.)	Limits Lower (% V.V.)	Ignition Point (°F)	Threshold Limit Value (ppm)
Cellosolve acetate	124		1.7	715	100
Chlorobenzene	85	7.1	1.3	1100	75
Chloroform	none			none	
Cresol	178		1.1	1100	5
Cyclohexane	1	8.0	1.3	514	400
Cyclohexanol	154				100
Cyclohexanone	147		1.1	847	100
Cyclohexene	-21				400
Diacetone alcohol	148			1118	50
Dichlorobenzene	151	9.2	2.2	1198	50
Dichlorodifluoromethane	none			none	1000
Dichloroethane	56	16.0	6.2	775	100
Methylene chloride (dichloromethane)	none	66.0	15.5	1224	100
Diethyl benzene	132			806	
Diethyl carbonate	77				
Diethyl cellosolve	95			406	
Dimethyl sulfate	182				
Dioxane	54	22.0	2.0	356	100
Dipetene	108				
Diphenyl	235			498	
Dipropylene glycol	244				
Ethyl acetate	24	9.0	2.5	800	400
Ethyl alcohol	55	19.0	4.3	793	1000
Ethyl benzene	59		1.0	870	200
Ethyl bromide	none	11.3	6.7	952	200
Ethyl chloride	-58	15.4	3.8	966	1000

MIL - HDBK - 406
31 October 1971

TABLE 7-2 (CON'T)

Solvent	Flash Point (°F)	Explosive Upper (% V.V.)	Limits Lower (% V.V.)	Ignition Point (°F)	Threshold Limit Value (ppm)
Ethyl cyclohexane		6.6	0.9	504	
Ethylene chlorohydrin	140	15.9	4.9	797	5
Ethylene dichloride	56	16.0	6.2	775	
Ethylene glycol	232		3.2	775	
Ethyl formate	-4	13.5	2.7	1071	100
Ethyl lactate	115		1.5	752	
Gasoline	-45	7.6	1.4	536	500
Glycerin	320			739	
Heptane	25	6.7	1.2	452	500
Iso-heptane	0	6.0	1.0		
Heptene	20				
Hexane	-15	7.5	1.2	500	500
Hexyl acetate	113				
Isophorone	205			864	25
Mesityl oxide	87			652	50
Methyl acetate	14	16.0	3.1	850	200
Methyl alcohol	52	36.0	7.3	876	200
Methyl cellosolve	105	19.8	2.5	551	25
Methyl cellosolve acetate	132	8.2	1.7		25
Methyl cyclohexane	25		1.2		500
Methyl cyclohexanone	118				100
Methyl formate	2	20.0	5.9	840	100
Methyl heptane					
Naptha	0	5.9	1.1	475	500
Nitrobenzene	190		1.8	9009	1
Nitrobutane					
Nitromethane	95			785	100
Paraldehyde	63		1.3	460	

MIL - HDBK - 406
31 October 1971

TABLE 7-2 (CON'T)

Solvent	Flash Point (°F)	Explosive Upper (% V.V.)	Limits Lower (% V.V.)	Ignition Point (°F)	Threshold Limit Value (ppm)
Pentane	-40	7.8	1.5	588	1000
Perchloroethylene	none				200
Propyl acetate	58	8.0	2.0	842	200
Propyl alcohol	59	13.5	2.1	700	
Iso-propyl alcohol	53	12.0	2.0	750	400
Propyl benzene	86				
Propyl chloride	0	11.1	2.6		
Iso-propyl ether	-81	21.0	1.4	830	500
Propylene dichloride	60	14.5	3.4	1035	75
Pyridine	68	12.4	1.8	900	10
Stoddard solvent	100	6.0	1.1	450	500
Tetrachloroethane					5
Toluene	40	6.7	1.4	1026	200
Trichloroethylene	none			770	200
Triethylene glycol	350	9.2	0.9	700	
Turpentine	95		0.8	464	100
Vinyl acetate	18	13.4	2.6	800	
Vinyl chloride	0	22.0	4.0		500
White spirit	80				
Xylene	63	6.0	1.0	900	200

MIL - HDBK - 406
31 October 1971

TABLE 7-3

Effect of solution composition on corrosion of Type 304 and mild steel exposed to uninhibited Trichloroethylene.

RANGE		CORROSION RATE, mils/yr		
PH	Water, ppm	Solution	Vapor	Condensate
Type 304 Steel				
0.5-7.0	< 100	< 1	< 1	< 1
3.0-7.0	> 200	< 1	< 1	2
0.5-2.9	> 200	1	1	> 100
Type 1008 Steel				
0.5-7.5	< 100	< 1	< 1	< 1
0.5-2.9	> 200	1	1	> 1000

TABLE 7-4

Corrosion of Type 304 Steel exposed to boiling Methylene Chloride and 1,1,2 Trichloroethane.

(200 to 600 ppm soluble water)		
	1,1,2 Trichloroethane (mils/yr)	Methylene Chloride (Mils/yr)
pH 3 to 7		
Solution	< 1	< 1
Vapor	1	< 1
Condensate	3	< 1

MIL - HDBK - 406
31 October 1971TABLE 7-4
(CON'T)

pH 3		
Solution	1	1
Vapor	< 1	< 1
Condensate	~ 1000	~ 150

TABLE 7-5

Corrosion of materials exposed to degraded Trichloroethylene

Solution range pH 0.5-2.5
Soluble water 100-200 ppm

Material	Solution Mils/yr	Vapor	Condensate
1008 Steel	1	1	> 1000
304 Annealed	< 1	< 1	> 100
304 Sensitized	4	< 1	> 1000
Hastelloy C	< 1	< 1	40-90
Hastelloy B	< 1	-	2
Nickel 200	-	-	> 100
Monel 400	< 1	-	> 100
Tantalum	-	-	3

TABLE 7-6

Condensate corrosion of Type 304 steel exposed to degraded Trichloroethylene.

(5cc H₂O added to 1500cc solvent)

pH Range	Cup Mils/yr	Condenser Mils/yr
3.5-7	1	2
2-3	50	150
1-1.9	250	600
1	400	> 1000

MIL - HDBK - 406
31 October 1971

TABLE 7-7

Effect of soluble water and acid content on corrosion of Type 304 steel exposed to solutions of chlorinated solvents.

Soluble H ₂ O (ppm)	pH	Corrosion Rates (mils/yr)	Form of attack
100	> 3	< 0.1	none
200-600	3-5	0.1	Pitting
200-600	1-3	1	General
1400	2-3	30	General

MIL - HDBK - 406
31 October 1971

TABLE 7-8

STRESS-CORROSION CRACKING OF TITANIUM IN METHANOL AND OTHER SOLUTIONS

Specimen Origin	Number of Specimens	Notched	Load, ksi	Test Fluid	Time to Failure Min	Remarks
Virgin	1	No	140	Methanol	300	
Virgin	2	No	140	Methanol	63	Aged additional 4 hours @1000 F in air before testing
Virgin	4	Yes	120	Methanol	31	
Virgin	5	Yes	120	Ethylene glycol/H ₂ O	3183	No failures
Virgin	4	Yes	120	H ₂ O/sodium	2880	No failures
Virgin	2	Yes	120	Methanol	44	Aged 30 Min @1000 F before testing
Virgin	1	Yes	130	Methanol	20	
Virgin	5	Yes	140	Methanol	19	
Virgin	8	Yes	140	Ethylene glycol/H ₂ O	3588	No failures
Virgin	1	Yes	140	Isopropyl alcohol	3042	No failures
SC	5	No	90	Methanol	28	
SC	4	No	100	Methanol	33	
SC	4	No	120	Methanol	12	
SC	1	No	120	H ₂ O/sodium chromate	2880	No failures
SC	5	No	140	Methanol	7	
SC	5	No	90	Methanol		
SC	5	No	100	Methanol		
SC	10	No	120	Methanol		
SC	2	No	120	Air		
SC	1	No	130	Methanol		
SC	5	No	140	Methanol		
SC	3	Yes	120	Methanol		
SC	3	Yes	120	Aerozine-50		Specimens loaded for 2 weeks with no failure
SC	2	Yes	120	Distilled H ₂ O	2565	No failures

Note: Several specimens were exposed to methanol for extended periods at stress levels below 100 ksi without failure. Due to the hygroscopic nature of the methanol, there were various amounts of water diluted with the methanol and this undoubtedly influenced the time to failure. These results have not been included in the chart.

SC-Spacecraft.

MIL - HDBK - 406
31 October 1971

TABLE 7-9

SMOOTH SPECIMEN TESTS IN ORGANIC LIQUIDS

Alloy	<u>Environments</u>				
	Methanol + NaCl + NaCl (sat) + 2% H ₂ O	Methanol	Abs. Ethyl Alcohol	Methanol + 1% Glycerine Alcohol	n-Hexane
T1-8A1-1Mo-1V (135 YS)	B (160, 3min)	NB (116, 83min)	NB (99, 20hr)	NB (99, 0.7hr)	NB (123, 69hr)
	B (145, 7min)			NB (107, 26hr)	
	B (116, 45min)	B (115, 5hr)		NB (115, 1.5hr)	
T1-8A1-1Mo-1V (123 YS)			NB (67, 2.7hr)		NB (100, 30hr)
			NB (125, 160hr)		B (YS, 1min)
T1-6A1-4V (135 YS)	B (weld) (74, 2.3hr)	NB (70, 6hr)		NB (109, 1hr)	
	B (base) (100, 2.4hr)	B (83, 3hr)			
		NB (67, 1.5hr)			
		B (79, 1.5hr)			
		B (109, 37hr)			
		B (138, 5hr)		B (138, 10hr)	

NOTE. YS=Yield Strength. B=Break. NB= No Brake. Values in parenthesis.

TABLE 7-10

Liquid	EXPECTED TIME TO FAILURE IN HOURS ^a							
	Ti-8-1-1 Mill annealed 140 YS	Ti-8-1-1 Heat Age	Ti-5-2.5 Annealed 125 YS	Ti-6-4 Annealed 130 YS	Ti-6-4 ST 145 YS	Ti-4-3-1 Annealed 120 TS	Ti-6-4 STA 145 YS	Ti-75A 70 YS
Methanol, anhydrous	0.8	0.4 0.36 ^f 0.169	1.6	4.9 4.0 ^c	9.4	10	15.8	60
Ethanol, anhydrous	^d		29.4 ^b					
Methanol with 5200 ppm H ₂ O + 2500 ppm HCl	24-45 ^e							
Ethylene Glycol		0.4 ^{f/h}						

NOTES:

(a) Metal surfaces etch cleaned in HNO₃ HF except as noted.

(b) For one specimen, another specimen did not fail.

(c) As-received surface.

(d) For one specimen, somewhat greater for another.

(e) Failure times for two specimens. In methanol with 9700 ppm H₂O, 5000 ppm HCl, two other specimens did not fail.

(f) Transverse specimens, acid cleaned and heat aged.

(g) Transverse specimens, as-received surface, heat aged.

(h) Three of nine specimens cracked.

MIL - HDBK - 406
31 October 1971

TABLE 7-11

RESULTS OBTAINED WITH UNALLOYED
(A55) U-BEND SPECIMENS

Environment	Time to failure
DMSO + 1% LiCl	N.F.
DMSO + 3% LiCl	N.F.
DMSO + 10% LiCl	N.F.
DMSO + 0.43% HCl + 0.73% H ₂ O	N.F.
DMSO + 73.23% CH ₃ OH + 0.55% HCl + 94% H ₂ O	22 hours
DMSO + 41.44% CH ₃ OH + 0.48% HCl + 0.84% H ₂ O	1 day
DMSO + 15.13% CH ₃ OH + 0.45% HCl + 0.78% H ₂ O	28 days
DMSO + 0.76% CH ₃ OH + 0.43% HCl + 0.73% H ₂ O	N.F.

NOTE: N.F. = No failure after 6 months of exposure.
DMSO = Dimethyl Sulfoxide.

RESULTS OBTAINED WITH ELI
Ti-5Al-2.5Sn ALLOY U-BEND SPECIMENS

Environment	Time to failure
CH ₃ OH (reagent grade 99.9 mol% pure)	8 days
CH ₃ OH (reagent grade, dried with CaO powder)	4 days
CH ₃ OH (reagent grade, redistilled)	2 days
CH ₃ OH vapor - dry air mixture	1 day

RESULTS OBTAINED WITH BINARY Ti-Al ALLOY
U-BEND SPECIMENS

Environment	Alloy	Time to failure
CH ₃ OH + 0.59% HCl + 1.01% H ₂ O	Ti	F. ^a
	Ti-2%Al	F. ^a
	Ti-5%Al	4 days
	Ti-7.5%Al	2 hours
CH ₃ OH + 0.35% Br ₂	Ti	3 days
	Ti-2%Al	3 days
	Ti-5%Al	2 hours
	Ti-7.5%Al	30 min.
CH ₃ OH + 1.25% I ₂	Ti	F. ^a
	Ti-2%Al	F. ^a
	Ti-5%Al	30 min.
	Ti-7.5%Al	20 min.
CH ₃ OH + 0.12% I ₂	Ti	2 weeks
	Ti-2%Al	2 weeks
	Ti-5%Al	2 hours
	Ti-7.5%Al	2 hours

NOTE: (a) Failed by intergranular corrosion after 1 month exposure.

MIL - HDBK - 406
31 October 1971

TABLE 7-12

RESULTS OBTAINED WITH UNALLOYED
(A55) U-BEND SPECIMENS

Environment	Time to failure
CH ₃ OH (reagent grade)	N.F.
H ₂ O (distilled)	N.F.
H ₂ O (distilled) + 0.59% HCl	N.F.
CH ₃ OH + 0.59% HCl + 1.01% H ₂ O	2 hours
CH ₃ OH + 0.59% HCl + 1.14% H ₂ O	6 days
CH ₃ OH + 0.59% HCl + 1.45% H ₂ O	N.F.
CH ₃ OH + 0.45% H ₂ SO ₄ + 0.001% H ₂ O	7 days
CH ₃ OH + 0.55% HCl + 0.94% H ₂ O	1 hour
CH ₃ OH + 1.10% HCl + 1.88% H ₂ O	2 days
CH ₃ OH + 1.65% HCl + 2.28% H ₂ O	N.F.

NOTE: N.F. = No failure after six months of exposure.

RESULTS OBTAINED WITH ELI
Ti-5Al-2.5Sn ALLOY U-BEND SPECIMEN

Environment	Time to failure
CH ₃ OH + 0.59% HCl + 1.01% H ₂ O	1 day
CH ₃ OH + 0.35% Br ₂ ^a	30 min.
CH ₃ OH + 3.5% Br ₂ ^a	5 hours
CH ₃ OH + 0.012% I ₂ ^a	2 days
CH ₃ OH + 1.35% I ₂ ^a	5 hours
CH ₃ OH + 0.074% NaCl	2 days
CH ₃ OH + 0.75% HF + 0.75% H ₂ O	N.F. (2 months)
CH ₃ OH + 0.129% NaBr	2 days
CH ₃ OH + 0.188% NaI	7 days
CH ₃ OH + 0.053% NaF	2 weeks ^b

NOTE: N.F. = No failure

(a) Bromine and iodine added as purified liquid and solid respectively.

(b) Surface cracking only.

TABLE 7 - 13
INFLUENCE OF ENVIRONMENTS ON TITANIUM ALLOY STRESS INTENSITIES REQUIRED FOR CRACKING

Environment	Ti-6Al-4V			Ti-13V-11Cr-3Al			Ti-8Al-1Mo-1V			Ti-8Al-1Mo-1V			Ti-5Al-2.5Sn		
	Solution treated and aged			Solution treated and aged			Mill annealed			Mill annealed			Mill anneal		
	Fail Value K, min	No fail Value K, min	Fail Value K, min	Fail Value K, min	No fail Value K, min	No fail Value K, min	Fail Value K, min	No fail Value K, min	Fail Value K, min	Fail Value K, min	No fail Value K, min	Fail Value K, min	Fail Value K, min	No fail Value K, min	Fail Value K, min
Air-room temperature	51,0.3	48,15	66,1.3	37,0.5	--	42,1.5	82,2	78,15	77,0.8	73,5	54,0.3	49,10	54,0.3	49,10	54,0.3
Distilled H ₂ O room temp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0.05 wt% NaCl in distilled H ₂ O Room temp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0.1 wt% NaCl in distilled H ₂ O room temp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
3.5 wt% NaCl in distilled H ₂ O room temp.	49,0.3	46,15	--	--	--	27,2.3	32,15	--	31,1.5	28,15	--	--	31,1.5	28,15	--
Trichloroethylene	54,0.4	49,25	56,5	--	--	23,15.3	--	32,2.8	51,15	31,8.5	28,15	--	--	--	--
Trifluoroethylene	52,2	48,10	--	38,1.5	31,10	--	--	--	--	--	--	--	34,2.3	--	--
boiling point	52,0.5	--	--	34,4	31,15	--	--	--	--	--	--	--	30,3	--	--
Trifluoroethylene	--	--	--	--	--	--	--	--	--	--	--	--	36,2.3	--	--
boiling point	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
sample loaded in air	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Trichloroethylene	--	--	25,3.2	--	--	--	--	26	1.7	22,15	--	24,2.8	22,15	--	--
methane, room temp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

TABLE 7-14
EFFECTS OF ORGANIC SOLVENTS AND SODIUM CHLORIDE
ON STRESSED TITANIUM U-BENDS

FLUID APPLIED	EXPOSURE ENVIRONMENT					
	EXPOSED		EXPOSED		EXPOSED	
	EXPOSED TO LIQUID FOR 24 HOURS	EXPOSED TO LIQUID DRIED & HEATED TO 700° F	EXPOSED TO LIQUID DRIED & HEATED TO 1450° F	EXPOSED TO 1 ATMOSPHERE VAPORS @ 700° F FOR 100 HOURS	EXPOSED TO 1 ATMOSPHERE VAPORS @ 1450° F FOR 8 HOURS	NOT CRACKED
	NOT CRACKED	NOT CRACKED	NOT CRACKED	NOT CRACKED	NOT CRACKED	NOT CRACKED
Trifluorotrichloroethane	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4
Trichlorofluoromethane	1,2,3,4				1,2,3,4	
Trifluorotrichloroethane/ methylene chloride azeotrope	1,2,3,4					1,2,3,4
Trifluorotrichloroethane/ acetone azeotrope	1,2,3,4					1,2,3,4
Trifluorotrichloroethane/ water/detergent solvent formulation	1,2,3,4					
Inhibited vapor-degreasing grade trichloroethylene	1,2,3,4			1,2	3,4	
Inhibited white-room-grade methyl chloroform 40 PPM aqueous Cl ⁻ 400 PPM aqueous Cl ⁻ 4000 PPM aqueous Cl ⁻	1,2,3,4 1,2,3,4 1,2,3,4 1,2,3,4	2,3 1,2,3 3 4	2,3 1,2,3,4 1,2,3,4 1,2,3,4	2,3 1,2,3,4 1,2,3,4 1,2,3	1,2,3,4 1,2,3,4 1,2,3,4 1,2,3	
Methyl alcohol, reagent grade						1,2,3

NOTE: Alloys and heat treatments;

- (1) Ti-5Al-2.5Sn, mill annealed
- (2) Ti-8Al-1Mo-1V, Mill annealed
- (3) Ti-6Al-4V, solution treated and aged
- (4) Ti-13V-11Cr-3Al, solution treated and aged

MIL - HDBK - 406
31 October 1971

TABLE 7-15
CHEMICAL RESISTANCE OF PLASTICS & METALS

Rating: A - No Effect - Excellent

B - Minor Effect - Good

C - Moderate Effect - Fair

D - Severe Effect - Not Recommended

Plastics: 1 - Epoxy
or metal

2 - Polypropylene

3 - PVC

4 - Nylon

5 - Stainless 316

6 - Stainless 304

7 - Titanium

8 - Buna N

9 - Viton

Media

1 2 3 4 5 6 7 8 9

Acetaldehyde	A	A	D	A	A	A	A	D	A
Acetamide	A	-	-	-	A	B	-	C	A
Acetate Solvent	A	D	-	A	A	B	-	D	-
Acetic Acid, Glacial	-	A	D	A	A	B	B	D	D
Acetic Acid	A	A	A	D	A	B	B	C	C
Acetic Anhydride	A	-	D	A	A	A	B	C	C
Acetone	A	A	D	A	A	A	A	D	D
Acetylene	A	D	-	A	A	A	-	A	A
Alcohols									
Amyl	A	B	A	A	A	A	-	A	A
Benzyl	A	A	-	A	A	A	-	D	A
Butyl	A	B	A	A	A	A	-	A	A
Diacetone	A	D	-	A	A	A	-	A	A
Ethyl	A	A	A	A	A	A	A	A	A
Hexyl	A	-	-	A	A	A	-	A	A
Isobutyl	A	-	-	A	A	A	-	C	A
Isopropyl	A	A	-	A	A	A	-	C	A
Methyl	A	A	A	A	A	A	B	A	A
Octyl	A	-	-	A	A	A	-	A	A
Propyl	A	A	A	A	A	A	-	A	A
Aluminum Chloride 20%	A	A	A	A	C	D	B	A	A
Aluminum Flouride	A	A	A	A	C	-	A	A	-
Alum	A	A	A	-	A	-	-	A	A
Aluminum Sulfate	A	A	A	A	C	C	A	A	A
Amines	A	-	C	A	A	A	B	B	D
Ammonia, Anhydrous	A	A	A	A	A	B	B	B	D
Ammonia Liquids	A	A	A	-	A	A	-	B	A

MIL - HDBK - 406
31 October 1971TABLE 7-15
(CON'T)

Media	1	2	3	4	5	6	7	8	9
Ammonia, Nitrate	A	A	-	-	A	A	-	C	-
Ammonium Chloride	A	A	A	A	A	A	A	B	A
Ammonium Hydroxide	A	A	A	A	A	A	A	B	B
Ammonium Nitrate	A	A	A	A	A	A	A	A	B
Ammonium Sulfate	A	A	A	A	B	B	A	A	A
Amy Acetate	A	D	D	A	A	A	-	D	D
Aromatic Hydrocarbons	A	-	D	-	A	-	-	D	A
Arsenic Acid	A	-	A	A	A	-	-	A	A
Barium Chloride	A	A	A	A	A	A	A	A	A
Barium Cyanide	-	-	-	-	A	-	-	C	-
Barium Hydroxide	A	A	A	A	A	-	B	A	A
Barium Nitrate	A	-	-	-	A	-	A	A	-
Benzaldehyde	A	D	D	C	A	-	-	D	C
Benzene	A	D	D	A	A	A	A	D	A
Benzoic Acid	A	D	A	D	A	A	A	-	-
Benzol	A	A	-	A	A	-	-	D	A
Boric Acid	A	A	A	A	C	C	A	A	A
Bromine	D	D	C	D	D	D	A	D	A
Butadiene	A	-	A	-	A	A	-	A	A
Butane	A	D	D	A	A	A	-	B	A
Butyl Acetate	A	D	D	-	C	-	-	D	D
Calcium Carbonate	A	A	A	A	A	-	A	A	-
Calcium Chloride	A	A	A	A	A	A	A	A	A
Calcium Hydroxide	A	A	A	A	A	A	A	B	A
Calcium Hypochlorite	A	A	A	D	C	D	A	B	-
Calcium Sulfate	A	-	A	A	A	A	-	B	A
Carbon Dioxide	A	A	A	A	A	A	A	A	A
Carbon Disulfide	D	D	D	A	A	A	-	D	A
Carbon Monoxide	A	-	A	A	A	A	-	A	A
Carbon Tetrachloride	A	D	D	A	B	D	A	D	A
Chlorine, Anhydrous Liquid	C	D	D	D	D	D	B	C	A
Chlorobenzene	A	D	D	-	A	A	-	D	C
Chloroform	A	D	D	A	A	A	A	D	A
Chromic Acid 5%	B	A	A	D	A	A	A	D	A
Chromic Acid 50%	C	A	D	D	B	B	A	D	A
Copper Chloride	A	A	A	A	D	D	A	A	A
Copper Cyanide	A	A	A	A	A	-	-	A	A
Copper Nitrate	A	-	A	A	A	A	A	A	A
Copper Sulfate 5% solution	A	A	A	D	A	A	A	A	A
Cyclohexane	A	D	-	-	A	-	A	B	A
Diethylamine	A	-	D	-	A	-	-	B	A
Diethylene Glycol	A	-	-	A	A	-	-	A	-
Diphenyl Oxide	A	-	-	-	A	-	-	-	A
Ethane	A	-	-	-	A	-	-	A	A

MIL - HDBK - 406
31 October 1971

TABLE 7-15
(CON'T)

Media	1	2	3	4	5	6	7	8	9
Ethanolamine	A	-	-	-	A	A	-	A	A
Ether	A	D	D	C	A	A	-	D	D
Ethyl Acetate	A	D	D	A	A	-	-	D	D
Ethyl Chloride	A	D	D	A	A	A	-	B	A
Ethyl Sulfate	A	-	-	-	D	-	-	A	-
Ethylene Chloride	A	D	-	-	A	A	B	D	A
Ethylene Dichloride	A	A	D	A	A	A	B	D	A
Ethylene Glycol	A	D	A	A	A	A	-	A	A
Ethylene Oxide	A	-	D	A	-	A	-	D	D
Ferric Chloride	A	A	A	D	D	D	A	A	A
Ferric Nitrate	A	A	A	-	A	A	-	A	A
Fluoboric Acid	A	-	A	-	C	D	D	B	-
Fluosilic Acid	A	-	A	-	A	-	-	A	-
Formaldehyde	A	A	A	-	A	A	B	C	A
Formic Acid	-	A	D	D	B	C	C	C	B
Freon 11	A	-	D	A	C	-	-	C	C
Freon 12 wet	A	A	D	A	D	-	-	C	B
Freon 22	A	-	D	A	C	-	-	D	D
Freon 113	A	-	-	A	-	-	-	C	C
Freon TF (trichlorotrifluoroethane)	A	D	B	A	A	-	-	A	A
Heptane	A	D	A	-	A	-	-	A	A
Hexane	A	D	D	-	A	A	-	A	A
Hydrazine	A	-	-	-	A	A	-	-	A
Hydrochloric Acid (20%)	A	C	A	D	D	D	C	B	A
Hydrochloric Acid (37%)	A	C	A	D	D	D	C	A	A
Hydrofluoric Acid (20%)	A	A	D	D	D	D	D	C	A
Hydrogen Peroxide	C	A	A	A	C	C	B	A	A
Hydrogen Sulfide Aqueous Solution	A	A	A	A	C	B	A	B	A
Isopropyl Acetate	A	-	-	-	-	-	-	D	-
Isopropyl Ether	-	D	-	-	A	-	-	A	-
Jet Fuel (FP3, JP 4 & JP5)	A	-	A	A	A	-	-	B	A
Ketones	C	A	D	A	A	A	-	D	D
Lead Acetate	A	A	A	-	B	B	A	A	-
Magnesium Carbonate	A	A	A	-	-	-	-	A	-
Magnesium Chloride	A	A	A	A	B	B	A	A	A
Magnesium Hydroxide	A	A	A	A	A	A	A	A	A
Magnesium Nitrate	A	A	A	-	A	A	-	A	-
Magnesium Oxide	A	-	-	-	A	A	-	A	-
Magnesium Sulfate	A	A	A	A	B	B	A	A	A
Methyl Acetate	-	-	-	-	A	-	-	D	D
Methyl Acrylate	A	-	-	-	-	-	-	D	D
Methyl Acetone	C	-	-	-	A	-	-	D	-
Methyl Butyl Ketone	B	-	-	-	A	-	-	D	D
Methyl Cellosolve	C	-	-	-	-	-	-	A	-

MIL - HDBK - 406
31 October 1971TABLE 7-15
(CON'T)

Media	1	2	3	4	5	6	7	8	9
Methyl Chloride	A	-	D	A	A	A	-	C	A
Methyl Dichloride	A	-	-	-	-	-	-	-	A
Methyl Ethyl Ketone	C	A	D	A	A	A	-	D	A
Methyl Isobutyl Ketone	C	D	D	A	A	-	-	D	D
Methyl Isopropyl Ketone	C	-	-	A	A	-	-	D	D
Methyl Methacrylate	A	-	-	-	-	-	-	D	D
Methylene Chloride	A	D	D	-	A	A	-	D	A
Nitric Acid 5-10% solution	A	A	A	A	A	A	A	D	A
Nitric Acid 20% solution	B	A	A	A	A	A	A	D	A
Nitric Acid 50% solution	D	D	A	A	B	B	A	D	A
Nitric Acid, Concentrated Solution	D	D	D	A	D	D	A	D	D
Pentane	A	-	-	-	C	C	-	A	A
Perchloroethylene	A	D	-	-	A	-	-	D	A
Phenol	C	A	A	D	A	A	B	D	A
Phosphoric Acid to 40% solution	A	A	A	D	A	B	B	C	A
Phosphoric Acid 40-100% solution	A	A	A	C	B	C	C	C	A
Potassium Chlorate	A	A	A	D	A	A	-	A	A
Potassium Chloride	A	A	A	A	A	A	A	A	A
Potassium Dichromate	C	A	A	-	A	A	A	-	A
Potassium Nitrate	A	-	A	-	A	A	-	A	A
Propane	A	D	D	A	A	A	-	A	-
Propylene Glycol	A	-	-	-	A	B	-	A	A
Silicone	A	A	-	A	A	B	-	A	A
Sodium Chloride	A	A	A	A	A	A	A	A	A
Sodium Nitrate	A	A	A	A	A	A	A	C	-
Stoddard Solvent	A	D	A	A	A	A	-	B	A
Styrene	A	-	-	-	A	A	-	D	B
Sulfuric Acid (to 10%)	A	A	A	D	C	D	A	C	A
Sulfuric Acid (10-75%)	C	D	A	D	D	D	D	D	A
Tetrachloroethane	A	A	-	-	A	-	A	D	A
Toluene	A	D	D	A	A	A	-	D	A
Trichloroethane	A	-	-	-	A	-	-	D	A
Trichloroethylene	A	D	D	A	A	C	B	D	A
Turpentine	A	D	A	A	A	A	-	A	A
Water, distilled	A	A	A	A	A	A	-	A	A
Water, Fresh	A	A	A	A	A	A	-	A	A
Water, Salt	A	A	A	A	A	A	-	A	A
Xylene	A	D	D	A	A	A	-	D	A
Zinc Chloride	A	A	A	A	B	B	A	C	A
Zinc Sulfate	A	A	A	A	B	B	A	A	A

Condensed from United States Plastics Corp.

MIL - HDBK - 406
31 October 1971

TABLE 7-16
CORROSION RESISTANCE OF VARIOUS METALS

Rating: E - Excellent
G - Good
F - Fair
N - No Good

Metals: 1 - Brass and Naval Bronze
2 - Silicone Bronze
3 - Monel
4 - Stainless types 410, 416, and 430
5 - Stainless types 302, 303, 304, and 305
6 - Stainless type 316
7 - Copper
8 - Aluminum

Media	Metal							
	1	2	3	4	5	6	7	8
Acetate Solvents, Crude	F	G	G	G	E	F	G	F
Acetate Solvents, Pure	E	E	E	E	E	E	E	E
Acetic Acid, Crude	F	G	G	N	G	E	G	G
Acetic Acid, Pure	F	G	G	N	G	E	G	E
Acetic, Anhydride	N	G	G	N	G	E	G	E
Acetone	E	E	E	E	E	E	E	E
Acetylene		N	G	E	E	E	N	E
Alcohols	G	E	E	E	E	E	E	G
Ammonium Chloride	F	G	E	F	F	E	G	N
Ammonium Hydroxide	N	N	F	E	E	E	N	G
Ammonium Nitrate	N	F	F	E	E	E	F	F
Benzene	E	E	E	E	E	E	E	E
Benzine	E	E	E	E	E	E	E	E
Butane	E	E	E	E	E	E	E	E
Carbon Dioxide (dry)	E	E	E	E	E	E	E	E
Carbon Dioxide (wet)	F	G	G	E	E	E	G	E
Carbon Tetrachloride	E	E	E	E	E	E	E	G
Chlorine (dry)	G	G	E	G	G	G	G	N
Chlorine (wet)	N	F	F	N	N	F	F	N
Ethers	E	E	E	E	E	E	E	E
Ethylene Glycol	G	E	E	E	E	E	E	G
Ferric Chloride	N	N	N	N	N	N	N	N
Formaldehyde	G	G	E	E	E	E	G	G
Formic Acid	F	G	G	N	G	E	G	N
Freon	E	E	E	E	E	E	E	G
Hydrochloric Acid	N	F	F	N	N	N	F	N
Hydrofluoric Acid	N	F	E	N	N	N	F	N
Hydrogen	E	E	E	E	E	E	E	E
Hydrogen Peroxide	N	F	G	E	E	E	F	G
Hydrogen Sulfide	F	N	F	G	E	E	N	E

MIL - HDBK - 406
31 October 1971TABLE 7-16
(CON'T)

Media	Metal							
	1	2	3	4	5	6	7	8
Magnesium Chloride	F	G	E	F	G	E	G	N
Magnesium Hydroxide	G	E	E	E	E	E	E	F
Magnesium Sulfate	G	E	E	E	E	E	E	G
Mercuric Chloride	N	N	N	N	N	F	N	N
Mercury	N	N	G	E	E	E	N	N
Nickel Chloride	N	F	G	N	F	G	F	N
Nitric Acid	N	N	N	G	G	G	N	F
Oleic Acid	F	G	E	G	G	E	G	E
Oxalic Acid	F	G	E	F	G	E	G	N
Oxygen	E	E	E	E	E	E	E	E
Phosphoric Acid 25%	N	G	G	N	F	E	G	N
Phosphoric Acid 50-80%	N	G	G	N	N	G	G	E
Potassium Chloride	F	G	E	F	G	E	G	N
Potassium Hydroxide	N	F	E	E	E	E	F	N
Potassium Sulfate	G	E	E	E	E	E	E	E
Propane	E	E	E	E	E	E	E	E
Sodium Hydroxide	N	F	E	E	E	E	F	N
Sodium Hypochlorite	N	F	F	N	F	G	F	N
Sodium Nitrate	F	G	E	E	E	E	G	E
Sodium Peroxide	F	G	E	E	E	E	G	F
Sulfur	F	F	F	E	E	E	F	F
Sulfur Dioxide (dry)	F	E	E	E	E	E	E	G
Sulfur Dioxide (wet)	N	G	N	N	G	E	G	F
Sulfuric Acid 10%	N	G	G	N	N	G	G	N
Sulfuric Acid 10-75%	N	F	G	N	N	N	F	N
Sulfuric Acid 75-95%	N	F	F	F	F	G	F	N
Sulfurous Acid	N	G	N	N	F	G	G	N
Toluene	E	E	E	E	E	E	E	E
Trichloroethylene	E	E	E	E	E	E	E	E
Turpentine	F	E	E	G	E	E	E	E
Water, Fresh	F	G	E	E	E	E	G	E
Water, Salt	F	G	E	F	G	G	G	G
Xylene	E	E	E	E	E	E	E	E
Zinc Chloride	N	G	E	N	N	G	G	N
Zinc Sulfate	F	G	E	F	G	E	G	G

Condensed from Harper, H.M. Co., Corrosion Guide, Tech. Bul., No. 101.

MIL - HDBK - 406
31 October 1971

TABLE 7 -17
TITANIUM CORROSION RESISTANCE

These media cause a corrosion rate of less than 5 Mils per year when in contact with titanium.

Solutions are not aerated unless otherwise specified.

Corrodent	Conc. by Wt. %	Temp. °F
Acetic Acid	5, 25, 50, 75, 99.5	Boiling
Acetic Anhydride	99	Room
Aluminum Chloride	5, 10	212
Aluminum Chloride	25	140
Aluminum Sulfate 25 g/l (+H ₂ SO ₄ , 25g/l)		160
Ammonia, Anhydrous, 200psi	100	104
Ammonium Chloride	1, 10 (Saturated)	212
Ammonium Hydroxide	28	Room
Ammonium Sulfate	3.2	105
Aniline Hydrochloride	5, 20	212
Aqua Regia (1HNO ₃ -3 HCL)		140
Barium Chloride	5, 20	212
Bromine Vapor		86
Calcium Bisulfite		80
Calcium Chloride	5, 10, 25, 28	212
Calcium Chloride	70	Boiling
Calcium Hypochlorite	2, 6	212
Carbon Tetrachloride (1% H ₂ O)		Boiling
Chlorine Saturated Water		165
Chloroacetic Acid	30	175
Chloroacetic Acid	100	Boiling
Chromic Acid	10	Boiling
Chromic Acid	36.5	195
Citric Acid, Aerated	10, 25, 50	212
Cupric Chloride	1, 20	212
Cupric Chloride	40, 55	Boiling
Dichloroacetic Acid	100	Boiling
Ethyl Alcohol	95	Boiling
Ethylene Dichloride	100	Boiling
Ferric Chloride	1, 30	212
Ferric Chloride	10, 50	Boiling
Formaldehyde	37	Boiling
Formic Acid, Aerated	10, 25, 50, 90	212
Formic Acid, Nonaerated	10	Boiling

MIL - HDBK - 406
31 October 1971

TABLE 7 -17 (CON'T)

Corrodent	Conc. by wt. %	Temp°F
Hydrochloric Acid	1	160
Hydrochloric Acid	1	Boiling
Hydrochloric Acid	3, 5	Room
Hydrochloric Acid (200 mgCu++/l)	37	Room
Hydrochloric/Nitric Acid Mixture	1:3	Room
Hydrochloric/Nitric Acid Mixture	2:1	Room
Hydrochloric/Nitric Acid Mixture	3:1	Room
Hydrochloric/Nitric Acid Mixture	4:1	Room
Hydrochloric/Nitric Acid Mixture	7:1	Room
Hydrochloric/Nitric Acid Mixture	20:1	Room
Hydrogen Peroxide	3, 6, 30	Room
Hydrogen Sulfide (Saturated H ₂ O)		70
Lactic Acid, Aerated	10, 25, 50, 85	212
Lactic Acid, Nonaerated	10, 25, 50, 85, 100	Boiling
Magnesium Chloride	5, 20, 40	Boiling
Magnesium Dichloride	5, 20	212
Mercuric Chloride	Saturated	212
Nickel Chloride	20	212
Nitric Acid	10, 20, 30, 40, 50, 60	212
Nitric Acid, Red Fuming*		Room
Nitric Acid, White Fuming	98	Room
Oxalic Acid, Aerated	0.5, 5, 10	95
Phosphoric Acid	5, 10, 20, 30	95
Potassium Chloride	36	Boiling
Potassium Hydroxide	10	Boiling
Sea Water, Kure Beach		Ambient
Sebastia Acid (Crude C ₁₀ Dibastic Acids)		465
Selenious Acid 100/1 (+H ₂ SO ₄ , 200 g/l)		75
Sodium Carbonate	20.0	Boiling
Sodium Chloride	Saturated	Boiling
Sodium Hydroxide	10	Boiling
Sodium Hydroxide	28	Room
Sodium Hypochlorite	0.5	212
Sodium Hypochlorite (5.6% Cl ₂)		Room
Sodium Sulfide	10	Boiling
Stannic Chloride	24	212
Stearic Acid	100	355
Sulfur, Molten	100	465
Sulfur, Water suspended		Room
Sulfur Dioxide, Water Saturated		Room

MIL - HDBK - 406
31 October 1971

TABLE 7-17 (CON'T)

Corrodent	Conc. by wt. %	Temp °F
Sulfuric Acid	5	95
Sulfuric Acid (0.05% CuSO ₄)	65.0	212
Sulfuric/Nitric Acid Mixture	10:90	95
Sulfuric/Nitric Acid Mixture	30:70	95
Sulfuric/Nitric Acid Mixture	50:50	95
Sulfuric/Nitric Acid Mixture	60:40	95
Sulfurous Acid	6	Room
Tannic Acid	25	212
Tartaric Acid	10, 25, 30	212
Water, Distilled, at 1235 psf		572
Zinc Chloride	5, 10, 20	Boiling

****Caution** - Anhydrous red fuming nitric acid has been known to cause explosions with titanium. Simulated service tests using suitable precautionary measures, should be made for titanium or its alloys are recommended for use in specific applications in contact with red fuming nitric acid. This is particularly important if the water content of the FNA is below 2 percent by weight.

TABLE 7-18

MIL - HDBK - 406

31 October 1971

CORROSION RESISTANCE OF STAINLESS
STEEL TYPES 430 302 & 316

- Key 1. Satisfactory for use in media indicated
 2. Slight to moderate attack; deserving of consideration for some uses
 3. Corrosive attack generally too high for consideration

Corrodent	Conc. %	Temp. °F	430	302	316
Acetic Acid					
Aerated	5-10	180	1	1	1
	20	180	2	1	1
	80	70	2	1	1
	80	Boiling	3	2	1
Acetic Anhydride	90	70	2	1	1
	90	Boiling	3	3	1
	60	180	-	1	1
	30	180	-	3	1
Acetone		Boiling	1	1	1
Acetylene		70	1	1	1
Ethyl Alcohol (Ethanol)		70-Boiling	1	1	1
Methyl Alcohol (Methanol)		70	1	1	1
		150	1	1	1
Alum (Potassium Aluminum Sulfate	2 and 10	70	2	1	1
	2 and 10	Boiling	3	1	1
	Sat	70-212	2	1	1
Aluminum Acetate	Sat	70	-	1	1
Aluminum Chloride	10-and 25	70	3	3	2
Alum (chrome)	5	70	-	1	1
Aluminum Hydroxide			1	1	1
Aluminum		Molten	3	3	3
Aluminum Sulfate	10 and Saturated	70-212	3	1	1
Ammonia	any conc	70-212	1	1	1
	anhydrous	70	1	1	1
	gas	to 600	1	1	1
Ammonium Bicarbonate		70 and hot	-	1	1
Ammonium Carbonate	1 and 5				
	still	70	1	1	1
	Aerated				
	or				
	Agitated	70	1	1	1
Ammonium Chloride	10	70	2	-	1
	20	70	-	1	1

MIL - HDBK - 406
31 October 1971

TABLE 7-18 (CON'T)

Corrodent	Conc. %	Temp. °F	430	302	316
Ammonium Nitrate	All				
	Agitated	70	1	1	1
Ammonium Oxalate	5	70	1	1	1
Ammonium Persulfate	5	70	1	1	1
Ammonium Sulfate	1 and 5				
	Agitated				
	and				
	Aerated	70	1	1	1
	10	68	2	2	1
	Saturated	Boiling	-	3	1
Ammonium Sulfite		Cold			
		and			
		Boiling	-	2	1
Aniline	3, conc				
	Crude	70	1	1	1
Aniline Hydrochloride		60	3	3	3
Amyl Acetate	Anhydrous	70	1	1	1
Amyl Chloride	Anhydrous	70	2	1	1
Arsenic Acid		150	-	1	1
		225	-	2	-
Arsenious Acid			2	1	1
Barium Carbonate		70	1	1	1
Barium Chloride	5 or Sat				
	Aqueous				
	Solution	Hot	-	1	1
Barium Nitrate	Aqueous				
	Solution	Hot	-	1	1
Barium Sulfate		70	1	1	1
Barium Sulfide	Saturated	70	1	1	1
Beer		70	-	1	1
Benzene		70	1	1	1
Benzoic Acid		70	1	1	1
Borax	5	Hot	1	1	1
Bordeaux Mixture			-	1	1
Boric Acid	5	Hot	1	1	1
	Saturated	Boiling	2	1	1
Bromine and					
Bromine Water		70	3	3	3
Butyric Acid	5	70+150	1	1	1
Butyl Acetate			1	1	1

MIL - HDBK - 406
31 October 1971

TABLE 7-18 (CON'T)

Corrodent	Conc. %	Temp. °F	430	302	316
Mercury	Dry		1	1	1
Methyl Chloride	Dry		-	1	1
Nitric Acid	5-50	70	1	1	1
		Boiling	3	1	1
	70	70	1	1	1
		Boiling	3	2	-
	Fuming				
	Conc.	70	1	1	1
	Fuming				
	Conc.	Boiling	3	3	3
Nitrous Acid	5,	70	1	1	1
Oleic Acid		70	1	1	1
		400	-	3	1
		300	2	-	-
Phenol	+ 10% H ₂ O	Boiling	1	1	1
	Crude	212	1	1	1
	Crude	Boiling	-	1	1
	Commercial,	70	1	1	1
Phosphoric Acid	1 and 9				
	Agitated or				
	Aerated	70	1	1	1
Potassium Nitrate		70 and Boiling	1	1	1
Sea Water			2	1	1
Sodium Chlorate	10 and 25		1	1	1
Sodium Chloride	All	70	1	1	1
Sodium Nitrate		Fused	2	1	1
Sodium Peroxide		212	-	1	1
Sulfur Dioxide	Wet Gas	70	3	3	1
	Dry Gas	575	1	1	1
Sulfuric Acid	5	70	3	1	1
		Boiling	-	-	1
	10	70	3	1	1
		Boiling	3	3	1
	50	70	3	1	1
		Boiling	3	3	3
	90	70	3	1	1

Condensed from; ARMCO Stainless Steels

MIL - HDBK - 406
31 October 1971

TABLE 7-19

CORROSION RESISTANCE OF TYPES 316, 304 & 430
STAINLESS STEELS IN VARIOUS MEDIA

Substance	Condition	Temp. °F	Stainless Type		
			316	304	430
Borax	5%	Hot	1	1	1
Boracic Acid	5%	Cold and Hot	1	1	1
Boric Acid	Saturated	Boiling	1	1	1
Bromine Water		70	4	5	5
Butyric Acid	5%	70	1	1	1
	5%	150	1	1	1
Calcium Carbonate		70	1	1	1
Calcium Chloride	Dilute	70	1	2	3
	Conc. Solutions	70	1	2	2
Calcium Chlorohypochlorite (Bleaching Powder)	1%	70	2	3	.....
	5%	70	3	3	.....
Calcium Hypochlorite	2%	70	1	2	3
	Aqueous Solution				
	Sp. G. 1.04	100	1	3	3
Calcium Sulphate	Saturated	70	1	1	1
Calcium Chlorate	Dilute Solution	70	1	1	.....
	Dilute Solution	Hot	1	1	.....
Calcium Hydroxide	10%	Boiling	1	1	.....
	20%	Boiling	1	1	.....
	50%	Boiling	2	3	.....
Cadmium		Molten	3	3	.....
Carbolic Acid (Phenol)	C.P. + 10% H ₂ O	Boiling	1	1	1
	C.P.	70	1	1	1
Carbon Bisulfide		70	1	1	1
Carbon Monoxide Gas		1400	1	1	1
		1600	1	1	1
Carbon Tetrachloride		70	1	1	1
Carbon Tetrachloride	C.P.	Boiling	1	1	...
	Commercial				
	Plus 1% water	Boiling	2	...	...
	Commercial plus 1% HCL	Boiling	2	...	...
Carbonic Acid	All concentrations	Cold and Hot	1	1	1
Caustic Soda (Sodium Hydroxide)					
Cellulose			1	1	1
Chloroacetic Acid		70	3	4	5
Chlorine Gas	Dry	70	1	1	3
	Wet	70	3	4	5
		212	4	5	5

MIL - HDBK - 406
31 October 1971

TABLE 7-19 (CON'T)

Substance	Condition	Temp. °F	316	304	430
Chlorinated Water	Saturated	70	2	3	4
Chlorobenzene (Phenyl Chloride)	C.P.	70	1	1	1
		Boiling	1	1	...
Chloroform		70	1	1	1
Chlorosulphonic Acid	Dilute	70	5	5	5
Chromic Acid	5% C.P.	70	1	1	2
	10% C.P.	70	2	2	...
	10% C.P.	Boiling	2	3	4
	50% C.P.	70	2	2	...
	50% C.P.	Boiling	...	3	...
	Commercial 50% (Cont. SO ₃)	70	1	1	...
	Commercial 50% (Cont. SO ₃)	Boiling	3	4	4
Chromium Plating Bath		70	1	1	...
Copper Acetate	Saturated Solution	70	1	1	1

MIL - HDBK - 406
31 October 1971

TABLE 7-20

THE CORROSION RESISTANCE OF 430, 302 & 316 STEEL

Corrosive Media	Concentration %	Temp. °F	430	Stainless 302	316
Calcium Carbonate		70	A	A	A
Calcium Chlorate	Dil. Sol.	70 and Hot	A	A	A
Calcium Hydroxide	10, 20	Boiling	-	A	A
Calcium Hypochlorite	10	70	B	B	A
Calcium Sulfate	Saturated	70	A	A	A
Carbonated Beverages			A	A	A
Carbon Bisulfide		70	A	A	A
Carbon Monoxide Gas		760 and 870	A	A	A
Carbon Tetrachloride	C.P.	70+ Boil	A	A	A
	Commercial moist at High Temp.				
Carbonic Acid	Saturated	70	C	C	C
Chloracetic Acid		70	A	A	A
Chlorobenzene	Conc. Pure	70	C	C	B
Chloric Acid		70	A	A	A
Chlorine	Dry Gas	70	C	C	C
	Moist Gas	70	B	B	B
	Dry Gas	212	C	C	C
Chloroform		70	C	B	B
Chromic Acid	5 and 10	70	A	A	A
	50 C.P.	70	B	A	A
	50 C.P.	Boiling	C	A	A
Citric Acid	5 Still	70 and 150	C	C	A
	15	70 and Boiling	A	A	A
Copper Acetate	Sat. Sol.	70	A	A	A
Copper Carbonate	Sat. Sol.		A	A	A
	in				
	50% NH ₄ OH		A	A	A
Copper Chloride	1 Agitated	70	A	A	A
	5 Agitated	70	A	A	A
Copper Cyanide	Sat. Sol.	Boiling	C	A	A
Copper Nitrate	1-5				
	Agitated	70	A	A	A
	50 Aqueous	Hot	A	A	A
Copper Sulfate	All	70-150	B	A	A
Cyanogen Gas		70	-	A	A
Dinitrochlorobenzene	Melted and Solidified	70	A	A	A
Epsom Salt		Hot and Cold	A	A	A

MIL - HDBK - 406

31 October 1971

TABLE 7-20 (CON'T)

Corrosive Media	Concentration %	Temp. °F	430	302	316
Ether (Ethyl)		70	A	A	A
Ethyl Acetate		70	A	A	A
Ethyl Chloride	Dry	70	A	A	A
Ethylene Chloride	Dry	70	-	A	A
Ethylene Glycol	Conc.	70	A	A	A
Ferric Chloride	All Conc.	70 and Boiling	C	C	C
Ferric Hydroxide		70	-	A	A
Ferric Nitrate	All Conc.	70	A	A	A
Ferric Sulfate	All Conc.	70		A	A
Ferrous Sulfate	10	70 and Boiling	-	A	A
Flourine	Dry	70	A	A	A
Formaldehyde	40	70	A	A	A
Formic Acid	5	150	B	A	A
	5	70	A	A	A
	10-50	70	B	A	A
	10-50	Boiling	C	C	A
	100	70	-	A	A
	100	Boiling	-	-	A
Hydrobromic Acid			C	C	C
Hydrochloric Acid	All Conc.	70	C	C	C
Hydrocyanic Acid		70	B	A	A
Hydrofluoric Acid		70	C	C	C
Hydrogen Peroxide	Acid Free	70	A	A	A
Hydrogen Sulfide	wet		C	A	A
	Dry		A	A	A
Iodine Solutions		70	C	C	C
Magnesium Carbonate			A	A	A
Magnesium Chloride	1, 5 Still	70	A	A	A
	10-30	68	-	A	-
	Saturated	70	C	A	A
Magnesium Sulfate		Hot and Cold	A	A	A
Magnesium Hydroxide			A	A	A
Magnesium Nitrate			A	A	A

MIL - HDBK - 406
31 October 1971

TABLE 7-21

Corrosion Resistance of Type 316, 304 and 430 Steel

Key: I - Fully Resistant
II - Satisfactorily Resistant
III - Fairly Resistant
IV - Slightly Resistant
V - Not Resistant

Substance	Condition Temp. °F.	316	304	430
Acetic Acid				
5% agitated.....	70	I	I	I
5% aerated.....	70	I	I	I
5%.....	100	I	I	I
5%.....	180	I	I	II
10% agitated.....	70	I	I	IV
10% aerated.....	70	I	I	I
10%.....	100	I	I	...
10%.....	180	I	I	...
10%.....	Boiling	I	III	...
10%.....	60	I	I	I
15%.....	100	I	I	IV
15%.....	180	I	I	IV
15%.....	Boiling	I	III	...
20% agitated.....	70	I	I	I
20% aerated.....	70	I	I	I
20% aerated.....	180	I	I	...
33%.....	70	I	I	III
33%.....	100	I	I	IV
33%.....	180	I	I	...
33%.....	Boiling	I	III	...
40% aerated.....	180	I	I	...
50%.....	70	I	I	III
50%.....	Boiling	I	III	V
60%.....	60	I	I	III
60%.....	100	I	I	IV
60%.....	180	I	I	...
60%.....	Boiling	II	III	...
80%.....	70	I	I	III
80%.....	100	I	I	IV
80%.....	180	I	I	...
80%.....	Boiling	II	IV	...
90% aerated.....	180	I	III	...
100%.....	70	I	I	I
100%.....	100	I	I	I
100%.....	180	I	I	III
100%.....	Boiling	II	III	...
100%.....	400-150 lb. pressure	III	V	...

MIL - HDBK - 406
31 October 1971

TABLE 7-21 (CON'T)

Substance	Condition Temp. °F.	316	304	430
Acetic Anhydride				
90% anhydride.....	70	I	I	I
90% anhydride.....	180	I	I	II
90% anhydride.....	Boiling	I	I	III
90% anhydride aerated....	180	III	IV	...
60% anhydride aerated....	180	II	II	...
30% anhydride aerated....	180	II	IV	...
Acetone.....	70	I	I	II
	Boiling	I	I	...
Acetyl Chloride.....	Cold	II	II	...
	Boiling.....	II	II	...
Acetylene.....	70	I	I	I
Alcohol, Ethyl.....	70	I	I	I
	Boiling	I	I	I
Alcohol, Methyl.....	70	I	I	I
	150	II	III	III
Aluminum, Molten.....	1400	V	V	V
Aluminum Acetate Saturated....	70	I	I	...
Saturated....	Boiling.....	I	I	...
Aluminum Chloride				
10% Quiescent.....	70	III	IV	IV
25% Quiescent.....	70	III	IV	IV
Aluminum Fluoride.....	70	III	IV	IV
Aluminum Hydroxine Saturated..	70	I	I	I
Aluminum Sulphate				
5%.....	150	I	I	I
10%.....	70	I	I	II
10%.....	Boiling.....	I	I	III
Saturated.....	70	I	I	IV
Saturated.....	Boiling.....	I	II	V
Aluminum Chromium				
Sulphate 5%.....	70	I	I	...
Sp. G. 1.6.....	Boiling.....		V	...

MIL - HDBK - 406
31 October 1971

TABLE 7-21 (CON'T)

Corrosion Resistance of Type 316, 304 and 430 Steel (CON'T)

Substance	Condition Temp. °F.	316	304	430
Aluminum Potassium Sulphate (Alum)				
2%.....	70	I	I	I
10%.....	70	I	I	II
10%.....	Boiling	I	II	III
Saturated.....	Boiling	II	III	IV
Ammonia (Dry or Moist)				
All Concentrations.....	70-212	I	I	I
Ammonia (Anhydrous).....	800 up	V	V	V
Ammonium Hydroxide.....	70	I	I	I
Ammonium Bicarbonate.....	70	I	I	...
	Hot.....	I	I	...
Ammonium Bromide				
5%.....	70	I	I	...
Ammonium Carbonate				
1% Quiescent.....	70			
5% Quiescent.....	70			
1% Aerated.....	70			
5% Aerated.....	70			
1% Agitated.....	70			
5% Agitated.....	70.....(ALL).....	I	I	I

MIL - HDBK - 406
31 October 1971

7.4 ACETONE.

7.4.1 PHYSICAL PROPERTIES.

Formula	CH ₃ COCH ₃
Molecular Weight	58.08
Pounds Per Gallon at 68°F	6.58
Boiling Range (°F)	132 - 134
Freezing Point (°F)	-138.6
Evaporation Rate (Carbon Tetrachloride = 100)	139
Coefficient of Expansion per °F	0.0008
Surface Tension at 68°F (dynes/cm)	23.7
Solubility, % by Weight at 68°F	
In water	Infinite
Of water	Infinite
Flash Point (°F)	0
Flammability Limits, % by Volume in Air	
Lower	2.6
Upper	12.8
Threshold Limit Value	1000
Specific Heat of the Liquid at 68°F, BTU/(lb)(°F)	0.51
Latent Heat at Boiling Point BTU/lb	224

7.4.2 SPECIFICATIONS.

Federal.

O-A-51F Acetone, Technical

7.4.3. GENERAL INFORMATION. Acetone is a volatile, highly flammable liquid. It is miscible with water, alcohol and chlorinated solvents and is a strong solvent for fats, oils, waxes, resins and rubber. Its rapid attack on rubber and resin materials and its extreme flammability, limit its large scale use.

Acetone is also known by the names; dimethyl ketone, methyl acetal and propanone-2.

Acetone is an effective solvent for vinyl resins, natural and synthetic laquers, varnishes, fats, waxes, oils, grease, crude rubber, shellac, asphalt and bitumens.

Acetone is not corrosive to metals except when age or reclamation has resulted in acid formation. It is not suited for the removal of particulate matter and is incompatible with many non metallics. It will form explosive mixtures with air. And, it is only suitable for cold cleaning applications.

7.4.4 SOLUBILITY DATA. Acetone posses the following solubility characteristics toward solvents:

Solvent	Miscibility	Solvent	Miscibility
Decyl Alcohol	Miscible	Ethylene Glycol Mono-	
Adiponitrile	Miscible	ethyl ether acetate	Miscible
2-Amino-2-Methyl-1-		Formamide	Miscible
Propanol	Miscible	Glycerol	Immiscible

MIL - HDBK - 406
31 October 1971

<u>SOLVENT</u>	<u>MISCIBILITY</u>	<u>SOLVENT</u>	<u>MISCIBILITY</u>
Amyl Alcohol	Miscible	Heptane	Miscible
Benzaldehyde	Miscible	Hexadecyl Alcohol	Miscible
Benzene	Miscible	Hexane	Miscible
Benzine	Miscible	Hexyl Alcohol	Miscible
Benzonitrile	Miscible	Hexyl Ether	Miscible
Benzyle Ether	Miscible	Isoamyl Alcohol	Miscible
n-Butyl Ether	Miscible	Isoamyl Sulfide	Miscible
Butyl Ether	Miscible	Isobutyl Alcohol	Miscible
Carbon Disulfide	Miscible	Isooctyl Alcohol	Miscible
Carbon Tetrachloride	Miscible	Isopropyl Acetate	Miscible
Chloroform	Miscible	Isopropyl Alcohol	Miscible
Cyclohexanone	Miscible	Isopropyl Ether	Miscible
Decyl Alcohol	Miscible	Methyl Acetate	Miscible
Diacetone Alcohol	Miscible	Methyl Alcohol	Miscible
Diethylene Glycol	Miscible	Methyl Ethyl Ketone	Miscible
Diisobutyl Ketone	Miscible	Methyl Isobutyl Ketone	Miscible
Dimethyl Aniline	Miscible	Naptha	Miscible
Ethyl Acetate	Miscible	Nitromethane	Miscible
Ethyl Alcohol	Miscible	Octane	Miscible
Ethyl Amyl Ketone	Miscible	Sec-Butyl Acetate	Miscible
Ethyl Benzoate	Miscible	Sec-Butyl Alcohol	Miscible
Ethyl Ether	Miscible	Toluene	Miscible
Ethylene Diacetate	Miscible	Water	Miscible
Ethylene Glycol	Miscible	Xylene	Miscible

Acetone possesses the following solubility characteristics toward rubbers and polymers:

<u>MATERIAL</u>	<u>SOLUBILITY</u>	<u>MATERIAL</u>	<u>SOLUBILITY</u>
Natural Rubber	Insoluble	Chloroprene	Slightly Sol.
Isoprene-Isobutylene		Polyisobutylene	Insoluble
Rubber	Insoluble	Butadiene-Meth	
Styrene-Butadiene	Insoluble	acrylate	Slightly Sol.
Acrylonitrile-Butadiene	Soluble	Butyl Latex	Insoluble
Polysulfide Rubbers	Insoluble		

Acetone possesses the following solubility toward synthetic resins:

<u>RESIN</u>	<u>SOLUBILITY</u>	<u>RESIN</u>	<u>SOLUBILITY</u>
Alkyd, non Drying	Soluble	Polyethylene	Insoluble
Alkyd, Maleic Modified	Soluble	Polyethylene Glycol	Soluble
Alkyd, Maleic-Rosin		Polypropylene	Insoluble
Modified	Soluble	Polystyrene	Part Soluble
Benzyl Cellulose	Part Soluble	Polyurethane	Soluble
Butadiene-Styrene,		Polyvinyl Acetate	Soluble
Modified	Soluble	Polyvinyl Butyral	Swelling

MIL - HDBK - 406

31 October 1971

<u>Resin</u>	<u>Solubility</u>	<u>Resin</u>	<u>Solubility</u>
Cellulose Acetate	Soluble	Polyvinyl Chloride	Gel
Cellulose Acetate Butyrate (Low Butyral)	Soluble	Polyvinyl Formal	Slightly Sol.
Cellulose Acetate Butyrate (High Butyral)	Soluble	Polyvinylidene Chloride	Part Soluble
Cellulose Acetate Propionate (Low Propionyl)	Soluble	Urea-Formaldehyde	Soluble
Cellulose Acetate Propionate (High Propionyl)	Soluble	Vinyl Chloride-Vinyl Acetate Copolymer	Soluble
Cellulose Triacetate	Insoluble	Vinyl Chloride-Vinyl Acetate Copolymer, Maleic Modified	Soluble
Chlorinated Diphenyl	Soluble	Vinyl Chloride-Vinyl Acetate Copolymer, vinyl Alcohol Modified	Soluble
Coumarone	Soluble	Vinyl Chloride-Vinylidene Chloride Copolymer	Soluble
Epoxy	Soluble	Vinylidene Chloride-Acrylonitrile Copolymer	Soluble
Ethyl Cellulose	Soluble		
Methylmethacrylate	Soluble		
Nitrocellulose	Soluble		
Phenolic	Soluble		

Acetone possesses the following solubility for Gums, Waxes and Natural Resins:

<u>Material</u>	<u>Solubility</u>	<u>Material</u>	<u>Solubility</u>
Accroides	Gel	Dammar	Part Sol.
Asphalt	Part Sol.	Elemi	Soluble
Beeswax	Part Sol.	Kauri	Part Sol.
Carnauba Wax	Part Sol.	Manila	Soluble
Ceresin Wax	Insoluble	Mastic	Part Sol.
Colophony	Soluble	Paraffin Wax	Insoluble
Congo	Part Sol.	Rosin	Soluble
Coumarone	Soluble	Shellac	Part Sol.

7.4.5 MATERIALS COMPATIBILITY. Acetone has the following effects on materials of construction:

<u>Material</u>	<u>Effect</u>	<u>Material</u>	<u>Effect</u>
Polystyrene	Dissolves	Neoprene Rubber	Swells
Polyvinyl Chloride	Dissolves	Silicone Rubber	Extracts
Polyethylene	None		Plasticizer
Bakelite (Phenolic)	Dissolves	Polyvinyl Formal	None
Teflon TFE	None	Bondar	None
Glyptal 1201	Dissolves	Glyptal 1202	Dissolves
GE 9740	Dissolves	Marking Ink	Removed

MIL - HDBK - 406

31 October 1971

7.5 BENZENE

7.5.1 PHYSICAL PROPERTIES

Formula	C_6H_6
Molecular Weight	78.11
Pounds Per Gallon at 68°F	7.32
Boiling Range (°F)	172-176
Freezing Point (°F)	41.9
Evaporation Rate (Carbon Tetrachloride = 100)	95
Coefficient of Expansion Per °F	0.00069
Surface Tension at 68°F (dynes/cm)	28.9
Solubility % by Weight at 68°F	
In Water	0.09
Of Water	0.06
Flash Point (°F)	12
Flammable Limits % by Volume in Air	
Lower	1.4
Upper	8.0
Threshold Limit Value	25
Specific Heat of the Liquid at 59°F BTU/(lb)(°F)	0.42
Latent Heat of the Liquid at the Boiling Point	170
Kauri-Butanol Value in cc	105-150

7.5.2 SPECIFICATIONS.

FEDERAL	VV-B-231	Benzene, Technical
ASTM	D-847-47	Acidity of Benzene, Toluene, Xylenes, Solvent Napthas and Similar Industrial Aromatic Hydrocarbons

7.5.3 GENERAL INFORMATION. Benzene is a clear, colorless, volatile and highly flammable liquid. Flammability and toxicity limit its usefulness. It is also known as Benzol, Phenyl Hydride and Coal Naptha.

Benzene is an effective solvent for methyl, ethyl, butyl and benzyl cellulose ethers, cellulose esters (cellulose dinapthenate, dilaurate, etc.) fats, waxes, gums and rubbers. It is virtually non corrosive toward metals, when in pure form. It is not, however, always compatible with non metallics.

Benzene can only be used in cold cleaning applications because of its extreme flammability, and reclamation of the solvent is hazardous.

7.6 CARBON TETRACHLORIDE

7.6.1 PHYSICAL PROPERTIES.

Formula	CCl_4
Molecular Weight	153.84
Pounds Per Gallon at 68°F	13.30
Boiling Range	171-172

MIL - HDBK - 406
31 October 1971

Freezing Point (°F)	-9.3
Evaporation Rate (Carbon Tetrachloride = 100)	100
Coefficient of Expansion Per °F	0.00069
Surface Tension at 68°F (dynes/cm)	26.8
Solubility % by Weight at 68 °F	
In Water	0.08
Of Water	0.01
Flash Point (°F)	None
Specific Heat of the Liquid at 68°F BTU/(lb)(°F)	0.21
Latent Heat of the Liquid at the Boiling Point BTU/lb	84
Kauri-Butanol Value	114

7.6.2 SPECIFICATIONS

FEDERAL

O-C-141a

Carbon Tetrachloride

7.6.3 GENERAL INFORMATION. Carbon Tetrachloride is a dense, water-white nonflammable and non-explosive liquid having good solvent power for most organic compounds. It is also known as Tetrachloromethane.

Carbon Tetrachloride is an effective solvent for mineral and essential oils, fats, greases, waxes, gums, camphor, metallic resins, bitumens, asphalt, unvulcanized rubber, some cellulose ethers, coumarone, dammar, ester gum, elemi, guarac, mastic, rosin, sandarac and alkyd and vinyl resins.

Carbon Tetrachloride will readily decompose, forming phosgene, chlorine and hydrochloric acid and is extremely toxic, even mild concentrations can rapidly induce unconsciousness and death. It is suitable for cold cleaning applications only.

7.6.4 DECOMPOSITION. At elevated temperature, in contact with various metals, carbon tetrachloride will readily decompose into toxic gases:

Temperature °F	Decomposition of Carbon Tetrachloride in Milligrams of Phosgene Per Gram of Solvent with;					
	Cast Iron	Copper	Zinc	Aluminum	Brass	Steel
295				0.048		
300	0.48		0.020			
395		7.10				
405	8.87					
450					0.70	
460	5.29		0.37	0.075		0.50
470		36.4				
540	133.0					1.68
635	275.0		5.60			
670				0.34	5.43	5.72
	(Decomposition to Hydrogen Chloride)					
540	56.6	29.0	1.98	0.73	0.83	8.52

MIL - HDBK - 406
31 October 1971

7.6.5 MATERIALS COMPATIBILITY. Carbon Tetrachloride has the following effects on some common materials of construction:

MATERIAL	EFFECT	MATERIAL	EFFECT
Polystyrene	Dissolves	Polyvinyl Formal	Slight Effect
Polyvinyl Chloride	None	Bondar	None
Polyethylene	Slight Swell	Glyptal 1201	Slight Effect
Bakelite (Phenolic)	None	Glyptal 1202	Slight Effect
Teflon TFE	None	GE 9740 (Baked)	Slight Effect
Neprene Rubber	Swell	Marking Ink	Part Removed
Silicone	Swell		

7.7 CHLOROFORM

7.7.1 PHYSICAL PROPERTIES

Formula	CHCl ₃
Molecular Weight	119.39
Pounds per Gallon at 68°F	12.43
Boiling Range (°F)	142
Freezing Point (°F)	-82.3
Evaporation Rate (Carbon Tetrachloride = 100)	118
Coefficient of Expansion per °F	0.00071
Surface Tension at 68°F (dynes/cm)	27.2
Solubility % by weight at 68°F	
In Water	0.82
Of Water	0.07
Flash Point (°F)	None
Flammability Limits % by Volume in Air	Nonflammable
Threshold Limit Value	50
Specific Heat of the Liquid at 68°F BTU/(lb)(°F)	0.23
Latent Heat of the Liquid at the Boiling Point (BTU/lb)	106
Kauri Butanol Value	208

7.7.2 SPECIFICATIONS

FEDERAL
MILITARY

O-C291 Chloroform, Technical
MIL-C-10655 Chloroform

7.7.3 GENERAL INFORMATION Chloroform is a heavy, colorless, volatile liquid. While a powerful solvent for oils, greases, tars and other organics, its use is limited because of its toxic properties. It is also known as trichloromethane.

It is an effective solvent for fats, miner and essential oils, waxes, alkaloids, resins and tars. In combination with ethyl alcohol or ethyl acetate, the mixture becomes a solvent for many cellulose esters and ethers.

MIL - HDBK - 406
31 October 1971

Chloroform will decompose to phosgene and hydrochloric acid with age. Dermatitis, burns, and cracking of the skin will result from the strong degreasing action of chloroform on the skin. Chloroform is toxic in low concentrations, inducing fatigue and headaches, at high exposure levels, anesthesia is rapid. Long term exposure will cause damage to the internal organs, and continued exposure can be fatal.

Chloroform can be used in cold cleaning applications provided adequate ventilation is employed. It is generally non corrosive to metals but exposure to light and air or moisture will cause it to become acid rapidly.

7.8 ETHYL ALCOHOL

7.8.1 PHYSICAL PROPERTIES.

Formula - Anhydrous	C ₂ H ₅ OH
95%	C ₂ H ₅ OH:H ₂ O
Molecular Weight	46.07
Pounds Per Gallon at 69°F - Anhydrous	6.59
95%	6.76
Boiling Range (°F) - Anhydrous	171-176
95%	161-175
Freezing Point (°F) - Anhydrous	-174.1
95%	-198.4
Evaporation Rate (Carbon Tetrachloride = 100)	37
Coefficient of Expansion per °F - Anhydrous	0.00063
95%	0.00062
Surface Tension at 68°F (dynes/cm) - Anhydrous	22.3
95%	22.8
Solubility % by Weight - In Water	Infinite
Of Water	Infinite
Flash Point (°F)	57
Flammable Limits % by Volume in Air - Lower	3.3
Upper	19.0
Threshold Limit Value	1000
Specific Heat of the Liquid at 68°F BTU/(lb)(°F)	
- Anhydrous	0.58 at 77°F
95%	0.63 at 73°F
Latent Heat at the Boiling Point BTU/lb	361

7.8.2 SPECIFICATIONS

FEDERAL

O-E-760

Ethyl Alcohol (Ethanol), Denatured
Alcohol and Proprietary Solvent

7.8.3 GENERAL INFORMATION. Commonly available as denatured alcohol, it is very flammable. Also known as Ethanol, Grain Alcohol and Alcohol.

Ethyl Alcohol is an effective solvent for oils, gums, natural resins, ethyl cellulose, polyvinyl acetate and polyvinyl butyral.

Although the TLV is 1000 ppm, long exposure can result in irritation to the respiratory tract. Ethanol is suited for cold cleaning applications only.

MIL - HDBK - 406
31 October 1971

7.8.4 MATERIALS COMPATIBILITY. Ethyl Alcohol has the following effects on common materials of construction:

Material	Effect	Material	Effect
Polystyrene	None	Silicone Rubber	None
Polyvinyl Chloride	Extracts Plasticizer	Polyvinyl Formal	None
		Bondar	None
Polyethylene	None	Glyptal 1201	None
Bakelite (Phenolic)	None	Glyptal 1202	None
Teflon TFE	None	GE 9740	None
Neoprene Rubber	None	Marking Ink	Varies

7.9 ETHYLENE CHLORIDE

7.9.1 PHYSICAL PROPERTIES.

Formula	CH ₂ CLCH ₂ CL
Molecular Weight	98.97
Boiling Point at 760mm Hg, °C	83.5
Freezing Point °C	-35.3
Density at 20°C - gm/ml	1.253
lb/gal	10.46
Vapor Density (air = 1.00)	3.42
Flash Point (°F) - Open Cup	65
Closed Cup	55
Explosive Limits % Volume in Air - Lower	6.2
Upper	15.9
Evaporation Rate (Carbon Tetrachloride = 100)	79
Coefficient of Expansion per °F	0.00065
Surface Tension at 68°F (dynes/cm	32.2
Solubility by Weight % at 68°F - In Water	0.90
Of Water	0.15
Threshold Limit Value	50
Specific Heat of the Liquid at 68°F BTU/(lb)(°F)	0.31
Latent Heat of the Liquid at the Boiling Point	139

7.9.2 SPECIFICATIONS MILITARY

MIL-E-10662b

Ethylene Chloride (Ethylene
Dichloride, Dichloroethane)

7.9.3 GENERAL INFORMATION. Ethylene chloride is an effective solvent for fats, oils, waxes, some alkaloids, camphor, rubber, laquers, various resins and gums, cellulose esters and ethers and oil extraction. It is generally non corrosive at normal temperatures, at elevated temperature, in contact with water, it will corrode iron and other metals. Aluminum and its alloys cannot be used with ethylene chloride.

MIL - HDBK - 406
31 October 1971

Ethylene chloride is toxic by inhalation, contact with the skin or mucus membranes or by oral intake. It is flammable and will form explosive mixtures with air.

7.10 ISOPROPYL ALCOHOL

7.10.1 PHYSICAL PROPERTIES

Formula	$(CH_3)_2CHOH$
Molecular weight	60.09
Pounds Per Gallon at 68°F	6.55
Boiling Range (°F)	171-181
Freezing Point (°F)	-126.0
Evaporation Rate (Carbon Tetrachloride = 100)	34
Coefficient of Expansion Per °F	0.00062
Surface Tension at 68°F (dynes/cm)	21.7
Solubility % by Weight at 68°F - In Water	Infinite
Of Water	Infinite
Flash Point (°F)	56
Flammable Limits % by Volume in Air - Lower	2.5
Upper	5.2
Threshold Limit Value	400
Specific Heat of the Liquid at 68°F BTU/(lb)(°F)	0.60
Latent Heat of the Liquid at the Boiling Point BTU/lb	287

7.10.2 SPECIFICATIONS.

FEDERAL	TT-I-735	Isopropyl Alcohol
ASTM	D-1722-68	Water Miscibility of Acetone, Isopropyl Alcohol and Methyl Alcohol

7.10.3 GENERAL INFORMATION. Isopropyl Alcohol is an effective solvent for oils, alkaloids, gums, shellacs, rosins, mastic, waxes and some synthetic resins. It is also known as Isopropanol, 2-Propanol, and Secondary. Propyl Alcohol.

Isopropyl alcohol possesses only fair compatibility with materials of construction and has a limited ability to dissolve inorganic soils and remove particulates. It is also highly flammable.

Internal consumption of isopropyl alcohol is unsafe, but contact with skin is not dangerous. Isopropyl alcohol is suitable for cold cleaning applications only and reclamation is hazardous.

7.10.4 MATERIALS COMPATIBILITY. Isopropyl alcohol has the following effects on some materials of construction:

MIL - HDBK - 406
31 October 1971

Material	Effect	Material	Effect
Polystyrene	None	Silicone Rubber	None
Polyvinyl Chloride	Extracts	Polyvinyl Formal	None
	Plasticizer	Bondar	None
Polyethylene	None	Glyptal 1201	None
Bakelite (Phenolic)	None	Glyptal 1202	None
Teflon TFE	None	GE 9740	None
Neoprene Rubber	None	Marking Ink	Varies

7.11 METHYL ALCOHOL

7.11.1 PHYSICAL PROPERTIES.

Formula	CH ₃ OH
Molecular Weight	32.04
Pounds Per Gallon at 68°F	6.61
Boiling Range (°F)	147-151
Evaporation Rate (Carbon Tetrachloride = 100)	50
Freezing Point (°F)	-144.0
Coefficient of Expansion Per °F	0.00066
Surface Tension at 68°F (dynes/cm)	22.6
Solubility % by Weight at 68°F - In Water	Infinite
Of Water	Infinite
Flash Point (°F)	54
Flammable Limits % volume in Air - Lower	6.0
Upper	36.5
Threshold Limit Value	200
Specific Heat of the Liquid at 68°F BTU/(lb)(°F)	0.60
Latent Heat of the liquid at the Boiling Point BTU/lb	473

7.11.2 SPECIFICATIONS.

FEDERAL	0-M-232	Methyl Alcohol
ASTM	D-1722-68	Water Miscibility of Acetone, Isopropyl Alcohol and Methyl Alcohol.

7.11.3 GENERAL INFORMATION. A very flammable liquid, with good solvency for plastics and inks. Toxicity and flammability limit its usefulness.

Methyl alcohol is an effective solvent for dyes, alkaloids, shellac, kauri, polyvinyl, butyrol, ethyl cellulose, inks and waxes.

Methyl alcohol is extremely toxic, it can cause death and blindness from intake. It is irritating to the eyes, nose and throat. Regular exposure can cause organic damage, ultimately sufficient to cause death.

It will attack aluminum and lead when in an anhydrous state, and an aqueous solution will attack steel and titanium. It is suited for cold cleaning applications only.

MIL - HDBK - 406
31 October 1971

7.11.4 MATERIALS COMPATIBILITY. Methyl Alcohol has the following effects on some common materials of construction.

Material	Effect	Material	Effect
Polystyrene	None	Polyvinyl Formal	None
Polyvinyl Chloride	None	Bondar	None
Polyethylene	None	Glyptal 1201	None
Bakelite (Phenolic)	None	Glyptal 1202	None
Teflon TFE	None	GE 9740	None
Neoprene Rubber	None	Marking Ink	Varies
Silicone Rubber	None		

Methyl Alcohol has the following effect on stressed titanium samples.

Specimen Origin	Number of Specimens	Notched	Load, ksi	Test Fluid	Time to Failure Minutes
Virgin	1	No	140	Methanol	300
Virgin	2	No	140	Methanol	69-aged 4 hours
Virgin	4	Yes	120	Methanol	31 @1000 in air
Virgin	2	Yes	120	Methanol	44-aged 30 min.
Virgin	1	Yes	130	Methanol	20 @1000
Virgin	5	Yes	140	Methanol	19
Space Craft	5	No	90	Methanol	28
Space Craft	4	No	100	Methanol	33
Space Craft	4	No	120	Methanol	12
Space Craft	5	No	140	Methanol	7

NOTE: Several specimens were exposed to methanol for extended periods at stress levels below 100ksi without failure. Due to the hygroscopic nature of methanol, there were various amounts of water diluted with the methanol and this undoubtedly influenced the time to failure.

7.12 METHYLENE CHLORIDE

7.12.1 PHYSICAL PROPERTIES.

Formula	CH ₂ CL ₂
Physical State	Colorless
Odor	Mild Sweet
Molecular Weight	84.93
Freezing Point °C	-96.7
Boiling Point °C	39.8
Flash Point	None
Fire Point	None

MIL - HDBK - 406
31 October 1971

Viscosity, centipoises at 20°C	0.425
Refractive Index	1.4244
Surface Tension at 20°C (dynes/cm)	28.12
Specific Gravity at 25/25°C	1.320
Pounds Per Gallon at 25°C	10.98
Vapor Pressure at 20°C (mm Hg)	350.0
Evaporation Rate (Ether = 100)	71
Dielectric Constant of the Liquid at 20°C	9.1

7.12.2 SPECIFICATIONS.

MILITARY MIL-D-6998a Methylene Chloride (Dichloromethane)

7.12.3 TYPICAL COMMERCIAL SPECIFICATION.

Appearance	Clear Liquid
Odor	Mild Sweet
Residual Odor	None
Color (APHA)	10 Max.
Acidity Weight % as HCl	0.0005 max.
Free Halogens	None
Specific Gravity at 25°C	1.319 - 1.322
Boiling Range at 760 mm Hg °C	39.0 - 41.0
Water, Weight %	0.010 Max.
Non volatile Matter, Weight %	0.001 Max.
Meets U.S. Military Spec	MIL-D-6998a

7.12.4 GENERAL INFORMATION. Methylene chloride is a colorless, heavy, non flammable, highly volatile liquid with a low boiling point, possessing excellent solvent power. It is also known as Dichloromethane and Methyl Dichloride.

Methylene chloride is a good solvent for fats, oils, waxes, rubbers, alkaloids, bitumens and cellulose triacetate.

Methylene chloride is generally non corrosive toward metals at normal temperatures, with the exceptions of aluminum and titanium. In contact with water at elevated temperatures, it will attack iron, some stainless steels, copper, nickel and other metals. It is non flammable and will not form explosive mixtures in air. At high temperature, it will decompose into toxic gases.

7.12.5 SOLUBILITY DATA. The following materials are soluble to the degree indicated in methylene chloride.

Material	Miscibility	Material	Miscibility
Abalyn [resin esterified with glycerin]	+100	Genepoxy [Epoxy]925	+100
Acrawax C [resin esterified with glycerin]	-1	Genepoxy [Epoxy]525	+100
Acryloid B-82 [acrylic ester]	+100	Genepoxy [Epoxy]1800	+100
		Hercolyn [resin esterified with glycerin]	+100

MIL - HDBK - 406
31 October 1971

Material	Miscibility	Material	Miscibility
Alfince Z2 [Linseed oil]	+100	Japan Wax	-1
Amberol 801-XLT [Phenolic]	+100	Lanolin Anhydrous	+100
Amberol ST-137-X [Phenolic Formaldehyde]	+100	Montan Wax	-1
Bakelite CKR-5254 [Phenolic]	-20	Nevindene RS [Coumarone Indene]	+100
Beckstite 1001 [Phenolic]	+100	OKO S-70 [Soy Bean Oil]	+100
Beckstite 1112 [Phenolic]	+100	Orange Shellac	-1
Bees Wax	-5	Paraffin 47-49°C	-15
Calcium Stearate	-1	Paraffin 54-56°C	-5
Candellia Wax	-1	Parlon S-5 [Chlorinated Rubber]	+100
Carnauba Wax	-1	Parlon S-20 [Chlorinated Rubber]	+100
Ceresin Wax	-1	Parlon S-300 [Chlorinated Rubber]	+60
Cumar W-1 [Paracoumarone - Indene]	+100	Pecco 420 ES Indene Polymer]	+100
DCR-5061 [Silicone]	+100	Picolastic A-75 [Polystyrene]	+100
DCR-5581 [Silicone]	+100	Piccolyte S-85 [Polyterpene]	+100
DEN 838 [Epoxy Novolac]	+100	Piccopale 100 [Hydrocarbon]	+100
DER 331 [Epoxy]	+100	Potassium Oleate	-1
DER 332 [Epoxy]	+100	Polyvinyl Chloride	-1
DER 667 [Epoxy]	+100	Resin 276-V9 [Polyalkyl Styrene]	+100
Dow Resin PS-3 [Polystyrene]	+100	Rosin [Wood]	+100
Epon 812 [Epoxy]	+100	Saran F-120 [Vinylidene Chloride Acrylonitrile]	-1
DER 334 [Epoxy]	+100	Saran F-220 [Vinylidene Chloride Acrylonitrile]	-1
DER 661 [Epoxy]	+100	Sodium Oleate	-1
DER 664 [Epoxy]	+100	Stearic Acid	-35
Epon 836 [Epoxy]	+100	White Petrolatum	-20
Epon 1004 [Epoxy]	+100		
Epon 1109 [Epoxy]	+100		
Genepoxy 175 [Epoxy]	+100		
Genepoxy M-180 [Epoxy]	+100		
Genepoxy 190 [Epoxy]	+100		

NOTE: Solubility was determined by the incremental addition of solute to 100 grams of methylene chloride at room temperature. Solute was added in the following increments; 1 gram, 5 gram, 10 gram and so on in 5 gram increments to a maximum of 100 grams. Thus, a notation of -5 indicates that more than 1 but less than 5 grams of solute can be dissolved in 100 grams of methylene chloride. Similarly, a notation of -40 indicates that more than 35 and less than 40 grams of solute will dissolve. Where 100 grams of solute dissolve, the result is reported as +100. Resin solubilities were obtained on uncured material suitable for use in paints, adhesives and coatings.

7.12.6 DECOMPOSITION. The determination of decomposition is based on the amount of free acid formed in the solution. The possible causes of decomposition are examined separately.

MIL - HDBK - 406
31 October 1971

7.12.6.1 EFFECT OF TEMPERATURE ON DECOMPOSITION. No decomposition occurred in sealed tubes heated for 24 hours at less than 120°C. Above that temperature, acid was formed:

Temperature °C	Acidity % by Weight	Comment
120	1.2cc of 8.01 n-HCl	Stable at this Temp. Vapor passed through iron tubes for 1-3 sec.
200	0.0002	
300	0.0032	Marked Decomposition
400	0.0115	
500	0.044	

7.12.6.2 EFFECTS OF WATER ON DECOMPOSITION. The amount of water present has a marked effect on the hydrochloric acid formed, measurements for formaldehyde build-up were also made. When enough water is added to saturate the solution at room temperature, decomposition will occur at 100°C. At 120 and 140°C, the decomposition is slightly greater. When there is an excess of water, hydrolysis occurs at as low as 60°C.

7.12.6.3 EFFECT OF OXYGEN ON DECOMPOSITION. Pure oxygen or oxygen in the air had no effect on the decomposition of the methylene chloride below 140°C.

7.12.6.4 EFFECT OF METALS ON DECOMPOSITION. Dry methylene chloride or methylene chloride saturated with water was not decomposed by exposure to soft steel on heating to 120°C in sealed tubes for periods of 24 hours. No decomposition occurred on refluxing with steel in the presence of 1.5% water for periods of eight days.

7.12.6.5 EFFECT OF WATER AND METALS ON DECOMPOSITION. The combined influence of both water and metals on decomposition is negligible up to 120°C, if there is just enough water to saturate the methylene chloride. In the presence of excess water and soft steel, decomposition is more pronounced than in the presence of excess water alone. Decomposition occurred only at temperatures above the boiling point of the solvent.

7.12.6.6 DECOMPOSITION UNDER VARIED CONDITIONS.

Condition	Decomposition on Heating for 24 Hours (in cc of 0.01 n-HCl per 25 cc of Methylene Chloride)					
	40°C	60°C	80°C	100°C	120°C	140°C
Methylene Chloride in Nitrogen:						
Dry	0	0	0	0	1.20	...
With Soft Steel	0	0	0	0	0	...
Saturated with water	1.30	0	0	6.55	4.65	...

MIL - HDBK - 406
31 October 1971

Condition	Decomposition on Heating for 24 hours (in cc of 0.01 n-HCL per 25 cc of Methylene Chloride)					
	40°C	60°C	80°C	100°C	120°C	140°C
Methylene Chloride in Nitrogen:						
With Soft Steel Saturated With Water	...	0	0	0	0.40	0.35
With Copper Saturated with Water	...	0	0	0	0	0
With Aluminum Saturated With Water	...	0	1.40	0.40	...	0.45
With Lead Saturated With Water	...	0	0.6	0.70	0.45	0
With Tin Saturated With Water	...	0	0.4	0	0	2.45
With Brass Saturated With Water	...	0	0	0	1.45	291.0
With Excess of Water	...	1.55	3.55	45.40	287.0	2281.0
With Soft Steel and Excess of Water	...	3.55	41.15	196.0	272.0	...
Methylene Chloride and Soft Steel in Air						
	0.15	0.20	0.45	22.0
Methylene Chloride With 1.5% Water, Refluxed with soft Steel for 24 Hours (Acidity - None)						

7.12.7 MATERIALS COMPATIBILITY

Methylene chloride has the following effect on some common materials of construction

Material	Effect	Material	Effect
Polystyrene	Dissolves	Silicone Rubber	Swells
Polyvinyl Chloride	Will Damage	Polyvinyl Formal	Severe Crazing
Polyethylene	Will Damage on Prolonged Exposure	Bondar	Slight Effect
Bakelite	None	Glyptal 1201	Lifted
Teflon TFE	None	Glyptal 1202	Lifted
Neoprene Rubber	Swells	GE 9740	Lifted
		Marking Ink	Removed

MIL - HDBK - 406
31 October 1971

Condition	Corrosion of Metals in Methylene Chloride (in Milligrams per Square Centimeter) Change in Weight on Heating for 24 Hours				
	60°C	80°C	100°C	120°C	140°C
Methylene Chloride and					
...Soft Steel in Nitrogen	0.03	0	0	0	...
...Soft Steel Saturated with Water in Nitrogen	0	0	0	+0.05	+0.05
...Soft Steel with an Excess of Water in Nitrogen	-0.1	-0.67	-3.1	-1.4	(a)
...Soft Steel in Air	0	0	0	0	0.013
...Soft Steel in Oxygen	0	0	0	0	0
...Soft Steel, 1.5% water Refluxed for 48 hours			(Very Slight)		
...Soft Steel Saturated with Water in Oxygen	-0.1	-0.4	-1.57	-3.0	(a)
...Soft Steel, 1.5% Water, Refluxed for 8 Days			(Very Slight)		
...Copper Saturated with Water in Nitrogen	0	0	0	0	0
...Aluminum Saturated with Water in Nitrogen	0	0	0	0	0
...Lead Saturated with Water in Nitrogen	0	-0.2	0	-0.1	0
...Brass Saturated with Water in Nitrogen	0	0.10(b)	0(b)	0(b)	1.5(b)
...Tin Saturated with Water in Nitrogen	0	0	0	0	2

NOTE: (a) Heavy Coat of Iron Oxide
(b) Copper Colored Surface

7.13 METHYL ETHYL KETONE

7.13.1 PHYSICAL PROPERTIES.

Formula	CH ₃ COC ₂ H ₅
Molecular Weight	72.07
Boiling Range (°F)	174-177
Freezing Point (°F)	-87.3
Critical Temperature (°C)	260.0
Critical Pressure, atm	43.3
Specific Gravity 20°C	0.8061
Density t/4, g/ml	
at 0°C	0.8255
at 20°C	0.8054
at 25°C	0.8002

MIL - HDBK - 406

31 October 1971

Pounds Per Gallon at 20°C	6.70
Refractive Index n_{20}^D	1.3785
Viscosity, cps at 25°C	0.40
Dielectric Constant at 20°C	18.4
Specific Heat of the Liquid at 20°C (g cal/g)	0.549
Heat of Vaporization, BTU/lb	191
Heat of Combustion, BTU/lb	14,540
Flash Point, Tag Open Cup °F	24
Explosive Limits, % by Volume in Air	Lower 1.8
	Upper 11.5
Coefficient of Expansion Per °F	0.00076
Vapor Pressure, mm Hg at 20°C	77.5
Solubility, % by Weight at 20°C	In Water 26.3
	Of Water 12.6
Evaporation Rate (Carbon Tetrachloride = 100)	97
Latent Heat of the Liquid at the Boiling Point BTU/lb	191

7.13.2 SPECIFICATIONS.

FEDERAL TT-M-261
ASTM D-740

Methyl Ethyl Ketone, Technical
Standard Specifications for Methyl
Ethyl Ketone

7.13.3 GENERAL INFORMATION. Methyl ethyl ketone (MEK) is a highly flammable liquid possessing good solvency for plastics and resinous materials.

It is an effective Solvent for natural and synthetic vinyl resins, laquers, varnishes, fats, waxes, oils, greases, crude rubber, shellac, bitumens and asphalts. It is generally not corrosive toward metals such as iron, mild steel, copper and aluminum and is suitable for cold cleaning applications only.

7.13.4 SOLUBILITY DATA. The following materials are soluble in methyl ethyl ketone, to the degree indicated.

Material	Solubility	Material	Solubility
Accroides	Part Soluble	Epoxy	Soluble
Asphalt	Part Soluble	Ethyl Cellulose	Soluble
Beeswax	Insoluble	Methyl Methacrylate	Soluble
Carnauba Wax	Insoluble	Nitrocellulose	Soluble
Ceresin Wax	Insoluble	Phenolic	Soluble
Colophony	Soluble	Polyethylene	Insoluble
Congo	Part Soluble	Polyethylene Glycol	Soluble
Coumarone	Soluble	Polypropylene	Insoluble
Dammar	Part Soluble	Polystyrene	Soluble
Elemi	Part Soluble	Polyurethane	Soluble
Kauri	Soluble	Polyvinyl Acetate	Soluble
Manila	Soluble	Polyvinyl Chloride	Slight Soluble
Mastic	Soluble	Polyvinyl Formal	Slight Soluble
Paraffin Wax	Insoluble	Polyvinylidene Chloride	Part Soluble
Rosin	Soluble	Urea-Formaldehyde	Soluble

MIL - HDBK - 406
31 October 1971

<u>Material</u>	<u>Solubility</u>	<u>Material</u>	<u>Solubility</u>
Sandarac	Swelling	Vinyl Chloride-Vinyl	
Shellac	Part Soluble	Acetate Copolymer	Soluble
Alkyd, Non Drying.	Soluble	Vinylidene Chloride-	
Alkyd, Maleic-Rosin		Acrylonitrile Copolymer	Soluble
Modified	Soluble	Natural Rubber	Swelling
Benzyl Cellulose	Soluble	Isoprene-Isobutylene	
Butadiene-Styrene Modif.	Soluble	Rubber	Swelling
Cellulose Acetate	Soluble	Styrene-Butadiene	Soluble
Cellulose Acetate		Cellulose Acetate	
Butyrate	Soluble	Propionate	Soluble
Cellulose Triacetate	Insoluble	Polysulfide Rubbers	Insoluble
Chlorinated Diphenyl	Soluble	Acrylonitrile-Butadiene	Soluble
Coumarone	Soluble	Chloroprene	Soluble
Coumarone-Indene	Soluble	Butadiene-Methacrylate	Slight Soluble
Butyl Latex	Insoluble	Mineral Oil	Soluble

The following Solvents are miscible with MEK to the extent indicated.

<u>Solvent</u>	<u>Miscibility</u>	<u>Solvent</u>	<u>Miscibility</u>
Acetone	Miscible	Formamide	Miscible
Acetyl Acetone	Miscible	Furfuryl Alcohol	Miscible
Amyl Alcohol	Miscible	Glycerol	Immiscible
Benzaldehyde	Miscible	Heptane	Miscible
Benzene	Miscible	Hexadecyl Alcohol	Miscible
Benzine	Miscible	Hexane	Miscible
Benzonitrile	Miscible	Hexyl Alcohol	Miscible
Benzyl Alcohol	Miscible	Hexyl Ether	Miscible
Benzyl Ether	Miscible	Isoamyl Acetate	Miscible
n-Butyl Acetate	Miscible	Isoamyl Alcohol	Miscible
n-Butyl Alcohol	Miscible	Isobutyl Alcohol	Miscible
Butylene Glycol	Miscible	Isooctyl Alcohol	Miscible
Butyl Ether	Miscible	Isopropyl Acetate	Miscible
Carbon Disulfide	Miscible	Isopropyl Alcohol	Miscible
Carbon Tetrachloride	Miscible	Isopropyl Ether	Miscible
Chloroform	Miscible	Methyl Acetate	Miscible
Cyclohexane	Miscible	Methyl Alcohol	Miscible
Decyl Alcohol	Miscible	Methyl Amyl Alcohol	Miscible
Diacetone Alcohol	Miscible	Methyl Disulfide	Miscible
Diethylene Glycol	Miscible	Methyl Isobutyl Ketone	Miscible
Diisobutyl Ketone	Miscible	Methyl Isobutyl Carbinol	Miscible
Dimethyl Aniline	Miscible	Naptha	Miscible
Dimethyl Formamide	Miscible	Nitromethane	Miscible
Ethyl Acetate	Miscible	Octane	Miscible
Ethyl Alcohol	Miscible	Propylene Oxide	Miscible
Ethyl Amyl Ketone	Miscible	Pyridine	Miscible

MIL - HDBK - 406
31 October 1971

<u>Solvent</u>	<u>Miscibility</u>	<u>Solvent</u>	<u>Miscibility</u>
Ethyl Chloroacetate	Miscible	Sec-Butyl Acetate	Miscible
Ethyl Ether	Miscible	Sec-Butyl Alcohol	Miscible
Ethylene Diacetate	Miscible	Tetrahydrofuran	Miscible
Ethylene Glycol	Miscible	Toluene	Miscible
Ethylene Glycol Mono-butyl Ether	Miscible	Tridecyl Alcohol	Miscible
Ethylene Glycol Mono-ethyl Ether	Miscible	Triethylene Glycol	Miscible
		Water	Part Miscible
		Xylene	Miscible

7.14 PERCHLOROETHYLENE

7.14.1 PHYSICAL PROPERTIES.

Formula	CCL ₂ CCL ₂
Boiling Point (°F)	250.0
Freezing Point (°F)	-8.2
Molecular Weight	165.85
Specific Gravity 20°C	1.628
Pounds Per Gallon at 68°F	13.57
Latent Heat of Vaporization at the Boiling Point Cal/gm	50.1
BTU/lb	90.2
Specific Heat of the Liquid at 68°F Cal/gm/°C or BTU/lb/°F	0.208
Vapor Density at the Boiling Point and 760 mm gm/Liter	5.22
lb/cu.ft.	0.326
Vapor Specific Gravity (Air = 1.00)	5.83
Evaporation Rate (Carbon Tetrachloride = 100)	39
Vapor Pressure at 68°F mm Hg	14.2
Flammability	Nonflammable
Viscosity of the Liquid at 68°F (centipoise)	0.88
Dielectric Constant of the Liquid at 25°C	2.365
Solubility % by Weight at 68°F In Water	0.02
Of Water	0.01
Coefficient of Expansion Per °F	0.00057

7.14.2 SPECIFICATIONS.

FEDERAL	O-T-236b	Tetrachloroethylene (Perchloroethylene)
MILITARY	MIL-P-12050	Perchloroethylene (Tetrachloroethylene)

7.14.3 TYPICAL COMMERCIAL ANALYSIS.

<u>Property</u>	<u>Specification</u>	<u>Typical</u>
Appearance	Clear, Free of Suspended Matter	Clear, Free of Suspended Matter
Color APHA	15 Maximum	8

MIL - HDBK - 406
31 October 1971

Property	Specification	Typical
Odor	Characteristic, No Residual	Characteristic, no Residual
Spot Test	No Spot or Stain	No Spot or Stain
Specific Gravity 20°C	1.623 - 1.627	1.624
Non Volatile Residue Wt. %	0.0025 Maximum	0.0004
Free Chlorine	None	None
Moisture	No Cloud at 0°C	-5°C
Distillation Range °C	120.0 - 122.0	120.8 - 121.7
pH		8.4

7.14.4 GENERAL INFORMATION. A colorless, heavy, nonflammable liquid with a chloroform like odor, also known as Tetrachloroethylene. Perchloroethylene is an effective solvent for fats, oils, camphor, cellulose triacetate, gums and resins.

Although generally considered to be of low toxicity, it will act as an anesthetic from inhalation. It is non flammable and non explosive. At high temperature (above 1300°F) it will decompose to toxic gases.

Perchloroethylene can be used in both vapor degreasing and cold applications. It can be reclaimed and purified.

7.14.5 MATERIALS COMPATIBILITY. Perchloroethylene has the following effects on some typical materials of construction.

Material	Effect	Material	Effect
Polystyrene	Dissolves on Long Exposure	Silicone Rubber	Swells
Polyvinyl Chloride	None	Polyvinyl Formal	None
Polyethylene	Slight	Bondar	None
Bakelite (Phenolic)	None	Glyptal 1201	None
Teflon TFE	None	Glyptal 1202	Slight
Neoprene Rubber	Swells on Long Contact	GE 9740 Marking Ink	Slight
			Partly Removed

Perchloroethylene has the following effects on specific plastics.

Plastic	Test 1	Test 2	Test 3	Test 4	Test 5
Polytetrafluoroethylene Resin	0	1	0	-	-
7050 Linear Polyethylene Resin	1	6	1	-	-
9140 Polypropylene Resin	0	6	2	-	-
Acetal Resins	0	0	0	-	-
Epoxy Resin	-	-	-	-	-
ABS Polymer	0	4	4	-	-
Polycarbonate Resin	2	4	2	-	-

MIL - HDBK - 406
31 October 1971

Plastic	Test 1	Test 2	Test 3	Test 4	Test 5
Methyl Methacrylate	1	4	4	-	-
Polyvinyl Chloride (Unplasticized)	0	4	4	-	-
Polyvinyl Alcohol	-	-	-	-	-
475 Polystyrene	5	6	6	-	-
A Ionomeric Resin	-	-	-	-	-
Polypropylene	0	6	2	-	-
Polyphenyl Oxide	5	6	6	-	-
Polysulfone	0	5	0	-	-
Normal Impact PVC	-	-	-	-	-
101 Nylon	0	1	11	-	--

NOTE: Test 1 - 4 Hours at 75°F
 Test 2 - 4 Hours at the Solvent Boiling Point
 Test 3 - 100 Hours at 130°F
 Test 4 - 5 Minutes at 75°F
 Test 5 - 5 Minutes at the Solvent Boiling Point
 Result:

- - No Test Run
- 0 - No Visible Effect
- 1 - Slightly Pliable, No Significant Swell
- 2 - Slightly Swollen and Pliable or Slightly Shrunk and Softened
- 3 - Stress Cracked and Brittle
- 4 - Swollen, Curled and Rubbery
- 5 - Partially Dissolved or Disintegrated
- 6 - Totally Dissolved or Disintegrated

7.15 TOLUENE

7.15.1 PHYSICAL PROPERTIES

Formula	C ₆ H ₅ (CH ₃)
Molecular Weight	92.13
Pounds Per Gallon at 68°F	7.20
Boiling Range (°F)	228 - 232
Freezing Point (°F)	-139.0
Evaporation Rate (Carbon Tetrachloride = 100)	58
Coefficient of Expansion Per °F	0.00061
Surface Tension at 68°F (dynes/cm)	28.4
Solubility % by Weight at 68°F	0.05
In Water	0.04
Of Water	40
Flash Point (°F)	1.3
Flammable Limits % by Volume in Air	7.0
Lower	200
Upper	
Threshold Limit Value	

MIL - HDBK - 406
31 October 1971

Specific Heat of the Liquid at 68°F BTU/(lb)(°F)	156
Kauri-Butanol Value	94 - 105

7.15.2 SPECIFICATIONS

FEDERAL	TT-T-548	Toluene, Technical
ASTM	D-847-47	Acidity of Benzene, Toluene, Xylenes, Solvent Napthas and Similar Industrial Aromatic Hydrocarbons
	D-362-65	Industrial Grade Toluene

7.15.3 GENERAL INFORMATION. Toluene, also known as Toluol, Methyl Benzene and Phenyl Methane, is an effective solvent for gums, resins, copals, coumarone glyptal, sandarac, oils, cellulose acetate, some cellulose ethers and chlorinated rubber.

Toluene is highly flammable and is suited for cold cleaning applications only. Vapor odors do not give warning of high concentrations. It is not corrosive to metals and can be stored in iron, mild steel copper and aluminum containers. Reclamation to toluene is hazardous.

7.16 1,1,1-Trichloroethane

7.16.1 PHYSICAL PROPERTIES.

Formula	CH ₃ CCl ₃
Molecular Weight	133.42
Boiling Point {°C}	74.1
{°F}	165.4
Freezing Point {°C}	-31
{°F}	-24
Dielectric Constant of the Liquid at 25°C	7
Evaporation Rate (Carbon Tetrachloride = 100)	100
Flammability	Nonflammable
Flash Point	None
Ignition Temperature {°C}	546
{°F}	1015
Kauri-Butanol Value	130
Latent Heat of Vaporization at the Boiling Point Cal/gm	58
BTU/lb	95
Refractive Index - Liquid N 20 D	1.4374
Solubility (g/100 ml) at 25°C In Water	0.05
Of Water	0.07
Specific Gravity at 25°C	1.319
Pounds Per Gallon at 25°C	10.82
Specific Heat of the Liquid (Cal/gm/°C or BTU/lb/°F)	0.258
Specific Resistivity Ohms/cm	7.3 X 10 ⁹
Surface Tension in Air (dynes/cm) at 25°C	28.1

MIL - HDBK - 406
31 October 1971

Threshold Limit Value	350
Vapor Pressure at 20°C mm Hg	101
Viscosity, Liquid, Centipoise	0.735
Appearance	Clear
Non Volatile Residue, Maximum	10 ppm

7.16.1.1 SPECIFIC PROPERTIES

<u>Viscosity, Centipoise</u>		<u>Density</u>	<u>Specific Gravity</u>
0°C	1.195	0°C 1.3565 gm/ml	0°C 1.3567
20°	0.858	15.56° 1.3302 gm/ml	51.56° 1.3314
40°	0.653	20° 1.3232 gm/ml	20° 1.3255
60°	0.519	25° 1.3146 gm/ml	25° 1.318
		10.97 lbs/gal	
<u>Refractive Index</u>		<u>Kilocalories/Mole</u>	<u>Specific Heat Cal/gm/°C</u>
15°C	1.4399	20°C 7.8	0°C 0.238
20°	1.4374	50° 7.5	20° 0.240
25°	1.4344	80° 7.1	40° 0.250
			60° 0.270
<u>Surface Tension dynes/cm</u>		<u>Vapor Pressure mm Hg</u>	
0°C	27.40	30°C 157	
10°	26.26	40° 238	
20°	25.12	50° 344	
30°	28.98	60° 490	

7.16.2 TYPICAL COMMERCIAL ANALYSIS.

The following is a purity analysis for the high purity grade of 1,1,1-Trichloroethane:

Particulate Matter		Trace Metal Content	
Count	Particles	Metal	Parts Per Million
Particle Size	Per 100 ml		
over 100 Microns	1.5	Lead	<0.01
50 to 100 Microns	4.1	Antimony	<0.02
25 to 50 Microns	12.8	Arsenic	<0.02
10 to 25 Microns	56.6	Cadmium	<0.004
		Mercury	<0.05
		Selenium	<0.05
		Barium	<0.003

7.16.3 SPECIFICATIONS.

FEDERAL O-T-620

1,1,1-Trichloroethane, Technical

MIL - HDBK - 406

31 October 1971

MILITARY MIL-T-81533a

NASA MSFC-SPEC-471

1,1,1-Trichloroethane (Methyl Chloroform)
 Technical, Inhibited, Vapor Degreasing
 Solvent, 1,1,1-Trichloroethane, High
 Purity, Inhibited

7.16.4 GENERAL INFORMATION. A dense, water white, nonflammable liquid with good solvency. Also known as Methyl Chloroform and Alpha Trichloroethane.

It possesses excellent solvency and is inhibited to prevent corrosive attack on metals, it is harmful to some non metallics. May be repeatedly recovered by distillation but must be monitored for inhibitor content. It is suitable for all types of cleaning, both hot and cold.

7.16.5 SOLUBILITY DATA. Methyl Chloroform possesses the following solubility characteristics toward solvents.

<u>Solvent</u>	<u>Miscibility</u>	<u>Solvent</u>	<u>Miscibility</u>
Acetone	Miscible	n-Heptane	Miscible
Benzene	Miscible	Methyl Alcohol	Miscible
Carbon Tetrachloride	Miscible	Water	Slightly
Ethyl Ether	Miscible		

The following resins are soluble in methyl chloroform to the degree indicated.

<u>Resin</u>	<u>Solubility</u>	<u>Resin</u>	<u>Solubility</u>
Abalyn Rosin Esterified		Genepoxy M-180	100
With Glycerin	100	Genepoxy 190 Epoxy	100
Acryloid B-82 Acrylic Ester	80	Hercolyn Rosin Esterified	
Amberol 801-XLT Phenolic	100	With Glycerin	100
Amberol ST-137-X Phenol		Methyl Methacrylate	100
Formaldehyde	100	Nevindene R5 Coumarone-	
Araldite 502 Epoxy	100	Indene	100
Araldite 508 Epoxy	100	Orange Shellac	Insoluble
Araldite 6010 Epoxy	100	Paradene Resin #3 Para-	
Araldite 0071 Epoxy	1	coumarone-Indene	100
Araldite 7079 Epoxy	1	Picco 420 ES Polyindene	100
Bakelite CKR-5254 Phenolic	100	Piccolastic A-75 Polystyrene	100
Beckacite 1001 Phenolic	100	Piccolyte S-85 Polyterpene	100
Beckacite 1112 Phenolic	100	Piccopale 100 Hydrocarbon	100
Cumar W-1 Paracoumarone-		Polyvinyl Alcohol	Insoluble
Indene	100	Polyvinyl Chloride	Insoluble
DEN 438 Epoxy Novolac	100	Resin 276-V9 Polyalkyl Styrene	100
DER 331 Epoxy	100	Rosin Wood	<1
DER 332 Epoxy	100	Saran F-120 Vinylidene	
DER 334 Epoxy	100	Chloride-Acrylonitrile	<1
DER 661 Epoxy	1	Saran F-220 Vinylidene	
DER 664 Epoxy	1	Chloride Acrylonitrile	<1
DER 667 Epoxy	1	Vesicol AE9 ETO Adducts	<10
Bow Resin PS-3 Epoxy	100	Versamide 940 Polyamide	<1

MIL - HDBK - 406
31 October 1971

Resin	Solubility	Resin	Solubility
Epon 812 Epoxy	100	Vynlite AYAA Vinyl Acetate	80
Epon 836 Epoxy	<5	Vynlite VYHH Vinyl	
Epon 1004 Epoxy	<1	Chloride Acetate	<1
Epon 1009 Epoxy	<1	Zytel 31 Nylon	Insoluble
Genepoxy 175 Epoxy	100	Zytel 101 Nylon	Insoluble

The following materials are soluble to the degree indicated in Methyl Chloroform.

Material	Solubility	Material	Solubility
Acacia Gum	Insoluble	Acrax C Amide Stearate	<1
Copal Gum	Insoluble	Calcium Stearate	<1
Ester Gum	100	Oleic Acid	Miscible
Gutta Percha Natural Gum		Potassium Oleate	<1
Rubber	Insoluble	Sodium Oleate	<1
Kauri Gum	<1	Stearic Acid	30
Ethylene Glycol Mono-		Crepe Rubber	<1
ethyl Ether Acetate	Miscible	Neoprene rubber	Insoluble
Ethylene Glycol		Paradene Resin #3 Para-	
Methyl Ether	Miscible	coumarone-Indene	100
Ethylene Glycol n-butyl		Picco 420 ES Polyindene	100
Ether	Miscible	Piccolastic A-74	
Propylene Glycol		Polystyrene	100
Methyl Ether	Miscible	Piccolyte S-85 Polyterpene	100
E 1000 Polyethylene		Piccopale 100 Hydrocarbon	100
Glycol	Miscible	Polyvinyl Alcohol	Insoluble
E 1450 Polyethylene		Polyvinyl Chloride	Insoluble
Glycol	Miscible	Resin 276-V9 Polyalkyl	
E 4000 Polyethylene		Styrene	100
Glycol	Miscible	Rosin Wood	<1
E 6000 Polyethylene		Alinco Z2 Linseed Oil	100
Glycol	Miscible	Lanolin Anhydrous	100
E 9000 Polyethylene		Lard Oil	Miscible
Glycol	Miscible	Linseed Oil Raw	Miscible
P 400 Polypropylene		Linseed Oil Boiled	Miscible
Glycol	Miscible	Mineral Oil	Miscible
P 1200 Polypropylene		Motor Oil	Miscible
Glycol	Miscible	OKO S-70 Soybean Oil	100
P 2000 Polypropylene		Petrolatum White Wax	1
Glycol	Miscible	Bees Wax	<5
P 4000 Polypropylene		Candelilla Wax	<1
Glycol	Miscible	Carnauba Wax	<1
Cellulose Acetate,		Ceresin Wax	<1
Acetone Soluble	Insoluble	Japan Wax	<1
Cellulose Triacetate	Insoluble	Motan Wax	<1
50cps Ethyl Cellulose	14	Ozokerite White	Insoluble

MIL - HDBK - 406
31 October 1971

Material	Solubility	Material	Solubility
100cps Ethyl Cellulose	14	Paraffin 47-49°C	25
400cps Methyl Cellulose	Insoluble	Paraffin 54-56°C	20
690cps Methyl Cellulose	Insoluble	Parlon S-5 Chlorinated	
4000cps Methyl Cellulose	Insoluble	Rubber	40
Dow Corning R5061		Parlon S-20 Chlorinated	
Silicone	100	Rubber	40
Dow Corning R-5581		Parlon S-300 Chlorinated	
Silicone	100	Rubber	40
Sealing Asphalt Electrical	<5	Sulphur Precipitated	Insoluble

Manufacturers:

Hercules Powder Company

Rohm & Hass Company

CIBA Corporation

Union Carbide Corporation

Reichold Chemicals Incorporated

Allied Chemical Corporation

the Dow Chemical Company

Shell Chemical Corporation

General Mills Incorporated

Neville Chemical Company

Pennsylvania Industrial Chemical Corp.

Velsicol Chemical Corporation

E.I. DuPont de Nemours and Company

Archer-Daniels-Midland Company

Glyco Chemicals, Incorporated

Dow Corning Corporation

7.16.6 MATERIALS COMPATIBILITY

7.16.6.1 EFFECTS ON PLASTICS.

Material	Effect	Material	Effect
Styron Polystyrene	Dissolves	Plexiglass, Acrylic	Negligible
Polyethylene	Slight Swell	Nitrocellulose	None
Polyvinyl Alcohol	None	Saran	None
Polyvinyl Chloride	None	Mylar Polyester	None
Polytetrafluoroethylene	None	Bakelite (Phenolic)	None
Neoprene Rubber	Swells on Long Contact	Buna Rubber	Swells on Long Contact

NOTE: None of the plastics are adversely affected, with the exception of the polystyrene, by contact incidental to spray or wipe cleaning.

The method of testing employed here was a brief spray contact with the material under test. It is probable that under conditions of prolonged submersion, there would be some effect on all of the materials tested. It is also likely that after the contact is ended, that the material would return to its original state. In any event, pretesting is advised prior to employing any given solvent.

MIL - HDBK - 406
31 October 1971

Plastic	Effect	
	Initial	After Drying
Polypropylene (General Purpose Grade)	1.0	-1.0
Polyethylene 3300 (High Density)	1.0	0
Polyethylene (Linear)	6.5	0.5
Polyallomer (Ethylene Propylene Copolymer)	8.0	1.0
Acetate (Cellulose Acetate)	1.5	-7.0
Butyrate (Cellulose Acetate Butyrate)	80.0	Sample Decreased in Size
Propionate (Cellulose Acetate Propionate)	Distorted and Softened	Sample Decreased in Size
	Partially Dissolved	

NOTE: Exposure; Immersion for 14 days at 77°F. Measurements were taken immediately after exposure and after drying in an oven at 100-102°F for 48 hours. The measurements indicate the percent of linear swell.

7.16.6.2 EFFECTS ON ELASTOMERS.

Elastomer or Rubber	Effect	
	Initial	After Drying
Chardon 15093	18.0	-2.5
Chardon 15096-2	31.5	-2.5
Chardon 15120	32.0	-2.5
Hycar 1000X132 (Acrylonitrile/Butadiene High Acrylonitrile Content)	15.5	0
Hycar 1014 (Buna N Low Acrylonitrile Content)	51.0	-3.0
Thiokol 300 FA (Polysulfide Rubber)	12.5	0
Thiokol 3600 ST-C	17.0	-0.5
Thiokol E 455	21.5	-2.0
Dow Corning 94-002 (Fluorosilicone Rubber)	14.5	-0.5
Silostic S-6526 (Silicone Rubber)	45.5	-0.5
Silostic LS-63 (Fluorosilicone Rubber)	14.0	-0.5
Silostic 80 (Silicone Rubber)	40.5	-1.0
Silostic 675	49.0	-1.5

NOTE: Exposure; Immersion for 14 days at 77°F. Measurements were taken immediately after exposure and after drying for 48 hours at 100-102°F. Measurements indicate the percent of linear swell.

7.16.6.3 EFFECT ON VARIOUS MATERIALS

Material	Effect	Material	Effect
Oil Cloth	None	Formica	None
Vinyl Plastic	None	Linoleum	None
Vinyl Floor Tile	None	Asbestos Asphalt Tile	Surface Soft- ened Color comes Off if Rubbed
Ceramic Wall Tile	None		
Porcelain	None		

MIL - HDBK - 406
31 October 1971

<u>Material</u>	<u>Effect</u>	<u>Material</u>	<u>Effect</u>
Rubber Floor Tile	Surface Softened, Color comes off if Rubbed	Terrazzo Floor Tile	None
Enamel	None	Polystyrene Wall Tile	Badly Frosted
Latex Wall Paint	No Visible Effect on Surface slight Color if Rubbed on Cloth	Varnish	Surface Dissolves
Acetate Rayon	None	Flat Oil Paint	No Visible Effect on Surface Slight Color if Rubbed, on Cloth
Viscose Rayon	None	Latex Foam Rubber	None
Pacron Polyester	None		Swells Foam, Weakens all Structure
Silk	None	Orlon Acrylic	None
Plexiglass Acrylic	None	Saran Yarn	None
Nylon Film	None	Polyurethane Foam	Very Slight Swell, no After Effect

7.16.6.4 EFFECT ON WIRE COATINGS

<u>Coating</u>	<u>Effect After 5 Minute Spraying</u>
GE Glyptal 1201 Red Enamel (Air Dried)	No Visible Effect
GE Glyptal 1201 Red Enamel (Baked)	No Visible Effect
GE Glyptal 1202 Insulating Varnish (Air Dried)	Varnish Lifted
GE Glyptal 1202 Insulating Varnish (Baked)	No Visible Effect
GE 9700 Insulating Varnish (Baked)	No Visible Effect
GE 9740 Insulating Varnish (Baked)	Varnish Lifted
Harvel 612C Insulating Coating (Baked)	No Visible Effect
Dow Corning Silicone 997 (Baked)	No Visible Effect
Westinghouse 166-1 (Baked)	No Visible Effect
Sherwin-Williams Ajax V61-V8 (Baked)	No Visible Effect
Pedigree Sealer #30 (Air Dried)	No Visible Effect
Lecton Insulating Coating (Baked)	No Visible Effect
Formvar Insulating Coating (Baked)	No Visible Effect
Nyclad Insulating Coating (Baked)	No Visible Effect

7.16.6.5 EFFECT ON ALUMINUM ALLOYS

<u>Alloy</u>	<u>Corrosion Rate (MILS/Year)</u>	<u>Water (ppm)</u>
2219	1.44	150
7075	3.78	50
7075	6.23	87

MIL - HDBK - 406
31 October 1971

<u>Alloy</u>	<u>Corrosion Rate (MILS/Year)</u>	<u>Water (ppm)</u>
1100	0.66	<50
2024	0.55	<50
2219 (48 Days)	0.03	300 approx
2219 (33 Days)	0.08	600 approx
2219 (33 Days)	Severe Corrosion	600 approx

NOTE: Seven day reflux test, except where otherwise noted. Corrosion rates of less than 10 MPY are considered insignificant. When a separate water phase is present, in nearly all cases, the corrosion becomes severe. In the case where a sample is placed in contact with both a solvent and water phase and a vapor phase, the corrosion begins in the water phase, then in the vapor phase and finally in the solvent.

7.16.6.6 EFFECTS ON VARIOUS METALS.

<u>Metal</u>	<u>Dry (100ppm H₂O)</u>	<u>Wet (400ppm H₂O)</u>
Aluminum 1100	1	1
Aluminum 2024	1	1
Aluminum 2219	1	1
Brass (70/30)	1	2.2
Magnesium AZ63	2.2	3.3
1010 Steel	1	1
Stainless Steel 316	1	1
Copper	1	1
1010 Galvanized Steel	1	1
Titanium Ti-6Al-4V	1	1
Tin	1	1
Zinc	1	1

NOTE: Seven day reflux tests, the results are in Mils per year of corrosion.

7.16.6.7 COMPATIBILITY WITH MISSILE FUELS.

A Major concern of aerospace industry is the compatibility of solvents with missile fuels. Since many components have areas of entrapment where a solvent could remain and ultimately become mixed with the fuel, Methyl Chloroform was tested with missile fuels.

<u>Fuel</u>	<u>Effect</u>
Hydrogen Peroxide, 90%	Immiscible - No Apparent Reaction
Hydrazine Hydrate 85%	Immiscible - No Apparent Reaction
Hydrazine 95+%	Immiscible - Hydrazine Turned Red
Monomethyl Hydrazine	Miscible - No Apparent Reaction
Unsymmetrical Dimethyl Hydrazine	Miscible - No apparent Reaction

MIL - HDBK - 406

31 October 1971

7.17 TRICHLOROETHYLENE

7.17.1 PHYSICAL PROPERTIES

Formula	CHCLCCL ₂
Molecular Weight	131.40
Boiling Point °F	188.4
°C	86.9
Freezing Point °F	-123.5
°C	-86.4
Specific Gravity at 20°C	1.466
Pounds Per Gallon at 68°F (20°C)	12.25
Latent Heat of Vaporization at the Boiling Point	Cal/gm 57.2
	BTU/lb 103.0
Specific Heat of the Liquid at 20°C	Cal/gm/°C or BTU/lb/°F 0.225
Vapor Density at the Boiling Point and 760 mm Hg	Gm/Liter 4.5
	BTU/lb 0.278
Vapor Specific Gravity (Air = 100)	4.54
Evaporation Rate (Ether = 100)	28
Vapor Pressure at 20°C (mm Hg)	57.8
Flammability (U.L. Rating)	3
Viscosity of the Liquid at 20°C (Centipoise)	0.58
Dielectric Constant, Liquid (16°C)	3.42
Solubility at 25°C (Gm/100 gm) Of Water	0.032
In Water	0.11
Acidity (as HCl % by Weight, Max.)	None
Maximum Allowable Concentration in Air (ppm)	200
Color	Clear
Distillation Range °C	86.4 - 87.5
Non Volatile Residue	0.001
Free Halogen	None

7.17.2 SPECIFICATIONS

FEDERAL	O-T-634	Trichloroethylene, Technical
MILITARY	MIL-T-7003	1,1,2-Trichloroethylene
	MIL-T-27602a	1,1,2-Trichloroethylene
NASA	NASA-SPEC-217	Trichloroethylene, Technical

7.17.3 SOLUBILITY DATA. Trichloroethylene possesses the following solubility characteristics toward various materials.

Material	Solubility	Material	Solubility
Ether	Soluble	Alcohol	Soluble
Acetone	Miscible	Benzene	Miscible
Toluene	Miscible	Carbon Tetrachloride	Miscible
n-Heptane	Miscible	Methanol	Miscible

MIL - HDBK - 406
31 October 1971

<u>Material</u>	<u>Solubility</u>	<u>Material</u>	<u>Solubility</u>
Pyridine	Miscible	Amyl Alcohol	Miscible
Butyl Alcohol	Miscible	Ethyl Acetate	Miscible
Methyl Acetate	Miscible	Ethanol	Miscible
Water	Insoluble		

7.17.4 MATERIALS COMPATIBILITY

7.17.4.1 EFFECT ON MATERIALS OF CONSTRUCTION.

<u>Material</u>	<u>Effect</u>	<u>Material</u>	<u>Effect</u>
Polystyrene	Dissolves	Polyvinyl Chloride	4 Hr. Swollen
Polyethylene	4 Hr. Slight	Bakelite (Phenolic)	None
Teflon TFE	None	Neoprene Rubber	Swells
Silicone Rubber	Swells	Formvar (Polyvinyl Formal)	Will Soften
Bondar	None	Glyptal 1201	Lifted
Glyptal 1202	Lifted	GE 9740	Lifted
Ink, Marking	Removed		

7.17.4.2 EFFECT ON PLASTICS, ELASTOMERS AND RUBBERS.

<u>Plastic, Elastomer or Rubber</u>	<u>Initial Measure</u>	<u>After Drying</u>
Polypropylene (General Purpose Grade)	4.0	0
Polyethylene 3300 (High Density)	1.0	0
Polyethylene (Linear)	8.0	-0.5
Polyallomer (Ethylene Propylene Copolymer)	10.0	-0.5
Acetate (Cellulose Acetate)	2.0	-12.5
Butyrate (Cellulose Acetate Butyrate)	153.0	-
Propionate (Cellulose Acetate Propionate)	(b,c)	-
Chardon 15093 (1)	22.5	-3.5
Chardon 15096	38.5	-4.5
Chardon 15120	36.0	-5.5
Hycar 1000 x 132 (Acrylonitrile/Butadiene High Acrylonitrile Content)	18.5	-3.0
Hycar 1014 (3) (Buna N Low Acrylonitrile Content)	54.0	-4.0
Thiokol 3000 FA (Polysulfide Rubber)	28.0	-1.5
Thiokol 3600 ST-C (4)	34.5	-0.5
Thiokol E 455	40.5	-4.5
Dow Corning 94-002 (2) (Fluorosilicone Rubber)	6.5	-2.0
Silastic S-6526 (Silicone Rubber)	49.5	-1.0
Silastic LS-63 (Fluorosilicone Rubber)	6.5	0
Silastic 80 (Silicone Rubber)	36.5	-1.5
Silastic 675	51.0	-0.5

MIL - HDBK - 406
31 October 1971

NOTE: a. Warped or Disintegrated b. Distorted and Softened c. Partially Dissolved or Disintegrated d. Totally Dissolved or Disintegrated

1. Chardon Rubber Corporation
2. Dow Corning Corporation
3. B.F. Goodrich Chemical Company
4. Thiokol Chemical Company

A negative sign indicates that the sample decreased in size, the data is to the nearest 1/2 of 1%. The samples were placed in the solvent for 14 days at 77°F. After exposure, the solvent was allowed to evaporate from the sample surface and the initial measurements were taken. The samples were then dried for 48 hours at 100 - 102°F and they were again measured.

7.17.4.3 EFFECT ON ALUMINUM ALLOYS.

Alloy	Corrosion Rate (Mils Per Year)	Water (ppm)
1100	0.132	119
2024	0.364	153
2219 (48 Days)	1.09	150

7.17.4.4 EFFECT ON VARIOUS METALS.

Metal	Dry (100ppm H ₂ O)	Wet (400ppm H ₂ O)
Aluminum 1100	1	1
Aluminum 2024	1	1
Aluminum 2219	1	1
Brass (70/30)	1	1
Copper	1	1
Magnesium AZ63	1.5	1.5
Steel 1010	1	1
Steel Galvanized 1010	1	1
316 Stainless Steel	1	1
Titanium (Ti-6Al-4V)	1	1
Tin	1	1
Zinc	1	1

NOTE: Seven Day Reflux Test. Less than 1 Mil per year is considered excellent.

7.17.4.5 LOX & NTO SENSITIVITY. Compounds have been known to explode violently with LOX after initiation with M36A1 blasting caps include: 1,1,1-Trichloroethane, Trichloroethylene, and chlorinated dye penetrants numbers 1 and 2.

There is also a known violent and unexplained reaction between nitrogen tetroxide and many halogenated hydrocarbons.

MIL - HDBK - 406
31 October 1971

Insufficient data is available to explain the reaction but it has been found that those solvents which are symmetrical are less likely to explode than asymmetrical solvents. Single bonds and more fluorine than chlorine in the composition of the solvent also seems to lessen the likelihood of explosive mixtures being formed.

7.18 TRICHLOROMONOFUOROETHANE

7.18.1 PHYSICAL PROPERTIES

Formula	CCL ₃ F
Molecular Weight	137.4
Boiling Point °F	74.8
°C	23.8
Freezing Point °F	-168.0
°C	-111.0
Critical Temperature °F	388.4
°C	198.0
Critical Pressure PSIA	635.0
ATM	43.2
Vapor Pressure PSIA at 70°F	13.4
at 130°F	39.0
Specific Heat of the Liquid at 70°F BTU/(lb)(°F)	
Liquid	0.21
Saturated Vapor	0.13
Density at the Boiling Point	
Liquid	12.34
lbs/gal	
lbs/cu.ft.	92.31
gm/cc	1.479
Saturated Vapor	
lbs/cu.ft.	0.3650
gm/cc	5.847
Latent Heat of Vaporization at the Boiling Point	
BTU/lb	78.31
cal/gm	43.51
Heat Capacity at 70°F (21.1°C) BTU/(lb)(°F) or Cal/gm(°C)	
Liquid	0.205
Saturated Vapor	0.134
Thermal Conductivity at 70°F (21.1°C) BTU/(hr)(sq.ft.)(°F/ft)	
Liquid	0.0629
Vapor	0.00473
Viscosity at 70°F (21.1°C), Centipoise	
Liquid	0.438
Vapor	0.0108
Refractive Index of the Liquid at 79.7°F (26.5°C)	1.384
Surface Tension at 77°F (25°C), (dynes/cm)	19.0
Relative Dielectric Strength at 1 ATM and 73°F (23°C)	
(Nitrogen = 1)	3.1

MIL - HDBK - 406
31 October 1971

Dielectric Constant	Liquid at 86°F (30°C)	2.28
	Vapor (0.5 ATM) at 79°F (26°C)	1.0019
Solubility at 70°F (21.1°C) % by Weight	Of Water	0.009
	In Water	0.14
Diffusibility in air at 77°F (25°C) and 1 ATM	Sq. Ft/Hr	0.307
	Sq. Cm/Sec	0.080
Rate of Evaporation (Carbon Tetrachloride = 100)		225

7.18.1.1 LIQUID DENSITY.

Temperature °F	Lbs/Cu.Ft.	Lbs/Gal	Grams/cc
60	93.5	12.50	1.498
70	92.7	12.39	1.485
80	91.9	12.28	1.472
90	91.0	12.27	1.458
100	90.2	12.06	1.445

7.18.2. GENERAL INFORMATION. A dense, colorless liquid, highly volatile, non flammable and miscible with most organic compounds. Also known as Trichlorofluoromethane. It is miscible in all proportions with acetone, benzene, carbon tetrachloride, chloroform, ether, ethanol, hexane, kerosene, methanol and mineral oils.

Under normal conditions, steel, cast iron, brass, copper, tin, lead, zinc, aluminum and magnesium can safely be cleaned. In the presence of water at elevated temperature, the solvent may suffer some adverse effects resulting in damage to zinc, aluminum, magnesium and steel.

While inhalation of the vapors does not present too great a hazard, the TLV is 1000, neoprene gloves must be worn to protect the skin. The total range of cleaning operations, both hot and cold may be employed with trichlorofluoromethane, and the solvent is very stable and readily recoverable.

7.18.3 SOLUBILITY DATA. The following organics are soluble to the degree indicated.

Alcohol	Solubility	Ketone	Solubility
Cetyl	Very Soluble	Acetone	Miscible
Ethanol	Miscible	Methyl Ethyl Ketone	Miscible
Isopropanol	Miscible	Methyl Isobutyl Ketone	Miscible
Isobutanol	Miscible	Diacetone Alcohol	Miscible
Oleyl Alcohol	Miscible	Isophorone	Miscible
		Acetophenone	Miscible
		Stearone	Insoluble
Ethers			
Diethyl Ether	Miscible		
1,4, Dioxane	Miscible		

MIL - HDBK - 406
31 October 1971

<u>Ethers</u>		<u>Esters</u>	
Anisole	Miscible	Ethyl Acetate	Miscible
Diphenyl Ether	Miscible	Phenyl Acetate	Miscible
		Phenyl Benzoate	Moderate Sol.
		Dibutyl Phthalate	Miscible
		Tricresyl Phosphate	Miscible
<u>Glycols</u>		<u>Chlorinated Hydrocarbons</u>	
Ethylene Glycol	Insoluble	Carbon Tetrachloride	Miscible
Propylene Glycol	Insoluble	Methylene Chloride	Miscible
Diethylene Glycol	Insoluble	Perchloroethylene	Miscible
Dipropylene Glycol	Miscible	Trichloroethylene	Miscible
Triethylene Glycol	Insoluble		
2-Ethylhexanediol-1,3	Miscible		
<u>Hydrocarbons</u>		<u>Organic Acids</u>	
Hexane	Miscible	Stearic Acid	Very Soluble
Benzene	Miscible	Myristic Acid	Miscible
SAE No 10 Motor Oil	Miscible	Coconut Oil Fatty Acids	Miscible
SAE No 20 Motor Oil	Miscible	Salicylic Acid	Insoluble
SAE No 30 Motor Oil	Miscible		
Mineral Oil	Miscible	<u>Waxes</u>	
Napthalene	Very Soluble	Beeswax	Slight Soluble
Diphenyl	Miscible	Paraffin	Moderately Sol.
Kerosene	Miscible	Carnauba	Insoluble
		Microcrystalline Wax	Slight Soluble
<u>Miscellaneous</u>		<u>Miscellaneous</u>	
Acetamide	Insoluble	Menthol	Miscible
Agar	Insoluble	Gelatin	Insoluble
Phenol	Miscible	Urea	Insoluble
Casein	Insoluble	SPAN 40	Moderate Sol.
Sucrose	Insoluble	SPAN 80	Miscible
SPAN 20	Slight Sol.	TWEEN 60	Insoluble
SPAN 60	Moderate Sol.	Thymol	Miscible
TWEEN 40	Insoluble		
TWEEN 80	Insoluble		
Gum Arabic	Insoluble		

7.18.4 MATERIALS COMPATIBILITY.

7.18.4.1 EFFECTS ON PLASTICS.

Plastic	Width	Length	%Change Thickness	Weight	Remarks
Bakelite	0.0	0.0	0.0	0.0	
Cellulose Acetate	0.0	0.4	0.0	4.9	Final Weight; 98.5% of original
Cellulose Nitrate	0.5	0.6	0.8	5.2	Final Weight; 98% of original

MIL - HDBK - 406
31 October 1971

Plastic	Width	Length	% Change Thickness	Weight	Remarks
Nylon 6	0.0	0.0	0.0	0.0	
Plexiglass	0.0	0.0	0.0	0.0	
Polyethylene	6.1	6.7	7.6	32.4	Dimensions/Weight 101% of original
Polyvinyl Alcohol	0.7	0.3	0.8	0.4	Little Effect
Polyvinyl Chloride	0.2	0.0	0.7	11.5	Final Weight; 110% of original
Saran	-0.3	-0.2	0.0	0.2	Little Effect
TFE	0.0	0.0	1.5	1.4	Weight; 100.5% of original and thickness; 101.5% of original
Nylon 66	0.0	0.0	0.0	0.0	

7.18.4.2 EFFECTS ON ELASTOMERS.

Elastomer	% Change		Final Change		Remarks
	Length	Volume	Length	Weight	
Neoprene	18.3	66.4	-4.5	-8.2	Extraction shown by weight loss and solvent coloration
Navy Gum	37.7	143.3	-4.6	-10.0	Same as Neoprene
Buna N	6.4	20.8	-5.2	-10.9	Same as Neoprene
Silicone	53.5	261.7	-1.8	-3.5	Fairly low extraction
Pure Gum	60.0	309.6	-2.7	-3.8	Same as Silicone

NOTE: Final Change indicates % of change after the elastomer has been dried.

Linear Swelling at Room Temperature

	% Increase in Length
Neoprene GN	17
Buna N (Butadiene/Acrylonitrile)	6
Buna S (Butadiene/Styrene)	21
Natural Rubber	23
GRI (Isobutylene/Isoprene)	41
Polysulfide	2.1
Silicone	38

7.18.4.3 EFFECTS ON MACHINERY ENAMEL.

Exposure: Test panel stored half in liquid and half in vapor at 75°F for 196 hours in closed glass bottle.

MIL - HDBK - 406

31 October 1971

(Effect on Machinery Enamel Cont.)Solvent: Trichloromonofluoromethane

Appearance of Test Panel: After 1 Hour; Paint Softened
 After 4 Hour; Small blisters
 After 22 Hour; Paint badly swollen
 At End of Test; Crack developed at edges.
 No discoloration or sagging. Paint
 discolored by undercoat penetrating
 topcoat.

Appearance of Solvent: Slightly cloudy.

7.18.4.4 EFFECT ON WIRE INSULATION.Exposure: 100 hours at 130°FMaterial

Formvar

EffectSlight crazing, Coating not softened,
No extraction

Bondar

No crazing, Coating not softened,
No extraction

Nylon

No crazing, Coating not softened,
No extraction

Lecton

No crazing, Coating not softened,
No extraction

Alkanex

No crazing, Coating not softened,
No extraction

Polyurethane

No crazing, Coating not softened,
No extraction7.18.4.5 NTO SENSITIVITYInduced Shock EquivalentReaction

1/4 gram equivalent of TNT

No Explosion

1/3 gram equivalent of TNT

No Explosion

25 gram equivalent of TNT

No Explosion

7.19 TRICHLOROTRIFLUOROETHANE7.19.1 PHYSICAL PROPERTIES

Formula		CCL ₂ FCCLF ₂
Molecular Weight		187.4
Boiling Point	°F	117.6
	°C	47.6
Freezing Point	°F	-31.0
	°C	-35.0

MIL - HDBK - 406
31 October 1971

Critical Temperature °F	417.4
°C	214.1
Critical Pressure PSIA	495.0
ATM	33.7
Density at Boiling Point Liquid Lbs/cu.ft.	94.29
Lbs/gal	12.60
Gm/cc	1.510
Saturated Vapor Lb/cu.ft.	0.4619
Gm/Liter	7.399
Density of the Liquid at 77°F Lbs/gal	13.06
Lbs/cu.ft.	97.7
Latent Heat of Vaporization at the Boiling Point BTU/lb	63.12
Cal/gm	35.07
Heat Capacity at 70°F (21.1°C), BTU/lb(°F) or Cal/Gm(°C) Liquid	0.694
Vapor	0.0102
Refractive Index of the Liquid at 79.7°F (26.5°C)	1.355
Surface Tension at 77°F (25°C), (dynes/cm)	19.0
Dielectric Constant Liquid at 86°F (30°C)	2.44
Vapor (0.5 ATM) at 79°F (26°C)	-
Solubility at 70°F (21.1°C), % by weight, of Water	0.009
Solubility at Saturation Pressure and 70°F (21.1°C), % by Weight, in Water	0.017

7.19.1.1 COMMERCIAL SOLVENT GRADE SPECIFICATION. Manufacturers have established the following criteria for the solvent grade of Trichlorotrifluoroethane:

Purity: 99.8 Weight % Minimum, 0.2 Weight % maximum other fluorocarbons
Residue Content: Not more than 2ppm by weight
Acid Number: (mg KOH/gm of sample); 0.003 maximum
Chloride Ion: 0.1ppm by weight maximum
Moisture: 10ppm by weight maximum

7.19.1.2 COMMERCIAL WHITE ROOM GRADE SPECIFICATION. Manufacturers have established the following criteria for the white room grade of Trichlorotrifluoroethane:

Purity: 99.9 Weight % minimum, 0.1 Weight % maximum other fluorocarbons
Residue Content: Not more than 1ppm by weight
Acid Number: (mg KOH/gm of sample); 0.003 maximum
Chloride Ion: 0.1ppm by weight maximum
Moisture: 10ppm by weight maximum

7.19.2 SPECIFICATIONS.

FEDERAL	BB-C-310	Chlorofluoro Hydrocarbons
MILITARY	HIL-C-81302	Cleaning Compound, Solvent, Trichlorotrifluoroethane

MIL - HDBK - 406
31 October 1971

7.19.2.1 COMMERCIAL SPECIFICATION AND TEST.

<u>Specification</u>	<u>Test</u>
a.) The product shall be a clear colorless liquid.	Visual Inspection
b.) The product shall be passed through a 1 micron filter upon loading into containers.	
c.) The product shall be packaged in an epoxy-modified, phenolic-lined drum containing either polyethylene or epoxy-modified Phenolic-coated steel bungs.	
d.) The product moisture content shall not exceed 10ppm by weight.	Titration with Karl Fischer reagent using a Beckman Aquameter model KF-2 automatic titrator.
e.) The product soluble residue content shall not exceed 2ppm by weight.	Gravimetric measurement of residue from evaporation of a 1000.0ml sample.
f.) The product shall give no positive test for chloride ion when tested with an alcoholic solution of silver nitrate.	5ml mixed with 5ml of absolute methyl alcohol to which 3 to 4 drops of silver nitrate in absolute methyl alcohol has been added.
g.) The product shall have an acid number of 0.003 mg KOH/gm of sample or less	ASTM - D974
h.) The product's boiling point shall be 47.6°C at standard barometric pressure. The product's boiling range from 5% to 95% distilled shall not exceed 0.3°C	ASTM - D1078 with distillation controlled to proceed at a rate of 0.4 - 0.5 ml/min.
i.) The product shall reveal no particulate matter and no more than a trace of residual color when filtered through a No. 40 Whatman filter paper.	Filtration of a 1000.0ml sample through a No 40 Whatman filter paper using lab glass apparatus #LG-7185.
j.) The purity of the product shall be 99.8% by weight minimum.	Gas chromatographic separation with temperature programing through a column composed of 20% by weight of polypropylene glycol on 60-8 mesh Chromosorb.

MIL - HDBK - 406
31 October 1971
7.19.2 SOLUBILITY DATA.

7.19.3.1 SOLUBILITY OF WATER.

Temperature °F	Solubility ppm by Wt.	Temperature °F	Solubility ppm by Wt.
-30	6	50	55
-20	8	60	70
-10	11	70	90
0	15	80	113
10	20	90	140
20	26	100	168
30	34	110	210
40	44		

7.19.3.2 SOLUBILITY OF VARIOUS MATERIALS.

<u>Alcohols</u>	<u>Solubility</u>	<u>Ketones</u>	<u>Solubility</u>
Cetyl	Insoluble	Acetone	Miscible
Ethanol	Miscible	Methyl Ethyl Ketone	Miscible
Isopropanol	Miscible	Methyl Isobutyl Ketone	Miscible
Isobutanol	Miscible	Diacetone Alcohol	Miscible
Oleyl Alcohol	Insoluble	Isophorone	Miscible
		Acetophenone	Miscible
		Benzophenone	Miscible
		Stearone	Insoluble
<u>Ethers</u>		<u>Chlorinated Hydrocarbons</u>	
Diethyl Ether	Miscible	Carbon Tetrachloride	Miscible
1,4 Dioxane	Miscible	Methylene Chloride	Miscible
Anisole	Miscible	Perchloroethylene	Miscible
Diphenyl Ether	Miscible	Trichloroethylene	Miscible
<u>Hydrocarbons</u>		<u>Organic Acids</u>	
Hexane	Miscible	Stearic Acid	Very Soluble
Benzene	Miscible	Myristic Acid	Miscible
SAE No 10 Motor Oil	Miscible	Coconut Oil Fatty Acids	Miscible
SAE No 20 Motor Oil	Miscible	Salicylic Acid	Insoluble
SAE No 30 Motor Oil	Miscible		
Mineral Oil	Miscible	<u>Glycols</u>	
Naphalene	Very Soluble	Ethylene Glycol	Insoluble
Diphenyl	Miscible	Propylene Glycol	Insoluble
Kerosene	Miscible	Diethylene Glycol	Insoluble
<u>Waxes</u>		Dipropylene Glycol	Miscible
Beeswax	Slight Soluble	Triethylene Glycol	Insoluble
Paraffin	Moderate Sol.	2-Ethylhexanediol-1,3	Miscible
Cariauba	Insoluble		
Microcrystalline Wax	Slight Soluble		

MIL - HDBK - 406
31 October 1971

<u>Miscellaneous</u>	<u>Solubility</u>	<u>Miscellaneous</u>	<u>Solubility</u>
Acetamide	Insoluble	Agar	Insoluble
Phenol	Miscible	Menthol	Miscible
Casein	Insoluble	Gelatin	Insoluble
Sucrose	Insoluble	Urea	Insoluble
SPAN 20	Slight Soluble	SPAN 40	Moderate Sol.
SPAN 60	Moderate Sol.	SPAN 80	Miscible
TWEEN 40	Insoluble	TWEEN 60	Insoluble
TWEEN 80	Insoluble	Thymol	Miscible
Gum Arabic	Insoluble		

7.19.3.3 VARIOUS OILS TOTALLY MISCIBLE WITH TRICHLOROTRIFLUOROETHANE.

<u>Oil</u>	<u>Manufacturer</u>
NuJol	Plough Inc.
Synjet Oil 15	Texas Company
Sunisco 3G	Sun Oil Company
Amoco 90 Wt Gear Oil	Americal Oil Company
Amoco 30 Wt Motor Oil	American Oil Company
Texaco Aircraft Hydraulic Oil	Texas Company
Socony Mobile DTE Lube Oil	Socony Mobile Company
Northia #27	Shell Oil Company
Texaco Sulley B Cutting Oil	Texas Company
Clorafin 40	Hercules Powder Company
Versilube F-50	General Electric Company

7.19.4 MATERIALS COMPATIBILITY.

7.19.4.1 EFFECT ON PLASTICS

<u>Plastic</u>	<u>Effect</u>	<u>Plastic</u>	<u>Effect</u>
Linear Polyethylene Resin	None	Polypropylene Resin	None
Acetal Resin	None	Ethyl Cellulose	Very Slight
ABS Polymer	None	Polycarbonate Resin	None
Polyvinyl Chloride	None	Polystyrene	None
Ionomeric Resin	None	101 Nylon Resin	None
TFE Resin	None	Polymonochlorotrifluoro ethylene	1% change in Weight
Polyester Resin Laminate	3% swell	Nylon	None
Polyvinyl Alcohol	None	Chlorinated Polyether	0.3% swell
Saran	None		
Cellulose Acetate	None		
Polyester/Styrene Copolymer	None		

MIL - HDBK - 406

31 October 1971

7.19.4.2 EFFECT ON PLASTICS AND RUBBER

Plastic	% Linear Swell	
	5 Min at Room Temp	5 Min at High Temp
C Urethane Rubber	None	
L Urethane Rubber	None	
Buna N	None	1.0
Buna S	1	9.0
Synthetic Rubber	1	5.0
Butyl	21	23.0
Natural Rubber	17	19.0
Neoprene W	1	3.0
Silicone	6	36.0
FA Polysulfide	0	1.0
A Fluoroelastomer	5	6.0
Hydrocarbon Rubber	1	18
Neoprene GN	3	
NBR	1	1
Compounded Polyvinyl Alcohol	-1	
SBR	9	9

7.19.4.3 EFFECT ON WIRE COATINGS

Coating	Contact Time	Effect
Bondar Wire (Cotton coating removed)	24 Hours	None
Bondar Wire (Cotton coated with varnish)	24 Hours	None
Insulating Cloth (Varnish coated)	24 Hours	None
Paper Insulation	24 Hours	None
Formvar Wire	24 Hours	None
Silicone-Treated Glass and Mica Mat Tape	1 Day	None
Silicone-Treated Glass and Asbestos Slot Liner	1 Day	None
Silicone-Treated Class H Motor Coil	1 Day	None
Dow Corning 996 Electric Insulating Varnish	2 Min	None
Dow Corning 997 Electric Insulating Varnish	6 Min	None

7.19.4.4 EFFECT ON WIRE INSULATION

Insulation	Effect	Insulation	Effect
Polyvinyl Formal	None	Bondar	None
Nylon Polyamide	None	Acrylic	None
Alkanex	None	Polyurethane	None
Polyamide	None		

MIL - HDBK - 406
31 October 1971

7.19.4.5 EFFECT ON VARIOUS METALS

<u>Metal</u>	<u>Temperature °F</u>	<u>Corrosion (Mils/Year)</u>
Aluminum	200	None
	248	None
	248 (Water added, 3%by Vol.)	None
	392	<0.01
Brass	200	None
	248	None
	248 (Water added, 3%by Vol.)	None
Copper	200	None
	392	> 0.1
Magnesium	200 (Contact time 14 Days)	0.01 to 0.1
Steel	200	None
	248	None
	248 (Water added, 3%by Vol.)	None
	392	<0.01

NOTE: Contact time = 260 days exposure unless otherwise indicated.

7.19.4.6 EFFECT ON ALUMINUM ALLOYS

<u>Alloy</u>	<u>Corrosion Rate (Mils per Year)</u>	<u>Water (ppm)</u>
2219	2.69	150
2219 (48 Days)	0.02	25
2219 (33 Days)	0.03	50
7075	2.32	<10
7075	4.95	49
7075	3.55	89
7075	3.22	Saturated

NOTE: Seven day reflux test where otherwise indicated. In the presence of zinc, the solvent is dechlorinated. The greater corrosion in the 7075 alloy is probably due to the presence of 5.6% zinc in that alloy. No significant corrosion was noted in systems where the water concentration did not at least approach the saturation point.

7.19.4.7 EFFECT ON VARIOUS METALS

<u>Metal</u>	<u>Time</u>	<u>% of Decomposition</u>
Mild Steel	360 Days	0.95
316 Stainless Steel	430 Days	0.25
Inconel	435 Days	0.21
Nickel	300 Days	0.30
Monel	250 Days	1.02

MIL - HDBK - 406
31 October 1971

NOTE: Metal samples were placed in glass ampules which were then evacuated, filled with solvent and sealed. The ampules were stored at 500°F for periods of 250 to 435 days.

Metal	Condition	Corrosion Rate (in./month)	Corrosion Appearance
Aluminum	1	N11	None
Zinc	1	6×10^{-6}	None
Magnesium	1	21×10^{-6}	Slight corrosion
Tin	2	N11	None
Copper	1	12×10^{-6}	Slight Tarnish

NOTE: 1 - Sealed tube test for 100 hours at 117.6°F

2 - Sealed tube test for 91 days at 194°F

N11 - Indicates that the corrosion rate was below the limit of weighing accuracy - (i.e. less than 6×10^{-6} inches per month)

7.19.4.8 EFFECT ON AIRCRAFT MATERIALS.

Material	Position	113 weeks			Position	113 + 0.1% water weeks		
		1	4	8		1	4	8
Ti 75A	Vapor(a)	G	0	G	Vapor(a)	G	G	G
	Condense	0	0	0	Condense	0.04	0	0
	Liquid	0	G	0	Liquid	0	G	G
Ti-6Al-4V	Vapor	0.08	00	0.02	Vapor	0	0	0
	Condense	0	G	0	Condense	0	0	0
	Liquid	0.04	0	0	Liquid	G	0	G
Al 6061	Vapor(a)	0	0	0	Vapor(a)	G	G	G
	Condense	0	0	0	Condense(a)	0	0	G
	Liquid	G	G	G	Liquid(a)	G	G	G
4130	Vapor	G	G ^b	0.01	Vapor	G	0.04	0.17 ^b
	Condense	G	G ^b	0.01	Condense	G	0	0.22 ^b
	Liquid	G	G ^b	0.01	Liquid	G	0.03	0.14 ^b

NOTE: All measurements are in Mils per year.

(a) Light Tarnish

(b) After rust removal

G Indicates slight weight gain

7.19.4.9 IMPACT SENSITIVITY

Material	Number of Specimens	Reactions at 70 FT.-lbs
Al - 1100	6	None
Al - 1100+alumina sand		
Al - 7075	4	None

MIL - HDBK - 406
31 October 1971

Material	Number of Specimens	Reactions at 70FT-lbs
Ti - 75A	1	None
Ti - 75A + Ti powder	1	None
Ti - 6AL - 4V	1	None
Ti - 6Al - 4V + Ti powder	1	None

7.19.4.10 IMPACT SENSITIVITY HEIGHT

Solvent	Minimum impact sensitivity Height in Inches (5 lb ball)						
	Metal						
	Al Powder	Mg Powder	Ti Powder	Ba Shavings	Li Shavings	Be Powder	BeH ₂ Powder
Monofluoro- trichloro- methane	F 50	0	0	X 20	X 50	0	0
Trichloro- trifluoro- ethane	F 50	0	F 50	F 4 X 10	X 20	0	0
Carbon Tetrachloride	X 50	F 50	0	F 10 X 15	X 18	F 50	0
Trichloro- ethylene	0	F 50	F 50	F 13 X 15	X 25	F 50	0
Perchloro- ethylene	0	0	0	F 15 X 20	X 30	0	0
1,1,1-Tri- chloro- ethane	0	0	0	0	0	0	0

NOTE: X - Height in inches at which detonation occurred
 0 - No reaction at 50 inches
 F - Height in inches at which a flash or heavy sparking occurred

7.20 TRICHLOROTRIFLUOROETHANE AND SDA-30 ETHYL ALCOHOL BLEND

7.20.1 PHYSICAL PROPERTIES.

Boiling Point at 1 atm.	°F	119
	°C	48.3
Freezing Point	°F	-108
	°C	-78
Liquid Density at 77°F (25°C)	Lbs/gal	9.75
	Lbs/cu.ft.	72.92
	Gm/cc	1.168
Vapor pressure at 77°F	PSIA	6.58

MIL - HDBK - 406

31 October 1971

Viscosity at 77°F, Centipoise	1.762
Surface Tension at 75°F dynes/cm	19.6
Refractive Index	1.359
Solubility of Water at 75°F Weight %	6.3
Latent Heat of Vaporization at the Boiling Point BTU/lb	149
Cal/gm	82.5
Heat Capacity at 68°F BTU/(lb)(°F) Liquid	0.472
Flash Point	None
Toxicity Threshold Limit Value	1000
Kauri-Butanol Value	500
Dielectric Constant of the Liquid at 75°F	18
D.C. Resistivity, Ohm-cm	10

7.2Q2 SOLUBILITY DATA

Substance	Solubility	Substance	Solubility
Acetone	Miscible	Chloroform	Miscible
Cottonseed Oil	Miscible	Ester Gum	40%
Ethyl Acetate	Miscible	Ethyl Alcohol	Miscible
Ethylene Glycol	5-8%	Glycerine	6-8%
Hexane	Miscible	Lube Oil	10-19%
Methyl Alcohol	Miscible	Paraffin 123-127°F	2.2%
Paraffin 140-142°F	0.3%	Propylene Glycol	47-48%
Silicone Oil 200 Cent.	26-30%	Silicone Oil 1000 Cent.	19-24

NOTE: Solubility is expressed as percent by weight.

7.2Q.3 MATERIALS COMPATIBILITY

7.2Q.3.1 EFFECT ON PLASTICS

Exposure: Immersion in liquid for 5 minutes at 75°F

Plastic	Effect	Plastic	Effect
7050 Linear Polyethylene Resin	0	9140 Polypropylene Resin	0
Acetal Resin	0	Epoxy Resin	0
Ethyl Cellulose	4	ABS Polymer	0
Polycarbonate Resin	0	Methylmethacrylate Resin	0
Polyvinyl Alcohol	1	Polyvinyl Chloride	0
Polystyrene	0	Ionomeric Resin	0
TFE Resin	0	101 Nylon Resin	0

NOTE: 0 - No visible effect 1 - Very slight effect

MIL - HDBK - 406
31 October 1971

7.20.3.2 EFFECT ON ELASTOMERS

Elastomer	Effect	Elastomer	Effect
Adiprene C	3	Adiprene L	1
Buna N	1	Buna S	1
Butyl	0	Hypalon 40	0
Natural Rubber	1	Neoprene W	1
Nordel	1	Silicone	5
Thiokol FA	0	Viton A	2

NOTE: Exposure; Immersion at room temperature for 5 minutes. Effect is expressed as percent of temporary change in linear dimensions.

7.20.3.3 EFFECT ON WIRE COATINGS. The solvent had no adverse effects on the following magnet wire coating materials after an exposure of 5 minutes at 75°F: Acrylic Epoxy Terephthalate Polyester

Polyvinyl Formal Polyurethane Isocyanate-Modified Poly-
ESX Solderable Polyimide vinyl Formal
Acrylic Nylon Coated Polyvinyl Formal

7.21 TRICHLOROTRIFLUOROETHANE AND ISOPROPYL ALCOHOL BLEND

7.21.1 PHYSICAL PROPERTIES

Boiling Point at 1 atm	°F	120.0
	°C	48.0
Freezing Point	°F	-94.0
	°C	-70.0
Liquid Density at 77°F	Lbs/gal	9.60
	Lbs/cu.ft.	71.79
	Gm/cc	1.150
Vapor Pressure at 77°F		5.5
Viscosity at 77°F	Centipoise	0.997
Surface Tension at 75°F, dynes/cm		21.0
Refractive Index		1.368
Solubility of Water at 75°F, Weight %		9.1
Latent Heat of Vaporization at the Boiling Point	BTU/lb	119.7
	Cal/gm	66.5
Heat Capacity at 68°F	BTU/(lb)(°F)	0.355
Flash Point		None to Boiling Point
Threshold Limit Values		750
Dielectric Constant of the Liquid at 75°F		9.2
D.C. Resistivity, Ohm-cm		2×10^7

7.21.2 SOLUBILITY DATA

Substance	Solubility	Substance	Solubility
Acetone	Miscible	Chloroform	Miscible

MIL - HDBK - 406
31 October 1971

Substance	Solubility	Substance	Solubility
Cottonseed Oil	Miscible	Ester Gum	63%
Ethyl Acetate	Miscible	Ethyl Alcohol	Miscible
Ethylene Glycol	31%	Glycerin	7.1%
Hexane	Miscible	Lube Oil	Miscible
Methyl Alcohol	Miscible	Mineral Oil	Miscible
Paraffin Wax 123-127°F	2.8%	Propylene Glycol	Miscible
Silicone Oil 200 Centi.	Miscible	Silicone Oil 1000 Centi.	Miscible

NOTE: Solubility is expressed as either total miscibility or percent by weight.

7.21.3 MATERIALS COMPATIBILITY

7.21.3.1 EFFECT ON PLASTICS

Plastic	Effect	Plastic	Effect
7050 Linear Polyethylene Resin	0	9140 Polypropylene Resin	0
Acetal Resin	0	Epoxy Resin	0
Ethyl Cellulose	3	ABS polymer	0
Polycarbonate Resin	0	Methylmethacrylate Resin	0
Polyvinyl Alcohol	0	Polyvinyl Chloride	0
Polystyrene	0	Ionomeric Resin	0
TFE Resin	0	101 Nylon Resin	0

NOTE: 0 - No visible effect 3 - Compatibility should be tested

7.21.3.2 EFFECT ON ELASTOMERS

Elastomer	Effect	Elastomer	Effect
C Urethane Rubber	0	L Urethane Rubber	0
Buna N	0	Buna S	0
Butyl	0	Hypalon 40 Synthetic Rubber	0
Natural Rubber	0	Neoprene W	0
Hydrocarbon Rubber	0	Silicone	2
Thiokol FA Polysulfide Rubber	0	Viton A Fluoroelastomer	0

NOTE: Exposure; Immersion in liquid at room temperature for 5 minutes.
The effect is expressed as the percent of temporary change in linear dimension.

7.21.3.3 EFFECT ON WIRE COATINGS

Coating	Effect	Coating	Effect
Acrylic	0	Terephthalate Polyester	1
Isocyanate-Modified Polyvinyl Formal	2	Polyurethane	0
Epoxy	0	ESX Solderable Acrylic	0
		Polyvinyl Formal	0

MIL - HDBK - 406
31 October 1971

Coating	Effect	Coating	Effect
Nylon Coated Polyvinyl Formal	2	Oleoresinous Enamel	1
Polyimide	1		

NOTE: 0 - No visible effect 1 - Very slight effect
2 - Compatibility should be tested.
Exposure; Immersion in liquid for 5 minutes at 75°F

7.22 TRICHLOROTRIFLUOROETHANE/WATER/SURFACTANT

7.22.1 PHYSICAL PROPERTIES

Boiling Point at 1 atm	°F	112.0
	°C	44.4
Freezing Point	°F	32.0
	°C	0
Liquid Density at 77°F	Lbs/gal	12.47
	Lbs/cu.ft.	93.27
	Gm/cc	1.494
Surface Tension at 75°F	dynes/cm	19.5
Viscosity at 77°F	centipoise	0.94
Vapor Pressure at 77°F		7.0
Flash Point		None
Toxicity Threshold Limit Value		1000
Kauri-Butanol Value		21

7.22.2 SOLUBILITY DATA

Substance	Solubility	Substance	Solubility
Acetone	1.0	Benzene	1.2
Chloroform	2.0	Cottonseed Oil	9.7
Ethyl Acetate	9.8	Ethyl Alcohol	10.4
Ethylene Glycol	1.5	Glycerin	1.7
n-Hexane	Miscible	Isopropanol	0.3
Methyl Alcohol	1.1	Mineral Oil	23.2
Paraffin Wax 123-127°F	5.0	Phenol	0.05
Propylene Glycol	2.0	Silicone Oil 1000 Centi.	1.3

7.22.3 MATERIALS COMPATIBILITY

7.22.3.1 EFFECT ON METALS. No problems should be encountered with the following metals; Steel, nickel, monel, copper, aluminum and magnesium. Prolonged exposure to zinc and zinc alloys may result in some corrosion and this solvent should not be used with metals which are galvanized. Aluminum poses a problem on long term exposure, as does magnesium.

MIL - HDBK - 406

31 October 1971

7.22.3.2 EFFECT ON PLASTICS

Plastic	5 Min	4 Hrs	Plastic	5 Min	4 Hrs
7050 Linear Polyethylene Resin	0	0	9140 Polypropylene Resin	0	0
Epoxy Resin	0	0	Acetal Resin	0	0
Ethyl Cellulose	0	3	ABS Polymer	0	0
Methylmethacrylate Resin	0	0	Polycarbonate Resin	0	0
Polyvinyl Chloride	0	0	Polyvinyl Alcohol	0	3
Ionomeric Resin	0	0	Polystyrene	0	2
101 Nylon Resin	0	0	TFE Resin	0	0

NOTE: 0 - No Visible Effect

2 - Compatibility should be tested

3 - Probably not suitable

7.22.3.3 EFFECT ON ELASTOMERS

Elastomer	Room Temperature	Boiling Point (112°F)
Urethane Rubber C	0.6	2.2
L Urethane Rubber	0.2	1.1
Buna N	-0.4	0.5
Buna S	0.9	5.5
Butyl	1.3	2.3
Hypalon 40 Synthetic Rubber	0.3	2.0
Natural Rubber	3.7	13.0
Neoprene W	-0.1	-0.2
Hydrocarbon Rubber	1.5	6.1
Silicone	20.0	15.0
FA Polysulfide	-0.7	1.2
Fluoroelastomer	0.4	0.8

NOTE: Exposure; Immersion in liquid at room and boiling temperatures for 5 Minutes. The effect is expressed as the percent of temporary linear dimension change.

7.23 TRICHLOROTRIFLUOROETHANE AND SDA-30 ETHYL ALCOHOL AZEOTROPE

7.23.1 PHYSICAL PROPERTIES

Boiling Point at 1 atm	°F	112.3
	°C	44.6
Freezing Point	°F	-43
	°C	-42
Liquid Density at 77°F	Lbs/gal	12.56
	Lbs/ cu.ft.	93.96
	Gm/cc	1.505
Vapor Pressure at 77°F		7.0

MIL - HDBK - 406
31 October 1971

Surface Tension at 75°F	dynes/cm	17.7
Refractive Index		1.358
Solubility of Water at 75°F	Weight %	0.22
Latent Heat of Vaporization at the Boiling Point	BTU/lb	77.2
	Cal/gm	42.9
Heat Capacity at 68°F	BTU/(lb)(°F)	0.272
	Liquid	0.189
	Vapor	None
Flash Point		None
Toxicity Threshold Limit Value		1000
Kauri-Butanol Value		40
D.C. Resistivity	Ohm-cm	1.8×10^{10}
Dielectric Constant at 100 Hz		3.0

7.232 SOLUBILITY DATA

Substance	Solubility	Substance	Solubility
Acetone	Miscible	Chloroform	Miscible
Cottonseed Oil	Miscible	Ethyl Acetate	Miscible
Ethyl Alcohol	Miscible	Hexane	Miscible
Lube Oil	Miscible	Methyl Alcohol	Miscible
Mineral Oil	Miscible	Silicone Oil 200 Centi.	Miscible
Silicone Oil 1000 Centi.	Miscible		

7.233 MATERIALS COMPATIBILITY

7.233.1 EFFECT ON PLASTICS

The following plastics were unaffected by a five minute exposure to the solvent at the boiling point:

7050 Linear Polyethylene Resin	Methylmethacrylate Resin
Polypropylene Resin	Polysulfone
Acetal Resin	Polyvinyl Chloride
Photopolymer	Polyphenylene Oxide
Epoxy Resin	Ionomeric Resin
ABS Polymer	TFE Resin
Polycarbonate Resin	101 Nylon Resin

The following plastics may be sensitive and warrant testing prior to solvent use:

Ethyl Cellulose	Polyvinyl Alcohol	Polystyrene
-----------------	-------------------	-------------

7.233.2 EFFECT ON WIRE COATINGS. The following wire coatings will not be affected by exposure to the solvent: OMP-6991 Acrylic, X-1414 Phenol-formaldehyde, Polyimide.

MIL - HDBK - 406
31 October 1971

7.23.3.3 EFFECT ON ELASTOMERS

<u>Elastomer</u>	<u>Effect</u>	<u>Elastomer</u>	<u>Effect</u>
Natural Rubber	32	Chlorobutyl Rubber	17
Buna S	14	Hypalon 40 Synthetic Rubber	8
Neoprene W	5	Buna N	4
Butyl Rubber	15		
Fluoroelastomer	6		

NOTE: Exposure; 8 days at 75°F. Results are expressed in terms of percent of temporary linear dimension change.

7.24 TRICHLOROTRIFLUOROETHANE AND CHLOROFORM AZEOTROPE

7.24.1 PHYSICAL PROPERTIES

Boiling Point at 1 atm	°F	117.3
	°C	47.4
Freezing Point	°F	-59.8
	°C	-51.0
Liquid Density at 77°F	Lbs/gal	12.99
	Lbs/cu.ft.	97.20
	Gm/cc	1.557
Vapor Pressure at 77°F	PSIA	6.5
Viscosity at 77°F	Centipoise	0.653
Surface Tension at 75°F	dynes/cm	19.8
Refractive Index		1.362
Solubility of Water at 75°F		0.01
Latent Heat of Vaporization at the Boiling Point	BTU/lb	68.2
	Cal/gm	37.9
Heat Capacity at 68°F	BTU/(lb)(°F)	0.214
	Liquid	
	Vapor	0.152
Flash Point		None
Toxicity Threshold Limit Value		500
Kauri-Butanol Value		37
Dielectric Constant of the Liquid at 75°F		2.53
D.C. Resistivity Ohm-cm		2.8 X 10 ¹⁴

7.24.2 SOLUBILITY DATA

<u>Substance</u>	<u>Solubility</u>	<u>Substance</u>	<u>Solubility</u>
Acetic Acid	Miscible	Acetone	Miscible
Benzene	Miscible	Carbon Tetrachloride	Miscible
Chloroform	Miscible	Cottonseed Oil	Miscible
Diethyl Ether	Miscible	Ester Gum	33%
Ethyl Acetate	Miscible	Ethyl Alcohol	Miscible
Ethylene Glycol	1.3 - 2.7%	Glycerin	1.1 - 1.7%

MIL - HDBK - 406
31 October 1971

Substance	Solubility	Substance	Solubility
Hexane	Miscible	Methyl Alcohol	Miscible
Mineral Oil	Miscible	Paraffin Wax 123-127°F	6.5%
Paraffin Wax 140-142°F	2.9	Phenol	20%

NOTE: Solubility is expressed as either complete miscibility or that percent which is soluble.

7.24.3 MATERIALS COMPATIBILITY

7.24.3.1 EFFECT ON METALS. This solvent can be used to clean most metals, however, the more reactive metals will cause solvent decomposition if there is any free water in the system. Such metals would include zinc and magnesium.

7.24.3.2 EFFECT ON PLASTICS

Plastic	Effect	Plastic	Effect
7050 Linear Polyethylene Resin	0	9140 Polypropylene Resin	0
Acetal Resin	0	Epoxy Resin	0
Ethyl Cellulose	3	ABS Polymer	0
Polycarbonate Resin	0	Methylmethacrylate Resin	0
Polyvinyl Alcohol	0	Polyvinyl Chloride	0
Polyphenylene Oxide	0	Polystyrene	1
Ionomeric Resin	0	TFE Resin	0
101 Nylon Resin	0		

NOTE: 0 - No visible effect 1 - Very slight effect 3 - Probably not suited
Exposure; Immersion in liquid for five minutes at the solvent boiling point.

7.24.3.3 EFFECT ON ELASTOMERS

Elastomer	Room Temperature	130°F
C Urethane Rubber	2	5
L Urethane Rubber	1	2
Buna N	1	2
Buna S	3	10
Butyl	3	3
Hypalon 40 Synthetic Rubber	2	3
Natural Rubber	12	21
Neoprene W	0	2
Hydrocarbon Rubber	1	10
Silicone	21	23
FA Polysulfide	0	0
Fluoroelastomer	1	1

NOTE: Exposure; Immersion in liquid for five minutes at the solvent boiling point. Effects are expressed as the percent of temporary change in linear dimension.

MIL - HDBK - 406

31 October 1971

7.25 TRICHLOROTRIFLUOROETHANE AND ACETONE AZEOTROPE

7.25.1 PHYSICAL PROPERTIES

Boiling Point at 1 atm	°F	110.5
	°C	43.6
Freezing Point	°F	-150
	°C	-101
Liquid Density at 77°F	Lbs/gal	11.73
	Lbs/cu.ft.	87.78
	Gm/cc	1.406
Vapor Pressure at 77°F PSIA		7.35
Viscosity at 77°F Centipoise		0.542
Surface Tension at 75°F dynes/cm		18.7
Refractive Index		1.358
Latent Heat of Vaporization at the Boiling Point	BTU/lb	85.4
	Cal/gm	47.4
Flash Point		None
Threshold Limit Value		1000
Kauri-Butanol Value		51
Dielectric Constant of the Liquid at 75°F		5.9
D.C. Resistivity	Ohm-cm	10 ⁸

7.25.2 SOLUBILITY DATA

Substance	Solubility	Substance	Solubility
Acetic Acid	Miscible	Acrylic Ester Resin	40 - 50%
Cellulosic Ether Resin	10 - 15%	Chloroform	Miscible
Cottonseed Oil	Miscible	Ester Gum	14%
Ethyl Acetate	Miscible	Ethyl Alcohol	Miscible
Ethylene Glycol	1.6 - 3%	Lube Oils	Miscible
Maleic Alkyd-Modified Rosin		Methyl Alcohol	Miscible
Ester	50%	Mineral Oil	Miscible
Paraffin Wax 123-127°F	3.4%	Paraffin Wax 140-142°F	1.6%
Phenolic Thermoplastic	50%	Polyisobutylene Resin	5%
Polymerized Rosin	50%	Propylene Glycol	1.4 - 2.9%
Silicone Oil 200 Centi.	Miscible	Silicone Oil 1000 Centi.	Miscible

7.25.3 MATERIALS COMPATIBILITY

7.25.3.1 EFFECT ON PLASTICS

Plastic	Effect	Plastic	Effect
7050 Linear Polyethylene Resin	0	9140 Polypropylene Resin	0
Acetal Resin	0	Epoxy Resin	0
Ethyl Cellulose	4	ABS Polymer	1

MIL - HDBK - 406
31 October 1971

<u>Plastic</u>	<u>Effect</u>	<u>Plastic</u>	<u>Effect</u>
Polycarbonate Resin	0	Methylmethacrylate Resin	0
Polyvinyl Alcohol	0	Polyvinyl Chloride	0
Polystyrene	2	Ionomeric Resin	0
TFE Resin	0	101 Nylon Resin	0

NOTE: Exposure; Immersion in liquid for five minutes at the solvent boiling point.

0 - No visible effect 2 - Compatibility should be tested
1 - Very slight effect 4 - Disintegrated or dissolved

7.25:3.2 EFFECT ON ELASTOMERS

<u>Elastomer</u>	<u>Room Temperature</u>	<u>Boiling</u>
Adiprene C	2	3
Adiprene L	1	2
Buna N	1	2
Buna S	2	3
Butyl	0	2
Hypalon 40 Synthetic Rubber	1	3
Natural Rubber	3	4
Neoprene W	1	2
Norde1	2	5
Silicone	4	11

NOTE: Exposure; Immersion in liquid for five minutes at room and boiling temperatures. Effect is expressed as the percent of temporary change in linear dimension.

MIL - HDBK - 406
31 October 1971

TABLE 7 - 22 (Con't)

KETONES	Formula	Molecular Weight	Pounds Per Gallon At 60°F	Boiling Range °F	Freezing Point °F	Evaporation Rate (Carbon Tetrachloride = 100)	Coefficient Of Expansion Per °F	Surface Tension at 60°F Dyne/cm	Solubility % By Weight At 60°F		Flash Point (Tag Closed Cup) °F	Flammable Limits % By Volume in Air		Toxicity TLV In PPM	Specific Heat Liquid At 60°F Btu/(lb·°F)	Latent Heat At 60°F Btu/lb	Kauri-Butanol Value
									In Water	Oil/Water		Lower	Upper				
ACETONE	CH ₃ COCH ₃	58.08	6.50	132-134	-128.6	133	0.00080	23.7	—	—	0	2.6	12.8	1000**	0.51	224	—
METHYL ETHYL KETONE	CH ₃ COCH ₂ CH ₃	72.10	6.31	134-137	-123.5	91	0.00076	24.6	26.8	11.8	28	1.4	11.5	200**	0.53	181	—
CYCLOHEXANONE	(CH ₂) ₅ CO	98.14	7.40	266-343	-49.0	12	0.00051	—	—	0.0	145	1.1	—	50**	0.49	—	—
METHYL ISOBUTYL KETONE	(CH ₃) ₂ CHCH ₂ COCH ₃	100.16	6.68	234-244	-120.5	47	0.00083	22.7	2.0	1.8	64	1.4	7.5	100**	0.50	157	—
METHYL n-BUTYL KETONE	CH ₃ COCH ₂ CH ₂ CH ₃	100.16	6.43	237-279	-78.4	32	0.00055	25.5	3.0**	3.7**	73	1.2	8.0	100**	0.55	148	—
METHYL CYCLOHEXANONE (Mixed Isomers)	(CH ₂) ₅ CH ₂ CO	112.17	7.61	237-343	—	7	0.00047	—	0.2	1.0	118	—	—	—	0.44**	—	—
METHYL n-AMYL KETONE	CH ₃ (CH ₂) ₄ COCH ₃	114.18	6.81	297-309	-31.9	15	0.00057	—	0.4	1.5	120**	—	—	100**	—	189	—
DIOCTANONE	(CH ₂) ₇ COCH ₂ CH ₂ COCH ₃	116.16	7.82	266-356	-63.2	4	0.00055	29.8	—	—	48	—	—	50**	0.50**	200	—

ESTERS	Formula	Molecular Weight	Pounds Per Gallon At 60°F	Boiling Range °F	Freezing Point °F	Evaporation Rate (Carbon Tetrachloride = 100)	Coefficient Of Expansion Per °F	Surface Tension at 60°F Dyne/cm	Solubility % By Weight At 60°F		Flash Point (Tag Closed Cup) °F	Flammable Limits % By Volume in Air		Toxicity TLV In PPM	Specific Heat Liquid At 60°F Btu/(lb·°F)	Latent Heat At 60°F Btu/lb	Kauri-Butanol Value
									In Water	Oil/Water		Lower	Upper				
METHYL ACETATE	CH ₃ COOCH ₃	74.08	7.58	127-136	-115.6	118	0.00074	24.8	24.5	8.2	15	4.1	13.9	200**	0.47**	177	—
ETHYL ACETATE (99%)	CH ₃ COOCH ₂ CH ₃	88.10	7.50	169-174	-118.5	—	0.00077	23.3	8.7	3.3	24	2.2	11.5	400**	0.46	156	—
ISOBUTYL ACETATE	(CH ₃) ₂ CHCOOCH ₂ CH ₃	116.16	7.74	220-246	-148.0	45	0.00066	23.3	0.75	1.1	64	—	—	150**	0.46	133	—
n-BUTYL ACETATE	CH ₃ COOCH ₂ CH ₂ CH ₃	116.16	7.76	244-262	-100.3	34	0.00067	27.6**	0.60	1.2	72	1.7	15.0	150**	0.51**	131	—
sec-BUTYL ACETATE	CH ₃ COOCH(CH ₃)CH ₃	116.16	7.77	219-239	-148.0	50	0.00067	—	0.74**	2.1**	66	1.7	—	200**	0.49**	140	—
METHYL CELLOSOLVE ACETATE	CH ₃ COOCH ₂ CH ₂ OC(CH ₃) ₃	118.13	8.37	279-306	-85.2	12	0.00061	31.8	—	—	132	1.7	8.2	75**	0.50**	150	—
AMYL ACETATE (Mixed Isomers)	CH ₃ COOCH ₂ CH ₂ CH ₂ CH ₃	130.18	7.21	259-311	—	23	0.00061	—	1.0	1.2	77	1.1	—	—	0.49	123	—
n-BUTYL PROPIONATE	CH ₃ CH ₂ COOCH ₂ CH ₂ CH ₃	130.18	7.27	255-340	-129.2	16	0.00060	—	0.15	0.8	90	—	—	—	0.46	129	—
CELLOSOLVE ACETATE	CH ₃ COOCH ₂ CH ₂ OC(CH ₃) ₃	132.16	8.10	302-370	-79.1	8	0.00062	31.8**	22.9	6.5	124	1.7	—	100**	0.49	145	—

TERPENES	Formula	Molecular Weight	Pounds Per Gallon At 60°F	Boiling Range °F	Freezing Point °F	Evaporation Rate (Carbon Tetrachloride = 100)	Coefficient Of Expansion Per °F	Surface Tension at 60°F Dyne/cm	Solubility % By Weight At 60°F		Flash Point (Tag Closed Cup) °F	Flammable Limits % By Volume in Air		Toxicity TLV In PPM	Specific Heat Liquid At 60°F Btu/(lb·°F)	Latent Heat At 60°F Btu/lb	Kauri-Butanol Value
									In Water	Oil/Water		Lower	Upper				
DIPENTENE (G)	C ₁₀ H ₁₆	136.23	7.10	342-374	-139.9	—	0.00048	27.5**	V551	—	109	—	—	—	—	125	62
TURPENTINE STEAM DISTILL.	C ₁₀ H ₁₆	136.23	7.13	311-343	-58	<1	0.00049	26.1**	V551	—	95	0.8	—	100**	—	123	55

ALCOHOLS	Formula	Molecular Weight	Pounds Per Gallon At 60°F	Boiling Range °F	Freezing Point °F	Evaporation Rate (Carbon Tetrachloride = 100)	Coefficient Of Expansion Per °F	Surface Tension at 60°F Dyne/cm	Solubility % By Weight At 60°F		Flash Point (Tag Closed Cup) °F	Flammable Limits % By Volume in Air		Toxicity TLV In PPM	Specific Heat Liquid At 60°F Btu/(lb·°F)	Latent Heat At 60°F Btu/lb	Kauri-Butanol Value
									In Water	Oil/Water		Lower	Upper				
METHANOL	CH ₃ OH	32.04	6.61	107-151	-144.9	50	0.00065	22.6	—	—	54	6.0	36.5	200**	0.60	473	—
ETHANOL ANHYDROUS	C ₂ H ₅ OH	46.07	6.59	171-176	-174.1	—	0.00063	22.3	—	—	57	3.3	19.0	1000**	0.59**	261	—
ETHANOL 95%	C ₂ H ₅ OH	46.07	6.76	166-175	-188.4	31	0.00062	22.8	—	—	57	3.3	19.0	1000	0.62**	—	—
ISOPROPANOL 95%	(CH ₃) ₂ CHOH	60.09	6.55	179-181	-126.0	34	0.00062	21.7	—	—	56	2.5	5.2	400**	0.60	287	—
n-PROPANOL	CH ₃ CH ₂ CHOH	60.09	6.74	202-208	-186.6	34	0.00063	23.8	—	—	59	2.5	13.5	200**	0.57**	296	—
ISOBUTYL ALCOHOL	(CH ₃) ₂ CHCHOH	74.12	6.72	225-232	-162.4	16	0.00053	22.8	10	15	64	1.7	—	100**	0.58	249	—
n-BUTYL ALCOHOL	CH ₃ (CH ₂) ₃ CHOH	74.12	6.75	239-245	-129.6	13	0.00052	24.6	7.7	20.1	84	1.7	18.0	100**	0.56	254	—
sec-BUTYL ALCOHOL	CH ₃ CH ₂ CH(CH ₃)CHOH	74.12	6.73	208-214	-174.5	21	0.00055	23.5	20.1	38.5	76	—	—	150**	0.57	242	—
AMYL ALCOHOL (Mixed Isomers)	C ₅ H ₁₁ OH	88.15	6.76	230-293	—	7	0.00052	23.6	2.4**	11.0	111	1.2	—	—	—	—	—
CYCLOHEXANOL	C ₆ H ₁₁ OH	100.16	7.91	320-324	-77.2	2	0.00043	34.2**	3.6	20.0	154	—	—	50**	0.49**	195	—
n-HEXANOL	C ₆ H ₁₃ OH	102.17	6.83	307-370	-60.9	—	0.00050	24.5	0.58	7.2	145	—	—	100	0.50**	205	—

MIL - HDBK - 406
31 October 1971

NOTES ON TABLE HEADINGS:

Table 7 - 22 (Con't)

Most of the headings in the table are self-explanatory but a few may need further clarification.

EVAPORATION RATE

The rate listed is not an absolute value but is based upon the evaporation of Carbon tetrachloride under a particular set of conditions. The relative rates will probably be similar under other conditions. However, the value listed in the table should be considered only as a guide.

COEFFICIENT OF EXPANSION

In most cases, the coefficient shown in the tables is the change in liquid volume at 68°F. For the fluorinated hydrocarbons and a few others it is an average over a range from 20°F to 100°F. The coefficient does not change much with temperature and the values listed can be used for ambient. Calculations are made upon a volume per volume basis. $V_2 = V_1(1 + m t)$ where m is the coefficient of expansion.

TOXICITY, MAC

Threshold limit values, (sometimes called maximum allowable concentrations), are recommended by the American Conference of Governmental Industrial Hygienists and are based upon the best available information from industrial experience and experimental studies. They should be used as a guide.

MIL - HDBK - 406
31 October 1971

8. Verification of Cleanliness

While all possible attention may be devoted to the methods and solutions for cleaning if the results cannot be evaluated, the precautions taken in cleaning are useless.

Just as there are numerous cleaning agents and solutions, there are also many means of determining surface cleanliness, and no one method is the answer to all situations.

Basically, all cleanliness verification methods fall into two broad categories of measurement, the direct and indirect methods.

8.1. Direct Cleanliness Measurement

The direct test measurement of cleanliness measures the amount of contamination remaining on a surface after cleaning. This is the only real test for cleaning effectiveness, but the results will vary widely.

8.2. Indirect Cleanliness Measurement

The indirect measurement concerns itself with the amount of soil removed from a surface, or the effect of an irregularity or blemish after cleaning, (i.e., in a plating operation, residue will result in the failure of the plating). The measurement of removed soil is more a test of the cleaning system and not the surface cleanliness.

8.3. Cleanliness Tests

8.3.1. Visual - Examination with the unaided eye or with a microscope. Characteristics or Limitations: Subjective, but widely used, the visual method is most effective with particulate matter, and least effective with invisible films. A trained microscopist will increase the accuracy of the test results.

MIL - HDBK - 406
31 October 1971

8.3.2. Tissue Paper or White Cloth - The surface is wiped with a piece of cloth or tissue and grease or other soils will be observed. Characteristics or limitations: Limited strictly to visible soils, this is a relatively insensitive test.

8.3.3. Water Break - Generally used after the last clean water rinse. Any break in continuity of the receding water film is observed as water drains off the part. Characteristics or limitations: an excellent qualitative test for hydrophobic soils; however, any contaminants in the water will lessen the sensitivity of the test. Using deionized water, a trained inspector can detect one molecular layer of contaminant.

8.3.4. Atomizer - The surface is dried and water is applied as a spray with an atomizer. The droplet pattern with the advancing contact angle is observed to determine the surface cleanliness. Characteristics and limitations: Only sensitive to hydrophobic soils. The results are affected by spray time, nozzle-to-part distance, atomizer air pressure and the ambient temperature. This method is applicable to small cross-sectional areas with 5X to 40X magnification. Cannot be used on steel or gold. The surface must be free of wettable detergent films.

8.3.5. Contact Angle - A light beam is directed into a water droplet on the surface of the part. The angle of the reflected light ray indicates the contact angle or angle of incidence. Greater contact angles indicate larger amounts of contamination. Characteristics or limitations: Effective only on non-wetting or hydrophobic soils.

8.3.6. Ring test - A droplet of water on a surface tension ring tester is repeatedly lowered to contact the test surface. The number of contacts, or B number, indicates the surface cleanliness. Characteristics or limitations: Must be performed by a trained operator to be repeatable. This test is a measurement of surface wettability.

8.3.7. Radioactive Tracer - A specific quantity and composition of tagged synthetic soil is applied to a test surface. After the part is cleaned, the part is monitored for residual tracer activity. Characteristics or limitations: This is primarily a test of cleaning method efficiency, not surface cleanliness. The test involves the statistical treatment of data; it is a highly sensitive and quantitative test.

MIL - HDBK - 406

31 October 1971

8.3.8. Radiochemical - A surface contaminant is dissolved in place by a small amount of radiochemical solution. The change in the rate of evaporation of the solution is measured and is indicative of the soil concentration. A stream of dry nitrogen is passed over the solution to standardize the evaporation rate. Characteristics or limitations: quantitative results are obtainable if the type of contaminant is known and calibration curves are constructed for use as standards. The sensitivity and accuracy of this test is sacrificed if the test surface is porous or absorbent. The variables include rate of solution, ambient temperature and pressure, rate of nitrogen flow, and the latent heat of vaporization of the radiochemical.

8.3.9. Gravimetric - A test piece is weighed before and after cleaning, or the soil remaining from the evaporated cleaning solvent is weighed. Characteristics or limitations: while the results will show good sensitivity in the neighborhood of 5×10^{-5} gm/cm², they are more a measure of the cleaning system than the surface cleanliness.

8.3.10. Ferrocyanide Paper - The paper is immersed in a solution of NaCl, $K_3Fe(CN)_6$ in water and dried. The paper is moistened and placed on the cleaned metal surface, then removed and rinsed in clear water. Clear areas on the paper are caused by soil on the metal surface. Characteristics or limitations: limited to ferrous metals.

8.3.11. Copper Dip - The cleaned metal panels are dipped in an acidic copper sulfate solution. Characteristics or limitations: adherence, continuity and appearance of the copper sulfate indicate the cleanliness of the part before the test. Limited to ferrous metals; requires an experienced operator.

8.3.12. Solvent Ring - A drop of solvent is repeatedly deposited and picked up from the test surface. It is finally deposited on a quartz or glass slide and dried. If contamination is present, a ring will form on the slide. Characteristics or limitations: permits subsequent soil identification by spectroscopy. Assumes the use of high purity solvent.

8.3.13. Solvent Monitoring - After each cleaning step, the used solvent is filtered through membrane filters and examined for levels of particulate contamination. The nonvolatile residue is also monitored. Deionized water rinses are monitored for resistivity

MIL - HDBK - 406
31 October 1971

if ionic cleaners are used. Characteristics or limitations: commonly used for indirect measurement which assumes that the part is clean if the solvent no longer removes contamination.

8.3.14. Indium Adhesion - The tip of a freshly broken indium rod is forced against the cleaned part surface with a force of 10 grams. The force is maintained for a period of less than 1 to 5 second. The rod is then removed from the surface and force-time characteristics and recorded. The coefficient of adhesion (ration of tensile force to break the bond to the compression force exerted to form the bond) indicates the degree of surface cleanliness. Characteristics or limitations: adaptable for production testing; it is a sensitive direct test. The coefficient values must be established for different soils and substrates. This test offers rapid feedback of test data, but the test surface must be accessible to the indium tip.

8.4. ASTM Test Methods

The following are some of the cleanliness test methods established by ASTM:

- F 21-65 Test for Hydrophobic Surface Films by the Atomizer Test
- F 22-65 Test for Hydrophobic Surface Films by the Water Break Test
- F 24-65 Measuring and Counting Particulate Contamination on Surfaces
- F 59-65T Identification of Metal Particulate Contamination Found in Electronic and Microelectronic Components and Systems Using the Ring Oven Technique, with Spot Tests (tentative)
- F 52-65T Test for Silting Index of Fluids for Processing Electronic and Microelectronic Devices (tentative)
- F 58-65T Measuring Resistivity of Electronic Grade Solvents (tentative)
- F 60-65T Detection and Enumeration of Microbiological Contaminants in Water Used for Processing Electronic and Microelectronic Devices (tentative)
- D 1901-61T Tests for Relative Evaporation Time of Halogenated Solvents and Their Admixtures
- D 2109-64 Tests for Nonvolatile Matter in Halogenated Organic Solvents and Their Admixtures

MIL - HDBK - 406
31 October 1971

9. MICROBIOLOGICAL CONTAMINATION

Microbiological contamination may be defined as the existence of viable microorganisms, on, or around objects or materials. Microbial contamination is similar to other types of contamination in that it has mass and volume. It is different in that it has the ability to reproduce, to survive adverse conditions and to perform physical and chemical processes.

For some of the functions of microbiological contamination control, it is not necessary to be a microbiologist; a basic knowledge of the subject will help one understand the complex nature of this form of contamination. It is advisable that counsel from a trained microbiologist be obtained in establishment of a microbiological contamination control program.

This section is designed to offer the uninitiated, a brief introduction to the subject of microbiological contamination, explain some of the problems and establish some basic guidelines.

9.1 Bacteria, What are They? How Many are There?

The microorganisms may be divided into seven basic groups; Algae, Protozoa, Fungi, Slime molds, Bacteria, Rickettsiae and Viruses.

Bacteria are the simplest form or group of non-green vegetable organisms. There are literally thousands of varieties of bacteria.

- 9.1.1 Algae - microscopic plants that contain chlorophyll and have undifferentiated tissues, simple sex organs and simple containers for spores or seeds.
- 9.1.2 Protozoa - may have evolved from the algae by loss of chlorophyll. The most primitive have flagella (whiplike appendages) which are used for locomotion, they are one-celled and, unlike plants are non-photosynthetic (cannot use light as a catalyst to synthesize carbohydrates from carbon dioxide and water).
- 9.1.3 Fungi - the most primitive types store glycogen rather than starch, thus they come from the protozoa rather than the algae. They are non-photosynthetic, with cell walls and usually grow a mass of interlacing filaments called mycellium. These forms are called molds. Fungi are larger than bacteria and have vacuoles, (clear spaces in the cells). Some move by streaming; they may have three or four different methods of reproduction.

MIL - HDBK - 406
31 October 1971

FIGURE 9-1
BACTERIA - PRIMARY CLASSIFICATION



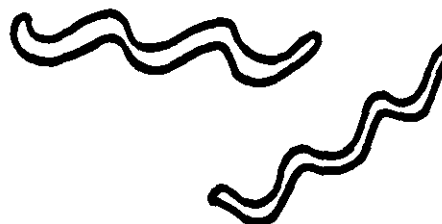
COCCI



BACILLI



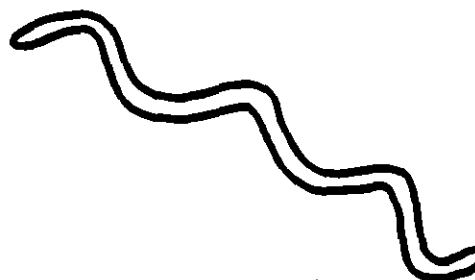
VIBRIOS



SPIRILLA

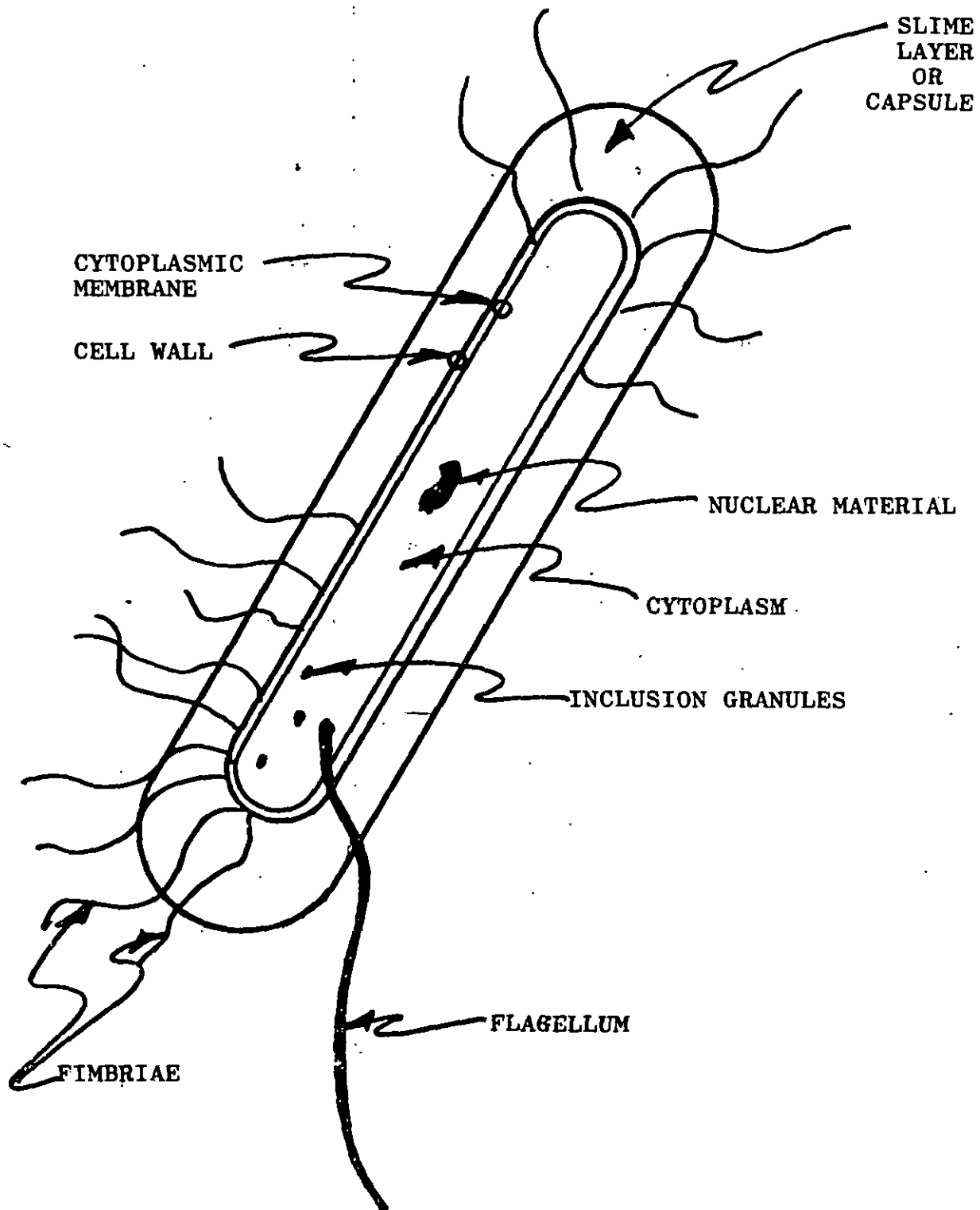


SPIROCHAETES



MIL - HDBK - 406
31 October 1971

FIGURE 9 - 2
TYPICAL BACTERIAL CELL



MIL - HDBK - 406
31 October 1971

9.1.4. Slime Molds - characterized by a multinucleate mass of protoplasm called plasmodium. They can grow to produce swarm spores or amoebas before dividing and growing into typical plasmodia again.

9.1.5. Bacteria - minute unicellular plants which do not contain chlorophyll. They reproduce by binary fission. They vary in size between 0.2 and 5 microns in diameter and 0.5 and 10 microns in length. Their shapes vary from round or spherical to rod shaped, some are comma-shaped and others are found in a corkscrew configuration. (Figure 9.1.)

The construction of the bacteria cell is composed of cytoplasm, a cytoplasmic membrane and a cell wall; and it often contains granules or vacuoles (Figure 9.2). The cell is usually surrounded by a slime layer or capsule. Some bacteria are motile due to the presence of one or more flagella.

Certain bacteria form spores (bacilli) when conditions are favorable. Most spores are highly resistant to heat, disinfectants and drying.

The growth rate of the vegetative bacteria, under ideal conditions (nutrient, temperature and moisture), may be as short as 15 minutes. This occurs in the logarithmic phase of growth and lasts for a matter of a few hours, during which time, the population doubles every 15-20 minutes.

9.1.6. Rickettsiae - are a group of microorganisms which live only as parasites, they resemble bacteria but are only 0.2 to 0.5 microns in size, or approximately 1/5 the size of bacteria.

9.1.7. Viruses - have only really been given study since the advent of the electron microscope. They cross the areas of animal and bacterial types, from particles which seem almost purely chemical (such as the ribonucleoprotein 'tobacco mosaic') to the more complex forms such as the psittacosis virus. They propagate only within living cells.

9.2. How are the Bacteria Classified?

There are a large number of different categories, for example:

Autotrophic - grow in the absence of organic matter, building

MIL - HDBK - 406
31 October 1971

their food from simple inorganic matter.

Heterotrophic - get their food from organic matter. Those which get their food from living matter and cause disease are known as pathogens. Those which live on dead organic matter are known as saprophytes.

Additionally, instead of classifying by food source, classification can be made according to the organisms oxygen requirements. The aerobes, which need air or free oxygen, and the anaerobes, which do not.

9.3. What is the Bacteria Life Cycle?

During the phase immediately after an organism is placed in a culture, there is a lag period where there is an increase in cell size without any change in number of cells. Then follows a period of maximum growth, which is shown geometrically as a logarithmic curve. They then enter a stationary period in which their death rate is as rapid as their growth. The final stage is reached when the growth rate declines and the death rate increases.

9.4. How can Microorganisms be Seen?

The limit of each type of microscope is determined by the wave length of the beam used for scanning. The normal light microscope can only be used with particles greater than about 0.2 micron in diameter. The ultraviolet microscope goes down to .1 micron while the electron microscope will go down to the range of .022 micron, showing the viruses and the 'innards' of bacteria.

9.5. How are Bacteria Counted?

There are several systems, but what is perhaps the simplest is a darkfield colony counter on cultured colonies. This device is simply a four-to-eight power lens system set so that when a petri dish culture is placed on the rack, no light reaches the eye unless it is reflected by a particle in the dish. This makes particles which are normally hard to see, visible to the eye.

A similar counting method is used with a microscope at about 100X magnification with phase contrast. With this method, the individual bacteria can be counted, as opposed to the darkfield method in which the number of specks are counted within a given grid. Electronic counting devices are also available which will count the particles in a suspension.

MIL - HDBK - 406
31 October 1971

9.6. What are Spores?

Certain bacteria, almost exclusively belonging to members of the bacillia family (rods), may be spore formers. That is, each cell may form a spore when conditions are favorable for the growth of the spore. Spores are metabolically inactive; they can withstand prolonged exposure to boiling and still remain viable, some for decades. It is one matter to kill a spore former, but it is quite a different problem to kill the spore itself.

9.7. What is Staining?

Staining is a technique used to make bacteria stand out from their backgrounds for easier identification. Bacterial cells are rich in nucleic acids, with their phosphate groups bearing negative charges. E.G. a basic stain is used (one having colored cation positive charge), it will attract the anion (negative charge); the bacteria will combine with the basic dye and take on its color. The background can also be stained using an acid dye with a colored anion.

9.8. Gram Staining

A process of identifying groups of bacteria by staining, using a basic dye (crystal violet). Iodine is added to the solution and the bacteria will appear blue. When alcohol is further added to the solution, some of the bacteria will remain blue and some will be decolorized by the alcohol. The bacteria are then stained with a red dye, those which remain blue are known as gram positive and those which are red are known as gram negative.

9.9. Chromosomes

Chromosomes are composed of deoxyribonucleoprotein; they duplicate themselves prior to fission of the organism and each resulting cell receive a duplicate or identical set of chromosomes or gene. There may be a change in this process once in a 100-million cell division, where a different gene structure is passed on to the new cell. This occurrence is known as a mutation.

9.9.1 Mutation

A mutation is a permanent, inherited change in the organism caused by an alteration of the genes in the organism. Mutation can result when the chromosomes reproduces itself and there is a copying error. It can be spontaneous, or it can be induced by such factors as X-ray, ultraviolet rays, or cobalt

MIL - HDBK - 406
31 October 1971

emission affecting the nucleus, which is comprised of protein and DNA.

Mutation can result in a strain of organism which is resistant to bactericides and disinfectants or cleaning agents. This may occur in a number of ways. Some bacteria secrete the enzyme penicillinase, and antitoxin which will destroy penicillin. Other organisms will find a way to metabolize around the specific block established by the antibiotic or germicide.

The resistant strain of organism poses a problem in contamination control where sterility is a requirement.

The process of an organism becoming resistant to an antibiotic or chemical agent may be basically described as the process of natural selection for survival of the species under a specific set of conditions.

9.10. Do Bacteria Effect Cleaning Materials?

Very little is known about the effect of bacteria upon cleaning materials; however, it would be safe to speculate that due to the many tens of thousands of microbial species and the wide range of environments that they can tolerate, there should be at least one or two types of microorganisms that will eventually attack any given solvent, cleaning solution or material. There are many well-documented cases of microbial contamination of jet fuel and other hydrocarbons, cutting oils, etc.

Microorganisms can utilize the hydrocarbon as a food source. They are capable of breaking down even the long chain hydrocarbons, thus changing the chemical composition of the solution. Bacteria, fungi and yeasts have been found to be responsible for the majority of contamination cases surveyed. They may occur in pure or mixed culture. Normally, in the most severe cases, several different species of microorganisms are involved.

Almost every deionized water installation has experienced serious bacterial contamination problems. Once one component of a deionizing system is contaminated, it may spread throughout the entire system. This necessitates the cleaning and sterilization of the system. The contaminating organism may reestablish itself if adequate preventive measures are not taken. Filtration (0.2 micron) is the most cost effective means available as a preventative measure.

MIL - HDBK - 406
31 October 1971

There are other which have proven equally effective such as hot storage with continuous recirculation (160°F or above). The solution is a trade-off of cost vs. process and water temperatures used at any specific plant or cleaning station.

Keeping the foregoing in mind, if a cleaning process that has proven satisfactory suddenly "goes sour", it would be wise to check for microbial contamination.

TABLE 9-1
Environmental Extremes of Microorganisms

<u>Factor</u>	<u>Lower Limit</u>	<u>Upper Limit</u>
Temperature	-250°C (Survival) -24°C (growth) Psychrophilic Bacteria	+160°C (Survival) +104°C at 1,000 atm. Sulfate Reducing & Thermophylic Bacteria
Eh pH	-450 mv at pH 9.5 0 (Thiobacilli)	+850 mv at pH 3 13 (Plectonma Nostocorum)
Hydrostatic Pressure	Essentially 0 (bacteria)	1,400 atmospheres (deep sea bacteria)
Salinity	Double distilled water & Deionized water (Heterotrophic bacteria)	Saturated Brines (Dunaliella, Halophilic bacteria)
Carbon Source	CO ₂ , Inorganic (Autotrophic bacteria)	Complex organic compounds (Heterotrophic bacteria)
Humidity or Available water	5%RH (multiplication) 0%RH (dormant)	none
Oxygen	0 (Anaerobes)	100% (Aerobic Bacteria)
Carbon Dioxide	0 (some aerobic)	100% (Anaerobic Bacteria)

MIL - HDBK - 406

31 October 1971

9.11. Do Microorganisms Effect Hardware

Microorganisms can live and reproduce in what may be considered harsh environments. They may use almost any organic matter as a source of food, therefore, any organic contaminant or hardware containing organic materials (plastics, paper, paints, inks etc.) is a potential host for microbial growth. Some types of organic materials are less susceptible than others; dense plastics are more resistant to attack than cellulose products. All paper products (cellulose) are prohibited in military electronics.

Microorganisms are known to attack and deteriorate insulation, circuit boards, phenolic-wax components, phenolic rubbers and fuels. They utilize the substrate as a food any aid in the breakdown of the substrate, ie., enzymes, acids, ketones, esters, etc.

9.12. Sources of Microbial Contamination

Microorganisms can be found in almost any natural environment, they have been isolated from the stratosphere and the deepest well drillings. (TABLE 9-2)

In the cleanroom environment, the major source of microbial contamination is man himself. Some individuals will shed as many as several million organisms per minute into the air. Physical contact, during improper handling, can deposit both organic and microbial contamination and is probably the most serious source of microbial contamination.

Contaminated solvents or cleaning agents have also been known to cause serious problems. The most notable is contaminated deionized water. In the manufacture of integrated circuits, one bacterium in the wrong place can ruin a component or even a series of them if it is located on the photographic mask. (Figure 9-3)

9.13. Detection and Prevention

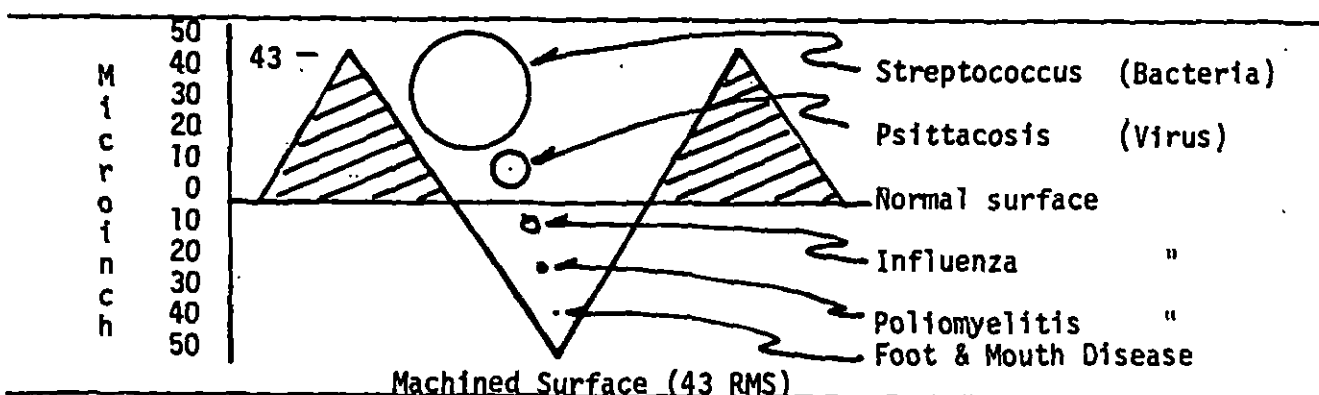
The detection of microbial contamination has usually taken place as the result of a product or system failure. This need not occur if proper controls are exercised. Microbial contamination can be detected and prevented in any stage of manufacture or work. However, a trained microbiologist is required to determine the source and prescribe the necessary steps to eliminate the microorganism.

MIL - HDBK - 406
31 October 1971

TABLE 9-2
Quantitative Distribution of Microorganisms

Environment	Numbers of Microorganisms/Unit of Measure	
Ultra-clean air	0 - 1	Ft ³
Clean air	1 - 10	Ft ³
Dirty air	10 ³ - 10 ⁵	Ft ³
Stratosphere	1 X 10 ⁻³	Ft ³
Water	1 10 ⁴	ml
Human skin	1 10 ⁴	in ²
Floors	10 - 10 ³	in ²
Raw milk	10 ³ - 10 ⁵	ml
Plant surfaces	10 ³ - 10 ⁶	gm
Soils	10 ⁴ - 10 ⁷	gm
Ocean sediment	10 ⁵ - 10 ⁷	gm
Sewage	10 ⁶ - 10 ⁷	ml
Human feces	10 ⁸ - 10 ¹⁰	gm

FIGURE 9-3
Relationship of a Machined Surface and Organisms



MIL - HD8K - 406
31 October 1971

10. CONCLUSIONS AND RECOMMENDATIONS

The sheer volume of information collected during this study effort makes a concise summary of conclusions an impossibility.

We can say that the bulk of our research has pointed to the fact that, in general, the more common solvents and cleaning agents can be safely used with most of the more common materials of construction. This is true provided that the solvent is monitored for acid, water or chloride build-up and that the exposure does not take place at too high a temperature, and that the cleaning agent is not permitted to remain within the cleansed item after the cleaning cycle.

We can also say that new metallics present problems in the cleaning cycle. Care must be taken in the selection of a solvent for a cleaning operation and if there is any doubt, prior testing is an absolute necessity.

Some of the more reactive metals pose problems because they corrode readily in some of the cleaning solutions. Here again testing prior to use is an absolute necessity.

We found in the course of the study that, of the information which is now available on many solvents, data is still much to be determined, especially in the area of compatibility.

We recommend that several areas of research be considered for the future:

Determine: (a) Compatibility of solvents and cleaning agents metals and (b) compatibility of solvents and cleaning agents with elastomers, rubbers and plastics.

The compatibility of solvents can be tested in various ways: Reflux exposure; exposures at both ambient and elevated temperatures; exposure to liquid vapor and condensate phases of the solution. Impact sensitivity testing with metal fines and chips and, with oxidizers such as LOX and missile fuels. Stress-corrosion studies should be performed to examine both crack initiation and propagation. Exposures at varying power levels. Each of these studies should be performed at varying pH levels from acid to alkaline and with varying water contents. This is necessary to determine the maximum tolerable working limits of each of the solvents.

A compilation of as many soils, lubricants and other liquids as possible should be made and testing should be performed to determine the extent to which each of these is miscible with each of the solvents.

MIL - HDBK - 406
31 October 1971

The objective of this proposed study is to assemble a block of information on each of the solvents that would cover as many cleaning and exposure conditions as possible. Such a listing would allow the designer, engineer and production personnel a means for rapid determination of solvent choice.

In the absence of such documentation, our recommendation must be that each new cleaning process and each new material to be cleaned must be tested for feasibility, suitability and compatibility.

MIL - HDBK - 406
31 October 1971

11. GLOSSARY

Absorb To engulf wholly; to take in and incorporate; assimilate.

Adsorption Adhesion of the molecules of a gas, liquid, or dissolved substance to a surface.

Agglomerate The combining, joining, clumping, or clustering of two or more particles of matter by any means.

Air Lock A chamber with doors functioning to maintain pressure differential during entry to and exit from a contamination controlled area.

Air Shower A chamber with interlocked doors and equipped with an exhaust system, having numerous air nozzles arranged in a pre-determined pattern, for the purpose of forcibly removing loose particles, fibers, dust and other particulate matter from the person and garments.

Ambient Condition Environments such as pressure, temperature, humidity, etc., which are normal for one specific location.

Clean Room A clean room is an enclosed area providing control over the particulate matter in its air with temperature, humidity, and pressure controlled as required. To meet the requirements of classification as a "clean room," it must meet the airborne particulate count as specified in Fed. Std. 209, Paragraph 6.1.3, or other specified standard as a minimum.

Clean iness Level An established maximum allowable distribution of contamination of a size or quantity in a stipulated area or volume.

Clean Work Station A work bench or similar working enclosure characterized by having its own filtered air or gas supply. The filters must be capable of providing the required air cleanliness level.

Component A series of two or more parts, subassemblies, assemblies, or any combination thereof, which in turn becomes a piece of functional equipment or assembly.

Contaminant (contamination) Any undesirable material in or on the material of interest.

Contaminate To make impure or unclean; to pollute, defile, sully, taint, soil of something dirty; soil, the act of introducing any unwanted material.

MIL - HDBK - 406
31 October 1971

Environment All the conditions, circumstances, and influences surrounding and affecting the temperature, humidity, air cleanliness, pressure and microbial, and illuminating conditions associated with a specific location.

Fiber A particle whose length is at least ten times its width.

First Air The air which issues directly from the HEPA filter.

First Work Location The work locations that is first in the path of airstream.

Flush A rinsing cleaning action applicable to a part component, system, etc., which employs a liquid as a medium.

Flux A substance, such as borax or rosin, used to help metals fuse together (as a soldering).

Gas A state of matter in which the molecules are partially unrestricted by cohesive forces. A gas has neither shape nor volume, and in form is neither liquid nor solid.

High Efficiency Particulate Air Filter (HEPA) M11-F-51068A Specifies filters with minimum efficiency of 99.97% determined by the homogeneous DOP method at air flows of 100% and 20% of the rated flow capacity of the filter. It is referred to as the HEPA filter.

Horizontal Laminar Air Flow Clean Room A room equipped with one entire vertical wall of HEPA filters, through which the air passes at a predetermined speed to an exhaust wall directly opposite the HEPA filter wall. The entire body of air moves horizontally across the room with uniform velocity along essentially parallel flow lines.

Hydrocarbon A chemically identifiable compound of carbon and hydrogen.

Laminar Air Flow Air flow in which the entire body of air within a confined area moves with uniform velocity along parallel flow lines and without turbulence.

Laminar Air Flow Clean Work Station A work station in which the laminar air flow characteristics predominate throughout the entire air space, with a minimum of eddies.

Laminar Air Flow Room A room in which the laminar air flow characteristics predominate throughout the entire air space, with a minimum of eddies.

Light-Scattering A technique for detecting, counting, and sizing

MIL - HDBK - 406
31 October 1971

Fluid-borne particulate matter passing through high intensity light beams, the distorted light beams being converted to electrical impulses by a photomultiplier tube and registered on appropriate counters and recording devices.

Liquid A state of matter in which the molecules are relatively free to change their positions with respect to each other but are restricted by cohesive forces so as to maintain a relatively fixed volume.

Membrane Filter Porous membrane composed of pure and biologically inert cellulose esters, polyethylene, or other materials.

Microbe An organism of microscopic or submicroscopic size, generally including viruses, rickettsiae, bacteria, algae, yeast, and molds.

Micron A unit of measurement equal to one millionth of a meter or approximately 0.00003937 inch (e.g., 25 microns are approximately 0.001 inch.)

Non-Laminar Flow Clean Bench A work station characterized by non-uniform air patterns and velocities. This includes work stations that have constricted air exhaust or ports.

Non-Laminar Flow Clean Room A room characterized by non-uniform air flow patterns and velocities.

Non-Volatile Residue (NVR) Soluble or suspended material and insoluble particulate matter remaining after temperature controlled evaporation of a filtered volatile liquid, usually measured in grams.

Organic Designating any chemical compound containing carbon.

Orifice A fixed restriction in a fluid passage that establishes the rate of fluid flow.

Oxide A compound of oxygen with some other element or with a radical.

Oxidizer A substance that supports the combustion reaction of a fuel.

Particle A piece of matter with observable, length, width, and thickness, usually measured in microns.

Particle Counters Automatic electronic devices designed to electronically or optically separate and size, and enumerate individual particles.

MIL - HDBK - 406
31 October 1971

Particle Size Particle size is expressed as the apparent maximum linear dimension or diameter of the particle. The linear dimension is implied unless otherwise specified.

Particulate Matter The general term applied to matter of miniature size, with observable length, width, and thickness that contrasted to non-particulate matter without definite dimension.

Plenum An enclosed space in which the pressure of the air is greater than that of the outside atmosphere.

Pre-Cleaning That cleaning which is accomplished outside of a controlled area, for the purpose of removing gross contaminants, such as rust, oxidation, grease oil, heavy scale or soil deposits in an effort to control the amount of contaminating matter brought into the clean room zone. This term is synonymous with rough cleaning.

Purge To flow an inert gas or system media through a system (or line tank, etc.) for the purpose of ridding the system of a residual fluid or for providing a positive flow of gas from some opening in the system.

Silt Particulate matter settled from fluid, generally in particle size range greater than 0.5 micron.

Silting An accumulation of minute particles, in the size range normally not counted, but of sufficient quantity to cause a haze or partial or complete obscuring of either grid lines or any portion of the grid on a test filter membrane, when viewed visually or under 40 power (maximum) magnification.

Solid A state of matter in which the relative motion of the molecules is restricted and they tend to retain a definite fixed position relative to each other, giving rise to crystal structure.

System Any combination of parts, assemblies, and sets joined together to perform a specific operational function or functions.

Test Examination, investigation, and evaluation of inherent properties, functionability, environmental reaction, variances and reliability of any product, system, sub-system, vehicle, equipment assembly, part, material, and process.

Vertical Laminar Air Flow Room A room equipped with a ceiling of HEPA filters, with a grated or perforated metal floor for the exhausting of the air issuing from the ceiling filters; the airflow is vertical and moves within the walled area along essentially parallel lines at a uniform velocity.

MIL - HDBK - 406

31 October 1971

12. BIBLIOGRAPHY

Accident Case Histories: Manufacturing Chemists Association, Case History 1465; March 1968

"Adhesion of Particles to Surfaces in Liquid and Gaseous Environments:" R.L. Walker and B.R. Fish; Presented at the 4th Annual Technical Meeting of the American Association for Contamination Control, Miami Beach, Florida; May 1965.

"Air for Ammonia Plants, Safer Preheat:" J.A. Brink Jr. and F.L. Linton; Chemical Engineering Progress; Vol. 63, No. 2; February 1967.

"Air Handling System in Detroit's Professional Plaza, Unique Equipment Arrangement for:" M.J. Kelly.

"Air Pollution Control with Fibre Mist Eliminators:" J.A. Brink Jr.; The Journal of Chemical Engineering; June 1963.

Aluminum Alloys-A Review of European Literature, Stress Corrosion Cracking of: Defense Metals Information Center, Memorandum 240; December 1968.

Aluminum Alloys-A review of the German Literature, Stress Corrosion Cracking of: Defense Metals Information Center, Memorandum 231; August 1967.

"Aluminum Corrodes-A New Theory, Why:" American Machinist; March 27, 1967.

AMSIL Technical Data: AMAX Copper, Inc.; Product Information Brochure, OF/69-3457.

American Association for Contamination Control, Journal of: Volume 1, Number 1, 1967.

Analysis and Control of Gas Atmospheres Used in the Processing of Electronic Parts and Devices, Method Of: M.J. Elkind and D.R. Benn; Bell Telephone Labs, Inc., Laboratory Procedure.

"Austin Contamination Index:" P. Austin; Presented at the 4th Annual Technical Meeting of the American Association for Contamination Control, Miami Beach, Florida; May 1965.

Biological Deterioration on Non-Metallic Materials, Symposium on: ASTM; Atlantic City New Jersey; January 1968.

"Borrowing from Nature; New Product Really Gets 'em Clean:" The Dow Chemical Company; The Dow Diamond; No. 2; 1968.

"Cascade Impactor for Adiabatic Measurements:" J.A. Brink, Jr.; Industrial Engineering Chemistry; Volume 50, Number 4,; April 1958.

MIL - HDBK - 406
31 October 1971

Cavi-Cide: Mettler Electronics Corporation; Product Information Brochure.

"Cavitation, the Measurement of" A.E. Crawford; Ultrasonics; July-September 1964.

"Chemical Cleaning Vital for Space Age Advanced Manufacturing Processes:" D.L. Anderson; Air Engineering; January 1966.

"Chemical Cleaning-Why a Checklist?:" Chemical Processing; January 1965.

Chemical Resistance Data for Pumps: United States Plastics Corporation; Product Information Brochure.

Chemical Resistance Permanence: The Dow Chemical Company; form Number 153-5292C-3M-167.

Chlorides and Chlorinated Solvents: Ethyl Corporation; Technical Bulletin, Number TC-9(127).

Chlorinated Hydrocarbons, The Effect of Alkaline Acid and Acid Substances on: Ethyl Corporation; Technical Bulletin Number TC-2(127).

"Chlorinated Solvent Cleaning on Weldments, The Effects of:" Welding Journal; December 1967.

Chlorinated Solvents: Ethyl Corporation; Technical Bulletin Number TCD-1005(58).

Chlorinated Solvents, Bulk Handling of "ETHYL": Ethyl Corporation; Technical Bulletin Number TC-47(529).

Chlorinated Solvents, Safe Usage of: Ethyl Corporation; Technical Bulletin Number TC-8(38).

"Chlorohydrocarbon Solvents:" Industrial and Engineering Chemistry; December 1943.

Chlorothene NU: the Dow Chemical Company; Product Information Brochure Number 124-296-68.

Chlorothene VG Press Conference: The Dow Chemical Company. 1968.

Clean Room and Work Station Requirements, Controlled Environment: Federal Standard 209; December 16, 1963.

MIL - HDBK - 406
31 October 1971

Clean Rooms and Clean Work Stations, Standards and Guidelines for the Design and Operation of: Air Force Technical Order; T.O. 00-25-203; 1, July 1963.

Clean Room Technology: J.W. Useller; NASA SP-5074; 1969.

"Clean Sweep for All Soils, A:" E.I. duPont de Nemours and Company, (Inc.); DuPont Magazine: March 1965.

Cleaning Agent Data: Bulletin No. FST-1; E.I. DuPont de Nemours and Company, (Inc.).

Cleaning and Degreasing Operations, Effect of Los Angeles County Air Pollution Control District Rule 66 on: Society of Automotive Engineers; 1967.

"Cleaning and Finishing, Trends. in:" L.P. Tarasov; Machinery; June 1968.

Cleaning and Materials Processing for Electronics and Space Apparatus, Symposium on: ASTM Special Technical Publication No. 342; 1962.

Cleaning Electric Motors and Generators: Ethyl Corporation; Technical Bulletin Number 1C-7(127).

"Cleaning Large Space-Simulation Chambers:" L.Katzer; Research and Development; April 1967.

"Cleaning of Electronic Assemblies, Proper:" W.A. Hume; Electrical, Electronic Assembly & Packaging.

Cleaning Printed Circuitry with Chlorinated Solvents: Ethyl Corporation; Technical Bulletin Number 1C-40(127).

Cleanliness, Cleaning, Controlled Environment and Protection Requirements, Degree of: Proposed Military Standard 1246A; 27 May 1966, Revised 30 June 1966.

Cleanliness Levels and Contamination Control Program, Product: Military Standard 1246A; 18 August 1967.

Cleanliness of Components for Use in Oxygen, Fuel and Pneumatic Systems, Specification for: Marshall Space Flight Center, SPEC 164; April 16, 1962.

Cleanliness of Components for Use in Oxygen, Fuel and Pneumatic Systems: Marshall Space Flight Center, SPEC 164; July 27, 1964.

MIL - HDBK - 406
31 October 1971

Cleanliness of Components for Use in Oxygen, Fuel and Pneumatic Systems: Marshall Space Flight Center SPEC 164; Amendment 5; February 14, 1969.

"Cold Cleaning Turns Hot": Products Finishing; May 1968.

Cold Cleaning With Halogenated Solvents: ASTM Special Technical Publication Number 405.

"Contamination Control Curbs Jet Fuel Tank Corrosion": W. J. Digman; Society of Automotive Engineers Journal; December 1962.

Contamination Control Handbook: NASA SP-5076; 1969.

Contamination Control Handbook for Ground Fluid Systems: Martin Marietta Corporation; September 1969.

Compatibility of Materials with Fluorine and Fluorine-Base Oxidizers: J. D. Jackson; Defense Metals Information Center, Technical Note; April 8, 1965.

Compatibility of Materials with Rocket Propellants and Oxidizers: Defense Metals Information Center, Memorandum 201; January 29, 1965.

Corroding Metals and Alloys, Transient Potential Changes Produced in: W. P. Iverson; Fort Detrick, Maryland.

Corrosion Inhibitor for Mild Steel, Sodium Nitrite as a: R. A. Legault and M. S. Walker; General Motors Corporation; 1964.

Corrosion Prevention/Deterioration Control in Electronic Components and Assemblies: R. H. Sparling; Final Engineering Report; CR 6-347-958-001.

Corrosion Prevention and Deterioration Control in Electronic Components and Assemblies: MIL STD 1250(MI); 31 March 1967.

"Corrosion Product Films Formed on Aluminum in High Temperature Water": D.F. MacLennan; Corrosion; Volume 17; April 1961.

Corrosion, Processes-Factors-Testing; Development and Research Division, the International Nickel Company, Inc.; 1951.

Corrosion Resistance of Phosphate-Coated Panels, Effect of Ultrasonic Cleaning on: M.S. Spivak; Technical Report; 2 October.

Corrosion of Ti-6Al-4V in Liquid Nitrogen Tetroxide, Stress: J.D. Jackson, W.K. Boyd and R. W. Staehle; Defense Metals Information Center, Technical Note; April 11, 1966.

Crack Propagation of Titanium by Methanol, Halogenated Hydrocarbons and other Solutions, Accelerated; Defense Metals Information Center, Memorandum 228; March 6, 1967.

MIL - HDBK - 406
31 October 1971

"Degradation of Electronic Equipment by Fungi:" Journal of the American Association for Contamination Control; Volume 1, Number 1; 1967.

Degreasing, Today's Concept of Solvent: Detrex Chemical Industries, Inc.

"Degreasing-What Every User Should Know, Solvent;" C.E. Kircher; ASTM Bulletin, Number 219; January 1957.

Degreasing with Chlorinated Solvents, Metal: E.I. DuPont de Nemours & Company, (INC.).

De-ionization Processes and Equipment: Illinois Water Treatment Company; Product Information Brochure Number 1-10.

"Determination of Particulate Contamination of Hydraulic Fluids by the Particle Count method, Procedure For:" SAE-ARP-598; Society of Automotive Engineers, Inc., 485 Lexington Avenue, New York, N.Y. 10017.

Dowclene EC Solvent: the Dow Chemical Company; Product Information Brochure Number 124-128-64.

Drying Process, A New Spot-Free: W.R. Steinacker; FREON Products Laboratory; E.I. DuPont de Nemours and Company, (Inc.).

Drying Systems Comparison Chart: E.I. DuPont de Nemours and Company, (Inc.); Product Bulletin Number FS-19A.

Dowanol Glycol-Ether Solvents: the Dow Chemical Company; Product Information Brochure Number 125-154-64.

Dowclene EC: the Dow Chemical Company; Product Information Brochure Number 124-141-63.

Dowclene WR: the Dow Chemical Company; Product Information Brochure Number 100-5152-69.

Dowclene WR Solvent: the Dow Chemical Company; Product Information Brochure Number 124-220-65.

Dowclene WR Solvent: The Dow Chemical Company; Product Information Brochure Number 124-225-65.

MIL - HDBK - 406
31 October 1971

Dowclene WR Solvent: The Dow Chemical Company; Product Information Brochure Number 124-232-65.

"Elements Study Leads to New Stainless." Chemical and Engineering News; March 25, 1968.

Ethyl Alcohol Handbook: Enjay Chemical Company.

Ethyl Chloride: Chemical Safety Data Sheet SD-50; Manufacturing Chemists Association; 1953.

Ethyl Chloride: Ethyl Corporation; Technical Bulletin Number IC-555 (R/3/65).

Ethylene Dichloride: Chemical Safety Data Sheet SD-18; Manufacturing Chemists Association; 1947.

Ethylene Dichloride; Ethyl Corporation; Technical Bulletin Number IC-556.

"Fibre Mist Eliminators for Higher Velocities:" J.A. Brink, Jr., W.F. Burgrabe and J. A. Rauscher; Chemical Engineering Progress; November 1964.

Filters for Industry, Widest Range of: Pall Trinity Micro Corporation.

Flammability of Chlorinated Solvents: Ethyl Corporation; Technical Bulletin Number IC-83/24/64.

FREON Solvent Drying System Bulletin FS-19: E. I. Du Pont de Nemours and Company, (Inc.)

FREON Solvent Drying Systems Bulletin S-900: Branson Instruments

FREON Fluorocarbons and other Halohydrocarbons on Elastomers, Effect of: R. O. Menard; E. I. Du Pont de Nemours and Company, (Inc.)

FREON Solvent Bulletin FS-1: E. I. Du Pont de Nemours and Company, (Inc.)

FREON Solvent Bulletin FS-6: "Solvent Properties Comparison Chart;" E. I. Du Pont de Nemours and Company, (Inc.).

FREON Solvents, Cleaning Precision Bearings with: E. I. Du Pont de Nemours and Company, (Inc.).

FREON Solvent Bulletin FS-20: "The Influence of Fluorocarbon

MIL - HDBK - 406
31 October 1971

Solvents on Titanium Alloys;" E.I. DuPont de Nemours & Company, (Inc.).

FREON Solvent Bulletin FST-3: E.I. DuPont de Nemours & Company, (Inc.).

FREON TF and Related Solvents, Purification and Reclamation of: E.I. DuPont de Nemours & Company, (Inc.); FREON Solvent Bulletin FST-6.

FREON Solvent Bulletin FST-10: "Maintenance Cleaning of Thermal-Vacuum Systems;" R.B. Ramsey, Fr., and E. Jackson; E.I. DuPont de Nemours & Company, (Inc.).

FREON Solvent Bulletin FST-11: E.I. DuPont de Nemours & Company, (Inc.).

FREON Solvent Formulation Data Bulletin Number FST-5A: E.I. DuPont de Nemours & Company, (Inc.).

FREON Solvent Formulation Data Bulletin Number FST-5B: E.I. DuPont de Nemours & Company, (Inc.).

FREON Solvent Formulation Data Bulletin Number FST-5C: E.I. DuPont de Nemours & Company, (Inc.).

FREON Solvent Formulation Data Bulletin Number FST-5D: E.I. DuPont de Nemours & Company, (Inc.).

FREON Solvent Formulation Data Bulletin Number FST-5E: E.I. DuPont de Nemours & Company, (Inc.).

FREON Solvent Formulation Data Bulletin Number FST-5F: E.I. DuPont de Nemours & Company, (Inc.).

FREON Solvent Formulation Data Bulletin Number FST-5G: E.I. DuPont de Nemours & Company, (Inc.).

FREON Precision Cleaning Agent, Quality Specification and Methods of Analysis for: E.I. DuPont de Nemours & Company, (Inc.); FREON Technical Bulletin FST-2.

" 'FREON-TF': Safe Solvent for Motor Maintenance;" J.H. Dowling; Industrial Refrigeration; February 1959.

FREON T-WD 602 Solvent: E.I. DuPont de Nemours & Company, (Inc.); Solvent Formulation Data Bulletin Number FST-5E.

MIL - HDBK - 406
31 October 1971

"Fungi on the Direct Current Surface Conductance of Electrical Insulating Materials, The Effects of:" L. Teitell, S. Berk, and A. Kravits; Applied Microbiology; Volume 3; 1954.

GAF Chemical Catalog: GAF; 1969.

Garments Required in Clean Rooms and Controlled Environments, Specification for: American Association for Contamination Control; 1968.

"Gemini Fuel Filtration Solved:" L.A. Mavros; Missiles and Rockets; Volume 17, number 5; August 2, 1965.

Genesolv D: Allied Chemical; Product Information Bulletin STB-6.

Genesolv D/Alcohol Blends: Allied Chemical; Product Information Bulletin STB-7.

Genesolv DI-15: Allied Chemical; Product Information Bulletin STB-8.

Genesolv DI: Allied Chemical; Product Information Bulletin STB-9.

HEPA Filters, Tentative Standard for; American Association for Contamination Control; Designation CSIT. Handbook of Chemistry and Physics, 46th Edition (1965-1966), Chemical Rubber Publishing Company. The Handbook of Solvent, L. Scheffan and M.B. Jacobs, D. Van Nostrand Company, Inc. (1953). Handbook of Solvents, 1, Pure Hydrocarbons, I. Mellan, Reinhold Publishing Corp. (1957).

Human Engineering Design Criteria for Military Systems, Equipment and Facilities: Proposed Military STD-1472A; 21 March 1969.

Hydraulic System Detail Parts, Components, Assemblies and Hydraulic Fluids for Space Vehicles, Cleaning, Testing and Handling: Marshall Space Flight Center PROC 166C; September 3, 1967.

Impact of Rule 66 on Industry: Society of Automotive Engineers; 1967.

Industrial Plastics: United States Plastic Corporation; Product Catalog.

"Inorganic Contaminants on the Corrosion of Metals in Chlorinated Solvents, Effect of:" J.J. Demo: Corrosion; Volume 24, Number 5; May 1968.

Isopropyl Alcohol: Enjay Chemical Company; 1961. International Critical Table, McGraw-Hill Book Company, Inc. 1933.

MIL - HDBK - 406
31 October 1971

Isotron M Solvent: Penwalt Corporation; Product Information Brochure IC-104.

Isotron PSC Solvent: Penwalt Corporation; Product Information Brochure IC-114.

Isotron Solvents, Recovery of: Penwalt Corporation; Product Information Brochure.

Isotron Solvents, Sampling and Analysis of: Penwalt Corporation; Product Information Brochure.

Isotron Solvents, Ultrasonic Cleaning with: Penwalt Corporation; Product Information Brochure IC-108.

Isotron T Solvent: Penwalt Corporation; Product Information Brochure IC-103.

Ketones Information Book: Enjay Chemical Comapny.

Laminar Flow Clean Air Devices, Tentative Standard for: American Association for Contamination Control; Designation CS-27.

"LOX Cleaning:" R. Cuthbertson; Test Engineering; March 1963.

LOX System and Component Cleaning with Trichlorotrifluoroethane Solvent: E.J. Bennett; FREON Product Division; E.I. DuPont de Nemours and Company, (INC.).

Membrane Filters for Use in Aerospace Liquid, Determinati n of Characteristics of: ASTM.

Metal Cleaning Equipment: Phillips Manufacturing Company; General Bulletin 20.

Merix-Anti-Statics: Merix Chemical Company; Product Information Brochure.

Metal Degreasing with Chlorinated Solvents: E.I. DuPont de Nemours & Company, (Inc.).

Methyl Chloride: Chemical Safety data Sheet SD-40; Manufacturing Chemists Association; 1951.

MIL - HDBK - 406
31 October 1971

Methyl Chloride: Ethyl Corporation; Technical Bulletin Number IC-557(R/3/65).

Methylene Chloride: Chemical Safety Data Sheet SD-86; Manufacturing Chemists Association; 1962.

Methylene Chloride: the Dow Chemical Company; Product Information Brochure Number 124-182-65.

Methylene Chloride: PPG Industries Inc.; Product Information Brochure Number 601.

Methylene Chloride: Ethyl Corporation; Technical Bulletin Number IC-59(4/67).

Microbial Accumulation on Surfaces in Industrial Clean Rooms: H. Findelstein and R. Scheir Douglas Aircraft Company; and J.J. McDade Jet Propulsion Labs.

Microbial Deterioration of Electronic Components, Progress Report on: G.W. Ganger, et. al. September 30, 1964.

Microbial Particles, Air Filtration of: U.S. Department of Health, Education and Welfare, Public Health Service and the Department of the Army; U.S. Army Chemical Corps.

Microbial Surface Contamination in Various Clean Room Environments, A Preliminary Investigation of: K. Kereluk, R. Meyer and A.J. Pilgrim; The Boeing Company.

Microbiological Contamination Control-A State of The Art Report: The Biological Contamination Control Committee of the American Association for Contamination Control; April 1965.

Microbiological Contamination of Fuels, Compilation of References on: Armed Forces Technical Information Agency.

Microbiological Sampling of Surfaces: Biological Contamination Control Committee; The American Association for Contamination Control; March 1967.

Organic Solvents: Central Solvents and Chemicals Company; Product Information Brochure.

Oxidation and Contamination of Titanium and its Alloys, The: J.M. Ferguson; Defense Metals Information Center, Memorandum 238; July 1969.

MIL - HDBK - 406
31 October 1971

Packaging of Aerospace Hardware, Films vs. Foil for Clean:
D.C. Anderson; Allied Chemical Corporation; 5th Annual Technical Meeting; American Association for Contamination Control.

Packaging Procedures for Precision Cleaned Parts and Assemblies:
Morotta Valve Corporation; SP-601-C.

Particle Detection in Electronic Components, Loose: K.E. Hofmockel; General Electric Company.

Particle Size Distribution Quickly, Determining: D.D. Doonan, H.L. Marrett; Bausch & Lomb, Incorporated.

Perchlorethylene: PPG Industries, Inc. Technical Service Bulletin Number 141-F-1.

Perchlorethylene, 'Ethyl': Ethyl Corporation; Product Information Brochure Number IC-55(47).

pH: An Introduction To: Beckman Bulletin 92-1.

"Plastic Materials that may be useful in various corrosive Environments, Cleaning: Chemical Engineering: November 4, 1968.

Proceedings: Fifth Annual Technical Meeting and Exhibit; American Association for Contamination Control; 1968.

Proceedings: Eighth Annual Technical Meeting and Exhibit; American Association for Contamination Control; 1969.

Proceedings of the NASA-University Conference on the Science and Technology of Space Exploration: Volume 2; NASA SP-11; 1962.

Product Bulletin HAN/DET: Detrex Chemical Industries, Inc.

Product Bulletin Sol. 6407.7" Detrex Chemical Industries, Inc.

Product Bulletin Sol. 6810.1: Detrex Chemical Industries, Inc.

Product Bulletin Sol. 8.3: Detrex Chemical Industries, Inc.

Product Catalog G-22: Pierce Chemical Company; September 1, 1969.

Product Information Brochure: L&R Manufacturing Company; 51F-26-4-N.

Product Information Brochure: L&R Manufacturing Company; 762RR-469-10N.

MIL - HDBK - 406
31 October 1971

Properties; Product Information Bulletin STB-1: Allied Chemical Corporation.

Product Information Sheet K-6: Diamond Shamrock Chemicals.

Product Information Sheet 468: Diamond Shamrock Chemicals.

Product Information Sheet 22368: Diamond Shamrock Chemicals.

Propylene Glycol U.S.P.: the Dow Chemical Company; Product Information Brochure Number 125-425-66.

Properties of 200, 300, 400, Series: Republic Steel; Product Information Brochure.

Quality by Remote Control, Quality Assurance; January 1969.

Reactivity of Metals with Liquid and Gaseous Oxygen: J.D. Jackson, W.K. Boyd and P.D. Miller; Defense Metals Information center 163; January 15, 1963.

Report on Cleaning Liquid: Underwriters Laboratories, Inc.; Film MH8127; Assignment 64C3603; September 8, 1964.

Report on Cleaning Liquid: Underwriters Laboratories, Inc.; Film MH8127; Assignment 64C3604; September 9, 1964.

Report on Cleaning Liquid: Underwriters Laboratories, Inc.; File MH8127; assignment 64C3605; September 10, 1964.

Safe-Tee Solvent: Fine Organic Incorporated: Technical Data Sheet F.O. 128.

Safety Information: Penwalt Corporation; Product Information Brochure IC-113.

Solvent Degreasing, Today's Concepts of: Detrex Chemical Industries, Incorporated; Product Bulletin Sol. 6412.1.

Solvent Degreasing, What Every User Should Know: C.E. Kircher; ASTM Bulletin Number 219; January 1957.

"Solvent Oxidizer Mixes are Explosive, The Count Down:" Safety News Letter; National Safety Council; March 1965.

Solvent Saves a Clean \$200,000 Yearly, Aids Customer Relations, The Right: Production; November 1966.

Solvent Specification Sheet J6: Diamond Shamrock Chemicals.

MIL - HDBK - 406
31 October 1971

Solvent 1,1,1-Trichloroethane, High Purity Inhibited: Marshall Space Flight Center Spec-471; July 11, 1966.

Solvents and Chemicals: Hogan Solvents and Chemicals; Product Information Brochure.

Solvents for Cleaning Metal Surfaces, Comparison of: D.S. Irwin, T.C. Johnson; the Dow Chemical Company.

Sonic Energy Cleaning Equipment, How to Evaluate: Bendix Instruments and Life Support Division; Bulletin 101. Sourcebook of Industrial Solvents, 2. Halogenated Hydrocarbons, I. Mellan, Reinhold Publishing Corp. 1957.

Specification Sheet: the Dow Chemical Company; Chloroethane VG:

Specification Sheet: the Dow Chemical Company; Dowclene WR.

Specification Sheet: Penwalt Corporation; Isotron Solvents.

"Stability of Chlorohydrocarbons: Industrial and Engineering Chemistry: P.J. Carlisle, A.A. Levine; February 1932.

Staining and Discoloration in Solvent Cleaning Operation, Causes of: Ethyl Corporation; Technical Bulletin; Form Number IC-4(127).

Stainless Steels, ARMCO: ARMCO Steel Corporation; Product Information Brochure.

Sterilization Environment on the Design Structural Systems For Planetary Landers, The Effects of the : P.J. DeMartino, R.J. Kepple, M.D. Mims; March 1967.

Storage Tanks...for Specially Denatured Alcohol and Proprietary Solvents, Bulk: USI Chemicals.

Stress Corrosion Cracking of Aluminum Alloys: Defense Metals Information Center Memorandum 202; February 15, 1965.

Stress-Corrosion Cracking of Aluminum Alloys, A review of European Literature: Defense Metals Information Center Memorandum 240; December 1968.

Sumia Processing: Molectrics Incorporated; Product Information Brochure.

Stress-Corrosion of TI-6Al-4V In Liquid Nitrogen Tetroxide: Defense Metals Information Center Technical Note; April 11, 1966.

MIL - HDBK - 406
31 October 1971

Tabulation of Designations, Properties and Treatments of Titanium and Titanium Alloys, A: R.A. Wood; Defense Metals Information Center Memorandum 71, July 15, 1963.

Technical Bulletin, Bulk Handling of Ethyl Chlorinated Solvents; Ethyl Corporation; Form Number IC 47(529).

Technical Bulletin: Cobehn Incorporated.

Technical Bulletin TB 1-364: Diamond Shamrock Chemicals.

Technical Bulletin ES-1: Monsanto Company; Brink Equipment Line.

Technical Bulletin Number-600b: Mona Industries, Incorporated.

Technical Meeting and Exhibit, Fourth Annual: American Association for Contamination Control; 1965.

Technical Service Bulletin 140-G-1, Typical Applications for Vapor Degreasing Solvents: PPG Industries Incorporated. The Technology of Solvents and Plasticizers, A.K. Doolittle, John Wiley and Sons, Inc., 1954.

Tetrachloroethylene (Perchloroethylene) Technical: Federal Spec. O-T-236B; February 28, 1967.

Thermal Decomposition of Trichloroethylene: Ethyl Corporation; Technical Bulletin Form Number IC-10(127).

"Thermal Stability of Methyl Chloroform and Carbon Tetrachloride," Industrial and Engineering Chemistry, Volume 48; W.B. Cummett, V.A. Stenger; March 1956.

Thermal Vacuum Systems, Maintenance Cleaning of: R.B. Ramsey, Jr.; FREON Products Division, E.I. DuPont de Nemours & Company, Inc.; Eugene Jackson Radio Corporation of America. Threshold Limit Values for 1969, American Conference of Governmental Industrial Hygienists.

Titanium, Basic Design Facts About: Reactive Metals Inc.; Product Information Brochure.

Titanium, Corrosion of: J.D. Jackson and W.K. Boyd; Defense Metals Information Center Memorandum 218; September 1, 1968.

"Titanium - 6Al-4V in HCL and Methanol, Corrosion of:" H.H. Takimoto, G.C. Denault & P.A. Marsh; SAMPE Journal: Volume 6, Number 3; April/May 1970.

Titanium and Titanium Alloys, the Stress Corrosion and Accelerated Crack Propagation Behavior of: J.D. Jackson and W.K. Boyd; Defense Metals Information center, Technical Note; February 1, 1966.

MIL - HDBK - 406
31 October 1971

Toxicology & Industrial Health Studies on Chloroethane VG: The Dow Chemical Company; Biomedical Research Laboratory.

1,1,1-Trichloroethane: Ethyl Corporation; Technical Bulletin Form Number IC-41(127).

1,1,1-Trichloroethane: Ethyl Corporation; Product Information Brochure 'Ethyl'; Form Number IC-53(47).

1,1,1-Trichloroethane and Trichloroethylene from a Flammability Standpoint, The Safety of: Dow Technical and Service and Development; June 1, 1966.

1,1,1-Trichloroethane (Methyl Chloroform) Inhibited, Vapor Degreasing: Mil. Spec. Mil-T-81533A; September 26, 1967.

Trichloroethylene: PPG Industries, Incorporated; Technical Service Bulletin 142-F-1.

Trichloroethylene 'Ethyl': Ethyl Corporation; Product Information Brochure Form Number IC-54(47).

Trichloroethylene: Technical Federal Spec. O-T6346; May 26, 1966.

Tri-ethane and 1,1,1-Trichloroethane: PPG Industries, Incorporated; Technical Service Bulletin 144-F-3.

Ultrasonic Cleaning, Fundamentals of: Phillips Manufacturing Company.

"Vapor Degreasing, Cleaning Missile Tanks by," Metal Progress; Courtesy Detrex; February 1960.

Vapor Degreasing, Modern: The Dow Chemical Company.

Vapor Degreasing Technology: K. Surprenant; The Dow Chemical Company.

Vapor Degreasing with Isotron Solvents: Penwalt Corporation; Product Information Brochure IC-109.

Vapor Degreasing with Trichlor and Perchlor: PPG Industries Incorporated; Product Information Brochure.

Vapor Degreasing with Tri-Ethane: PPG Industries, Incorporated; Product Information Brochure Number A-925R.

Water Contaminants and Possible Sources, A classification of Pure: V. Smith; Second Annual Convention of American Association for Contamination Control.

Water, Microbiological Analysis of: Millipore; Application Report AR-81.

MIL - HDBK - 406
31 October 1971

IDENTIFICATION OF INTEREST IN DOCUMENT BY ACTIVITY

Custodians

Army - MI
Navy - AS
Air Force - 84

Preparing Activity Project No. 3694-0026
Army - MI

Civilian Agencies

Review
- NASA - MSFC

Review Activities

Army - AV, AV, E1, MU, MI
Navy - AS, OS, SA
Air Force - 12, 14, 44, 84

User Activities

Army - AT, GL, ME, WC
Navy -
Air Force -

INSTRUCTIONS: In a continuing effort to make our standardization documents better, the DoD provides this form for use in submitting comments and suggestions for improvements. All users of military standardization documents are invited to provide suggestions. This form may be detached, folded along the lines indicated, taped along the loose edge (**DO NOT STAPLE**), and mailed. In block 5, be as specific as possible about particular problem areas such as wording which required interpretation, was too rigid, restrictive, loose, ambiguous, or was incompatible, and give proposed wording changes which would alleviate the problems. Enter in block 6 any remarks not related to a specific paragraph of the document. If block 7 is filled out, an acknowledgement will be mailed to you within 30 days to let you know that your comments were received and are being considered.

NOTE: This form may not be used to request copies of documents, nor to request waivers, deviations, or clarification of specification requirements on current contracts. Comments submitted on this form do not constitute or imply authorization to waive any portion of the referenced document(s) or to amend contractual requirements.

(Fold along this line)

(Fold along this line)

DEPARTMENT OF THE ARMY

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE \$300

BUSINESS REPLY MAIL

FIRST CLASS PERMIT NO. 12062 WASHINGTON D. C.

POSTAGE WILL BE PAID BY THE DEPARTMENT OF THE ARMY

Commander
US Army Missile Command
ATTN: DRSMI-RSDS
Redstone Arsenal, AL 35898

NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

(See Instructions - Reverse Side)

1. DOCUMENT NUMBER		2. DOCUMENT TITLE					
3a. NAME OF SUBMITTING ORGANIZATION		4. TYPE OF ORGANIZATION (Mark one)					
b. ADDRESS (Street, City, State, ZIP Code)		<input type="checkbox"/> VENDOR					
		<input type="checkbox"/> USER					
		<input type="checkbox"/> MANUFACTURER					
		<input type="checkbox"/> OTHER (Specify): _____					
5. PROBLEM AREAS							
a. Paragraph Number and Wording:							
				b. Recommended Wording:			
				c. Reason/Rationale for Recommendation:			
6. REMARKS							
7a. NAME OF SUBMITTER (Last, First, MI) - Optional		b. WORK TELEPHONE NUMBER (Include Area Code) - Optional					
c. MAILING ADDRESS (Street, City, State, ZIP Code) - Optional		8. DATE OF SUBMISSION (YYMMDD)					