

METRIC

DOD-STD-1445

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DEPARTMENT OF DEFENSE STANDARD
METAL ORGANIC COMPOUNDS, TECHNICAL GRADE (METRIC)



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DOD-STD-1445

DEPARTMENT OF DEFENSE
Washington, DC 20301

Metal Organic Compounds, Technical Grade (Metric)

DOD-STD-1445

1. This Department of Defense Standard is approved for use by all Departments and Agencies of the Department of Defense.
2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, U.S. Army Chemical Research, Development and Engineering Center, Attn: SMCCR-SPD-TS, Aberdeen Proving Ground, MD 21010-5423, by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

DOD-STD-1445

FOREWORD

This standard is approved for use by all Departments and Agencies of the Department of Defense in the selection of items for application. It is intended to prevent the entry of unnecessary items (sizes, types, varieties) into the Department of Defense logistics system. This document is not intended to restrict any service in selecting new items resulting from state-of-the-art changes.

DOD-STD-1445

CONTENTS

| <u>Paragraph</u> | | <u>Page</u> |
|------------------|--|-------------|
| 1. | SCOPE | 1 |
| 1.1 | Purpose | 1 |
| 1.2 | Application | 1 |
| 2. | REFERENCED DOCUMENTS | 2 |
| 2.1 | Government documents | 2 |
| 2.1.1 | Specifications, standards, and handbooks | 2 |
| 2.1.2 | Other Government documents, drawings, and publications | 2 |
| 2.2 | Other publications | 3 |
| 2.3 | Order of precedence | 4 |
| 3. | DEFINITIONS | 5 |
| 4. | GENERAL REQUIREMENTS | 6 |
| 4.1 | Packaging data and labeling | 6 |
| 4.2 | Hazardous materials information | 6 |
| 4.3 | Safety | 6 |
| 4.3.1 | Personal protective measures | 6 |
| 4.3.1.1 | Respiratory protection | 6 |
| 4.3.1.2 | Skin protection | 6 |
| 4.3.1.3 | Face and eye protection | 6 |
| 4.3.1.4 | Training | 6 |
| 4.3.1.5 | Exercises | 7 |
| 4.3.2 | Storage conditions | 7 |
| 4.3.2.1 | Flammable, combustible, pyrophoric and ignitable materials | 7 |
| 4.3.2.2 | Water-sensitive fire and explosive hazardous materials | 7 |
| 4.3.2.3 | Incompatible materials | 7 |
| 4.3.3 | Chemical hazardous exposure limits | 8 |
| 4.3.4 | Toxicity | 8 |
| 4.3.4.1 | EPA Toxic (T) | 8 |
| 4.3.4.2 | EPA Acute Hazardous Toxicity (H) | 8 |
| 4.3.4.3 | Hazardous toxic constituents | 8 |
| 4.4 | Pollution and disposal | 8 |
| 4.4.1 | Pollution potential | 8 |
| 4.4.2 | Disposal of excess or unserviceable material | 8 |
| 4.4.3 | Disposal and storage of hazardous wastes | 9 |
| 4.4.3.1 | Cleanup of liquid spills | 9 |
| 4.4.3.2 | Ultimate disposal | 10 |
| 4.4.4 | Disclaimer | 10 |
| 5. | DETAILED REQUIREMENTS | 11 |
| 5.1 | METAL ALKOXIDES | 11 |
| 5.1.1 | Aluminum Alkoxides | 11 |
| 5.1.1.1 | Aluminum n-Butoxide | 11 |
| 5.1.1.2 | Aluminum sec-Butoxide | 11 |
| 5.1.1.3 | Aluminum tert-Butoxide | 12 |
| 5.1.1.4 | Aluminum Ethoxide | 12 |
| 5.1.1.5 | Aluminum Isopropoxide | 12 |
| 5.1.1.6 | Use | 12 |
| 5.1.1.7 | Safety | 13 |

DOD-STD-1445

CONTENTS (Continued)

| <u>Paragraph</u> | | <u>Page</u> |
|------------------|------------------------------------|-------------|
| 5.1.1.8 | Storage | 13 |
| 5.1.1.9 | Disposal | 13 |
| 5.1.2. | Antimony Alkoxides | 13 |
| 5.1.2.1 | Antimony n-Butoxide | 13 |
| 5.1.2.2 | Antimony Ethoxide | 13 |
| 5.1.2.3 | Antimony Methoxide | 14 |
| 5.1.2.4 | Use | 14 |
| 5.1.2.5 | Safety | 14 |
| 5.1.2.6 | Storage | 14 |
| 5.1.2.7 | Disposal | 14 |
| 5.1.3. | Boron Alkoxides | 14 |
| 5.1.3.1 | Boron n-Butoxide | 14 |
| 5.1.3.2 | Boron Ethoxide | 15 |
| 5.1.3.3 | Boron Methoxide | 15 |
| 5.1.3.4 | Boron n-Octoxide | 15 |
| 5.1.3.5 | Boron n-Propoxide | 16 |
| 5.1.3.6 | Use | 16 |
| 5.1.3.7 | Safety | 16 |
| 5.1.3.8 | Storage | 16 |
| 5.1.3.9 | Disposal | 16 |
| 5.1.4. | Germanium Alkoxides | 16 |
| 5.1.4.1 | Germanium n-Butoxide | 16 |
| 5.1.4.2 | Germanium Ethoxide | 17 |
| 5.1.4.3 | Germanium Isopropoxide | 17 |
| 5.1.4.4 | Germanium Methoxide | 17 |
| 5.1.4.5 | Use | 17 |
| 5.1.4.6 | Safety | 17 |
| 5.1.4.7 | Storage | 17 |
| 5.1.4.8 | Disposal | 17 |
| 5.1.5. | Sodium Alkoxides | 18 |
| 5.1.5.1 | Sodium n-Butoxide | 18 |
| 5.1.5.2 | Sodium Ethoxide | 18 |
| 5.1.5.3 | Sodium Methoxide | 19 |
| 5.1.5.4 | Use | 20 |
| 5.1.5.5 | Safety | 20 |
| 5.1.5.6 | Storage | 20 |
| 5.1.5.7 | Disposal | 20 |
| 5.1.6. | Titanium Alkoxides | 21 |
| 5.1.6.1 | Titanium n-Butoxide | 21 |
| 5.1.6.2 | Titanium Ethoxide | 21 |
| 5.1.6.3 | Titanium 2-Ethylhexoxide | 21 |
| 5.1.6.4 | Titanium Isobutoxide | 22 |
| 5.1.6.5 | Titanium Isopropoxide | 22 |
| 5.1.6.6 | Titanium Methoxide | 22 |
| 5.1.6.7 | Use | 22 |
| 5.1.6.8 | Safety | 22 |
| 5.1.6.9 | Storage | 23 |
| 5.1.6.10 | Disposal | 23 |
| 5.1.7. | Zirconium Alkoxides | 23 |
| 5.1.7.1 | Zirconium n-Butoxide | 23 |
| 5.1.7.2 | Zirconium Ethoxide | 23 |

DOD- STD-1445

CONTENTS (Continued)

| Paragraph | | Page |
|-----------|--|------|
| 5.1.7.3 | Zirconium Isopropoxide | 23 |
| 5.1.7.4 | Zirconium n-Propoxide | 24 |
| 5.1.7.5 | Use | 24 |
| 5.1.7.6 | Safety | 24 |
| 5.1.7.7 | Storage | 24 |
| 5.1.7.8 | Disposal | 24 |
| 5.2 | METAL CARBOXYLATES | 24 |
| 5.2.1 | Aluminum Stearate | 25 |
| 5.2.2 | Barium Stearate | 26 |
| 5.2.3 | Calcium Resinate | 27 |
| 5.2.4 | Calcium Stearate | 28 |
| 5.2.5 | Chromium 2-Ethylhexanoate | 29 |
| 5.2.6 | Copper Naphthenate | 30 |
| 5.2.7 | Lead 2-Ethylhexanoate | 31 |
| 5.2.8 | Lead Salicylate | 32 |
| 5.2.9 | Lead Stearate | 33 |
| 5.2.10 | Lithium Stearate | 34 |
| 5.2.11 | Magnesium Stearate | 36 |
| 5.2.12 | Sodium Acetate, Anhydrous. | 37 |
| 5.2.13 | Sodium Gluconate | 38 |
| 5.2.14 | Sodium Oxalate | 38 |
| 5.2.15 | Sodium Resinate | 39 |
| 5.2.16 | Zinc Stearate | 40 |
| 5.3 | METAL CHELATES | 41 |
| 5.3.1 | Aluminum Acetylacetonate | 42 |
| 5.3.2 | Barium Oxalate | 43 |
| 5.3.3 | Calcium Oxalate | 44 |
| 5.3.4 | Chromic Acetylacetonate | 45 |
| 5.3.5 | Cobaltic Acetylacetonate | 46 |
| 5.3.6 | Cobaltous Acetylacetonate | 46 |
| 5.3.7 | Copper Acetylacetonate | 47 |
| 5.3.8 | Copper 8-Quinolinolate | 48 |
| 5.3.9 | Ferric Acetylacetonate | 49 |
| 5.3.10 | Magnesium Acetylacetonate | 49 |
| 5.3.11 | Manganic Acetylacetonate | 50 |
| 5.3.12 | Manganous Acetylacetonate | 51 |
| 5.3.13 | Nickel Acetylacetonate | 51 |
| 5.3.14 | Ruthenium Acetylacetonate | 52 |
| 5.3.15 | Strontium Oxalate | 53 |
| 5.3.16 | Dibutyl Tin Acetylacetonate | 54 |
| 5.3.17 | Titanium Ammonium Dihydroxy Lactate | 54 |
| 5.3.18 | Titanium Diisopropoxide Acetylacetonate | 55 |
| 5.3.19 | Titanium Diisopropoxide Bis(triethanolamine) | 56 |
| 5.3.20 | Titanium Diisopropoxide Ethylacetoacetate | 57 |
| 5.3.21 | Titanium Potassium Oxalate, Dihydrate | 58 |
| 5.3.22 | Vanadyl Acetylacetonate | 58 |
| 5.3.23 | Zinc Acetylacetonate | 59 |
| 5.3.24 | Zinc 8-Quinolinolate | 60 |
| 5.3.25 | Zirconium Acetylacetonate | 60 |

DOD-STD-1445

CONTENTS (Continued)

| Paragraph | | Page |
|-----------|---|------|
| 5.4 | ORGANOMETALLIC COMPOUNDS | 61 |
| 5.4.1 | Aluminum Alkyls | 61 |
| 5.4.1.1 | Tri-n-Butylaluminum | 61 |
| 5.4.1.2 | Triethylaluminum | 62 |
| 5.4.1.3 | Triisobutylaluminum | 63 |
| 5.4.1.4 | Tri-n-Hexylaluminum | 64 |
| 5.4.1.5 | Trimethylaluminum | 65 |
| 5.4.1.6 | Tri-n-Propylaluminum | 65 |
| 5.4.1.7 | Safety | 66 |
| 5.4.1.8 | Storage | 66 |
| 5.4.1.9 | Disposal | 66 |
| 5.4.2 | Aluminum Alkyl Alkoxide | 67 |
| 5.4.2.1 | Diethylaluminum Ethoxide | 67 |
| 5.4.3 | Aluminum Alkyl Halides | 68 |
| 5.4.3.1 | Diethylaluminum Chloride | 68 |
| 5.4.3.2 | Diethylaluminum Iodide | 69 |
| 5.4.3.3 | Diisobutylaluminum Chloride | 70 |
| 5.4.3.4 | Dimethylaluminum Chloride | 71 |
| 5.4.3.5 | Ethylaluminum Dichloride | 72 |
| 5.4.3.6 | Ethylaluminum Sesquichloride | 73 |
| 5.4.3.7 | Isobutylaluminum Dichloride | 75 |
| 5.4.3.8 | Isobutylaluminum Sesquichloride | 76 |
| 5.4.3.9 | Methylaluminum Dichloride | 77 |
| 5.4.3.10 | Methylaluminum Sesquichloride | 78 |
| 5.4.4 | Aluminum Alkyl Hydrides | 79 |
| 5.4.4.1 | Diisobutylaluminum Hydride | 79 |
| 5.4.4.2 | Sodium Aluminum Diethyl Dihydride | 80 |
| 5.4.5 | Magnesium Alkyl | 81 |
| 5.4.5.1 | Di-n-Hexylmagnesium | 81 |
| 5.4.6 | Metallocenes | 82 |
| 5.4.6.1 | 2,2-Bis(Ethylferrocenyl) Propane | 82 |
| 5.4.6.2 | Ferrocene | 83 |
| 5.4.6.3 | Methylcyclopentadienylmanganese tricarbonyl | 84 |
| 5.4.7 | Zinc alkyl | 85 |
| 5.4.7.1 | Diethylzinc | 85 |
| 6 | NOTES | 87 |
| 6.1 | Abbreviations | 87 |
| 6.2 | Subject term (key word) listing | 87 |
| | INDEX | 90 |

DOD- STD-1445

TABLES

| Table | Page |
|---|------|
| I. Sodium n-Butoxide solution in butanol - physical properties. | 18 |
| II. Sodium n-Butoxide solution in butanol - typical chemical analysis. | 18 |
| III. Sodium Ethoxide, Anhydrous - requirements and properties. | 18 |
| IV. Sodium Ethoxide solution in ethanol - physical properties. | 19 |
| V. Sodium Ethoxide solution in ethanol - typical chemical analysis. | 19 |
| VI. Sodium Methoxide, anhydrous - chemical and physical requirements. | 19 |
| VII. Sodium Methoxide solution in methanol - physical properties. | 19 |
| VIII. Sodium Methoxide solution in methanol - requirements and typical chemical analysis. | 20 |
| IX. Sodium Methoxide solution in methanol - requirements. | 20 |
| X. Barium Stearate - chemical and physical requirements. | 26 |
| XI. Calcium Resinate - chemical and physical requirements. | 27 |
| XII. Calcium Stearate - chemical and physical requirements. | 28 |
| XIII. Chromium 2-Ethylhexoate - chemical and physical requirements. | 29 |
| XIV. Lead 2-Ethylhexoate - chemical and physical requirements. | 31 |
| XV. Lead Salicylate - chemical and physical requirements (MIL-L-13788). | 32 |
| XVI. Lead Salicylate - chemical and physical requirements MIL-L-17700). | 33 |
| XVII. Lead Stearate - chemical and physical requirements. | 34 |
| XVIII. Lithium Stearate - chemical and physical requirements. | 35 |
| XIX. Magnesium Stearate - chemical and physical requirements. | 36 |
| XX. Sodium Acetate, Anhydrous - specification requirements. | 37 |
| XXI. Sodium Gluconate - chemical and physical requirements. | 38 |
| XXII. Sodium Oxalate, technical - chemical requirements. | 39 |
| XXIII. Sodium Oxalate, technical - granulation requirements. | 39 |
| XXIV. Sodium Resinate - chemical and physical requirements. | 40 |
| XXV. Polydentate Chelate Ligands. | 41 |
| XXVI. Barium Oxalate - chemical and physical requirements. | 43 |
| XXVII. Calcium Oxalate - chemical and physical requirements. | 44 |
| XXVIII. Copper 8-Quinolinolate - commercial specification requirements. | 48 |
| XXIX. Strontium Oxalate - chemical and physical requirements. | 53 |
| XXX. Zinc 8-Quinolinolate - commercial chemical and physical requirements. | 60 |
| XXXI. Tri-n-Butylaluminum - commercial specification requirements. | 62 |
| XXXII. Tri-n-Butylaluminum - commercial specification requirements. | 62 |
| XXXIII. TEA - chemical requirements. | 63 |
| XXXIV. Triethylaluminum - commercial specification requirements. | 63 |

DOD-STD-1445

TABLES (Continued)

| Table | Page |
|--|------|
| XXXV. Triethylaluminum - commercial specification requirements. | 63 |
| XXXVI. Triisobutylaluminum - commercial specification requirements. | 64 |
| XXXVII. Triisobutylaluminum - commercial specification requirements. | 64 |
| XXXVIII. Tri-n-Hexylaluminum - commercial specification requirements. | 64 |
| XXXIX. Trimethylaluminum - commercial specification requirements. | 65 |
| XL. Trimethylaluminum - commercial specification requirements. | 65 |
| XLI. Tri-n-Propylaluminum - commercial specification requirements. | 66 |
| XLII. Tri-n-Propylaluminum - commercial specification requirements. | 66 |
| XLIII. Diethylaluminum Ethoxide - commercial specification requirements. | 67 |
| XLIV. Diethylaluminum Ethoxide - commercial specification requirements. | 67 |
| XLV. Diethylaluminum Chloride - commercial specification requirements. | 68 |
| XLVI. Diethylaluminum Chloride - requirements and typical analysis. | 68 |
| XLVII. Diethylaluminum Iodide - requirements and typical analysis. | 69 |
| XLVIII. Diisobutylaluminum Chloride - requirements and typical analysis. | 70 |
| XLIX. Diisobutylaluminum Chloride - requirements and typical analysis. | 71 |
| L. Ethylaluminum Dichloride - commercial analysis range. | 73 |
| LI. Ethylaluminum Dichloride - requirements and typical analysis. | 73 |
| LII. Ethylaluminum Sesquichloride - commercial analysis range. | 74 |
| LIII. Ethylaluminum Sesquichloride - requirements and typical analysis. | 74 |
| LIV. Isobutylaluminum Dichloride - commercial analysis range. | 75 |
| LV. Isobutylaluminum Sesquichloride - requirements and typical analysis. | 76 |
| LVI. Methylaluminum Sesquichloride - commercial analysis range. | 78 |
| LVII. Methylaluminum Sesquichloride - requirements and typical analysis. | 78 |
| LVIII. Diisobutylaluminum Hydride - commercial specification requirements. | 79 |
| LIX. Diisobutylaluminum Hydride - commercial specification requirements. | 80 |

DOD- STD-1445

TABLES (Continued)

| Table | | Page |
|--------|--|------|
| LX. | Sodium Aluminum Diethyl Dihydride solution - typical analysis. | 81 |
| LXI. | Di-n-Hexylmagnesium solution - typical analysis. | 82 |
| LXII. | 2,2-Bis(Ethylferrocenyl) Propane - chemical and physical requirements | 83 |
| LXIII. | Ferrocene (Dicyclopentadienyliron) - commercial requirements. | 84 |

DOD-STD-1445

1. SCOPE

1.1 Purpose. The purpose of this standard is to present the nomenclature, formulas, physical and chemical properties, specification requirements, military and typical commercial uses, safety information, storage information and disposal information for metal organic compounds, technical grade. This standard does not necessarily include all of the items represented by the title or all those items which are commercially available. It does contain items preferred for use in the selection of metal organic compounds, for application by the Department of Defense. The metal organic compounds are classified and presented as four chemical types.

1. Metal alkoxides
2. Metal carboxylates
3. Metal chelates
4. Organometallic compounds

1.2 Application. Metal organic compounds, technical grade, are used in formulating munition fillings, in formulating lubricants, as chemical intermediates, as catalysts for polymerization reactions, and the formulation of chemical products for a variety of applications.

DOD-STD-1445

2. REFERENCED DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. Unless otherwise specified, the following specifications, standards, and handbooks of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DODISS) specified in the solicitation form a part of this standard to the extent specified herein.

SPECIFICATIONS

FEDERAL

- O-S-607 - Sodium Resinate, Technical
- TT-P-595 - Preservative Coating for Canvas
- PPP-C-2020 - Chemicals, Liquid, Dry and Paste, Packaging of

MILITARY

- MIL-S-210 - Sodium Oxalate, Technical
- JAN-C-263 - Calcium Stearate
- MIL-B-366 - Barium Stearate
- MIL-M-542 - Magnesium Stearate
- JAN-C-628 - Calcium Oxalate (For Use in Ammunition)
- JAN-B-660 - Barium Oxalate (For Use in Ammunition)
- MIL-L-758 - Lead Stearate (For Use in Ammunition)
- MIL-S-12210 - Strontium Oxalate
- MIL-L-13788 - Lead Salicylate
- MIL-L-17699 - Lead 2-Ethyl Hexoate
- MIL-L-17700 - Lead Salicylate
- MIL-W-18142 - Wood Preservative Solutions, Oil Soluble, Ship and Boat Use
- MIL-C-20470 - Calcium Resinate
- MIL-F-46032 - Fungus Resistant Treatment for Sandbags, Copper Processes
- MIL-C-51131 - Lithium Stearate
- DOD-C-82660 - Chromium 2-Ethyl Hexoate, Technical
- MIL-C-85493 - Catalyst, Burn-Rate 2,2-Bis(Ethylferrocenyl) Propane
- Purchase Description EA-T-1009 - Triethylaluminum, Technical

STANDARDS

FEDERAL

- FED-STD-313 - Material Safety Data Sheets, Preparation And The Submission Of

MILITARY

2.1.2 Other Government documents, drawings, and publications. The following other Government documents, drawings, and publications form a part of this standard to the extent specified herein.

DOD-STD-1445

CODE OF FEDERAL REGULATIONS (CFR)

Title 29 - Department Of Labor, Occupational Safety And Health Administration.

Title 40 - Protection of the Environment; Environmental Protection Agency.

Title 49 - Department Of Transportation; Hazardous Materials Regulations

DEPARTMENT OF DEFENSE (DOD)

DOD 4145.19-R-1 - Storage And Materials Handling

DOD 4160.21-M - Defense Utilization And Disposal Manual

DOD 6050.5 - DOD Hazardous Materials Information System, Hazardous Item Listing

TB MED 502 - Occupational And Environmental Health Respiratory Protection Program
(DLAM 1000.2)

TB MED 506 - Occupational And Environmental Health Occupational Vision

TM 38-250 - Packaging, Materials Handling - Preparation Of Hazardous Materials For Military Air Shipment

DEPARTMENT OF HEALTH AND HUMAN SERVICES (DHHS)

U. S. Public Health Service National Toxicology Program,
Fourth Annual Report on Carcinogens, Summary of 1985.

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH (NIOSH)

Registry of Toxic Effects of Chemical Substances
Recommendation for Environmental Exposure Limits

(Copies of specifications, standards, handbooks, drawings, and publications required by contractors in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting officer.)

2.2 Other publications. The following document(s) form a part of this standard to the extent specified herein. Unless otherwise specified, the issues of the documents which are DOD adopted shall be those listed in the issue of DODISS specified in the solicitation. The issues of documents which have not been adopted shall be those in effect on the date of the cited DODISS.

AMERICAN CONFERENCE OF GOVERNMENT INDUSTRIAL HYGIENISTS (ACGIH)

TLVs® Threshold Limit Values for Chemical Substances in the Work Environment Adopted by American Conference of Government Industrial Hygienists (ACGIH) with Intended Changes.

Volume 13: Transactions of ACGIH Activities 1985 Conference.

(Application for copies should be addressed to American Conference of Governmental Industrial Hygienists, 6500 Glenway Avenue, Bldg D-7, Cincinnati, OH 45211.)

DOD-STD-1445

ASTM

ASTM E 11 - Wire-Cloth Sieves for Testing Purposes

(Application for copies should be addressed to ASTM, 1916 Race Street, Philadelphia, PA 19103.)

INTERNATIONAL AGENCY FOR RESEARCH ON CANCER (IARC)

Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man.

(Application for copies should be addressed to World Health Organization, International Agency for Research on Cancer, 49 Sheridan Street, Albany, New York.)

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

National Fire Codes

(Application for copies should be addressed to National Fire Protection Association, Battery March Park, Quincy, MA 02269.)

(Nongovernment standards are generally available for reference from libraries. They are also distributed among nongovernment standards bodies and using Federal agencies.

2.3 Order of precedence. In the event of a conflict between the text of this standard and the references cited herein, the text of this standard shall take precedence.

DOD-STD-1445

3. DEFINITIONS

3.1 Oxidizing agent - A substance that gains electrons as a result of an oxidation-reduction reaction. It causes an increase in the oxidation state of another substance.

3.2 pH - A numerical measure of the hydrogen ion concentration, indicating degree of acidity or alkalinity of a solution. It is expressed as $\text{pH} = -\log_{10}[\text{H}^+]$. At the neutral point, $\text{pH}=7$. At a pH lower than 7, a solution is acidic. At a pH higher than 7, a solution is alkaline.

3.3 Reducing agent - A substance that loses electrons during an oxidation-reduction reaction. It causes a decrease in the oxidation state of another substance.

DOD-STD-1445

4. GENERAL REQUIREMENTS

4.1 Packaging data and labeling. All chemicals included in this standard shall be packaged in accordance with Federal Specification PPP-C-2020 and all applicable documents referenced therein. Shipping containers shall be labeled in accordance with current Department of Transportation (DOT) Hazardous Materials Regulations applicable to each chemical. When shipping by military aircraft the requirements of TM 38-250 shall apply. In addition, each item shall be packaged and labeled as specified in the applicable contract or order. All labels shall also comply with Hazard Communication Standard, 29 CFR 1910.1200 (f).

4.2 Hazardous materials information. DOD 6050.5, DOD Hazardous Materials Information System (HMIS) acquires, reviews, stores, and disseminates Material Safety Data Sheet (MSDS) information for all hazardous materials used by DOD. The contractual acquisition of a MSDS is accomplished through use of Federal Acquisition Regulation, paragraph 52.223-3, Hazardous Material Identification and Material Safety Data. The MSDS is prepared in accordance with the instructions in FED-STD-313; and shall comply with requirements of Hazard Communication Standard, 29 CFR 1910.1200 (g).

4.3 Safety.

4.3.1 Personal protective measures. The necessary respiratory, eye and skin protection to be used when handling chemicals shall be prescribed by the responsible installation industrial hygiene, medical and safety authorities.

4.3.1.1 Respiratory protection. Respirators, approved by the National Institute for Occupational Safety and Health (NIOSH) or the Mine Safety and Health Administration (MSHA) or by particular respiratory schedules of the Bureau of Mines (BM) for the compounds being used, may be employed for intermittent exposure or for supplementing other control measures (refer to TB MED 502 or DLAM 1000.2). Ventilation shall be adequate to remove hazardous concentrations.

4.3.1.2 Skin protection. Personnel using these compounds shall be provided with and required to use impervious gloves, sleeves, aprons, and boots whenever indicated. Protective creams and ointments commonly known as "barrier creams" may be of value in certain cases. However, barrier creams shall not be used to replace protective clothing. In case of contact with the skin, wash affected areas thoroughly with water. Eye lavages and emergency showers shall be located where there is a potential for direct contact with harmful chemicals.

4.3.1.3 Face and eye protection. Personnel using these compounds shall be provided with and required to wear chemical splash-proof safety goggles. In addition, face shields shall be provided and worn over the goggles if splashing could occur. In case of contact with the eyes, immediately irrigate with copious amounts of water for at least 20-30 minutes, and obtain medical attention. (Refer to TB MED 506.)

4.3.1.4 Training. Employers shall provide employees with training and information including MSDS on all chemical items in their work area, in accordance with 29 CFR 1910.1200 (h), to ensure that employees know potential hazards of the chemicals with which they come in contact and the symptoms of exposure as well as how these chemicals affect the body and bodily functions. Employees shall be adequately trained to render first aid.

DOD-STD-1445

4.3.1.5 Exercises. Participation in exercises shall be stressed to demonstrate skills in the use of personal protective equipment and emergency response equipment.

4.3.2 Storage conditions. DOD 4145.19-R-1 describes general storage practices and requirements for hazardous materials in the DOD supply system. Specific requirements provided in the following paragraphs are supplementary in nature and shall be observed in consonance with the DOD storage regulations.

4.3.2.1 Flammable, combustible, pyrophoric and ignitable materials. A flammable material is generally any solid, liquid, vapor or gas that ignites easily and burns rapidly. Combustible materials are generally those that are difficult to ignite and burn slowly. The DOT, in Part 173, Subpart D, Section 173.115 of 49 CFR, defines a flammable liquid as one having a closed cup flash point below 37.8°C (100°F). A combustible liquid is defined, by DOT in the above reference, as one having a closed cup flash point at or above 37.8°C and below 93.3°C (200°F). A pyrophoric liquid is defined, by DOT in the above reference, as one that ignites spontaneously in dry or moist air at or below 54.5°C (130°F). Materials with flash points of 93.3°C or higher are not considered to be nonflammable or noncombustible, but are to be considered as burnable. The Environmental Protection Agency (EPA), in Part 261, Subpart C, Section 261.21 of 40 CFR*, designates the criteria for flammable and combustible materials and oxidizers that exhibit the characteristic of ignitability (I). Liquids with closed cup flash points of less than 60°C (140°F) are defined by EPA as ignitable. The autoignition point (temperature) of a substance is generally defined as the minimum temperature required to initiate or cause self-sustained combustion in the absence of a spark or flame. Materials that ignite easily under normal industrial conditions are considered to be dangerous fire hazards. Such materials shall be stored in a manner to prevent ignition and combustion. Easily ignitable substances, such as reducing agents, shall be kept away from strong oxidizing agents. All containers shall be tightly sealed. It is important to provide adequate ventilation in storage areas, and to locate the storage areas of these items away from fire hazards. Ample fire-control equipment shall be easily accessible. Storage buildings, rooms and cabinets shall comply with provisions of the National Fire Codes. The building shall be electrically grounded and signs posted to prevent the lighting of matches or smoking in the area. Flammable storage areas shall be equipped with smoke or fire detection equipment.

4.3.2.2 Water-sensitive fire and explosive hazardous materials. These are materials that react on contact with water or steam to ignite or evolve heat or explosive gases. Such materials exhibit the characteristic of reactivity (R) as designated by the EPA in Section 261.23 of the above reference.* These materials shall be stored in well-ventilated, cool, dry areas. All containers shall be tightly sealed. These materials are a fire hazard in contact with water or moisture; therefore, it is essential that no sprinkler be used. Otherwise, the building shall conform to that required for storage of flammable materials. The building shall be waterproof, located on high ground, and separated from other storage areas.

4.3.2.3 Incompatible materials. Materials that are chemically incompatible shall be segregated in the storage of both serviceable and unserviceable items.

*Refers only to materials that have become waste materials.

DOD-STD-1445

The degree of segregation will depend upon DOD 4145.19-R-1 and local supplementary requirements that insure safe storage conditions. Hazardous storage compatibility codes are provided in the HMIS referred to in 4.2.

4.3.3 Chemical hazardous exposure limits. Chemical hazardous exposure limits for airborne concentrations of substances are obtained from the current TLVs® Threshold Limit Values for Chemical Substances in the Work Environment, adopted by the American Conference of Government Industrial Hygienists (ACGIH); current Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PEL), 29 CFR, Part 1910 Subpart Z; and NIOSH Recommendation for Environmental Exposure Limits. Such information is also shown in MSDSs and the HMIS referred to in 4.2. Carcinogenic substances are listed by OSHA in Category I for confirmed carcinogens, and in Category II for suspected carcinogens. Category I substances have standard exposure limits set at the lowest possible levels. Category II substances have standard exposure limits set to prevent acute or chronic effects.

4.3.4 Toxicity. Toxicity information for chemical compounds is available from various publications and from MSDSs, which are collected in DOD 6050.5 Hazardous Materials Information System.

4.3.4.1 EPA Toxic (T). Some chemical compounds have been designated by the EPA as toxic (T) in accordance with the criteria shown in Part 261, Subpart B, Section 261.11(a)(3) of 40 CFR.* Some commercial chemical products are listed as toxic under Subpart D, Section 261.33(f).

4.3.4.2 EPA Acute Hazardous Toxicity (H). Some chemical compounds have been designated by the EPA as acute hazardous (H) in toxicity in accordance with the criteria shown in Subpart B, Section 261.11(a)(2) of the above reference.* Some commercial chemical products are listed as acute hazardous in toxicity under Subpart D, Section 261.33(e).

4.3.4.3 Hazardous toxic constituents. A list of chemical compounds and substances, shown to have toxic effects on humans or other life forms, is contained in Appendix VIII to 40 CFR Part 261; and the Registry of Toxic Effects of Chemical Substances.

4.4 Pollution and disposal.

4.4.1 Pollution potential. All items described in this standard shall be assumed to have a pollution potential. However, to minimize this potential, the proper use, storage and disposal methods shall be strictly followed.

4.4.2 Disposal of excess or unserviceable material. To minimize disposal problems, it is recommended that no more than a one year's supply of each item listed in this standard be stocked. When stocks have been declared excess or unserviceable, they will be disposed of in accordance with the Defense Utilization and Disposal Manual, DOD 4160.21-M, and applicable DOD Policy Memoranda. Guidance can be obtained from your servicing Defense Reutilization and Marketing Office (DRMO) on procedures required for proper reporting and turn-in.

*Refers only to materials that have become waste materials.

DOD-STD-1445

4.4.3 Disposal and storage of hazardous wastes. Items are classified and managed as hazardous wastes as defined by the Resource Conservation and Recovery Act (RCRA) (Public Law 94-580). Items have been identified as meeting the characteristics (i.e., ignitable, corrosive, reactive or EP toxic) or are listed (i.e., toxic or acute hazardous) according to Identification and Listing of Hazardous Waste, Part 261; 40 CFR; or have been determined to be hazardous wastes by declaration of the Defense Reutilization and Marketing Service (DRMS) in accordance with procedures set forth in DOD 4160.21-M. Disposal of such items shall be managed in accordance with the Installation Environmental Office, the DRMO, or the Safety and Health Office to insure proper reporting of disposal and treatment actions to the US EPA and State; and shall be managed in accordance with Federal, State and local laws. The three main disposal methods are turn-in to the DRMO, on-post disposal by installation personnel, or disposal by commercial contract. Hazardous wastes that cannot be used, or disposed of as stated in 4.4.3.2, shall be stored under environmentally safe conditions until suitable methods of disposal are determined. Short-term storage (less than 90 days) requires proper containment (i.e., packaging and facilities) in accordance with Section 262.34, Part 262 of the above reference. Long-term storage (greater than 90 days) requires permitting by the EPA or by the state under Public Law 94-580 (RCRA), in compliance with the requirements of 40 CFR Parts 264 and 265. Physical custody will be accomplished by the activity with conforming storage or most nearly conforming storage. When physical custody is in question, the Post Commander will make the final decision. In all cases where the wastes are to be collected, stored, transported and disposed of at a state or local permitted disposal facility, the identity and description of the waste shall be maintained and recorded in accordance with Part 262 of the above reference. Transportation of the waste shall be in accordance with Part 263 of the above reference, Standards Applicable to Transporters of Hazardous Waste.

4.4.3.1 Cleanup of liquid spills. To control the migration of spilled or leaking liquids, dike around the item with an inert, dry absorbent (e.g., clay, sawdust or vermiculite) or follow installations spill plans (Spill Prevention Control and Countermeasure Plan and Installations Spill Contingency Plan). Control entry to the spill site and segregate salvageable materials away from the spill area. Initiate waste cleanup operations immediately in accordance with local procedures. The residue shall be safely handled and transported to an approved or permitted disposal or storage facility. Packaging, labeling, transportation and record-keeping requirements for this waste material are determined by the appropriate Federal and State agencies and local procedures. It is recommended that all activities involving disposal preparation and transportation to commercial facilities be properly coordinated with the appropriate Federal and State agencies responsible for health and environmental aspects of hazardous materials. It is imperative that the proper description of waste accompany the packaged item at all times. Final disposal of the waste item shall be accomplished by reutilization, transfer, donation or sales by DRMS in accordance with DOD 4160.21-M or by ultimate disposal as described in 4.4.3.2. Spill residue, including contaminants, to be turned in to the DRMO shall first be properly identified, containerized, and labeled. For large scale spills that grossly contaminate the environment, the Chemical Transportation Emergency Center (CHEMTREC), can be called for assistance. Applicable procedures

DOD-STD-1445

of the local spill control plan shall be followed. Necessary respiratory, eye, and skin protection measures are to be used while performing cleanup operations.

4.4.3.2 Ultimate disposal. Ultimate disposal shall be accomplished at a permitted or approved hazardous waste treatment or disposal facility designated by the Installation Environmental Office, DRMO, or Safety and Health Offices.

4.4.4 DISCLAIMER. RECOMMENDED DISPOSAL INSTRUCTIONS ARE FORMULATED FOR USE BY ELEMENTS OF THE DEPARTMENT OF DEFENSE. THE UNITED STATES OF AMERICA IN NO MANNER WHATSOEVER EITHER EXPLICITLY OR IMPLICITLY WARRANTS, STATES, OR INTENDS SAID INSTRUCTION, TO HAVE ANY APPLICATION, USE OR VIABILITY BY OR TO ANY PERSON OR PERSONS CONTRACTING OUTSIDE THE DEPARTMENT OF DEFENSE OR ANY PERSON OR PERSONS CONTRACTING WITH ANY INSTRUMENTALITY OF THE UNITED STATES OF AMERICA AND DISCLAIMS ALL LIABILITY FOR SUCH USE. ANY PERSON USING THESE INSTRUCTIONS WHO IS NOT A MILITARY OR CIVILIAN EMPLOYEE OF THE UNITED STATES OF AMERICA SHOULD SEEK COMPETENT PROFESSIONAL ADVICE TO VERIFY AND ASSUME RESPONSIBILITY FOR THE SUITABILITY OF THESE INSTRUCTIONS TO THEIR PARTICULAR SITUATION REGARDLESS OF SIMILARITY TO A CORRESPONDING DEPARTMENT OF DEFENSE OR OTHER GOVERNMENT SITUATION.

DOD-STD-1445

5. DETAILED REQUIREMENTS

5.1 Metal Alkoxides

Alcohols, as weak acids, can react with active metals, such as sodium, to form hydrogen gas and the metal alkoxides. Since alcohols are weaker acids than water, sodium alkoxides cannot be prepared by the reaction of the alcohol with sodium hydroxide. Aluminum, as an active metal, can also react with alcohols in the presence of mercuric chloride catalyst to form the metal alkoxides. Aluminum alkoxides can also be prepared by reacting aluminum chloride with sodium alkoxides.

Many metal chlorides undergo solvation and/or partial solvolysis with alcohols. In the presence of a base, such as ethoxide ion, ammonia, or pyridine, the replacement of chloride is complete and the metal alkoxide are formed. Titanium alkoxides and other transition metal alkoxides can be obtained by such reactions.

The metal alkoxides are polymeric, and the titanium alkoxides, $Ti(OC_2H_5)_4$, $Ti(OC_3H_7)_4$, and $Ti(OC_4H_9)_4$, are known to be trimeric. The metal alkoxides are also polymeric in solution in inert organic solvents. Monomeric species can exist in very dilute solutions.

The metal alkoxides are reactive with water. They are useful in organic synthesis.

Alcohols can react with a number of inorganic oxygen acids or very reactive inorganic halides to form esters. Some metal alkoxides, such as those of boron and titanium, are also considered to be inorganic esters, and can be named as trialkyl borates and tetraalkyl titanates.

5.1.1 Aluminum Alkoxides

5.1.1.1 Name. Aluminum n-Butoxide $Al[O(CH_2)_3CH_3]_3$ FW 246.33
Aluminum butylate

5.1.1.1.1 Technical description. Aluminum n-butoxide (pure) is in the form of white crystals with a density of 1.025 g/cm^3 . It has a melting point of 101.5°C and a boiling point of 290 to 310°C at 30 mm Hg . It is soluble in aliphatic, aromatic and chlorinated hydrocarbons.

5.1.1.1.2 Specification. Manufacturer's requirements. (No Government specification)

5.1.1.1.2.1 Requirements. Commercially available aluminum n-butoxide has a purity of 90 to 95 percent.

5.1.1.2 Name. Aluminum sec-Butoxide $Al[OCH(CH_3)C_2H_5]_3$ FW 246.33
Aluminum sec-butylate

5.1.1.2.1 Technical description. Aluminum sec-butoxide is a liquid with a density of 0.967 g/cm^3 , and a boiling point of 200 to 206°C at 30 mm Hg . The closed cup flash point is 27°C (81°F). The theoretical aluminum content is 10.97 percent.

DOD-STD-1445

5.1.1.2.2 Specification. Manufacturer's requirements. (No Government specification)

5.1.1.2.2.1 Requirements. Commercially available aluminum sec-butoxide has an aluminum content of 10.7%, minimum, corresponding to a minimum assay of 97.7 percent.

5.1.1.3 Name. Aluminum tert-Butoxide $Al[OC(CH_3)_3]_3$ FW 246.33
Aluminum tert-butylate

5.1.1.3.1 Technical description. Aluminum tert-butoxide (pure) is in the form of white crystals with a density of 1.0251 g/cm³. It sublimes at 180°C, and has a melting point above 300°C in a sealed tube. It is very soluble in organic solvents.

5.1.1.3.2 Specification. Manufacturer's requirements. (No Government specification)

5.1.1.3.2.1 Requirements. Commercially available aluminum tert-butoxide is supplied without an assay.

5.1.1.4 Name. Aluminum Ethoxide $Al(OC_2H_5)_3$ FW 162.16
Aluminum ethylate
Triethoxyaluminum

5.1.1.4.1 Technical description. Aluminum ethoxide (pure) is in the form of white crystals with a density of 1.142 g/cm³. It has a melting point of 134°C, and a boiling point of 205°C at 14 mm Hg. It is very slightly soluble in alcohol and ether. It is decomposed by water.

5.1.1.4.2 Specification. Manufacturer's requirements. (No Government specification)

5.1.1.4.2.1 Requirements. Commercially available aluminum ethoxide is supplied without an assay.

5.1.1.5 Name. Aluminum Isopropoxide $Al[OCH(CH_3)_2]_3$ FW 204.25
Aluminum isopropylate

5.1.1.5.1 Technical description. Aluminum isopropoxide (pure) is in the form of white crystals with a density of 1.0346 g/cm³. It has a melting point of 118.5°C, and a boiling point of 140.5°C at 8 mm Hg. It is soluble in alcohol, benzene and chloroform. The theoretical aluminum content is 13.2 percent.

5.1.1.5.2 Specification. Manufacturer's requirements. (No Government specification)

5.1.1.5.2.1 Requirements. Commercially available aluminum isopropoxide has an aluminum content of 12.9%, minimum, corresponding to a minimum assay of 97.5 percent.

5.1.1.6 Use. Aluminum alkoxides provide a nonaqueous solvent soluble form of aluminum for use in the synthesis of organic compounds, as reducing agents and as transesterification catalysts. Other uses include the production of

DOD-STD-1445

fabric water-proofing agents, printing ink modifiers, lubricants, and the curing of epoxy resins.

5.1.1.7 Safety. Aluminum alkoxides are flammable liquids or solids, and can emit irritating and toxic fumes if heated to decomposition. They are decomposed by water with the release of flammable alcohol vapors. There are no PELs or TLVs referenced for aluminum alkoxides. They are strong local irritants of eyes, skin and mucous membranes, so contact shall be avoided. (Refer to 4.3.1)

5.1.1.8 Storage. Aluminum alkoxides shall be stored in tightly sealed corrosion-resistant containers in a cool, dry place. (Refer to 4.3.2)

5.1.1.9 Disposal. In case of solid spills, recover in dry state and place in containers for disposal. In case of small liquid spills, absorb with non-reactive absorbent and place in containers for disposal. In case of large liquid spills, dike to prevent spreading. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

Aluminum alkoxides have an EPA Hazardous Waste Classifications - Ignitable, Waste No. D001; and Reactive, Waste No. D003.

5.1.2 Antimony Alkoxides

5.1.2.1 Name. Antimony n-Butoxide $Sb[O(CH_2)_3CH_3]_3$ FW 341.10
 Antimonous butoxide
 Antimony(III) butoxide
 Antimony butylate
 Tributyl antimonite

5.1.2.1.1 Technical description. Antimony n-butoxide is a liquid with a boiling point of 133 to 195°C at 4 mm Hg. The theoretical antimony content is 35.7 percent.

5.1.2.1.2 Specification. Manufacturer's requirements. (No Government specification)

5.1.2.1.2.1 Requirements. Commercially available antimony n-butoxide has an analysis for antimony content of 36.0 percent.

5.1.2.2 Name. Antimony Ethoxide $Sb(OC_2H_5)_3$ FW 256.93
 Antimonous ethoxide
 Antimony(III) ethoxide
 Antimony ethylate
 Triethyl antimonite

5.1.2.2.1 Technical description. Antimony ethoxide (pure) is a colorless liquid with a density of 1.524 g/cm³, and a boiling point of 95°C at 11 mm Hg. It is soluble in organic solvents. The theoretical carbon content is 28.1%, and the hydrogen content is 5.88 percent.

5.1.2.2.2 Specification. Manufacturer's requirements. (No Government specification)

DDO-STD-1445

5.1.2.2.2.1 Requirements. Commercially available antimony ethoxide has an analysis for carbon content of 27.9% and a hydrogen content of 5.87 percent.

5.1.2.3 Name. Antimony Methoxide $Sb(OCH_3)_3$ FW 214.88
 Antimonous methoxide
 Antimony(III) methoxide
 Antimony methylate
 Trimethyl antimonite

5.1.2.3.1 Technical description. Antimony methoxide is a crystalline solid. It is a water-sensitive compound.

5.1.2.3.2 Specification. Manufacturer's requirements. (No Government specification)

5.1.2.3.2.1 Requirements. Commercially available antimony methoxide with an assay of 95 percent.

5.1.2.4 Use. Antimony alkoxides provide a nonaqueous solvent soluble form of antimony for use in chemical synthesis.

5.1.2.5 Safety. Antimony alkoxides are flammable liquids, or flammable or burnable solids, and can emit irritating and toxic fumes if heated to decomposition. They are decomposed by water with the release of flammable alcohol vapors. The PEL and TLV for antimony compounds, as Sb, is 0.5 mg/m^3 . Antimony alkoxides are strong irritants of the eyes, skin and mucous membranes, so contact shall be avoided. (Refer to 4.3.1)

5.1.2.6 Storage. Antimony alkoxides shall be stored in tightly sealed corrosion-resistant containers in a cool, dry place. (Refer to 4.3.2)

5.1.2.7 Disposal. In case of solid spills, recover in dry state and place in containers for disposal. In case of small liquid spills, absorb with non-reactive absorbent and place in containers for disposal. In case of large liquid spills, dike to prevent spreading. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

Antimony alkoxides have an EPA Hazardous Waste Classifications - Ignitable, Waste No. D001; Reactive, Waste No. D003; and Toxic.

5.1.3 Boron Alkoxides

5.1.3.1 Name. Boron n-Butoxide $B[O(CH_2)_3CH_3]_3$ FW 230.16
 Boron tributoxide
 Tributoxyborine
 Tributyl borate

5.1.3.1.1 Technical description. Boron n-butoxide is a colorless liquid with a boiling point of 103 to 106°C at 8 mm Hg. It is decomposed by water.

5.1.3.1.2 Specification. Manufacturer's requirements. (No Government specification)

DOD-STD-1445

5.1.3.1.2.1 Requirements. Commercially available boron butoxide has a density of 0.853 g/cm^3 , a refractive index of 1.4100, a melting point of -70°C , and a boiling point of 230 to 235°C . The closed cup flash point is 93.3°C (200°F).

| | | | |
|---------|--|-------------------------------------|-----------|
| 5.1.3.2 | <u>Name.</u> Boron Ethoxide Boron triethoxide Triethoxyborine Triethyl borate | $\text{B}(\text{OC}_2\text{H}_5)_3$ | FW 146.00 |
|---------|--|-------------------------------------|-----------|

5.1.3.2.1 Technical description. Boron ethoxide (pure) is a colorless liquid with a refractive index of 1.381, and a density of 0.864 g/cm^3 , a melting point of -84.8°C , and a boiling point of 117.4°C . It is decomposed by water.

5.1.3.2.2 Specification. Manufacturer's requirements. (No Government specification)

5.1.3.2.2.1 Requirements. Commercially available boron ethoxide has an assay of 97 percent. The closed cup flash point is 11°C (52°F).

| | | | |
|---------|--|----------------------------|-----------|
| 5.1.3.3 | <u>Name.</u> Boron Methoxide Boron trimethoxide Trimethoxyborine Trimethyl borate | $\text{B}(\text{OCH}_3)_3$ | FW 103.92 |
|---------|--|----------------------------|-----------|

5.1.3.3.1 Technical description. Boron methoxide (pure) is a colorless liquid with a refractive index of 1.3610 at 20°C , and a density of 0.915 g/cm^3 , a melting point of -29°C , and a boiling point of 68.7°C . It is soluble in alcohol and ether, and is decomposed by water.

5.1.3.3.2 Specification. Manufacturer's requirements. (No Government specification)

5.1.3.3.2.1 Requirements. Commercially available boron methoxide has a boiling range of 67 to 69°C . It has a closed cup flash point of -8°C (17°F).

| | | | |
|---------|---|--|-----------|
| 5.1.3.4 | <u>Name.</u> Boron n-Octoxide Boron trioctoxide Trioctoxyborine Tri-n-octyl borate | $\text{B}[\text{O}(\text{CH}_2)_7\text{CH}_3]_3$ | FW 398.47 |
|---------|---|--|-----------|

5.1.3.4.1 Technical description. Boron n-octoxide is a colorless liquid with a refractive index of 1.4350 at 25°C , a density of 0.846 g/cm^3 at 23°C , a boiling point of 192 to 194°C at 2 mm Hg, and 378 to 379°C at 760 mm Hg. It is soluble in hydrocarbon fluids and carbon tetrachloride. It is decomposed by water or moisture by hydrolysis. The theoretical boron content is 2.72 percent.

5.1.3.4.2 Specification. Manufacturer's requirements. (No Government specification)

5.1.3.4.2.1 Requirements. Commercially available boron octoxide has a boron content of 2.74 percent. It has an open cup flash point of 188°C (370°F).

DOD-STD-1445

5.1.3.5 Name. Boron n-Propoxide $B(OCH_2CH_2CH_3)_3$ FW 188.08
 Boron tripropoxide
 Tripropoxyborine
 Tripropoxyboron
 Tripropyl borate

5.1.3.5.1 Technical description. Boron n-propoxide (pure) is a liquid with a density of 0.867 g/cm^3 , a refractive index of 1.3948 at 20°C , and a boiling point of 175°C .

5.1.3.5.2 Specification. Manufacturer's requirements. (No Government specification)

5.1.3.5.2.1 Requirements. Commercially available boron n-propoxide has a boiling point of 175° to 177°C . The closed cup flash point is 32°C (90°F).

5.1.3.6 Use. Boron alkoxides provide a nonaqueous solvent soluble form of boron for use in chemical synthesis. Other applications include uses as solvents, as dehydrating agents, in flame retardants for textiles, in brazing and welding fluxes, and in neutron scintillation counters.

5.1.3.7 Safety. Boron alkoxides are flammable, combustible or burnable liquids, and can emit irritating and toxic fumes if heated to decomposition. They are decomposed by water with the release of flammable alcohol vapors. There are no PELs or TLVs referenced for boron alkoxides. They are local irritants of eyes, skin and mucous membranes, so contact shall be avoided. (Refer to 4.3.1)

5.1.3.8 Storage. Boron alkoxides shall be stored in tightly sealed corrosion-resistant containers in a cool, dry place. (Refer to 4.3.2)

5.1.3.9 Disposal. In case of small liquid spills, absorb with nonreactive absorbents and place in containers for disposal. In case of large liquid spills, dike to prevent spreading. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

Boron alkoxides have an EPA Hazardous Waste Classifications - Ignitable, Waste No. D001 (depending on the flash point); and Reactive, Waste No. D003.

5.1.4 Germanium Alkoxides

5.1.4.1 Name. Germanium n-Butoxide $Ge[O(CH_2)_3CH_3]_4$ FW 365.05
 Germanium(IV) butoxide
 Tetrabutoxygermanium
 Tetrabutyl germanate

5.1.4.1.1 Technical description. Germanium n-butoxide is a liquid with a refractive index of 1.4255, a density of 1.0173 g/cm^3 at 20°C , and a boiling point of 143°C .

5.1.4.1.2 Specification. None.

DOD-STD-1445

5.1.4.2 Name. Germanium Ethoxide $\text{Ge}(\text{OC}_2\text{H}_5)_4$ FW 252.84
 Germanium(IV) ethoxide
 Tetraethoxygermanium
 Tetraethyl germanate

5.1.4.2.1 Technical description. Germanium (IV) ethoxide is a liquid with a melting point of -81°C and a boiling point of 185.5°C .

5.1.4.2.2 Specification. None.

5.1.4.3 Name. Germanium Isopropoxide $\text{Ge}[\text{OCH}(\text{CH}_3)_2]_4$ FW 308.94
 Germanium(IV) isopropoxide
 Tetraisopropoxygermanium
 Tetraisopropyl germanate

5.1.4.3.1 Technical description. Germanium isopropoxide is a liquid with a refractive index of 1.4141 at 20°C , a density of 1.0245 g/cm^3 at 20°C , and a boiling point of 108°C .

5.1.4.3.2 Specification. None.

5.1.4.4 Name. Germanium Methoxide $\text{Ge}(\text{OCH}_3)_4$ FW 196.73
 Germanium(IV) methoxide
 Tetramethoxygermanium
 Tetramethyl germanate

5.1.4.4.1 Technical description. Germanium methoxide is a liquid with a refractive index of 1.4015 and a density of 1.3254 g/cm^3 at 20°C , a melting point of -18°C , and a boiling point of 145°C .

5.1.4.4.2 Specification. None.

5.1.4.5 Use. Germanium alkoxides provide a nonaqueous soluble form of germanium for use in the synthesis of organic compounds.

5.1.4.6 Safety. Germanium alkoxides are flammable or combustible liquids, and can emit irritating and toxic fumes if heated to decomposition. They are decomposed by water with the release of flammable alcohol vapors. There are no PELs or TLVs referenced for germanium alkoxides, but they are strong local irritants of eyes, skin and mucous membranes, and contact shall be avoided. (Refer to 4.3.1)

5.1.4.7 Storage. Germanium alkoxides shall be stored in tightly sealed corrosion-resistant containers in a cool, dry place. (Refer to 4.3.2)

5.1.4.8 Disposal. In case of small liquid spills, absorb with nonreactive absorbents, and place in containers for disposal. In case of large liquid spills, dike to prevent spreading. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

Germanium alkoxides have an EPA Hazardous Waste Classifications - Ignitable, Waste No. D001; and Reactive, Waste No. D003.

DOD-STD-1445

5.1.5 Sodium Alkoxides

5.1.5.1 Name. Sodium n-Butoxide $\text{Na}[\text{O}(\text{CH}_2)_3\text{CH}_3]$ FW 96.11
Sodium n-butate

5.1.5.1.1 Technical description. Sodium n-butoxide is in the form of a solid that is soluble in n-butanol. It is decomposed by water.

5.1.5.1.2 Specification. Manufacturer's requirements. (No Government specification)

5.1.5.1.2.1 Requirements. Commercially available sodium n-butoxide is in the form of a solution (19%) in n-butanol with the physical properties shown in Table I, and the typical chemical analysis shown in Table II.

TABLE I. Sodium n-butoxide solution in butanol - physical properties.

| | |
|--------------------------|-------------------------------|
| Color and appearance | Light yellow, slightly turbid |
| Specific gravity (20°C) | 0.861 |
| Freezing point | -21°C |
| Initial boiling point | 115°C |
| Flash point (closed cup) | 42.9°C (109°F) |

TABLE II. Sodium n-butoxide solution in butanol - typical chemical analysis.

| | |
|---------------------------------|-------|
| NaOC_4H_9 | 19.6% |
| Na_2CO_3 | 0.04% |
| NaOH | 0.14% |
| $\text{C}_4\text{H}_9\text{OH}$ | 80.5% |

5.1.5.2 Name. Sodium Ethoxide NaOC_2H_5 FW 68.05
Sodium ethylate

5.1.5.2.1 Technical description. Sodium ethoxide, anhydrous, is in the form of a white powder with a melting point above 300°C. Its adduct with ethanol, $\text{NaOC}_2\text{H}_5 \cdot 2\text{C}_2\text{H}_5\text{OH}$, is also a white powder or needles which decomposes on heating with loss of $\text{C}_2\text{H}_5\text{OH}$. It is soluble in ethanol, and is decomposed by water.

5.1.5.2.2 Specification. Manufacturer's requirements. (No Government specification)

5.1.5.2.2.1 Requirements. Commercially available sodium ethoxide is an anhydrous free-flowing powder with requirements and properties shown in Table III.

TABLE III. Sodium ethoxide, anhydrous - requirements and properties.

| | |
|--|-------------------------|
| Appearance | Powder, white-yellowish |
| NaOC_2H_5 content | 94% min, 94-97% average |
| Total alkalinity (estimated as NaOR) | 98-100% |
| $\text{NaOH} + \text{Na}_2\text{CO}_3$ (estimated as NaOH) | 2-3% average |
| Particle size, mm | 0.01-0.3 |
| Properties | Hygroscopic, Caustic |

DOD- STD-1445

Commercially available sodium ethoxide solution (21%) in ethanol, with the physical properties shown in Table IV, has a typical chemical analysis shown in Table V.

TABLE IV. Sodium ethoxide solution in ethanol - physical properties.

| | |
|--------------------------|----------------|
| Color and appearance | Yellow, turbid |
| Specific gravity (20°C) | 0.879 |
| Freezing point | -12°C |
| Initial boiling point | 77°C |
| Flash point (closed cup) | 23.9°C (75°F) |

TABLE V. Sodium ethoxide solution in ethanol - typical chemical analysis.

| | |
|----------------------------------|-------|
| NaOC ₂ H ₅ | 21.2% |
| Na ₂ CO ₃ | 0.04% |
| NaOH | 0.02% |
| C ₂ H ₅ OH | 78.5% |

5.1.5.3 Name. Sodium Methoxide NaOCH₃ FW 54.02
Sodium methylate

5.1.5.3.1 Technical description. Sodium methoxide, anhydrous, is in the form of a white powder with a melting point above 300°C. It's adduct with methanol, NaOCH₃·2CH₃OH, is also a white powder which decomposes on heating with loss of CH₃OH. It is soluble in methanol, and is decomposed by water.

5.1.5.3.2 Specification. Manufacturer's requirements. (No Government specification)

5.1.5.3.2.1 Requirements. Commercially available sodium methoxide is an anhydrous powder with the chemical and physical requirements shown in Table VI.

TABLE VI. Sodium methoxide, anhydrous - chemical and physical requirements.

| | Specification | Typical Average |
|----------------------------------|---------------------------------------|-----------------|
| NaOCH ₃ | 97% min | 98.7% |
| NaOH | 1.1% max | 0.5% |
| Na ₂ CO ₃ | 0.4% max | 0.3% |
| † Sieve size, US Standard Sieve: | | |
| | Retained on No. 10 (2.00 millimeter) | 1% max |
| | Pass through No. 150 (104 micrometer) | 75% min |

† NOTE: Standard sieve designation in accordance with ASTM E 11.

A sodium methoxide solution (25%) in methanol, is available with the physical properties shown in Table VII, and with the requirements and typical chemical analysis shown in Table VIII.

TABLE VII. Sodium methoxide solution in methanol - physical properties.

| | |
|---|----------------|
| Color and appearance | Clear |
| Specific gravity (25°C) | 0.945 |
| Crystallization temperature after equilibrium | -1.1°C (30°F) |
| Initial boiling point (for 25% concentration) | 86.7°C (188°F) |
| Flash point (open cup) | 29°C (84°F) |

DOD-STD-1445

TABLE VIII. Sodium methoxide solution in methanol - requirements and typical chemical analysis.

| | Specification | Typical Average |
|---------------------------------|---------------|-----------------|
| NaOCH ₃ | 25.0% min | 25.3% |
| NaOH | 0.35% max | 0.12% |
| Na ₂ CO ₃ | 0.10% max | 0.05% |
| CH ₃ OH | ---- | 74.5% |

Sodium methoxide solution (25%) in methanol is available from a second manufacturer with the requirements as shown in Table IX.

TABLE IX. Sodium methoxide solution in methanol - requirements.

| | |
|---|---|
| NaOCH ₃ content | 24.0-25.5% |
| Total alkalinity | 24.5-26.0% |
| NaOH+Na ₂ CO ₃ (calculated as NaOH) | 0.2-0.6% |
| Mercury content | Less than 2 ppm |
| Density (as 25°C) | 0.94 kg/L |
| Flash point (closed cup) | 12.2°C (54°F) |
| Crystallization | From approx 2°C |
| Properties | Highly sensitive to water and air. Caustic. |
| Solubility | Miscible with methanol, ethanol, isopropanol. Insoluble in hydrocarbons. Reactive with esters, ketones, cyclic ethers, and halogenated organic compounds. |

5.1.5.4 Use. Sodium alkoxides are intended for use in the synthesis of organic compounds by esterification and transesterification reactions, and condensation and polycondensation reactions. They are used for the preparation of other metal alkoxides, and in the preparation of ethers.

5.1.5.5 Safety. Sodium alkoxides are flammable solids or solutions, and can emit irritating and toxic fumes if heated to decomposition. They are decomposed by water with the release of flammable alcohol vapors. There are no PELs or TLVs referenced for sodium alkoxides, but they are strong local irritants of eyes, skin and mucous membranes. They can cause caustic burns, so contact shall be avoided. (Refer to 4.3.1)

5.1.5.6 Storage. Sodium alkoxides shall be stored in tightly sealed corrosion-resistant containers in a cool, dry place. (Refer to 4.3.2)

5.1.5.7 Disposal. In case of solid spills, recover in dry state and place in containers for disposal. In case of small liquid spills, absorb with non-reactive absorbent and place in containers for disposal. In case of large liquid spills, dike to prevent spreading. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

Sodium alkoxides have an EPA Hazardous Waste Classifications - Ignitable, Waste No. D001; and Reactive, Waste No. D003.

DOD-STD-1445

5.1.6 Titanium Alkoxides

5.1.6.1 Name. Titanium n-Butoxide $Ti[O(CH_2)_3CH_3]_4$ FW 340.36
 Tetrabutoxytitanium
 Tetrabutyl titanate

5.1.6.1.1 Technical description. Titanium n-butoxide is in the form of a colorless liquid with a boiling point of about 312°C. It is soluble in n-butanol and n-heptane. It is hydrolyzed by water. The theoretical Ti content is 13.95 percent.

5.1.6.1.2 Specification. Manufacturer's requirements. (No Government specification)

5.1.6.1.2.1 Requirements. Titanium n-butoxide is available as a pale yellow liquid with a specific gravity of 0.99 (25°/25°C), a viscosity of 65 cP (mPa·s) at 25°C, a thickening point below -40°C, and a closed cup flash point of 47°C (116°F). The Ti content of the product is 14.1 percent.

5.1.6.2 Name. Titanium Ethoxide $Ti(OC_2H_5)_4$ FW 228.15
 Tetraethoxytitanium
 Tetraethyl titanate

5.1.6.2.1 Technical description. Titanium ethoxide (pure) is a colorless oily liquid with a refractive index of 1.5082 at 25°C, a density of 1.1066 g/cm³ at 25°C, and a boiling point of 133 to 135°C at 5 mm Hg. It is soluble in ethanol. It is hydrolyzed by water. The theoretical Ti content is 21 percent.

5.1.6.2.2 Specification. Manufacturer's requirements. (No Government specification)

5.1.6.2.2.1 Requirements. Titanium ethoxide, technical grade, is available with a refractive index of 1.5043 at 20°C, a density of 1.088 g/cm³ at 20°C, a boiling point of 150° to 152°C at 10 mm Hg, and a closed cup flash point of 28°C (84°F). The product has a Ti content of 20%, and is stabilized with excess ethanol.

5.1.6.3 Name. Titanium 2-Ethylhexoxide $Ti[OCH_2CH(C_2H_5)C_4H_9]_4$ FW 564.79
 Tetrakis(2-ethylhexoxy)titanium
 Tetrakis(2-ethylhexyl)titanate

5.1.6.3.1 Technical description. Titanium 2-ethylhexoxide is a liquid with a density of 0.926 g/cm³ at 25°C, and a boiling point of 194°C at 0.25 mm Hg. It is soluble in isopropanol and n-heptane. It is hydrolyzed by water. The theoretical Ti content is 8.5 percent.

5.1.6.3.2 Specification. Manufacturer's requirements. (No Government specification)

5.1.6.3.2.1 Requirements. Titanium 2-ethylhexoxide is available as a pale yellow liquid with a specific gravity of 0.91 (25°/25°C), a viscosity of 140 cP (mPa·s) at 25°C, a thickening point below -25°C, and a closed cup flash point of 60°C (140°F). The Ti content of the product is 8.6 percent.

DOD-STD-1445

5.1.6.4 Name. Titanium Isobutoxide $Ti[OCH_2CH(CH_3)_2]_4$ FW 340.36
 Tetraisobutoxytitanium
 Tetraisobutyl titanate

5.1.6.4.1 Technical description. Titanium isobutoxide (pure) is a crystalline solid with a melting point of 30°C. The liquid has a density of 0.960 g/cm³, a refractive index of 1.475, and a boiling point of 269°C at 760 mm Hg. It is soluble in isobutyl alcohol and n-heptane. It is hydrolyzed by water.

5.1.6.4.2 Specification. Manufacturer's requirements. (No Government specification)

5.1.6.4.2.1 Requirements. Titanium isobutoxide is available as a liquid with a boiling point of 141°C at 1 mm Hg.

5.1.6.5 Name. Titanium Isopropoxide $Ti[OCH(CH_3)_2]_4$ FW 284.25
 Tetraisopropoxytitanium
 Tetraisopropyl titanate

5.1.6.5.1 Technical description. Titanium isopropoxide (pure) is a liquid with a density of 0.9550 g/cm³ at 25°C, a melting point of 20°C and a boiling point of 58°C at 1 mm Hg. It is soluble in isopropanol and n-heptane. It is hydrolyzed by water. The theoretical Ti content is 16.85 percent.

5.1.6.5.2 Specification. Manufacturer's requirements. (No Government specification)

5.1.6.5.2.1 Requirements. Titanium isopropoxide is available as a pale yellow liquid with a specific gravity of 0.95 (25°/25°C), a freezing point of 18°C, a viscosity of 3 cP (mPa·s), and a closed cup flash point of 21°C (70°F). The Ti content of the product is 16.7 percent.

5.1.6.6 Name. Titanium Methoxide $Ti(OCH_3)_4$ FW 172.04
 Tetramethoxytitanium
 Tetramethyl titanate

5.1.6.6.1 Technical description. Titanium methoxide (pure) is in the form of a solid with a melting point of 210°C and a boiling point of 243°C at 52 mm Hg. It is hydrolyzed by water.

5.1.6.6.2 Specification. None.

5.1.6.7 Use. Titanium alkoxides provide a nonaqueous soluble form of titanium for use in the synthesis of organic compounds, as esterification and transesterification catalysts, as polymerization catalysts, and as crosslinking agents for polymers.

5.1.6.8 Safety. Titanium alkoxides are flammable solids, or flammable or combustible liquids, and can emit irritating and toxic fumes if heated to decomposition. They are decomposed by water with the release of flammable alcohol vapors. There are no PELs or TLVs referenced for titanium alkoxides, but they are strong local irritants of the eyes, skin and mucous membranes. (Refer to 4.3.1)

DOD-STD-1445

5.1.6.9 Storage. Titanium alkoxides shall be stored in tightly sealed corrosion-resistant containers in a cool, dry place. (Refer to 4.3.2)

5.1.6.10 Disposal. In case of solid spills, gather up and place in containers for disposal. In case of small liquid spills, absorb with nonreactive absorbent, and place in containers for disposal. In case of large liquid spills, dike to prevent spreading. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

Titanium alkoxides have an EPA Hazardous Waste Classifications - Ignitable, Waste No. D001; and Reactive, Waste No. D003.

5.1.7 Zirconium Alkoxides

5.1.7.1 Name. Zirconium n-Butoxide $Zr[O(CH_2)_3CH_3]_4$ FW 383.69
 $Zr[O(CH_2)_3CH_3]_4 \cdot C_4H_9OH$ FW 457.81
 Tetrabutoxyzirconium
 Tetrabutyl zirconate

5.1.7.1.1 Technical description. Zirconium n-butoxide is a white solid. It forms an adduct with n-butanol, $(C_4H_9O)_4Zr \cdot C_4H_9OH$, that is a liquid with a density of 1.05 to 1.08 g/cm³, and a melting point below -70°C. The theoretical ZrO₂ content of the adduct is 27 percent.

5.1.7.1.2 Specification. Manufacturer's requirements. (No Government specification)

5.1.7.1.2.1 Requirements. Zirconium n-butoxide is available as the adduct with butanol, with an analysis of 28% ZrO₂.

5.1.7.2 Zirconium Ethoxide $Zr(OC_2H_5)_4$ FW 271.47
 Tetraethoxyzirconium
 Tetraethyl zirconate

5.1.7.2.1 Technical description. Zirconium ethoxide is a crystalline solid with a melting point of 171 to 173°C.

5.1.7.2.2 Specification. None.

5.1.7.3 Zirconium Isopropoxide $Zr[OCH(CH_3)_2]_4$ FW 327.56
 $Zr[OCH(CH_3)_2]_4 \cdot C_3H_7OH$ FW 387.67
 Tetraisopropoxyzirconium
 Tetraisopropyl zirconate

5.1.7.3.1 Technical description. Zirconium isopropoxide is a white solid that decomposes on heating before melting. It forms an adduct with isopropanol, $(C_3H_7O)_4Zr \cdot C_3H_7OH$, that is a crystalline solid. The theoretical carbon content is 46.5% and the theoretical hydrogen content is 9.1 percent.

5.1.7.3.2 Specification. Manufacturer's requirements. (No Government specification)

5.1.7.3.2.1 Requirements. Zirconium isopropoxide is available as the adduct with isopropanol, with an analysis of 43.8% carbon and 8.8% hydrogen.

DOD-STD-1445

5.1.7.4 Zirconium n-Propoxide $Zr[O(CH_2)_2CH_3]_4$ FW 327.56
 Tetrapropoxyzirconium
 Tetrapropyl zirconate

5.1.7.4.1 Technical description. Zirconium n-propoxide is a liquid with a density of 1.058 g/cm^3 and a refractive index of 1.454 at 20°C . The theoretical Zr content is 27.8 percent.

5.1.7.4.2 Specification. Manufacturer's requirements. (No Government specification)

5.1.7.4.2.1 Requirements. Zirconium n-propoxide is available as a liquid with a density of 1.05 g/cm^3 and a refractive index of 1.457 at 20°C . The product has a Zr content of 21.6 percent.

5.1.7.5 Use. Zirconium alkoxides provide a nonaqueous soluble form of zirconium for use in organic synthesis as a condensation catalyst and cross-linking agent.

5.1.7.6 Safety. Zirconium alkoxides are flammable solids, or flammable or combustible liquids, and can emit irritating and toxic fumes if heated to decomposition. They are decomposed by water with the release of flammable alcohol vapors. The PEL and TLV for zirconium compounds, as Zr, is 5 mg/m^3 . They are strong local irritants of the eyes, skin and mucous membranes. (Refer to 4.3.1)

5.1.7.7 Storage. Zirconium alkoxides shall be stored in tightly sealed corrosion-resistant containers in a cool, dry place. (Refer to 4.3.2)

5.1.7.8 Disposal. In case of dry spills, gather up and place in containers for disposal. In case of small liquid spills, absorb with nonreactive absorbent and place in containers for disposal. In case of large liquid spills, dike to prevent spreading. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

Zirconium alkoxides have an EPA Hazardous Waste Classifications - Ignitable, Waste No. D001; and Reactive, Waste No. D003.

5.2 Metal Carboxylates

Metal carboxylates are the alkali, alkaline-earth, and heavy metal salts of the carboxylic acids. The salts of the carboxylic acids are nonvolatile solids. In general, the alkali metal salts, with the exception of lithium, are soluble in water but insoluble in non-polar solvents. The salts of the alkaline-earth and heavy metals are insoluble in water, but show solubility or solvation in non-polar solvents. The alkaline-earth and heavy metal salts of the monocarboxylic acids are called metallic soaps, although salts of the acids of less than seven carbon atoms in the aliphatic series are not classed as such.

Carboxylic acids are converted to alkali metal salts by reaction with aqueous alkali hydroxides. Metallic soaps may be prepared by either a fusion or a precipitation process. In the fusion process a metal oxide, hydroxide, or salt of a weak acid such as an acetate or carbonate, are reacted with a select-

DOD-STD-1445

ed fatty acid at an elevated temperature in the absence of added water. Under these conditions, a neutralization reaction takes place, and as the water is driven off a metallic soap is formed as a molten mass which after solidification is crushed and pulverized to desired particle size ranges. In the precipitation process, a solution of sodium soap is first prepared by reaction of a selected fatty acid with caustic soda solution. When a separately prepared solution of the appropriated metal salt is added to the sodium salt solution a metathetic reaction occurs and the desired metallic soap precipitates, while an inorganic sodium salt remains in solution.

5.2.1 Name. Aluminum Stearate $\text{Al}(\text{OOCH}_2\text{C}_{17}\text{H}_{35})_2\text{OH}\cdot\text{C}_{17}\text{H}_{35}\text{COOH}$ FW 895.44
 $\text{Al}(\text{OOCH}_2\text{C}_{17}\text{H}_{35})_2\text{OH}$ FW 611.0
 Aluminum octadecanoate

5.2.1.1 Technical description. Aluminum tristearate, $\text{Al}(\text{OOCH}_2\text{C}_{17}\text{H}_{35})_3$, is nonexistent. This psuedo triacid aluminum stearate is actually composed of one mole of free fatty acid for each mole of aluminum distearate. The aluminum distearate is a polymeric compound where the aluminum has a coordination number of six. Aluminum stearate is a white powder with a slight fatty acid odor. The "tristearate" has a specific gravity of 1.010 and a melting point of 103°C. It is insoluble in water, alcohol and ether. It dissolves in hydrocarbon liquids at elevated temperatures, and on cooling forms viscoelastic solutions or "gels." It is decomposed by strong aqueous acid and alkali solutions. The theoretical aluminum content of aluminum distearate is 4.4 percent. The theoretical aluminum content of the "triacid" aluminum stearate is 3.0%, and the theoretical free fatty acid content is 32 percent. Aluminum stearate with aluminum contents above 4.4% are mixtures of aluminum distearate and aluminum hydroxide.

5.2.1.2 Specification. Manufacturer's requirements. (No Government specification).

5.2.1.3 Requirements. Commercial grades of aluminum stearate are white powders with aluminum oxide contents ranging from 6.0 to 17.0% which corresponds to aluminum contents of 3.7 to 7.9%, and with free fatty acid contents ranging from 28.4 to 2.0 percent. The moisture contents range from 0.5 to 0.7 percent.

NOTE: Stearic acid is available in varying states of purity depending on the refining process. Commercial grades of stearic acid can contain, in addition to octadecanoic acid, up to 50% palmitic acid (hexadecanoic acid), and also some oleic acid (cis-9-octadecenoic acid) and palmitoleic and (cis-9-hexadecenoic acid).

5.2.1.4 Use. Aluminum stearate is intended for military use as an ingredient in nonaqueous paints and related products such as varnishes and lacquers. Commercial applications include the above, and also uses as a thickening agent for lubricating oils to form greases, and as a waterproofing agent for masonry surfaces, leather, paper, and wood.

5.2.1.5 Safety. Aluminum stearate powder is burnable, and can form explosive dust mixtures in air. It can emit irritating and toxic fumes if heated to decomposition. The aluminum ion is nontoxic, but aluminum stearate can be irritating to the eyes, skin and mucous membranes. The TLV for aluminum

DOD-STD-1445

stearate, as a nuisance particulate, is 10 mg/m³ of total dust, so inhalation of dust shall be avoided. (Refer to 4.3.1)

5.2.1.6 Storage. Aluminum stearate shall be stored in corrosion-resistant containers in a cool, dry place. (Refer to 4.3.2)

5.2.1.7 Disposal. In case of dry spills, gather up and place in containers for disposal. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

‡ An EPA Hazardous Waste Classification is not listed in 40 CFR.

5.2.2 Name. Barium Stearate Ba(OOCH₃₅C₁₇)₂ FW 704.13
Barium octadecanoate

5.2.2.1 Technical description. Barium stearate is a white powder with a specific gravity of 1.145 and a melting point of 160°C. Its solubility in water is 0.004 g/100 mL at 15°C and 0.006 g/100 mL at 50°C. Its solubility in alcohol is 0.005 g/100 mL at 16.5°C and 0.008 g/100 mL at 25°C. Its solubility in ether is 0.001 g/100 mL at 25°C. It solvates in hydrocarbon liquids. It is decomposed by strong aqueous acid solutions. The theoretical barium content of barium distearate is 19.5 percent.

5.2.2.2 Specification. Military, JAN-B-366, Barium Stearate.

5.2.2.2.1 Requirements. This specification covers one grade of barium stearate with the chemical and physical properties conforming to the requirements shown in Table X.

TABLE X. Barium stearate - chemical and physical requirements.

| | |
|---|------------|
| Melting point, °C, min | 240 |
| Barium content, % | 20.0 + 0.5 |
| Moisture, %, max | 0.2 |
| Water-soluble salts, %, max | 0.5 |
| Acidity or alkalinity, %, max | 0.01 |
| Grit | None |
| † Granulation, US Standard Sieves | |
| Through No. 100 (150 micrometer), %, min | 95.5 |
| Through No. 200 (75 micrometer), %, min | 95 |

† Standard sieve designation in accordance with ASTM E 11.

5.2.2.3 Use. Barium stearate is intended for military use as a binder and lubricant in the pelleting of explosives. Commercial applications include use as a lubricant in metal working and wire-drawing, and as an ingredient in wax polishing compounds.

5.2.2.4 Safety. Barium stearate powder is burnable, and can form explosive dust mixtures in air. It can emit irritating and toxic fumes if heated to decomposition. The barium ion is toxic when the compound is soluble, and its compounds can be irritating to the eyes, skin and mucous membranes. The PEL and TLV for soluble barium compounds, as Ba, is 0.5 mg/m³, so breathing of dust shall be avoided. (Refer to 4.3.1)

DOD-STD-1445

5.2.2.5 Storage. Barium stearate shall be stored in corrosion-resistant containers in a cool, dry place. (Refer to 4.3.2)

5.2.2.6 Disposal. In case of dry spills, gather up and place in containers for disposal. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

Barium stearate has an EPA Hazardous Waste Classification - EP Toxic; Waste No. D005.

5.2.3 Name. Calcium Resinate $\text{Ca}(\text{OOCCH}_2\text{C}_{19})_2$ FW 643.00
Calcium abietate

5.2.3.1 Technical description. Calcium resinate is a yellowish-white amorphous powder or yellow to brown lumps dependent on the method of preparation. It is insoluble in water. It is soluble in ether, amyl alcohol, and esters such as butyl acetate and amyl acetate. It is decomposed by strong aqueous acid solutions. The above formula and formula weight are for calcium abietate, since abietic acid is the predominant acid in rosin.

5.2.3.2 Specification. Military, MIL-C-20470A, Calcium Resinate.

5.2.3.2.1 Requirements. This specification covers two types of calcium resinate:

Type I - Fused
Type II - Precipitated

Type I fused calcium resinate shall be yellow or brown in color. Type II shall be a yellowish-white amorphous powder, free from lumps, cakes and agglomerations. The chemical and physical properties shall conform to the requirements shown in Table XI.

TABLE XI. Calcium resinate - chemical and physical requirements.

| | Type I | Type II |
|--|------------|------------|
| Calcium resinate content, %, min | 56.0 | 77.0 |
| Acid number, max | 64 | 33 |
| Chloroform insoluble matter, %, max | 2.0 | 3.0 |
| Water content, %, max | 2.0 | 5.0 |
| † Granulation, US Standard Sieves | | |
| Through No. 60 (250 micrometer), %, min | None | 75 |
| Through No. 4 (4.75 millimeter), %, min | 90 | --- |
| Flame test | Yellow-red | Yellow-red |

† Standard sieve designation in accordance with ASTM E 11.

5.2.3.3 Use. Calcium resinate is intended for military use in pyrotechnic compositions. Commercial applications include use in varnishes to cause thickening and to increase the hardness of the dried film.

5.2.3.4 Safety. Calcium resinate is a flammable solid, and the powder can form explosive dust mixtures in air. It can emit irritating and toxic fumes if heated to decomposition. The calcium ion is nontoxic, but its compounds can be

DOD-STD-1445

irritating to the eyes, skin and mucous membranes. There is no PEL or TLV referenced for calcium resinate, but breathing of dust shall be avoided. (Refer to 4.3.1)

5.2.3.5 Storage. Calcium resinate shall be stored in corrosion-resistant containers in a cool, dry place. (Refer to 4.3.2)

5.2.3.6 Disposal. In case of dry spills, gather up and place in containers for disposal. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

An EPA Hazardous Waste Classification is not listed in 40 CFR.

5.2.4 Name. Calcium Stearate $\text{Ca}(\text{OOCCH}_2\text{C}_{17})_2$ FW 607.04
Calcium octadecanoate

5.2.4.1 Technical description. Calcium stearate is a white granular powder with a melting point of 179° to 180°C. Its solubility in water is 0.004 g/100 mL at 15°C. It is insoluble in alcohol and ether. It solvates in hydrocarbon liquids. It is decomposed by strong aqueous acid solutions. The theoretical calcium content of calcium distearate is 6.6 percent.

5.2.4.2 Specification. Military, JAN-C-263, Calcium Stearate.

5.2.4.2.1 Requirements. This specification covers one grade of calcium stearate with the chemical and physical properties conforming to the requirements shown in Table XII.

TABLE XII. Calcium stearate - chemical and physical requirements.

| | |
|---|-----------|
| Calcium, as CaO, % | 9.2 ± 0.2 |
| Acidity or alkalinity, %, max | 0.01 |
| Moisture, %, max | 3.0 |
| Water-soluble salts, %, max | 0.25 |
| Grit | None |
| Melting point, °C, min | 150 |
| † Granulation, US Standard Sieves | |
| Through No. 100 (150 micrometer), %, min | 98 |
| Through No. 200 (75 micrometer), %, min | 95 |

† Standard sieve designations in accordance with ASTM E 11.

NOTE: The CaO content of 9.0 to 9.4% is equivalent to a Ca content of 6.4 to 6.7 percent.

5.2.4.3 Use. Calcium stearate is intended for military use as a binder and lubricant in the pelleting of explosives. Commercial applications include use as a thickener for lubricating oils to form greases; as a waterproofing agent for concrete, paper, rope, fabric and wood; as a mold lubricant and internal lubricant for plastics; and as an ingredient in nonaqueous protective coatings.

5.2.4.4 Safety. Calcium stearate powder is burnable, and can form explosive dust mixtures in air. It can emit irritating and toxic fumes if heated to decomposition. The calcium ion is nontoxic, but its compounds can be irritat-

DOD- STD-1445

ing to the eyes, skin and mucous membranes. The TLV for calcium stearate, as a nuisance particulate, is 10 mg/m³ as total dust, so inhalation of dust shall be avoided. (Refer to 4.3.1)

5.2.4.5 Storage. Calcium stearate shall be stored in corrosion-resistant containers in a cool, dry place. (Refer to 4.3.2)

5.2.4.6 Disposal. In case of dry spills, gather up and place in containers for disposal. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

An EPA Hazardous Waste Classification is not listed in 40 CFR.

5.2.5 Name. Chromium(III) 2-Ethylhexanoate
 $\text{Cr}[\text{OOCCH}(\text{C}_2\text{H}_5)\text{C}_4\text{H}_9]_3$ FW 481.62
 Chromium(III) 2-ethylhexoate
 Chromium(III) octoate

5.2.5.1 Technical description. Chromium(III) has a coordination number of six, and the composition of chromium soaps is complex. The properties of specific compounds are not available. The theoretical chromium content of chromium(III) 2-ethylhexanoate is 10.8 percent.

5.2.5.2 Specification. Military, DOD-C-82660, Chromium 2-Ethyl Hexoate.

5.2.5.2.1 Requirements. This specification covers one type of chromium 2-ethylhexoate. The material shall be a dark green liquid that is essentially pure chromium 2-ethylhexoate diluted with 2-ethylhexanoic acid. The chemical and physical properties of the solution shall conform to the requirements shown in Table XIII.

TABLE XIII. Chromium 2-ethylhexoate - chemical and physical requirements.

| | Minimum | Maximum |
|------------------------------|---------|---------|
| Chromium content, wt % | 5.3 | 5.7 |
| Specific gravity, (25°/25°C) | 0.97 | 1.03 |

5.2.5.3 Use. Chromium 2-ethylhexoate solution in 2-ethylhexanoic acid is intended for military use as an ingredient in solid propellants for cartridge devices.

5.2.5.4 Safety. The flash point (closed cup) of 2-ethylhexanoic acid is 124°C (256°F), and a solution of chromium 2-ethylhexoate in this solvent is burnable. The solution can emit irritating and toxic fumes if heated to decomposition. The chromium(III) ion is toxic and is a potential carcinogen. The PEL and TLV for chromium(III) compounds, as Cr, is 0.5 mg/m³, and breathing of mists and fumes shall be avoided. Burning of Cr(III) can form some Cr(VI). Chromium(VI) is considered a confirmed carcinogen by the International Agency for Research on Cancer (IARC) and Transactions of ACGIH. The TLV for chromium (VI) is 0.05 mg/m³. Breathing of mists or fumes of chromium(VI) shall be avoided. The Cr(III) compound solution can be irritating to the eyes, skin, and mucous membranes. (Refer to 4.3.1)

5.2.5.5 Storage. Chromium 2-ethylhexoate solution shall be stored in corrosion-resistant containers in a cool, dry place. (Refer to 4.3.2)

DOD- STD-1445

5.2.5.6 Disposal. In case of small solution spills absorb with nonreactive absorbent and place in containers for disposal. In case of large solution spills, dike to prevent spreading. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

Chromium(III) 2-ethylhexoate has an EPA Hazardous Waste Classification - EP Toxic; Waste No. D007.

| | | | |
|-------|---|--|-----------|
| 5.2.6 | Name. Copper Naphthenate Copper cyclohexanecarboxylate Copper hexahydrobenzoate | $\text{Cu}(\text{OOCCH}_2\text{C}_6\text{H}_{11})_2$ | FW 317.87 |
|-------|---|--|-----------|

5.2.6.1 Technical description. Copper naphthenate is a green-blue or dark-green solid. It is soluble in hydrocarbon liquids. The formula and formula weight and synonyms are for copper naphthenate derived from cyclohexanecarboxylic acid, which is one of the components of naphthenic acids. The component acids of the naphthenic acid mixture also include alkylated cyclopentanecarboxylic acids of the general formula $\text{C}_n\text{H}_{2n-2}\text{O}_2$ containing 8 to 12 carbons, and other alkylated cyclic carboxylic acids of the general formula $\text{C}_n\text{H}_{2n-4}\text{O}_2$ containing 12 to 23 carbons. The properties of specific copper naphthenate compounds are not available.

5.2.6.2 Specifications

5.2.6.2.1 Federal, TT-P-595A, Preservative Coating, Canvas.

5.2.6.2.1.1 Requirements. This specification covers two types of preservative coatings. Type I(b) shall be copper naphthenate combined with copper-8-quinolinolate. The properties of the copper naphthenate are not specified.

5.2.6.2.2 Military, MIL-W-18142B, Wood Preservative Solutions, Oil-Soluble, Ship and Boat Use.

5.2.6.2.2.1 Requirements. This specification covers two types of oil-borne wood preservatives. Type A shall be copper naphthenate in mineral spirits solution at a minimum concentration of 68 g/gal. The properties of the copper naphthenate are not specified.

5.2.6.2.3 Military, MIL-F-46032A, Fungus-Resistant Treatment for Sandbags, Copper Processes.

5.2.6.2.3.1 Requirements. This specification covers three types of processes. Type I shall be a copper naphthenate treatment. The copper naphthenate used shall consist of a clear, green-colored solution containing no sediment; and manufactured from naphthenic acid, with an acid number of not less than 180, containing not more than 25% unsaponifiable matter. The metal content of this copper naphthenate solution is not specified.

5.2.6.3 Use. Copper naphthenate is intended for military use in preservative coatings for canvas tentage and tarpaulins, in oil-soluble preservative solutions for treatment of ship and boat lumber and plywood, and in solutions for treatment of sandbags against fungus attack. Commercial appli-

DOD-STD-1445

5.2.7.3 Use. Lead 2-ethylhexoate is intended for use in various military applications. Commercial applications include use as an ingredient in nonaqueous paints, and as a curing agent for silicone paints and insulating varnishes.

5.2.7.4 Safety. Lead 2-ethylhexoate is burnable, and can form explosive dust mixtures in air. It can emit irritating and toxic fumes if heated to decomposition. The lead ion is toxic and considered to be a potential carcinogen by the National Toxicology Program (NTP). The PEL for organic lead soaps, as Pb, is $50 \mu\text{g}/\text{m}^3$, so breathing of dust and fumes shall be avoided. (Refer to 4.3.1)

5.2.7.5 Storage. Lead 2-ethylhexoate shall be stored in corrosion-resistant containers in a cool, dry place. (Refer to 4.3.2)

5.2.7.6 Disposal. In case of dry spills, gather up and place in containers for disposal. In case of small solution spills, absorb with nonreactive absorbent and place in containers for disposal. In case of large solution spills, dike to prevent spreading. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

An EPA Hazardous Waste Classification - EP Toxic; Waste No. D008.

| | | |
|-------------------------------------|---|-----------|
| 5.2.8 <u>Name</u> . Lead Salicylate | $\text{Pb}(\text{OCC}_6\text{H}_4\text{OH})_2$ | FW 481.43 |
| Lead 2-hydroxybenzoate | $\text{Pb}(\text{OCC}_6\text{H}_4\text{OH})_2 \cdot \text{H}_2\text{O}$ | FW 499.45 |

5.2.8.1 Technical description. The properties of the anhydrous lead salicylate compound are not available. Lead salicylates are in the form of white crystals. The monohydrate has a specific gravity of 2.3 and a refractive index of 1.78. Lead salicylate is soluble in hot water and alcohol. It is decomposed by strong aqueous acid solutions. The theoretical lead content of the anhydrous form is 43.04%, and the lead content of the monohydrate is 41.49 percent. The salicylic acid content of the anhydrous form is 57.38%, and the salicylic acid content of the monohydrate is 55.31 percent.

5.2.8.2 Specifications.

5.2.8.2.1 Military, MIL-L-13788, Lead Salicylate.

5.2.8.2.1.1 Requirements. This specification covers one grade of lead salicylate with the chemical and physical properties conforming to the requirements shown in Table XV.

TABLE XV. Lead salicylate - chemical and physical requirements (MIL-L-13788).

| | |
|--|---------------|
| Lead content, %, min | 43.0 |
| Salicylate content, %, min | 55.4 |
| Volatile matter, %, max | 0.25 |
| Form | Soft crystals |
| Color | White |
| † Granulation, US Standard Sieve Retained on No. 325 (45 micrometer), %, max | 0.1 |

† Standard sieve designation in accordance with ASTM E 11.

DOD-STD-1445

5.2.9.2.1 Requirements. This specification covers one grade of lead stearate with the chemical and physical properties conforming to the requirements shown in Table XVII.

TABLE XVII. Lead stearate - chemical and physical requirements.

| | |
|---|--------------|
| <i>Purity</i> | |
| Lead content, as Pb, % | 26.8 to 29.5 |
| Stearate, as stearic acid, % | 70.8 to 73.5 |
| Moisture, %, max | 1.0 |
| Water soluble material, %, max | 0.5 |
| <i>Acidity and alkalinity</i> | |
| <i>Alkalinity</i> | |
| Alkalinity | None |
| <i>Acidity, as acetic acid,</i> | |
| To phenolphthalein, %, max | 0.05 |
| To methyl orange | None |
| Melting point of lead stearate, °C, min | 104 |
| Melting point of fatty acid, °C, min | 55 |
| Iodine number of fatty acid, max | 5.0 |
| † Granulation, US Standard Sieves | |
| Retained on No. 100 (150 micrometer), %, max | 5.0 |
| Through No. 100 (150 micrometer) and retained on No. 200 (75 micrometer), %, max | 13.0 |
| Through No. 200 (75 micrometer) and re- tained on No. 325 (45 micrometer), %, max | 15.0 |

† Standard sieve designation in accordance with ASTM E 11.

5.2.9.3 Use. Lead stearate is intended for military use in propellant powder. Commercial applications include use in extreme pressure lubricants, as an ingredient in nonaqueous paints and varnishes, and in the manufacture of polyvinyl chloride plastics.

5.2.9.4 Safety. Lead stearate powder is burnable, and can form explosive dust mixtures in air. It can emit irritating and toxic fumes if heated to decomposition. The lead ion is toxic and considered to be a potential carcinogen by the National Toxicology Program (NTP). The PEL for organic lead soaps, as Pb, is $50 \mu\text{g}/\text{m}^3$, so breathing of dust and fumes shall be avoided. (Refer to 4.3.1)

5.2.9.5 Storage. Lead stearate shall be stored in corrosion-resistant containers in a cool, dry place. (Refer to 4.3.2)

5.2.9.6 Disposal. In case of dry spills, gather up and place in containers for disposal. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

Lead stearate has an EPA Hazardous Waste Classification - EP Toxic; Waste No. D008.

5.2.10 Name. Lithium Stearate
Lithium octadecanoate

$\text{LiOOC}(\text{C}_{17})_2$

FW 290.41

DOD-STD-1445

5.2.10.1 Technical description. Lithium stearate is in the form of white crystals with a melting point of 220.5 to 221.5°C. Its solubility in water is 0.010 g/100 mL at 18°C. Its solubility in alcohol is 0.010 g/100 mL at 25°C; 0.040 g/100 mL in ether at 18°C; and 0.457 g/100 mL in acetone at 15°C. It solvates in hydrocarbon liquids. It is decomposed by strong aqueous acid solutions. The theoretical lithium content is 2.4%, and the theoretical stearate content is 97.6 percent.

5.2.10.2 Specification. Military, MIL-L-51131A, Lithium Stearate.

5.2.10.2.1 Requirements. This specification covers two types of lithium stearate.

Type I - Maximum moisture content of 0.1%

Type II - Maximum moisture content of 0.2%

The chemical and physical properties shall conform to the requirements shown in Table XVIII.

TABLE XVIII. Lithium stearate - chemical and physical requirements.

| | Type I | Type II |
|---|--------------|--------------|
| Lithium content, % | 2.2 to 2.8 | 2.2 to 2.8 |
| Stearate content, % | 94.6 to 97.8 | 94.6 to 97.8 |
| Moisture, %, max | 0.1 | 0.2 |
| Free acid, calculated as stearic acid, %, max | ---- | 0.5 |
| Free alkali, calculated as LiOH·H ₂ O, %, max | ---- | None |
| Chloride, %, max | ---- | 0.01 |
| Water soluble material, %, max | 1.5 | 0.5 |
| pH value | 8 to 10 | 8 to 10 |
| Melting point, °C min | 200 | 200 |
| Melting point of fatty acid, °C, min | 55 | 55 |
| Iodine number of fatty acid, max | 5.0 | 5.0 |
| † Granulation, US Standard Sieve Through No. 100 (150 micrometer), %, min | 99 | 99 |

† Standard sieve designation in accordance with ASTM E 11.

5.2.10.3 Use. Lithium stearate is intended for military use as a lubricant in ammunition. Commercial applications include the thickening of lubricating oils for the manufacture of multipurpose greases, and use as a lubricant in powder metallurgy.

5.2.10.4 Safety. Lithium stearate is burnable, and can form explosive dust mixtures in air. It can emit irritating and toxic fumes if heated to decomposition. The lithium ion is toxic to the central nervous system, and its compounds can be irritating to the eyes, skin and mucous membranes. The TLV for lithium stearate, as a nuisance particulate is 10 mg/m³ of total dust, so inhalation of dust and fumes shall be avoided. (Refer to 4.3.1)

5.2.10.5 Storage. Lithium stearate shall be stored in corrosion-resistant containers in a cool, dry place. (Refer to 4.3.2)

DOD-STD-1445

5.2.10.6 Disposal. In case of dry spills, gather up and place in containers for disposal. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

An EPA Hazardous Waste Classification is not listed in 40 CFR.

5.2.11 Name. Magnesium Stearate $Mg(OOCH_{35}C_{17})_2$ FW 591.27
Magnesium octadecanoate

5.2.11.1 Technical description. Magnesium stearate is in the form of white powder or lumps with a melting point of 186 to 188°C. Its solubility in water is 0.003 g/100 mL at 15°C and 0.008 g/100 mL at 50°C. Its solubility in alcohol is 0.020 g/100 mL at 25°C; and 0.003 g/100 mL in ether at 25°C. It solvates in hydrocarbon liquids. It is decomposed by strong aqueous acid solutions. The theoretical magnesium content of magnesium distearate is 4.1%, and the theoretical stearate content as stearic acid is 96 percent.

5.2.11.2 Specification. Military, MIL-M-542A, Magnesium Stearate.

5.2.11.2.1 Requirements. This specification covers one grade of magnesium stearate with the chemical and physical properties conforming to the requirements shown in Table XIX.

TABLE XIX. Magnesium stearate - chemical and physical requirements.

| | |
|---|-----------|
| Magnesium content, % | 4.3 ± 0.2 |
| Stearate content as stearic acid, total, % | |
| %, max | 97 |
| %, min | 92 |
| Moisture, %, max | 6.5 |
| Water-soluble salts, %, max | 0.6 |
| Alkalinity, %, max | 0.03 |
| Mineral acidity | None |
| Melting point, °C, min | 130 |
| Iodine number of fatty acid, max | 5.0 |
| Melting point of fatty acid, °C min | 55 |
| Grit | None |
| † Granulation, US Standard Sieve | |
| Passing through No. 100 (150 micrometer), % | 100 |
| Passing through No. 200 (75 micrometer), % | 95 |

† Standard sieve designation in accordance with ASTM E 11.

5.2.11.3 Use. Magnesium stearate is intended for military use as an ingredient in rocket propellants. Commercial applications include the thickening of drying oils, and as an ingredient in varnishes, printing inks, and plastics.

5.2.11.4 Safety. Magnesium stearate is burnable, and can form explosive dust mixtures in air. It can emit irritating and toxic fumes if heated to decomposition. The magnesium ion is nontoxic, but its compounds can be irritating to the eyes, skin and mucous membranes. The TLV for magnesium stearate, as a nuisance particulate, is 10 mg/m³ of total dust, so inhalation of dust and fumes shall be avoided. (Refer to 4.3.1)

DOD-STD-1445

5.2.11.5 Storage. Magnesium stearate shall be stored in corrosion-resistant containers in a cool, dry place. (Refer to 4.3.2)

5.2.11.6 Disposal. In case of dry spills, gather up and place in containers for disposal. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

An EPA Hazardous Waste Classification is not listed in 40 CFR.

5.2.12 Name. Sodium Acetate, Anhydrous NaOOCCH₃ FW 82.03
Sodium ethanoate

5.2.12.1 Technical description. Anhydrous sodium acetate is a white granular powder in the form of monoclinic crystals with a specific gravity of 1.528. It has a melting point of 324°C, and decomposes above its melting point. Its solubility in water is 119 g/100 mL at 0°C, and 170 g/100 mL at 100°C. Its solubility in methanol is 26 wt % at 25°C, and is 3.2 wt % in ethanol at 25°C. It is decomposed by strong aqueous acid solutions.

5.2.12.2 Specification. Manufacturer's requirements. (No Government specification).

5.2.12.2.1 Requirements. Sodium acetate, anhydrous, technical, is available from a chemical producer with the chemical properties that conform to the requirements shown in Table XX.

TABLE XX. Sodium acetate, anhydrous - specification requirements.

| | |
|---|-------------|
| Purity, as NaOOCCH ₃ , dry basis, wt % | 99.0 to 101 |
| Acetic acid, wt %, max | 1.0 |
| Halides, as NaCl, wt %, max | 0.3 |
| Iron, as Fe, ppm, max | 50 |
| pH of 10% aqueous solution, at 25°C | 6.5 to 9.5 |
| Alkalinity, as NaOH, %, max | 0.3 |
| Carbonates, as Na ₂ CO ₃ , %, max | 1.0 |
| Loss on drying, wt %, max | 2.0 |

5.2.12.3 Use. Sodium acetate, anhydrous, is intended for military use in the manufacture of chemical items. Commercial applications include use as an intermediate in the production of dyes and colors.

5.2.12.4 Safety. Sodium acetate can emit irritating and toxic fumes if heated to decomposition. The compound is nontoxic, but can be irritating to the eyes, skin and mucous membranes. There is no PEL or TLV referenced for sodium acetate, but inhalation of dust shall be avoided. (Refer to 4.3.1)

5.2.12.5 Storage. Sodium acetate, anhydrous, shall be stored in corrosion-resistant containers in a cool, dry place. (Refer to 4.3.2)

5.2.12.6 Disposal. In case of dry spills, gather up and place in containers for disposal. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

An EPA Hazardous Waste Classification is not listed in 40 CFR.

DOD-STD-1445

5.2.13 Name. Sodium Gluconate $\text{NaOOC}(\text{CHOH})_4\text{CH}_2\text{OH}$ FW 218.13
Sodium dextronate

5.2.13.1 Technical description. Sodium gluconate is a white crystalline powder. Its solubility in water is 59 g/100 mL at 25°C. It is sparingly soluble in alcohol, and insoluble in ether. It is decomposed by strong aqueous acid solutions. It forms water soluble complexes with calcium in alkaline solutions, and with iron in near neutral solutions.

5.2.13.2 Specification. Manufacturer's requirements. (No Government specification).

5.2.13.2.1 Requirements. Sodium gluconate is available from a chemical producer with the chemical and physical properties conforming to the requirements shown in Table XXI.

TABLE XXI. Sodium gluconate - chemical and physical requirements.

| | |
|---|------|
| Assay, %, min | 99.0 |
| Loss on drying, %, max | 1.0 |
| Reducing sugars, %, max | 0.5 |
| pH in solution, approximately | 7 |
| Specific rotation, °, approximately | +12 |
| Coloration in solution at 40%, Gardner, max | 5 |

5.2.13.3 Use. Sodium gluconate is intended for military use as a sequestering agent in the formulation of cleaning compounds, in metal plating solutions, and as an aluminum deoxidizer. Commercial applications are the same as above.

5.2.13.4 Safety. Sodium gluconate can emit irritating and toxic fumes if heated to decomposition. The compound is nontoxic, but can be irritating to the eyes, skin and mucous membranes. There is no PEL or TLV referenced for sodium gluconate, but inhalation of dust shall be avoided. (Refer to 4.3.1)

5.2.13.5 Storage. Sodium gluconate shall be stored in corrosion-resistant containers in a cool, dry place. (Refer to 4.3.2)

5.2.13.6 Disposal. In case of dry spills, gather up and place in containers for disposal. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

An EPA Hazardous Waste Classification is not listed in 40 CFR.

5.2.14 Name. Sodium Oxalate $\text{Na}_2(\text{OOC-COO})$ FW 134.00
Sodium ethanedioate

5.2.14.1 Technical description. Sodium oxalate is in the form of colorless crystals or white powder. It has a specific gravity of 2.34. It decomposes at 250° to 270°C on heating. Its solubility in water is 3.7 g/100 mL at 20°C and 6.33 g/100 mL at 100°C. It is insoluble in alcohol and ether. It is decomposed by strong aqueous acid solutions.

DOD- STD-1445

5.2.14.2 Specification. Military, MIL-S-210, Sodium Oxalate, Technical (Metric).

5.2.14.2.1 Requirements. This specification covers one grade of sodium oxalate in three granulation classes. The chemical properties shall conform to the requirements shown in Table XXII.

The granulation requirements for the three classes are shown in Table XXIII.

TABLE XXII. Sodium oxalate, technical - chemical requirements.

| | |
|-----------------------------|------|
| Purity, as oxalate, %, min | 99.0 |
| Sodium acid oxalate, %, max | 1.50 |
| Moisture, %, max | 0.50 |
| Insoluble matter, %, max | 0.50 |

TABLE XXIII. Sodium oxalate, technical - granulation requirements.

| † US Standard Sieves | Class A | Class B | Class C |
|--|---------|---------|---------|
| Passing through No. 40 (425 micrometer), %, min | 99 | --- | --- |
| Passing through No. 60, (250 micrometer), %, min | --- | 99.9 | --- |
| Passing through No. 100, (150 micrometer), %, min | 90 | --- | 99.9 |

† Standard sieve designation in accordance with ASTM E 11.

5.2.14.3 Use. Sodium oxalate is intended for military use as an ingredient in pyrotechnic compositions. Commercial applications include use as an ingredient in metal cleaning compounds, and also use in textile and leather finishing.

5.2.14.4 Safety. Sodium oxalate can emit irritating and toxic fumes if heated to decomposition. Oxalate salts are irritants of the eyes, skin and mucous membranes. There is no PEL or TLV referenced for sodium oxalate, but inhalation of dust shall be avoided. (Refer to 4.3.1)

5.2.14.5 Storage. Sodium oxalate shall be stored in corrosion-resistant containers in a cool, dry place. (Refer to 4.3.2)

5.2.14.6 Disposal. In case of dry spills, gather up and place in containers for disposal. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

An EPA Hazardous Waste Classification is not listed in 40 CFR.

5.2.15 Name. Sodium Resinate NaOOC₂H₂₉CO₂ FW 324.45
Sodium abietate

5.2.15.1 Technical description. Sodium resinate is in the form of a white or yellowish-white powder. The formula and formula weight are for sodium abietate; since abietic acid is the predominant acid. Sodium resinate is soluble in water and ethyl alcohol. It is decomposed by strong aqueous acid solutions.

5.2.15.2 Specification. Federal, O-S-607, Sodium Resinate, Technical.

DOD-STD-1445

5.2.15.2.1 Requirements. This specification covers one grade of sodium resinate (rosin soap) with the chemical and physical properties conforming to the requirements shown in Table XXIV.

TABLE XXIV. Sodium resinate - chemical and physical requirements.

| | |
|--|------|
| Sodium resinate, % by wt, min | 90.0 |
| Free acid, as abietic acid, % by wt, max | 2.0 |
| Free alkali, as NaOH, % by wt, max | 0.10 |
| Moisture and volatile matter, % by wt, max | 5.0 |
| Matter insoluble in water, % by wt, max | 0.10 |
| Matter insoluble in alcohol, % by wt, max | 1.0 |

5.2.15.3 Use. Sodium resinate is intended for military use as an ingredient of cleaning and degreasing compounds for cleaning metal parts. Commercial applications include use as an ingredient in soaps and detergents.

5.2.15.4 Safety. Sodium resinate is burnable, and the powder can form explosive dust mixtures in air. It can emit irritating and toxic fumes if heated to decomposition. It can be irritating to the eyes, skin and mucous membranes. There is no PEL or TLV referenced for sodium resinate, but inhalation of dust shall be avoided. (Refer to 4.3.1)

5.2.15.5 Storage. Sodium resinate shall be stored in corrosion-resistant containers in a cool, dry place. (Refer to 4.3.2)

5.2.15.6 Disposal. In case of dry spills, gather up and place in containers for disposal. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

An EPA Hazardous Waste Classification is not listed in 40 CFR.

5.2.16 Name. Zinc Stearate $Zn(OOCH_{35}C_{17})_2$ FW 632.33
Zinc octadecanoate

5.2.16.1 Technical description. Zinc stearate is a white powder with a melting point of 130°C. It is insoluble in water, alcohol and ether. It dissolves in hot hydrocarbon liquids and oils. It is decomposed by strong aqueous acid and alkali solutions. Zinc stearate, as the diacid metal soap, has a theoretical zinc content of 10.3 percent.

5.2.16.2 Specification. Manufacturer's requirements. (No Government specification).

5.2.16.2.1 Requirements. Zinc stearate is available from a chemical producer with total ash contents ranging from 13.0 to 14.5%, corresponding to zinc contents of 10.4 to 12.7 percent. The free fatty acid contents range from 0.5 to 1.0%, and the moisture contents range from 0.2 to 0.5 percent.

5.2.16.3 Use. Zinc stearate is intended for military use as an ingredient in nonaqueous paints, varnishes and lacquers; and rubber and plastics. Commercial applications include use as a lubricant in powder metallurgy.

DOD-STD-1445

5.2.16.4 Safety. Zinc stearate is burnable, and the powder can form explosive dust mixtures in air. It can emit irritating and toxic fumes if heated to decomposition. The zinc ion is nontoxic, but the compound can be irritating to the eyes, skin and mucous membranes. The TLV for zinc stearate, as a nuisance particulate is 10 mg/m^3 total dust, so breathing of dust shall be avoided. (Refer to 4.3.1)

5.2.16.5 Storage. Zinc stearate shall be stored in corrosion-resistant containers in a cool, dry place. (Refer to 4.3.2)

5.2.16.6 Disposal. In case of dry spills, gather up and place in containers for disposal. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

An EPA Hazardous Waste Classification is not listed in 40 CFR.

5.3 Metal Chelates

Complex coordination compounds or ions are those in which negative groups or neutral polar molecules are attached to metal ions or atoms. Formation of a complex compound or ion requires the combination of an ion or molecule which has at least one pair of electrons available for bonding with a metal ion or atom, which has a sufficient attraction for electrons, to form a coordinate covalent bond with the attaching group. The coordination number is the number of electron pairs which an acceptor metal ion attracts in forming a complex ion. The groups attached to the central metal ion are referred to as coordinating groups or ligands. Ligands which have more than one electron pair available for coordination with metal ions are said to be bi-, tri-, or polydentate. Polydentate ligands whose structures permit the attachment of two or more electron donor sites to the same metal ion simultaneously, thus closing one or more rings, are called chelate ligands. Chelation refers to the coordination of a metal ion with a polydentate ligand. The metal chelate so formed may be an insoluble compound that precipitates or a water-soluble compound. Ligands that form stable, water-soluble metal chelates are said to be sequestering agents. Metal chelate stability decreases with increasing ring size and no compounds are known with a ring size greater than seven. Examples of polydentate chelate ligands are shown in Table XXV.

TABLE XXV. Polydentate chelate ligands.

A. Bidentate Ligands

Acetylacetonato ion (AcAc^-)
 Dimethylglyoxime anion
 2,2'-Dipyridyl (dipy)
 Ethyl acetoacetate
 Ethylenediamine
 Lactic acid anion
 Oxalate ion
 1,10-Phenanthroline (o-phen)
 8-Quinolinolate anion
 Salicylaldehyde anion

DOD-STD-1445

B. Tridentate Ligands

o-Azophenoxide ion
 Citrate anion
 Diethylenetriamine
 Iminodiacetic acid anion
 Triethanolamine

C. Tetradentate Ligands

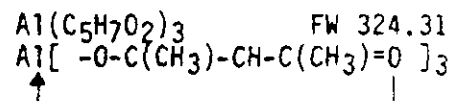
Bisacetylacetonethylenediamine
 Nitriloacetic acid anion
 , , "-Triaminotriethylamine
 Triethylene tetramine

D. Pentadentate Ligand

Ethylenediaminetriacetic acid

E. Hexadentate Ligand

Ethylenediaminetetraacetic acid anion (EDTA)

5.3.1 Name. Aluminum Acetylacetonate

Aluminum(III) 2,4-pentanedionate

5.3.1.1 Technical description. Aluminum acetylacetonate is in the form of colorless monoclinic crystals with a specific gravity of 1.27, a melting point of 193°C, and a boiling point of 314°C. It is insoluble in water, very soluble in ethyl alcohol, and soluble in ether and benzene. The theoretical composition is 8.3% aluminum, 55.5% carbon, 6.5% hydrogen, and 29.6% oxygen.

5.3.1.2 Specification. Manufacturer's requirement. (No Government specification)

5.3.1.2.1 Requirements. Commercially available aluminum acetylacetonate is a white crystalline powder with a melting point of 193°C, a sublimation point of 315°C, and a specific gravity (20°/4°C) of 1.213. The typical analysis is 8.3% aluminum, 55.4% carbon, and 6.5% hydrogen. The solubility of the compound at 25°C is 27.4 g/100 mL in benzene, 9.8 g/100 mL in methyl alcohol, <3.3 g/100 mL in water, and <0.01 g/100 mL in cyclohexane.

5.3.1.3 Use. Aluminum acetylacetonate is intended for use as an olefinic polymerization catalyst, and as a crosslinking agent for epoxy resins.

5.3.1.4 Safety. Aluminum acetylacetonate is burnable, and can form explosive dust mixtures in air. It can emit irritating and toxic fumes if heated to decomposition. The aluminum ion is nontoxic, but aluminum acetylacetonate can be irritating to the eyes, skin and mucous membranes. There is no PEL or TLV referenced for aluminum acetylacetonate, but inhalation of dust shall be avoided. (Refer to 4.3.1)

DOD-STD-1445

5.3.1.5 Storage. Aluminum acetylacetonate shall be stored in corrosion-resistant containers in a cool, dry place. (Refer to 4.3.2)

5.3.1.6 Disposal. In case of dry spills, gather up and place in containers for disposal. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

An EPA Hazardous Waste Classification is not listed in 40 CFR.

5.3.2 Name. Barium Oxalate Ba(OOCCOO) FW 225.36
Barium ethanedioate

5.3.2.1 Technical description. Barium oxalate is crystalline with a specific gravity of 2.658. It decomposes at 400°C. Its solubility in water is 0.0093 g/100 mL at 18°C, and 0.0228 g/100 mL at 100°C. It is insoluble in alcohol. It is decomposed by strong aqueous acid solutions.

5.3.2.2 Specification. Military, JAN-B-660, Barium Oxalate (For Use In Ammunition).

5.3.2.2.1 Requirements. This specification covers one grade of barium oxalate, manufactured by a precipitation process, with the chemical and physical properties conforming to the requirements in Table XXVI.

TABLE XXVI. Barium oxalate - chemical and physical requirements.

| | |
|---|--|
| Barium oxalate, %, min | 92 |
| Moisture, %, max | 0.3 |
| Material insoluble in dilute acid, %, max | 0.5 |
| Material soluble in water, %, max | 0.3 |
| Water-soluble alkalinity, %, max | 0.1 |
| Water-soluble acidity | Water extract not acid to methyl orange. |
| Calcium salts, %, max | 0.5 |
| Grit | None |
| Color | White |
| † Granulation, US Standard Sieve | |
| Through No. 100 (150 micrometer), %, min | 90 |
| Apparent density, g/mL max | 0.50 |

† US Standard Sieve designation in accordance with ASTM E 11.

5.3.2.3 Use. Barium oxalate is intended for military use in the manufacture of pyrotechnic compositions. The compound does not have commercial uses.

5.3.2.4 Safety. Barium oxalate can emit irritating and toxic fumes if heated to decomposition. The barium ion is toxic when the compound is soluble. Oxalate salts are toxic, and are irritants of the eyes, skin and mucous membranes. The PEL and TLV for soluble barium compounds, as Ba, is 0.5 mg/m³, so breathing of dust shall be avoided. (Refer to 4.3.1)

5.3.2.5 Storage. Barium oxalate shall be stored in corrosion-resistant containers in a cool, dry place. (Refer to 4.3.2)

DOD-STD-1445

5.3.2.6 Disposal. In case of dry spills, gather up and place in containers for disposal. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

Barium oxalate has an EPA Hazardous Waste Classification - EP Toxic; Waste No. D005.

| | | |
|-------------------------------------|-----------------------------|-----------|
| 5.3.3 <u>Name</u> . Calcium Oxalate | Ca(OOCCOO) | FW 128.10 |
| Calcium ethanedioate | Ca(OOCCOO)·H ₂ O | FW 146.12 |

5.3.3.1 Technical description. Anhydrous calcium oxalate is in the form of colorless cubic crystals with a specific gravity of 2.2. The monohydrate is colorless and loses water on heating to 200°C. The anhydrous form decomposes on heating. Its solubility in water is 0.00067 g/100 mL at 13°C and 0.0014 g/100 mL at 95°C. The monohydrate is also insoluble in water. It is insoluble in acetic acid, and is decomposed by strong aqueous mineral acid solutions. The theoretical calcium content of the monohydrate is 27.5%, and the theoretical oxalate content is 60.4 percent.

5.3.3.2 Specification. Military, JAN-C-628, Calcium Oxalate (For Use In Ammunition).

5.3.3.2.1 Requirements. This specification covers one grade of calcium oxalate, consisting essentially of the monohydrate, with the chemical and physical properties conforming to the requirements in Table XXVII.

TABLE XXVII. Calcium oxalate - chemical and physical requirements.

| | |
|---|------|
| Calcium, %, min | 26.6 |
| Oxalate, %, min | 58.4 |
| Ba salts, %, max | 0.5 |
| Moisture, %, max | 0.5 |
| Grit | None |
| Material soluble in water, %, max | 0.4 |
| Material, soluble in dilute acid (10% HCl), %, max | 0.5 |
| Apparent density, g/mL, max | 0.60 |
| † Granulation, US Standard Sieve Through No. 100 (150 μm), %, min | 99 |

† US Standard Sieve designation in accordance with ASTM E 11.

5.3.3.3 Use. Calcium oxalate is intended for military use in the manufacture of pyrotechnic compositions. Commercial applications include the use in the manufacture of oxalic acid and organic oxalates.

5.3.3.4 Safety. Calcium oxalate can emit irritating and toxic fumes if heated to decomposition. The calcium ion is not toxic, but oxalate salts are toxic and are irritants of the eyes, skin and mucous membranes. There is no PEL or TLV referenced for calcium oxalate, but breathing of dust shall be avoided. (Refer to 4.3.1)

5.3.3.5 Storage. Calcium oxalate shall be stored in corrosion-resistant containers in a cool, dry place. (Refer to 4.3.2)

DOD-STD-1445

5.3.3.6 Disposal. In case of dry spills, gather up and place in containers for disposal. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

An EPA Hazardous Waste Classification is not listed in 40 CFR.

5.3.4 Name. Chromium Acetylacetonate $\text{Cr}(\text{C}_5\text{H}_7\text{O}_2)_3$ FW 349.33
 $\text{Cr}[-\text{O}-\text{C}(\text{CH}_3)=\text{CH}-\text{C}(\text{CH}_3)=\text{O}]_3$

Chromic acetylacetonate
 Chromium(III) 2,4-pentanedionate

5.3.4.1 Technical description. Chromium acetylacetonate has a melting point of 216°C and a boiling point of 340°C. It is insoluble in water and soluble in organic solvents. The theoretical composition is 14.9% chromium, 51.5% carbon, 6.0% hydrogen, and 27.6% oxygen.

5.3.4.2 Specification. Manufacturer's requirement. (No Government specification)

5.3.4.2.1 Requirements. Commercially available chromium acetylacetonate is a violet monoclinic crystalline powder with a melting point of 217° to 220°C, a boiling point of 340°C, and a specific gravity of 1.35. It has an apparent bulk density of 0.47 g/cm³. The typical analysis is 14.9% chromium. The total solids are 100%, and the methylene chloride insoluble is 0.5% maximum. The solubility of the product is 0.15 g/100 g in water at 30°C, 4.7 g/100 g in methanol at 25°C, 34 g/100 g in benzene at 30°C, 5.03 g/100 g in xylene at 30°C, and 13.6 g/100 g in toluene at 30°C.

5.3.4.3 Use. Chromic acetylacetonate is intended for use as a catalyst for organic synthesis, as a stabilizer for nitroparaffins, and also for tinting glass.

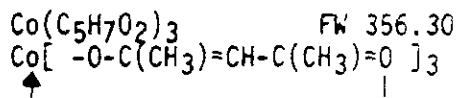
5.3.4.4 Safety. Chromic acetylacetonate is burnable, and can form explosive dust mixtures in air. It can emit irritating and toxic fumes if heated to decomposition. The chromium(III) ion is toxic and is a potential carcinogen. The PEL and TLV for chromium(III) compounds, as Cr, is 0.5 mg/m³, so breathing of mists and fumes shall be avoided. Burning of Cr(III) can form some Cr(VI). Chromium(VI) is considered a confirmed carcinogen by the International Agency for Research on Cancer (IARC) and Transactions of ACGIH. The TLV for chromium (VI) is 0.05 mg/m³. Breathing of mists or fumes of chromium(VI) shall be avoided. The Cr(III) compound solution can be irritating to the eyes, skin, and mucous membranes. (Refer to 4.3.1)

5.3.4.5 Storage. Chromic acetylacetonate shall be stored in corrosion-resistant containers in a cool, dry place. (Refer to 4.3.2)

5.3.4.6 Disposal. In case of dry spills, gather up and place in containers for disposal. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

Chromic acetylacetonate has an EPA Hazardous Waste Classification - EP Toxic; Waste No. D007.

DOD- STD-1445

5.3.5 Name. Cobaltic Acetylacetonate

Cobalt tris(acetylacetonate)
Cobalt(III) 2,4-pentanedionate

5.3.5.1 Technical description. Cobaltic acetylacetonate is in the form of dark green or black crystals with a specific gravity of 1.43. The theoretical composition is 16.5% cobalt, 50.6% carbon, 5.9% hydrogen, and 27.0% oxygen.

5.3.5.2 Specification. Manufacturer's requirement. (No Government specification)

5.3.5.2.1 Requirements. Commercially available cobaltic acetylacetonate is a dark green crystalline powder with a specific gravity of 1.43, and a melting point of 214 to 215°C. It has an apparent bulk density of 0.63 g/cm³. The typical analysis is 16.6% cobalt(III), and 0.22% cobalt(II). The total solids are 99.96%, and the methylene chloride insolubles are 0.5% maximum. The solubility of the product, at 30°C, is 0.3 g/100 g in water, 16.3 g/100 g in benzene, 1.9 g/100 g in xylene, and 0.031 g/100 g in heptane. It is soluble in hot methanol, hot acetone, and hot ethylene glycol monoethyl ether.

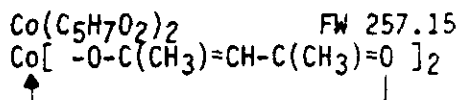
5.3.5.3 Use. Cobaltic acetylacetonate is intended for use as a catalyst for organic synthesis, polymerization and vulcanization reactions, combustion of solid propellants, and as coloring for synthetic resins and glass tinting. It is also used for the vapor deposition of cobalt metal and oxide.

5.3.5.4 Safety. Cobaltic acetylacetonate is burnable, and can form explosive dust mixtures in air. It can emit irritating and toxic fumes if heated to decomposition. The PEL and TLV for cobalt fumes is 0.1 mg/m³, so breathing of fumes shall be avoided. Cobalt(III) compounds can be irritating to eyes, skin and mucous membranes. (Refer to 4.3.1)

5.3.5.5 Storage. Cobaltic acetylacetonate shall be stored in corrosion-resistant containers in a cool, dry place. (Refer to 4.3.2)

5.3.5.6 Disposal. In case of dry spills, gather up and place in containers for disposal. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

An EPA Hazardous Waste Classification is not listed in 40 CFR.

5.3.6 Name. Cobaltous Acetylacetonate

Cobalt bis(acetylacetonate)
Cobalt(II) 2,4-pentanedionate

5.3.6.1 Technical description. Cobaltous acetylacetonate is crystalline and moisture-sensitive. It has a melting point of 172°C. The theoretical composition is 22.9% cobalt, 46.7% carbon, 5.4% hydrogen, and 24.9% oxygen.

5.3.6.2 Specification. Manufacturer's requirement. (No Government specification)

DOD- STD-1445

5.3.6.2.1 Requirements. Commercially available cobaltous acetylacetonate is a purple powder that sublimates without melting. The typical analysis is 24.0% cobalt, 43.6% carbon, and 5.6% hydrogen. It is soluble in water. The solubility of the product at 25°C is 2.4 g/100 mL in methanol, and 8.1 g/100 mL in benzene.

5.3.6.3 Use. Cobaltous acetylacetonate is intended for use as a catalyst for the hydrogenation of diolefins and fatty acids; and for polymerization of olefins.

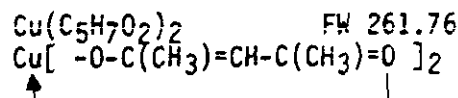
5.3.6.4 Safety. Cobaltous acetylacetonate is burnable and can form explosive dust mixtures in air. It can emit irritating and toxic fumes if heated to decomposition. The PEL and TLV for cobalt fumes is 0.1 mg/m³, so breathing of fumes shall be avoided. Cobalt(II) compounds can be irritating to eyes, skin and mucous membranes. (Refer to 4.3.1) section V A.3.a.

5.3.6.5 Storage. Cobaltous acetylacetonate shall be stored in corrosion-resistant containers in a cool, dry place. (Refer to 4.3.2)

5.3.6.6 Disposal. In case of dry spills, gather up and place in containers for disposal. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

An EPA Hazardous Waste Classification is not listed in 40 CFR.

5.3.7 Name. Copper Acetylacetonate



Copper(II) 2,4-pentanedionate
Cupric acetylacetonate

5.3.7.1 Technical description. Copper acetylacetonate is in the form of blue crystals with a melting point of >230°C and sublimation. It is insoluble in water and slightly soluble in alcohol. The theoretical composition is 42.3% copper, 45.8% carbon, 5.4% hydrogen, and 24.5% oxygen.

5.3.7.2 Specification. Manufacturer's requirement. (No Government specification)

5.3.7.2.1 Requirements. Commercially available copper acetylacetonate is a light blue crystalline powder with a melting point of 240°C. The typical analysis is 24.2% copper, 45.8% carbon, and 5.5% hydrogen. The solubility of the product at 25°C is 0.2 g/100 mL in benzene and 0.3 g/100 mL in methanol.

5.3.7.3 Use. Copper acetylacetonate is intended for use as a catalyst for urethanes, diazo compounds, and dimerization reactions.

5.3.7.4 Safety. Copper acetylacetonate is burnable, and can emit irritating and toxic fumes if heated to decomposition. The PEL for copper fumes is 0.1 mg/m³, and the TLV is 0.2 mg/m³, so breathing of fumes shall be avoided. Copper(II) compounds can be irritating of the eyes, skin and mucous membranes. (Refer to 4.3.1)

5.3.7.5 Storage. Copper acetylacetonate shall be stored in a cool, dry place. (Refer to 4.3.2)

DOD-STD-1445

5.3.7.6 Disposal. In case of dry spills, gather up and place in containers for disposal. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

An EPA Hazardous Waste Classification is not listed in 40 CFR.

5.3.8 Name. Copper 8-Quinolinolate $\text{Cu}(\text{C}_9\text{H}_6\text{NO})_2$ FW 351.83
Copper bis(8-oxyquinoline)

5.3.8.1 Technical description. Copper 8-quinolinolate is a nonhygroscopic odorless powder. It is insoluble in water and most organic solvents. It is somewhat soluble in pyridine and quinoline. It is decomposed by strong acids.

5.3.8.2 Specification. Manufacturer's requirement. (No Government specification)

5.3.8.2.1 Requirements. Commercially available copper 8-quinolinolate is a yellow-green to olive-green powder with the specification requirements shown in Table XXVIII.

TABLE XXVIII. Copper 8-quinolinolate - commercial specification requirements.

| | |
|---|------|
| Assay, %, min | 90.0 |
| Loss on drying, %, max | 1.0 |
| † Sieve size, US Standard Sieve Through No. 10 (2.00 mm), %, min | 90 |

† US Standard Sieve designation in accordance with ASTM E 11.

5.3.8.3 Use. Copper 8-quinolinolate is intended for military use as a mildew inhibitor in preservative coatings for canvas and in formulations for the treatment of sandbags for fungus resistance, as described in federal specification TT-P-595 and military specification MIL-F-46032. Commercial applications include the fungus-proofing of cloth, paper, wood and other cellulose materials; treatment of vinyl resins to prevent fungus deterioration; and the control of fungus diseases in agriculture.

5.3.8.4 Safety. Copper 8-quinolinolate is burnable, and can form explosive dust mixtures in air. It can emit irritating and toxic fumes if heated to decomposition. There PEL for copper fumes is 0.1 mg/m^3 and the TLV is 0.2 mg/m^3 , so breathing of fumes shall be avoided. 8-Quinolinol has moderate toxicity and is a suspected carcinogen. Copper(II) compounds can be irritating to the eyes, skin and mucous membranes shall be avoided. (Refer to 4.3.1)

5.3.8.5 Storage. Copper 8-quinolinolate shall be stored in corrosion-resistant containers in a cool, dry place. (Refer to 4.3.2)

5.3.8.6 Disposal. In case of dry spills, gather up and place in containers for disposal. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

An EPA Hazardous Waste Classification is not listed in 40 CFR.

DOD-STD-1445

5.3.9 Name. Ferric Acetylacetonate $\text{Fe}(\text{C}_5\text{H}_7\text{O}_2)_3$ FW 353.18
 $\text{Fe}[-\text{O}-\text{C}(\text{CH}_3)-\text{CH}-\text{C}(\text{CH}_3)=\text{O}]_3$
 Iron(III) 2,4-pentanedionate

5.3.9.1 Technical description. Ferric acetylacetonate is in the form of ruby red rhombic crystals with a specific gravity of 1.33 and a melting point of 184°C. It is slightly soluble in water, and soluble in alcohol, acetone, and benzene. The theoretical composition is 15.8% iron, 51.0% carbon, 6.0% hydrogen, and 27.1% oxygen.

5.3.9.2 Specification. Manufacturer's requirement. (No Government specification)

5.3.9.2.1 Requirements. Commercially available ferric acetylacetonate is a bright orange-red rhombic crystalline powder with a specific gravity of 1.36 and a melting point of 181°C. The typical analysis is 16.14% iron, 0.25% sulfate, and 99.56% total solids. The methylene chloride insoluble is 0.5% maximum. The solubility of the product in water is <3.5%, and 22.3 g/100 g in benzene.

5.3.9.3 Use. Ferric acetylacetonate is intended for use as a catalyst for polymerization, combustion of solid propellants, and as coloring for synthetic resins and glass tinting.

5.3.9.4 Safety. Ferric acetylacetonate is burnable and can form explosive dust mixtures in air. It can emit irritating and toxic fumes if heated to decomposition. The PEL for iron oxide fumes is 10 mg/m³ and the TLV for iron oxide fumes, as Fe, is 5 mg/m³, so breathing of fumes shall be avoided. The iron(III) compounds can be irritating to the eyes, skin and mucous membranes. (Refer to 4.3.1)

5.3.9.5 Storage. Ferric acetylacetonate shall be stored in corrosion-resistant containers in a cool, dry place. (Refer to 4.3.2)

5.3.9.6 Disposal. In case of dry spills, gather up and place in containers for disposal. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

An EPA Hazardous Waste Classification is not listed in 40 CFR.

5.3.10 Name. Magnesium Acetylacetonate $\text{Mg}(\text{C}_5\text{H}_7\text{O}_2)_2$ FW 222.53
 $\text{Mg}[-\text{O}-\text{C}(\text{CH}_3)=\text{CH}-\text{C}(\text{CH}_3)=\text{O}]_2$
 Magnesium 2,4-pentanedionate

5.3.10.1 Technical description. Magnesium acetylacetonate is in the form of a white powder. The theoretical composition is 10.9% magnesium, 53.9% carbon, 6.3% hydrogen and 28.4% oxygen.

5.3.10.2 Specification. Manufacturer's requirement. (No Government specification)

5.3.10.2.1 Requirements. Commercially available magnesium acetylacetonate is available from a chemical manufacturer as a white powder with a specific

DOD- STD-1445

gravity of 1.162 and a melting point of 262° to 263°C. The typical analysis is 11.1% magnesium. The solubility of the product at 25°C is 0.7 g/100 mL in benzene, and 2.9 g/100 mL in methanol.

5.3.10.3 Use. Magnesium acetylacetonate is intended for use as a curing agent and curing accelerator for epoxy resins.

5.3.10.4 Safety. Magnesium acetylacetonate is burnable, and can form explosive dust mixtures in air. It can emit irritating and toxic fumes if heated to decomposition. The PEL for magnesium oxide fumes is 15 mg/m³, and the TLV is 10 mg/m³, so breathing of fumes shall be avoided. The magnesium ion is nontoxic but its compounds can be irritating to the eyes, skin and mucous membranes. (Refer to 4.3.1)

5.3.10.5 Storage. Magnesium acetylacetonate shall be stored in corrosion-resistant containers in a cool, dry place. (Refer to 4.3.2)

5.3.10.6 Disposal. In case of dry spills, gather up and place in containers for disposal. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

An EPA Hazardous Waste Classification is not listed in 40 CFR.

5.3.11 Name. Manganic Acetylacetonate $\text{Mn}(\text{C}_5\text{H}_7\text{O}_2)_3$ FW 352.27
 $\text{Mn} \left[\begin{array}{c} \text{-O-C(CH}_3\text{)=CH(CH}_3\text{)=O} \\ | \\ \text{---} \end{array} \right]_3$
 Manganese tris(acetylacetonate)
 Manganese(III) 2,4-pentanedionate

5.3.11.1 Technical description. Manganic acetylacetonate is in the form of a black or brown crystalline powder. The theoretical composition is 15.6% manganese, 51.1 % carbon, 6.0% hydrogen, and 27.3% oxygen. It is very slightly soluble in water, and soluble in acetone.

5.3.11.2 Specification. Manufacturer's requirements. (No Government specification)

5.3.11.2.1 Requirements. Commercially available manganic acetylacetonate is a black powder with a melting point of 171°C. The typical analysis is 15.7% manganese, 50.9% carbon, and 5.9% hydrogen. The solubility of the product in benzene is 13.6 g/100 mL at 25°C, and in methanol it is 34.8 g/100 mL at 30°C.

5.3.11.3 Use. Manganic acetylacetonate is intended for use as a catalyst for the polymerization of vinyl polymers, and as a curing agent for isocyanate resins.

5.3.11.4 Safety. Manganic acetylacetonate is burnable, and can form explosive dust mixtures in air. It can emit irritating and toxic fumes if heated to decomposition. The PEL and TLV for manganese compounds, as Mn, is 5 mg/m³ as a ceiling limit. The TLV for manganese fumes is 1 mg/m³, so breathing of fumes shall be avoided. The manganic ion is toxic, and its compounds can be irritating to the eyes, skin and mucous membranes. (Refer to 4.3.1)

5.3.11.5 Storage. Manganic acetylacetonate shall be stored in corrosion-resistant containers in a cool, dry place. (Refer to 4.3.2)

DOD-STD-1445

5.3.11.6 Disposal. In case of dry spills, gather up and place in containers for disposal. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

An EPA Hazardous Waste Classification is not listed in 40 CFR.

5.3.12 Name. Manganous Acetylacetonate $\text{Mn}(\text{C}_5\text{H}_7\text{O}_2)_2$ FW 253.14
 $\text{Mn}[-\text{O}-\text{C}(\text{CH}_3)=\text{CH}-\text{C}(\text{CH}_3)=\text{O}]_2$
 Manganese bis(acetylacetonate)
 Manganese(II) 2,4-pentanedionate

5.3.12.1 Technical description. Manganous acetylacetonate is in the form of light tan crystals. The theoretical composition is 21.7% manganese, 47.3% carbon, 5.6% hydrogen, and 25.4% oxygen.

5.3.12.2 Specification. Manufacturer's requirement. (No Government specification)

5.3.12.2.1 Requirements. Commercially available manganous acetylacetonate is a light tan crystalline powder with a melting point of 180°C. The typical analysis is 21.5% manganese. The solubility of the product at 25°C is 4.4 g/100 mL in benzene, and 7.0 g/100 mL in methanol.

5.3.12.3 Use. Manganous acetylacetonate is intended for use as a catalyst for hydrogenation of olefins, polymerization of urethanes, and oxidation synthesis reactions.

5.3.12.4 Safety. Manganous acetylacetonate is burnable, and can form explosive dust mixtures in air. It can emit irritating and toxic fumes if heated to decomposition. The PEL for manganese is 5 mg/m³ as a ceiling limit. The TLV for manganese compounds, as Mn, is 5 mg/m³ as a ceiling limit. The TLV for manganese fumes is 1 mg/m³, so breathing of fumes shall be avoided. The manganous ion is toxic, and its compounds can be irritating to the eyes, skin and mucous membranes. (Refer to 4.3.1)

5.3.12.5 Storage. Manganous acetylacetonate shall be stored in corrosion-resistant containers in a cool, dry place. Refer to section V.A.3.b.

5.3.12.6 Disposal. In case of dry spills, gather up and place in containers for disposal. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

An EPA Hazardous Waste Classification is not listed in 40 CFR.

5.3.13 Name. Nickel Acetylacetonate, Hydrate $\text{Ni}(\text{C}_5\text{H}_7\text{O}_2)_2 \cdot \text{H}_2\text{O}$ FW 274.94
 $\text{Ni}[-\text{O}-\text{C}(\text{CH}_3)=\text{CH}-\text{C}(\text{CH}_3)=\text{O}]_2 \cdot \text{H}_2\text{O}$
 Nickel(II) 2,4-pentanedionate, hydrate

5.3.13.1 Technical description. Nickel acetylacetonate is in the form of green crystals. The theoretical composition is 21.4% nickel, 43.7% carbon, 5.8% hydrogen, and 29.1% oxygen.

DOD-STD-1445

5.3.13.2 Specification. Manufacturer's requirement. (No Government specification)

5.3.13.2.1 Requirements. Commercially available nickel acetylacetonate is a bright green crystalline material with a melting point of 228°C, and a sublimation point of 220°C at 11 mm Hg. The typical analysis is 21.5% nickel, 42.5% carbon, and 5.9% hydrogen. The solubility of the product at 25°C is 1.5 g/100 mL in benzene, 2.2 g/100 mL in methanol, and 10.6 g/100 mL in ethyl alcohol. It is also soluble in chloroform.

5.3.13.3 Use. Nickel acetylacetonate is intended for use as a catalyst for hydrogenation reactions.

5.3.13.4 Safety. Nickel acetylacetonate is burnable, and can form explosive dust mixtures in air. It can emit irritating and toxic fumes if heated to decomposition. The PEL for soluble nickel compounds is 1 mg/m³ and the TLV is 0.1 mg/m³, as Ni, so breathing of fumes shall be avoided. Nickel compounds are toxic and are confirmed carcinogens. They can be irritating to the eyes, skin and mucous membranes. (Refer to 4.3.1)

5.3.13.5 Storage. Nickel acetylacetonate shall be stored in corrosion-resistant containers in a cool, dry place. (Refer to 4.3.2)

5.3.13.6 Disposal. In case of dry spills, gather up and place in containers for disposal. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

Nickel acetylacetonate has an EPA Hazardous Waste Classification - Toxic.

5.3.14 Name. Ruthenium Acetylacetonate Ru(C₅H₇O₂)₃
FW 398.40



5.3.14.1 Technical description. Ruthenium acetylacetonate is in the form of red crystals. The theoretical composition is 25.5% ruthenium, 45.2% carbon, 5.3% hydrogen, and 24.0% oxygen.

5.3.14.2 Specification. Manufacturer's requirement. (No Government specification)

5.3.14.2.1 Requirements. Commercially available ruthenium acetylacetonate is a red crystalline material with a melting point of 235° to 237°C. The typical analysis is 26.0% ruthenium. It is soluble in acetone, chloroform, ethanol, and toluene.

5.3.14.3 Use. Ruthenium acetylacetonate is intended for use as a catalyst.

5.3.14.4 Safety. Ruthenium acetylacetonate is burnable, and can form explosive dust mixtures in air. It can emit irritating and toxic fumes if heated to decomposition. There is no PEL or TLV referenced for ruthenium compounds, but breathing of fumes shall be avoided. Ruthenium compounds can be irritating to the eyes, skin and mucous membranes. (Refer to 4.3.1)

DOD- STD-1445

5.3.14.5 Storage. Ruthenium acetylacetonate shall be stored in corrosion-resistant containers in a cool dry place. (Refer to 4.3.2)

5.3.14.6 Disposal. In case of dry spills, gather up and place in containers for disposal. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

An EPA Hazardous Waste Classification is not listed in 40 CFR.

| | | |
|--|-----------------------------|-----------|
| 5.3.15 <u>Name</u> . Strontium Oxalate | Sr(OOCCOO) | FW 175.62 |
| Strontium Ethanedioate | Sr(OOCCOO)·H ₂ O | FW 193.64 |

5.3.15.1 Technical description. Hydrated strontium oxalate is in the form of colorless crystals. It loses water on heating to 150°C. The anhydrous form decomposes on heating. The solubility in water of the hydrated form is 0.0051 g/100 mL at 15°C and 5 g/100 mL at 100°C. It is decomposed by strong aqueous mineral acids.

5.3.15.2 Specification. Military, MIL-S-12210, Strontium Oxalate.

5.3.15.2.1 Requirements. This specification covers two grades of strontium oxalate. Grade A shall be the anhydrous form and Grade B the hydrated form. The chemical and physical properties shall conform to the requirements shown in Table XXIX.

TABLE XXIX. Strontium oxalate - chemical and physical requirements.

| | Grade A | Grade B |
|-----------------------------------|---------|---------|
| Strontium oxalate, % min | 94.0 | 84.0 |
| Moisture, % max | 0.25 | 10.0 |
| Iron, % max | 0.01 | --- |
| Impurities by flame test | | |
| Barium compounds | None | None |
| Calcium compounds, amount max | Slight | Slight |
| † Granulation, US Standard Sieves | | |
| Thru No. 60 (250 μm), % min | --- | 99.0 |
| Thru No. 140 (100 μm), % min | 99.0 | --- |
| Color | White | White |

† US Standard Sieve designations in accordance with ASTM E 11.

5.3.15.3 Use. Strontium oxalate is intended for military use in the manufacture of pyrotechnic compositions. Commercial applications include use in catalyst manufacture.

5.3.15.4 Safety. Strontium oxalate can emit irritating and toxic fumes if heated to decomposition. The strontium ion is low in toxicity, but oxalate salts are toxic and corrosive, and are strong irritants of the eyes, skin and mucous membranes. There is no PEL or TLV referenced for strontium compounds, but breathing of fumes shall be avoided. (Refer to 4.3.1)

5.3.15.5 Storage. Strontium oxalate shall be stored in corrosion-resistant containers in a cool, dry place. (Refer to 4.3.2)

DOD- STD-1445

5.3.15.6 Disposal. In case of dry spills, gather up and place in containers for disposal. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

An EPA Hazardous Waste Classification is not listed in 40 CFR.

5.3.16 Name. Dibutyl Tin Acetylacetonate $(C_4H_9)_2Sn(C_5H_7O_2)_2$ FW 431.14
 $(C_4H_9)_2Sn[-O-C(CH_3)=CH-C(CH_3)=O]_2$

Dibutyl tin(IV) 2,4-pentanedionate

5.3.16.1 Technical description. Dibutyl tin acetylacetonate is in the form of a liquid above 21°C. The theoretical composition is 27.6% tin, 50.1% carbon, 7.5% hydrogen, and 14.9% oxygen. It is insoluble in water, but hydrolyzes on exposure to water.

5.3.16.2 Specification. Manufacturer's requirements. (No Government specification)

5.3.16.2.1 Requirements. Commercially available dibutyl tin acetylacetonate is an amber liquid with a specific gravity (25°C) of 1.20, a melting point of 21°C, a Gardner viscosity of A-3, and a flash point (closed cup) of 91.1°C (195°F). The typical analysis is 27.3% tin.

5.3.16.3 Use. Dibutyl tin acetylacetonate is intended for use as a catalyst for polymerization of olefins and unsaturated polyesters.

5.3.16.4 Safety. Dibutyl tin acetylacetonate is a combustible liquid or a burnable solid depending on the temperature. It can emit irritating and toxic fumes if heated to decomposition. The PEL, as an organic tin compound, is 0.1 mg/m³, and the TLV is 0.1 mg/m³ (including skin), as Sn. The breathing of fumes shall be avoided. The compound is toxic and can be absorbed through the skin. It can be irritating to the eyes, skin and mucous membranes, and may cause burns and tissue damage. In case of contact with the skin, flush with water, then wash with soap and water. In case of contact with the eyes, flush with water for at least 20 minutes, and obtain medical attention. (Refer to 4.3.1)

5.3.16.5 Storage. Dibutyl tin acetylacetonate shall be stored in corrosion-resistant containers in a cool dry place. (Refer to 4.3.2)

5.3.16.6 Disposal. In case of dry spills of solid (below 21°C), recover in dry state and place in containers for disposal. In case of small liquid spills (above 21°C) absorb with nonreactive absorbent, and place in containers for disposal. In case of large liquid spills, dike to prevent spreading. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

An EPA Hazardous Waste Classification is not listed in 40 CFR.

5.3.17 Name. Titanium Ammonium Dihydroxy Lactate
 $Ti(OH)_2[OCH(CH_3)COO]_2(NH_4)_2$ FW 294.12
 Ammonium dihydroxy bis(lactato)titanate
 Ammonium dihydroxy bis(2-hydroxypropanato-0¹, 0²)titanate

DOD-STD-1445

5.3.17.1 Technical description. Titanium ammonium dihydroxy lactate is in the form of a solid. It is soluble in water, and hydrolyzes very slowly. The theoretical Ti content is 16.3 percent.

5.3.17.2 Specification. Manufacturer's requirement. (No Government specification)

5.3.17.2.1 Requirements. Commercially available titanium ammonium dihydroxy lactate is a 50% solution in water with a Ti content of 8.2 percent. The solution is light amber in color with a specific gravity (25°/25°C) of 1.05, an approximate thickening point of -10°C, and an approximate viscosity (25°C) of 8 cP(mPa·s)

5.3.17.3 Use. Titanium ammonium dihydroxy lactate is intended for use as a crosslinking agent for resins and polymers in aqueous systems.

5.3.17.4 Safety. Titanium ammonium dihydroxy lactate solution is not burnable. It can emit irritating and toxic fumes if heated to decomposition. The PEL is 15 mg/m³ and the TLV is 10 mg/m³ for the resulting titanium dioxide as total dust as a nuisance particulate. The PEL for the resulting ammonia fumes is 35 mg/m³ and the TLV is 18 mg/m³. The compound solution is not toxic, but can be irritating to the eyes, skin and mucous membranes. (Refer to 4.3.1)

5.3.17.5 Storage. Titanium ammonium dihydroxy lactate solution shall be stored in corrosion-resistant containers in a cool dry place. (Refer to 4.3.2)

5.3.17.6 Disposal. In case of small liquid spills, absorb with nonreactive absorbent and place in containers for disposal. In case of large liquid spills, dike to prevent spreading. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

An EPA Hazardous Waste Classification is not listed in 40 CFR.

5.3.18 Name. Titanium Diisopropoxide Acetylacetonate
 $Ti[OCH(CH_3)_2]_2(C_5H_7O_2)_2$ FW 364 30
 Titanium diisopropoxide bis(2,4-pentanedionate)
 Bis(2,4-pentanedionate-0, 0')bis(2-propanolato)titanium

5.3.18.1 Technical description. Titanium diisopropoxide acetylacetonate is in the form of a solid. It is soluble in isopropanol. It is insoluble in water, but hydrolyzes slowly.

5.3.18.2 Specification. Manufacturer's requirement. (No Government specification)

5.3.18.2.1 Requirements. Commercially available titanium diisopropoxide acetylacetonate is a 75% solution in isopropanol, with a Ti content of 9.9 percent. The solution is red in color with a specific gravity (25°/25°C) of 0.99, an approximate thickening point of -46°C, an approximate viscosity (25°C) of 15 cP(mPa·s), and a flash point (closed cup) of 12°C (54°F). The solution is soluble in ethyl acetate, isopropyl acetate, and methyl ethyl ketone. It is immiscible with water.

DOD-STD-1445

5.3.18.3 Use. Titanium diisopropoxide acetylacetonate is intended for use as a crosslinking agent for resins, polymers and heat-set printing inks; and for surface modification of plastic, metal, textile or paper for deposition by hydrolysis of an amorphous polar film of titanium dioxide.

5.3.18.4 Safety. Titanium diisopropoxide acetylacetonate solution in isopropanol is flammable. It can emit irritating and toxic fumes if heated to decomposition. The PEL is 15 mg/m³ and the TLV is 10 mg/m³ for the resulting titanium dioxide as total dust as a nuisance particulate. The compound solution is not toxic, but can cause eye burns and be irritating to the skin and mucous membranes. (Refer to 4.3.1)

5.3.18.5 Storage. Titanium diisopropoxide acetylacetonate solution shall be stored in corrosion-resistant containers in a cool, dry place; away from heat, sparks and open flame. (Refer to 4.3.2)

5.3.18.6 Disposal. In case of small spills, absorb with nonreactive absorbent and place in containers for disposal. In case of large spills, dike to prevent spreading. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

An EPA Hazardous Waste Classification is not listed in 40 CFR.

5.3.19 Name. Titanium Diisopropoxide Bis(triethanolamine)
 $Ti[OCH(CH_3)_2]_2[OCH_2CH_2N(CH_2CH_2OH)_2]_2$ FW 462.44
 Bis(2,2',2"-nitrilotriethanol)bis(2-propanolato)titanium(4+)
 Bis(triethanolamine)titanium diisopropoxide
 Titanium diisopropoxide bis(2,2',2"-nitrilotriethanol)

5.3.19.1 Technical description. Titanium diisopropoxide bis(triethanolamine) is in the form of a solid. It is soluble in water and hydrolyzes very slowly. It is also soluble in isopropanol.

5.3.19.2 Specification. Manufacturer's requirement. (No Government specification)

5.3.19.2.1 Requirements. Commercially available titanium diisopropoxide bis(triethanolamine) is actually a mixture of chelates corresponding to the average formula above. The product is an 80% solution in isopropanol, with a Ti content of 8.3 percent. The solution is pale yellow in color with a specific gravity (25°/25°C) of 1.06, an approximate thickening point of -35°C, an approximate viscosity (25°C) of 90 cP(mPa·s), and a flash point (closed cup) of 16°C (60°F). The solution is miscible with water.

5.3.19.3 Use. Titanium diisopropoxide bis(triethanolamine) is intended for use as a crosslinking agent for resins, polymers and heat-set printing inks; and for surface modification of pigments.

5.3.19.4 Safety. Titanium diisopropoxide bis(triethanolamine) solution in isopropanol is flammable. It can emit irritating and toxic fumes if heated to decomposition. The PEL is 15 mg/m³ and the TLV is 10 mg/m³ for the resulting titanium dioxide as total dust as a nuisance particulate. The compound solution is not toxic, but can be irritating to the eyes, skin, and mucous membranes. (Refer to 4.3.1)

DOD-STD-1445

5.3.19.5 Storage. Titanium diisopropoxide bis(triethanolamine) solution shall be stored in corrosion-resistant containers in a cool dry place away from heat, sparks and open flame. (Refer to 4.3.2)

5.3.19.6 Disposal. In case of small liquid spills, absorb with nonreactive absorbent and place in containers for disposal. In case of large liquid spills, dike to prevent spreading. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

An EPA Hazardous Waste Classification is not listed in 40 CFR.

5.3.20 Name. Titanium Diisopropoxide Ethylacetoacetate
 $[(CH_3)_2CHO]_2Ti[-O-C(CH_3)=CHCO(OC_2H_5)]_2$ FW 424.34
 Bis(ethyl-3-oxobutanolato-0¹, 0³)bis(2-propanolato)titanium
 Titanium diisopropoxide ethyl-3-oxobutanoate

5.3.20.1 Technical description. Titanium diisopropoxide ethylacetoacetate is in the form of a liquid. It is soluble in acetone, ethanol, and isopropanol. It hydrolyzes very slowly in water.

5.3.20.2 Specification. Manufacturer's requirement. (No Government specification)

5.3.20.2.1 Requirements. Commercially available titanium diisopropoxide ethylacetoacetate is a yellow to amber colored liquid with a Ti content of 11.1 percent. The product is 100% of the compound with a specific gravity (25°/25°C) of 1.05, an approximate thickening point of 20°C, an approximate viscosity (25°C) of 50 cP(mPa·s), and a flash point (closed cup) of 27°C (81°F).

5.3.20.3 Use. Titanium diisopropoxide ethylacetoacetate is intended for use as a crosslinking agent for resins and polymers.

5.3.20.4 Safety. Titanium diisopropoxide ethylacetoacetate is a flammable liquid. It can release irritating and toxic fumes if heated to decomposition. The PEL is 15 mg/m³ and the TLV is 10 mg/m³ for the resulting titanium dioxide as total dust as a nuisance particulate. The compound is not toxic, but can be irritating to the eyes, skin and mucous membranes. (Refer to 4.3.1)

5.3.20.5 Storage. Titanium diisopropoxide ethylacetoacetate shall be stored in corrosion-resistant containers in a cool dry place away from heat, sparks and open flame. (Refer to 4.3.2)

5.3.20.6 Disposal. In case of small liquid spills, absorb with nonreactive absorbent and place in containers for disposal. In case of large liquid spills, dike to prevent spreading. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

An EPA Hazardous Waste Classification is not listed in 40 CFR.

DOD-STD-1445

5.3.21 Name. Titanium Potassium Oxalate, Dihydrate
 $K_2[TiO(C_2O_4)_2] \cdot 2H_2O$ FW 354.17
 Potassium bis(oxalato)oxotitanate, dihydrate
 Potassium titanium oxalate, dihydrate
 Titanyl potassium oxalate, dihydrate

5.3.21.1 Technical description. Titanium potassium oxalate, dihydrate, is in the form of a white crystalline powder that is very soluble in water.

5.3.21.2 Specification. Manufacturer's requirement. (No Government specification)

5.3.21.2.1 Requirements. None available.

5.3.21.3 Use. Titanium potassium oxalate, dihydrate, is intended for use as a mordant in dyeing cotton and leather, and for the sensitization of aluminum for photography.

5.3.21.4 Safety. Titanium potassium oxalate, dihydrate, is not burnable. It can emit irritating and toxic fumes if heated to decomposition. The PEL is 15 mg/m^3 and the TLV is 10 mg/m^3 for the resulting titanium dioxide as total dust as a nuisance particulate. The compound, as an oxalate, is toxic and corrosive; and can be very irritating to the eyes, skin and mucous membranes. (Refer to 4.3.1)

5.3.21.5 Storage. Titanium potassium oxalate shall be stored in corrosion-resistant containers in a cool, dry place. (Refer to 4.3.2)

5.3.21.6 Disposal. In case of dry spills, gather up and place in containers for disposal. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

An EPA Hazardous Waste Classification is not listed in 40 CFR.

5.3.22 Name. Vanadyl Acetylacetonate $VO(C_5H_7O_2)_2$ FW 265.16
 $O=V[\text{-O-C(CH}_3\text{)=CH-C(CH}_3\text{)=O}]_2$
 Vanadium(IV) oxide bis(2,4-pentanedionate)
 Vanadyl 2,4-pentanedionate

5.3.22.1 Technical description. Vanadyl acetylacetonate is in the form of blue-green crystals. The theoretical composition is 19.3% vanadium, 45.3% carbon, 5.28% hydrogen, and 30.12% oxygen. It is moderately soluble in acetone, chloroform, and ether.

5.3.22.2 Specification. Manufacturer's requirement. (No Government specification)

5.3.22.2.1 Requirements. Commercially available vanadyl acetylacetonate is a blue-green crystalline product with a melting point of 250°C . Its solubility at 25°C is 0.9 g/100 mL in benzene and 6.4 g/100 mL in methanol.

5.3.22.3 Use. Vanadyl acetylacetonate is intended for use as a catalyst for polymerization of olefins and the hydro-refining of heavy oils.

DOD-STD-1445

5.3.22.4 Safety. Vanadyl acetylacetonate is burnable, and can form explosive dust mixtures in air. It can emit irritating and toxic fumes if heated to decomposition. The resulting vanadium oxide has a PEL (ceiling values) of 0.5 mg/m³ as dust and 0.1 mg/m³ as fumes. The TLV for vanadium compounds, as V₂O₅ respirable dust and fumes, is 0.05 mg/m³, so breathing of dust and fumes shall be avoided. Vanadium compounds can be irritating to the eyes, skin and mucous membranes. (Refer to 4.3.1)

5.3.22.5 Storage. Vanadyl acetylacetonate shall be stored in corrosion-resistant containers in a cool dry place. (Refer to 4.3.2)

5.3.22.6 Disposal. In case of dry spills, gather up and place in containers for disposal. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

An EPA Hazardous Waste Classification is not listed in 40 CFR.

5.3.23 Name. Zinc Acetylacetonate $Zn(C_5H_7O_2)_2$ FW 263.59
 $Zn[-O-C(CH_3)=CH-C(CH_3)=O]_2$

Zinc 2,4-pentanedionate

5.3.23.1 Technical description. Zinc acetylacetonate is in the form of white needle crystals with a melting point of 138°C. The theoretical composition is 24.8% zinc, 45.5% carbon, 5.3% hydrogen, and 24.4% oxygen. It is soluble in water with decomposition. It is soluble in acetone and acetylacetonone. It is insoluble in ethanol.

5.3.23.2 Specification. Manufacturer's requirement. (No Government specification)

5.3.23.2.1 Requirements. Commercially available zinc acetylacetonate is a white crystalline product with a melting point of 138°C. The typical analysis is 24.8% zinc. Its solubility at 25°C is 1.3 g/100 mL in benzene and 5.4 g/100 mL in methanol.

5.3.23.3 Use. Zinc acetylacetonate is intended for use as a catalyst for polyesters and polyethers, and for alkylene oxides. It is also used as a rapid hardening agent for epoxy resins.

5.3.23.4 Safety. Zinc acetylacetonate is burnable and can form explosive dust mixtures in air. It can emit irritating and toxic fumes if heated to decomposition. The PEL and TLV is 5 mg/m³ for the resulting zinc oxide fumes, so inhalation of fumes shall be avoided. The zinc ion is not toxic, but its compounds can be irritating to the eyes and mucous membranes. (Refer to 4.3.1)

5.3.23.5 Storage. Zinc acetylacetonate shall be stored in corrosion-resistant containers in a cool dry place. (Refer to 4.3.2)

5.3.23.6 Disposal. In case of dry spills, gather up and place in containers for disposal. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

An EPA Hazardous Waste Classification is not listed in 40 CFR.

DOD-STD-1445

5.3.24 Name. Zinc 8-Quinolinolate $Zn(C_9H_6NO)_2$ FW 353.65
Zinc bis(8-oxyquinoline)

5.3.24.1 Technical description. Zinc 8-quinolinolate is in the form of a yellow solid. It is insoluble in water. It is decomposed by strong aqueous acid solutions.

5.3.24.2 Specification. Manufacturer's requirement. (No Government specification)

5.3.24.2.1 Requirements. Commercially available zinc 8-quinolinolate is a yellow powder that conforms to the chemical and physical requirements shown in Table XXX.

TABLE XXX. Zinc 8-quinolinolate - commercial chemical and physical requirements.

| | |
|--|------|
| Assay, %, min | 98.0 |
| Water, %, max | 0.5 |
| Chlorides, %, max | 0.1 |
| Sulfates, %, max | 0.1 |
| Water-soluble zinc, %, max | 0.1 |
| † Sieve size, US Standard Sieves Through No. 10 (2.00 mm), %, min | 90 |

† US Standard Sieve designation in accordance with ASTM E 11.

5.3.24.3 Use. Zinc 8-quinolinolate is intended for use as a mildew inhibitor and for the fungus-proofing of cloth, wood and other cellulose materials, where the discoloration due to copper compounds shall be avoided.

5.3.24.4 Safety. Zinc 8-quinolinolate is burnable, and can form explosive dust mixtures in air. It can emit irritating and toxic fumes if heated to decomposition, including nitrogen oxides. The PEL and TLV is 5 mg/m^3 for the resulting zinc oxide fumes. The PEL for nitric oxide is 30 mg/m^3 and the TLV is 6 mg/m^3 for nitrogen dioxide, so breathing of fumes shall be avoided. The zinc ion is not toxic, but 8-quinolinol is a suspected carcinogen. The compound can be irritating to the eyes, skin and mucous membranes. (Refer to 4.3.1)

5.3.24.5 Storage. Zinc 8-quinolinolate shall be stored in corrosion-resistant containers in a cool dry place. (Refer to 4.3.2)

5.3.24.6 Disposal. In case of dry spills, gather up and place in containers for disposal. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

An EPA Hazardous Waste Classification is not listed in 40 CFR.

5.3.25 Name. Zirconium Acetylacetonate $Zr(C_5H_7O_2)_4$ FW 487.66
Zr[$-O-C(CH_3)=CH-C(CH_3)=O$]₄
Zirconium(IV) 2,4-pentanedionate
Zirconium tetraacetylacetonate

5.3.25.1 Technical description. Zirconium acetylacetonate is in the form of a colorless white crystalline solid with a specific gravity of 1.415, and a

DOD-STD-1445

melting point of 194° to 195°C. Decomposition begins at 125°C. The theoretical zirconium content is 18.7 percent. It is soluble in acetone and benzene. It is slightly soluble in water.

5.3.25.2 Specification. Manufacturer's requirement. (No Government specification)

5.3.25.2.1 Requirements. Commercially available zirconium acetylacetonate is an anhydrous white powder with a specific gravity of 1.42, and a melting point of 194°C. The typical analysis is 19.9% zirconium. Its solubility in water is 0.73 g/100 mL.

5.3.25.3 Use. Zirconium acetylacetonate is intended for use as a polymerization catalyst, a curing accelerator, and a crosslinking agent.

5.3.25.4 Safety. Zirconium acetylacetonate is burnable, and can form explosive dust mixtures in air. It can emit irritating and toxic fumes if heated to decomposition. The PEL and TLV for zirconium compounds, as Zr, is 5 mg/m³, so breathing of dust and fumes shall be avoided. Zirconium compounds can be irritating to the eyes, skin and mucous membranes. (Refer to 4.3.1)

5.3.25.5 Storage. Zirconium acetylacetonate shall be stored in corrosion-resistant containers in a cool, dry place. (Refer to 4.3.2)

5.3.25.6 Disposal. In case of spills, gather up and place in containers for disposal. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

An EPA Hazardous Waste Classification is not listed in 40 CFR.

5.4 Organometallic Compounds

An organometallic compound is defined as one in which there is a bonding interaction (ionic or covalent, localized or delocalized) between one or more carbon atoms, of an organic group or molecule, and a main group, transition, lanthanide, or actinide metal atom or atoms. Organic derivatives of the metalloids (boron, silicon, germanium, arsenic and tellurium) are included, and are also termed as organometalloidal compounds.

Compounds in which carbon-containing moieties are bound to a metal via some other atom, such as oxygen, nitrogen, or sulfur, are not included in the category of organometallic compounds.

5.4.1 Aluminum Alkyls

5.4.1.1 Name. Tri-n-Butylaluminum Al[CH₂(CH₂)₂CH₃]₃ FW 198.33
Aluminum tri-n-butyl

5.4.1.1.1 Technical description. Tri-n-butylaluminum is a colorless liquid with a density of 0.824 g/cm³ at 25°C. It has a freezing point of -60°C and a boiling point of 98°C at 1 mm Hg. It is miscible with liquid hydrocarbons. It is decomposed by water, and is reactive with polar compounds including halogenated hydrocarbons. The theoretical aluminum content is 13.6 percent.

DOD-STD-1445

5.4.1.1.2 Specification. Manufacturer's requirements. (No Government specification)

5.4.1.1.2.1 Requirements. Tri-n-butylaluminum is available from two manufacturers with the requirements and typical analyses shown in Tables XXXI and XXXII.

TABLE XXXI. Tri-n-butylaluminum - commercial specification requirements.

| | Percent by Weight | |
|------------------------------|-------------------|------------------|
| | Requirement | Typical Analysis |
| Aluminum, as Al | 13.2 min | 13.4 |
| Hydride, as AlH ₃ | 0.2 max | 0.1 |
| Tri-n-butylaluminum | 95.0 min | 97.0 |

TABLE XXXII. Tri-n-butylaluminum - commercial specification requirements.

| | Percent by Weight | |
|--|-------------------|------------------|
| | Requirement | Typical Analysis |
| Tri-n-butylaluminum | 92.0 min | 94.0 |
| Trimethylaluminum | 0.5 max | 0.3 |
| Triethylaluminum | 1.8 max | 0.8 |
| Tri-n-propylaluminum | 0.5 max | 0.3 |
| Triisobutylaluminum | 3.0 max | 1.5 |
| Al(C ₈ H ₁₇) ₃ isomers | 3.5 max | 2.2 |
| 1-Butane | 1.0 max | 0.6 |
| Hydride, as AlH ₃ | 0.8 max | 0.3 |
| Aluminum, as Al | 13.4 min-13.9 max | 13.6 |

5.4.1.1.3 Use. Tri-n-butylaluminum is used as a component of catalyst systems for olefin and diene polymerization. Other uses are as an alkylating agent for other metals and in organic synthesis, and as a reducing agent for transition metal salts.

5.4.1.2 Name. Triethylaluminum Al(C₂H₅)₃ FW 114.16
Aluminum triethyl

5.4.1.2.1 Technical description. Triethylaluminum (pure) is a colorless liquid with a refractive index of 1.480 at 6.5°C and a density of 0.837 g/cm³ at 20°C. It has a freezing point of about -46°C, producing two crystalline forms. It has a boiling point of 194°C. It is miscible with liquid hydrocarbons. The compound is dimerized in the liquid state and in solution. It is decomposed by water, and is reactive with polar compounds including halogenated hydrocarbons. The theoretical aluminum content, as Al, is 23.6 percent.

5.4.1.2.2 Specification. Purchase Description EA-T-1009, Triethylaluminum, Technical

5.4.1.2.2.1 Requirements. This specification covers one grade of triethylaluminum (TEA). The TEA shall be a clear liquid, free from suspended or settled solids. The chemical characteristics of the TEA shall conform to the requirements shown in Table XXXIII.

DOD-STD-1445

TABLE XXXIII. TEA - chemical requirements.

| | Percent by weight | |
|---|-------------------|---------|
| | Minimum | Maximum |
| Soluble aluminum, as Al | 21.8 | 23.7 |
| Aluminum hydride equivalent, as AlH ₃ | ---- | 1.2 |
| Triethylaluminum | 92.0 | ---- |

Triethylaluminum is available from two manufacturers with the requirements and typical analyses shown in Table XXXIV and XXXV.

TABLE XXXIV. Triethylaluminum - commercial specification requirements.

| | Percent by weight |
|--|----------------------|
| | Aluminum, as Al, min |
| n-Butyl groups (calculated as tri-n-butylaluminum), max | 7.0 |
| Hydride (calculated as AlH ₃), max | 0.8 |

TABLE XXXV. Triethylaluminum - commercial specification requirements.

| | Percent by Weight | |
|------------------------------|-------------------|------------------|
| | Requirement | Typical Analysis |
| Triethylaluminum | 92.0 min | 94.1 |
| Tri-n-propylaluminum | 0.7 max | 0.1 |
| Tri-n-butylaluminum | 6.0 max | 4.6 |
| Triisobutylaluminum | 1.0 max | 0.5 |
| Hydride, as AlH ₃ | 2.0 max | 0.6 |
| Aluminum | 23.0 min | 23.3 |
| Chloride | nil | nil |

5.4.1.2.3 Use. Triethylaluminum is intended for military use in the manufacture of flame-producing munitions. Commercial uses are primarily as a component of Ziegler-type catalyst systems for the polymerization of olefins and dienes. Other uses include the production of long-chain alkyl aluminum compounds for conversion to primary alcohols.

5.4.1.3 Name. Triisobutylaluminum $Al[CH_2CH(CH_3)_2]_3$ FW 198.33
Aluminum triisobutyl

5.4.1.3.1 Technical description. Triisobutylaluminum is a colorless liquid with a density of 0.788 g/cm³ at 20°C. It has a freezing point of 1.0°C and a boiling point of 113.8°C at 30 mm Hg. It is miscible with liquid hydrocarbons. It is decomposed by water and is reactive with polar compounds including halogenated hydrocarbons. Triisobutylaluminum undergoes conversion to diisobutylaluminum hydride when heated above 50°C. Triisobutylaluminum exists in monomeric form because of the steric bulk of the isobutyl groups. The theoretical Al content is 13.6 percent.

5.4.1.3.2 Specification. Manufacturer's requirements. (No Government specification)

DOD-STD-1445

5.4.1.3.2.1 Requirements. Triisobutylaluminum is available from two manufacturers with the requirements and typical analyses shown in Table XXXVI and XXXVII.

TABLE XXXVI. Triisobutylaluminum - commercial specification requirements.

| | Percent by Weight | |
|------------------------------|-------------------|------------------|
| | Requirement | Typical Analysis |
| Aluminum, as Al | 13.4 min | 13.6 |
| Hydride, as AlH ₃ | 0.5 max | 0.1 |
| Dissolved isobutylene | 2.5 max | 0.2 |

TABLE XXXVII. Triisobutylaluminum - commercial specification requirements.

| | Percent by Weight | |
|------------------------------|-------------------|------------------|
| | Requirement | Typical Analysis |
| Triisobutylaluminum | 95.0 min | 95.5 |
| Tri-n-butylaluminum | 0.5 max | 0.4 |
| Tri-n-propylaluminum | 0.5 max | 0.4 |
| Hydride, as AlH ₃ | 0.8 max | 0.5 |
| Isobutylene | 4.0 max | 3.2 |
| Aluminum | 13.4 min | 13.6 |

5.4.1.3.3 Use. Triisobutylaluminum is used as a component of catalyst systems for olefin and diene polymerization. Other uses are as a reducing agent in organic reduction reactions and as a chemical intermediate.

5.4.1.4 Name. Tri-n-Hexylaluminum: Al[CH₂(CH₂)₄CH₃]₃ FW 282.49
Aluminum, tri-n-hexyl

5.4.1.4.1 Technical description. Tri-n-hexylaluminum is a colorless liquid with a density of 0.837 g/cm³ at 25°C. It has a freezing point of -87°C and a boiling point of 308.5°C. It is dimerized at 25°C but is 97% dissociated to the monomer at its boiling point. It is miscible with liquid hydrocarbons. It is decomposed by water, and is reactive with polar compounds including halogenated hydrocarbons. The theoretical aluminum content is 9.6 percent.

5.4.1.4.2 Specification. Manufacturer's requirements. (No Government specification)

5.4.1.4.2.1 Requirements. Tri-n-hexylaluminum is available from a manufacturer with the requirements and typical analysis shown in Table XXXVIII.

TABLE XXXVIII. Tri-n-hexylaluminum - commercial specification requirements.

| | Percent by Weight | |
|------------------------------|-------------------|------------------|
| | Requirement | Typical Analysis |
| Tri-n-hexylaluminum | 92.0 min | 95.1 |
| Aluminum, as Al | 9.0 min | 9.5 |
| Hydride, as AlH ₃ | 1.0 max | 0.02 |

5.4.1.4.3 Use. Tri-n-hexylaluminum is used as a component of catalyst systems for alkene and diene polymerization, and as a chemical intermediate.

DOD-STD-1445

5.4.1.5 Name. Trimethylaluminum $\text{Al}(\text{CH}_3)_3$ FW 72.09
Aluminum trimethyl

5.4.1.5.1 Technical description. Trimethylaluminum (pure) is a colorless liquid with a refractive index of 1.432 at 12°C and a density of 0.752 g/cm³ at 20°C. It has a freezing point of 15.4°C and a boiling point of 127°C. It is miscible with liquid hydrocarbons. The compound is dimerized in the liquid state and in solution. It is decomposed by water, and is reactive with polar compounds including halogenated hydrocarbons. The theoretical aluminum content is 37.4 percent.

5.4.1.5.2 Specification. Manufacturer's requirements. (No Government specification)

5.4.1.5.2.1 Requirements. Trimethylaluminum is available from two manufacturers with the requirements and typical analyses shown in Table XXXIX and LX.

TABLE XXXIX. Trimethylaluminum - commercial specification requirements.

| | Percent by Weight | |
|-----------------|-------------------|---------|
| | Minimum | Maximum |
| Aluminum, as Al | 36.5 | 37.4 |
| Chlorine, as Cl | ---- | 0.1 |

TABLE XL. Trimethylaluminum - commercial specification requirements.

| | Percent by Weight | |
|----------------------------|-------------------|------------------|
| | Requirement | Typical Analysis |
| Trimethylaluminum | 97.0 min | 99.0 |
| Triethylaluminum | 2.0 max | 0.5 |
| Tri-n-propylaluminum | 0.3 max | 0.0 |
| Triisobutylaluminum | 0.5 max | 0.3 |
| Tri-n-butylaluminum | 0.3 max | 0.1 |
| Hydride, as AlH_3 | 0.5 max | 0.1 |
| Aluminum | 36.3 min | 37.1 |
| | 37.4 max | |
| Chloride | 0.1 max | nil |

5.4.1.5.3 Use. Trimethylaluminum is intended for military use in formulations for pyrophoric fuels. Commercial uses are primarily as a component of catalyst systems for the polymerization of olefins.

5.4.1.6 Name. Tri-n-Propylaluminum $\text{Al}(\text{CH}_2\text{CH}_2\text{CH}_3)_3$ FW 156.25
Aluminum tri-n-propyl

5.4.1.6.1 Technical description. Tri-n-propylaluminum is a colorless liquid with a density of 0.824 g/cm³ at 20°C. It has a freezing point of -60°C and a boiling point of 114°C at 20 mm Hg. It is miscible with liquid hydrocarbons. The compound is dimerized in the liquid state and in solution. It is decomposed by water, and is reactive with polar compounds, including halogenated hydrocarbons. The theoretical aluminum content is 17.4 percent.

5.4.1.6.2 Specification. Manufacturer's requirements. (No Government specification)

DOD-STD-1445

5.4.1.6.2.1 Requirements. Tri-n-propylaluminum is available from two manufacturers with the requirements and typical analyses shown in Table XLI and XLII.

TABLE XLI. Tri-n-propylaluminum - commercial specification requirements.

| | |
|--|------|
| Aluminum, as Al, % by wt, min | 16.4 |
| Aluminum hydride equivalent, as AlH ₃ % by wt, max | 1.0 |

TABLE XLII. Tri-n-propylaluminum - commercial specification requirements.

| | Percent by weight | |
|------------------------------|-------------------|------------------|
| | Requirement | Typical Analysis |
| Tri-n-propylaluminum | 92.0 min | 95.2 |
| Triethylaluminum | 2.0 max | 0.8 |
| Tri-n-butylaluminum | 1.0 max | 0.4 |
| Triisobutylaluminum | 2.5 max | 1.4 |
| Hydride, as AlH ₃ | 3.5 max | 2.2 |
| Aluminum | 17.0 min | 18.3 |

5.4.1.6.3 Use. Tri-n-propylaluminum is intended for military use in formulations for pyrophoric fuels. Commercial uses are as a component of catalyst systems for the polymerization of olefins, and also for use as a chemical intermediate.

5.4.1.7 Safety. Aluminum alkyls are pyrophoric liquids that flame spontaneously and give off dense smoke on exposure to air. They are reactive with water with the release of flammable and explosive vapors that can be ignited by the heat of reaction. Hydrocarbon solutions of aluminum alkyls may not be pyrophoric depending on concentration and temperature. The burning liquid can release irritating and toxic fumes and smoke. The TLV for aluminum alkyls (not otherwise classified) is 2 mg/m³ and inhalation of fumes from burning liquid shall be avoided. Aluminum alkyls produce severe burns, predominantly thermal, on contact with skin or eyes by reaction with body moisture, so contact shall be avoided. (Refer to 4.3.1)

5.4.1.8 Storage. Aluminum alkyls shall be stored in special containers, blanketed with dry nitrogen under a slight positive pressure, in a cool dry place. (Refer to 4.3.2)

5.4.1.9 Disposal. Liquid spills of aluminum alkyls will ignite spontaneously. Small liquid spill fires can be controlled with dry powder extinguishers, absorbed by nonreactive dry powders and placed in sealed containers. In case of large liquid spills, the burning liquid shall be isolated by use of sandbags to prevent spreading. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

Aluminum alkyls have an EPA Hazardous Waste Classification - Ignitable, Waste No. D001; and Reactive, Waste No. D003.

DOD-STD-1445

5.4.2 Aluminum Alkyl Alkoxide

5.4.2.1 Name. Diethylaluminum Ethoxide $\text{Al}(\text{C}_2\text{H}_5)_2\text{OC}_2\text{H}_5$ FW 130.17
Aluminum diethylethoxide

5.4.2.1.1 Technical description. Diethylaluminum ethoxide is a colorless liquid with a density of 0.851 g/cm^3 at 25°C . It is soluble in liquid hydrocarbons and ether. It is decomposed by water, and is reactive with polar compounds including halogenated hydrocarbons.

5.4.2.1.2 Specification. Manufacturer's requirements. (No Government specification)

5.4.2.1.2.1 Requirements. Diethylaluminum ethoxide is available from two manufacturers with the requirements and typical analyses shown in Table XLIII and XLIV.

TABLE XLIII. Diethylaluminum ethoxide - commercial specification requirements.

| | Requirement | Theoretical |
|------------------------|--------------|-------------|
| Aluminum, wt % | 19.0 to 20.6 | 20.7 |
| Hydrolysis gas, mmol/g | 13.6 to 15.2 | 15.4 |

TABLE XLIV. Diethylaluminum ethoxide - commercial specification requirements.

| | Requirement | Analysis |
|-----------------------------------|--------------|----------|
| Product composition, wt % | | |
| Aluminum | 19.5 to 20.7 | 20.4 |
| Ethoxide | 33.4 to 36.5 | 35.1 |
| Hydrolysis gas composition, mol % | | |
| Ethane | 96.0 min | 97.4 |
| n-Butane | 3.8 max | 1.6 |
| Isobutane | 2.5 max | 0.5 |
| Propane | 0.3 max | 0.1 |
| Methane | 0.4 max | 0.2 |
| Hydrogen | 0.6 max | 0.2 |

5.4.2.1.3 Use. Diethylaluminum ethoxide is used as a co-catalyst for olefin and diene polymerization, olefin isomerization, and as an alkylating agent.

5.4.2.1.4 Safety. Diethylaluminum ethoxide is a pyrophoric liquid that flames spontaneously and gives off dense smoke on exposure to air. It is reactive with water with the release of flammable and explosive vapors that can be ignited by the heat of reaction. Hydrocarbon solutions of diethylaluminum ethoxide may not be pyrophoric depending on concentration and temperature. The burning liquid can release irritating and toxic fumes and smoke. There is no PEL or TLV referenced for diethylaluminum ethoxide, but the TLV, as Al, is 2 mg/m^3 for aluminum alkyls not otherwise classified. Inhalation of fumes from burning liquid shall be avoided. Diethylaluminum ethoxide produces severe burns, predominantly thermal, on contact with skin or eyes by reaction with body moisture, so contact shall be avoided. (Refer to 4.3.1)

5.4.2.1.5 Storage. Diethylaluminum ethoxide shall be stored in special containers, blanketed with dry nitrogen under a slight positive pressure, in a cool, dry place. (Refer to 4.3.2)

DOD-STD-1445

5.4.2.1.6 Disposal. Liquid spills of diethylaluminum ethoxide will ignite spontaneously. Small liquid spill fires can be controlled with dry powder extinguishers, absorbed by nonreactive dry powders, and placed in sealed containers. In case of large liquid spills, the burning liquid shall be isolated by use of sandbags to prevent spreading. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

Diethylaluminum ethoxide has an EPA Hazardous Waste Classification - Ignitable, Waste No. D001; and Reactive, Waste No. D003.

5.4.3 Aluminum Alkyl Halides

5.4.3.1 Name. Diethylaluminum Chloride $Al(C_2H_5)_2Cl$ FW 120.56
Aluminum diethyl chloride

5.4.3.1.1 Technical description. Diethylaluminum chloride is a colorless liquid with a density of 0.971 g/cm^3 at 25°C . It has a freezing point of -74°C and a boiling point of 214.1°C at 760 mm Hg. It is miscible with liquid hydrocarbons. It is decomposed by water, and is reactive with polar compounds including halogenated hydrocarbons. The theoretical composition is 22.4% Al and 29.4% Cl, and the compound is dimeric.

5.4.3.1.2 Specification. Manufacturer's requirements. (No Government specification)

5.4.3.1.2.1 Requirements. Diethylaluminum chloride is available from two manufacturers with the requirements and typical analyses shown in Table XLV and XLVI.

TABLE XLV. Diethylaluminum chloride - commercial specification requirements.

| | Requirement |
|---|--------------|
| Aluminum, wt % | 21.9 to 22.4 |
| Chlorine/Aluminum (atom ratio) | 1.00 to 1.03 |
| Hydrogen (in hydrolysis gas) mol %, max | 0.05 |

TABLE XLVI. Diethylaluminum chloride - requirements and typical analysis.

| | Requirement | Analysis |
|-----------------------------------|--------------|----------|
| Product composition, wt % | | |
| Aluminum | 21.9 to 22.4 | 22.1 |
| Chloride | 29.2 to 29.8 | 29.5 |
| Hydrolysis gas composition, mol % | | |
| Ethane | 97.0 min | 97.4 |
| n-Butane | 2.2 max | 2.0 |
| Isobutane | 0.5 max | 0.2 |
| Hydrogen | 0.8 max | 0.4 |

5.4.3.1.3 Use. Diethylaluminum chloride is used as a component of catalyst systems for olefin and diene polymerizations, linear oligomerization and cyclization of unsaturated hydrocarbons, and in alkylation reactions.

5.4.3.1.4 Safety. Diethylaluminum chloride is a pyrophoric liquid that flames spontaneously and gives off dense smoke on exposure to air. It is reac-

DOD-STD-1445

tive with water with the release of flammable and explosive vapors that can be ignited by the heat of reaction. Hydrocarbon solutions of diethylaluminum chloride may not be pyrophoric depending on concentration and temperature. The burning liquid can release irritating and toxic fumes and smoke. There is no PEL or TLV referenced for diethylaluminum chloride, but the TLV, as Al, is 2 mg/m³ for aluminum alkyls not otherwise classified. Inhalation of fumes from burning liquid shall be avoided. Diethylaluminum chloride produces severe burns, predominantly thermal, on contact with skin or eyes, by reaction with body moisture, so contact shall be avoided. (Refer to 4.3.1)

5.4.3.1.5 Storage. Diethylaluminum chloride shall be stored in special containers, blanketed with dry nitrogen under a slight positive pressure, in a cool dry place. (Refer to 4.3.2)

5.4.3.1.6 Disposal. Spills of diethylaluminum chloride will ignite spontaneously. Small spill fires can be controlled with dry powder extinguishers, absorbed by nonreactive dry powders and placed in sealed containers. In case of large liquid spills, the burning liquid shall be isolated by use of sandbags to prevent spreading. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

Diethylaluminum chloride has an EPA Hazardous Waste Classification - Ignitable, Waste No. D001; and Reactive, Waste No. D003.

5.4.3.2 Name. Diethylaluminum Iodide Al(C₂H₅)₂I FW 212.01
Aluminum diethyl iodide

5.4.3.2.1 Technical description. Diethylaluminum iodide is a clear liquid with a density of 1.577 g/cm³ at 25°C. It has a freezing point of -43.4°C and a boiling point of 262°C (extrapolated) at 760 mm Hg. It is miscible with most hydrocarbons. It is decomposed by water, and is reactive with polar compounds including halogenated hydrocarbons. The theoretical composition is 12.73% Al and 59.86% iodine, and the compound is dimeric.

5.4.3.2.2 Specification. Manufacturer's requirements. (No Government specification)

5.4.3.2.2.1 Requirements. Diethylaluminum iodide is available from a manufacturer with the requirements and typical analysis shown in Table XLVII.

TABLE XLVII. Diethylaluminum iodide - requirements and typical analysis.

| | Requirement | Analysis |
|-----------------------------------|--------------|----------|
| Product composition, wt % | | |
| Aluminum | 12.4 to 12.9 | 12.6 |
| Iodide | 59.0 to 60.0 | 59.2 |
| Hydrolysis gas composition, mol % | | |
| Ethane | 96.8 min | 97.8 |
| n-Butane | 2.2 max | 1.3 |
| Isobutane | 0.4 max | 0.1 |
| Propane | 0.4 max | 0.1 |
| Methane | 0.4 max | 0.2 |
| Hydrogen | 1.0 max | 0.5 |

DOD-STD-1445

5.4.3.2.3 Use. Diethylaluminum iodide is used as a catalyst component for polymerization and other reactions.

5.4.3.2.4 Safety. Diethylaluminum iodide is a pyrophoric liquid that flames spontaneously and gives off dense smoke on exposure to air. It is reactive with water with the release of flammable and explosive vapors that can be ignited by the heat of reaction. Hydrocarbon solutions of diethylaluminum iodide may not be pyrophoric depending on concentration and temperature. The burning liquid can release irritating and toxic fumes and smoke. There is no PEL or TLV referenced for diethylaluminum iodide, but the TLV, as Al, is 2 mg/m³ for aluminum alkyls not otherwise classified. Inhalation of fumes from burning liquid shall be avoided. Diethylaluminum iodide produces severe burns, predominantly thermal, on contact with skin or eyes, by reaction with body moisture, so contact shall be avoided. (Refer to 4.3.1)

5.4.3.2.5 Storage. Diethylaluminum iodide shall be stored in special containers, blanketed with dry nitrogen under a slight positive pressure, in a cool dry place. (Refer to 4.3.2)

5.4.3.2.6 Disposal. Spills of diethylaluminum iodide will ignite spontaneously. Small spill fires can be controlled with dry powder extinguishers, absorbed by nonreactive dry powders and placed in sealed containers. In case of large liquid spills, the burning liquid shall be isolated by use of sandbags to prevent spreading. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

Diethylaluminum iodide has an EPA Hazardous Waste Classification - Ignitable, Waste No. D001; and Reactive, Waste No. D003.

5.4.3.3 Name. Diisobutylaluminum Chloride $Al[CH_2CH(CH_3)_2]_2Cl$ FW 176.67
Aluminum diisobutyl chloride

5.4.3.3.1 Technical description. Diisobutylaluminum chloride is a colorless liquid with a density of 0.912 g/cm³ at 25°C. It has a freezing point of -40°C and a boiling point of 289°C at 760 mm Hg. It is miscible with most liquid hydrocarbons. It is decomposed by water, and is reactive with polar compounds including halogenated hydrocarbons. The theoretical composition is 15.3% Al and 20.1% Cl, and the compound is dimeric.

5.4.3.3.2 Specification. Manufacturer's requirements. (No Government specification)

5.4.3.3.2.1 Requirements. Diisobutylaluminum chloride is available from two manufacturers with the requirements and typical analysis shown in Table XLVIII and XLIX.

TABLE XLVIII. Diisobutylaluminum chloride - requirements and typical analysis.

| | Requirement | Analysis |
|---|--------------|----------|
| Aluminum, wt % | 15.2 to 15.5 | 15.2 |
| Chlorine, wt % | 19.8 to 20.7 | 20.6 |
| Hydrolysis gas- Isobutane, mol % min | 96.0 | 96.5 |

DOD-STD-1445

TABLE XLIX. Diisobutylaluminum chloride - requirements and typical analysis.

| | Requirement | Analysis |
|-----------------------------------|--------------|----------|
| Product composition, wt % | | |
| Aluminum | 15.2 to 15.5 | 15.4 |
| Chloride | 19.8 to 20.7 | 20.1 |
| Hydrolysis gas composition, mol % | | |
| Isobutane | 96.0 min | 97.4 |
| n-Butane | 0.5 max | 0.3 |
| Propane | 0.6 max | 0.5 |
| Ethane | 1.4 max | 0.7 |
| Methane | 0.6 max | 0.5 |
| Propylene | 0.2 max | 0.0 |
| Isobutylene | 1.3 max | 0.1 |
| Hydrogen | 1.5 max | 0.5 |

5.4.3.3.3 Use. Diisobutylaluminum chloride is used as a catalyst component for polymerization of olefins and dienes.

5.4.3.3.4 Safety. Diisobutylaluminum chloride is a pyrophoric liquid that flames spontaneously and gives off dense smoke on exposure to air. It is reactive with water with the release of flammable and explosive vapors that can be ignited by the heat of reaction. Hydrocarbon solutions of diisobutylaluminum chloride may not be pyrophoric depending on concentration and temperature. The burning liquid can release irritating and toxic fumes and smoke. There is no PEL or TLV referenced for diisobutylaluminum chloride, but the TLV, as Al, is 2 mg/m³ for aluminum alkyls not otherwise classified. Inhalation of fumes from burning liquid shall be avoided. Diisobutylaluminum chloride produces severe burns, predominantly thermal, on contact with skin or eyes, by reaction with body moisture, so contact shall be avoided. (Refer to 4.3.1)

5.4.3.3.5 Storage. Diisobutylaluminum chloride shall be stored in special containers, blanketed with dry nitrogen under a slight positive pressure, in a cool dry place. (Refer to 4.3.2)

5.4.3.3.6 Disposal. Spills of diisobutylaluminum chloride will ignite spontaneously. Small spill fires can be controlled with dry powder extinguishers, absorbed by nonreactive dry powders and placed in sealed containers. In case of large liquid spills, the burning liquid shall be isolated by use of sandbags to prevent spreading. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

Diisobutylaluminum chloride has an EPA Hazardous Waste Classification - Ignitable, Waste No. D001; and Reactive, Waste No. D003.

5.4.3.4 Name. Dimethylaluminum Chloride $\text{Al}(\text{CH}_3)_2\text{Cl}$ FW 92.50
Aluminum dimethyl chloride

5.4.3.4.1 Technical description. Dimethylaluminum chloride is a colorless liquid with a density of 0.995 g/cm³ at 25°C. It has a freezing point of -21°C and a boiling point of 126 to 127°C at 760 mm Hg. It is miscible with most liquid hydrocarbons. It is decomposed by water, and is reactive with polar compounds including halogenated hydrocarbons. The theoretical composition is 29.2% Al and 38.3% Cl, and the compound is dimeric.

DOD-STD-1445

5.4.3.4.2 Specification. Manufacturer's requirements. (No Government specification)

5.4.3.4.2.1 Requirements. Dimethylaluminum chloride is available from two manufacturers without specification requirements.

5.4.3.4.3 Use. Dimethylaluminum chloride is used as a catalyst component for polymerization reactions and as a methylating agent.

5.4.3.4.4 Safety. Dimethylaluminum chloride is a pyrophoric liquid that flames spontaneously and gives off dense smoke on exposure to air. It is reactive with water with the release of flammable and explosive vapors that can be ignited by the heat of reaction. Hydrocarbon solutions of dimethylaluminum chloride may not be pyrophoric depending on concentration and temperature. The burning liquid can release irritating and toxic fumes and smoke. There is no PEL or TLV referenced for dimethylaluminum chloride, but the TLV, as Al, is 2 mg/m³ for aluminum alkyls not otherwise classified. Inhalation of fumes from burning liquid shall be avoided. Dimethylaluminum chloride produces severe burns, predominantly thermal, on contact with skin or eyes, by reaction with body moisture, so contact shall be avoided. (Refer to 4.3.1)

5.4.3.4.5 Storage. Dimethylaluminum chloride shall be stored in special containers, blanketed with dry nitrogen under a slight positive pressure, in a cool dry place. (Refer to 4.3.2)

5.4.3.4.6 Disposal. Spills of dimethylaluminum chloride will ignite spontaneously. Small spill fires can be controlled with dry powder extinguishers, absorbed by nonreactive dry powders and placed in sealed containers. In case of large liquid spills, the burning liquid shall be isolated by use of sandbags to prevent spreading. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

Dimethylaluminum chloride has an EPA Hazardous Waste Classification - Ignitable, Waste No. D001; and Reactive, Waste No. D003.

| | | | |
|---------|--|---|-----------|
| 5.4.3.5 | <u>Name</u> . Ethylaluminum Dichloride | AlC ₂ H ₅ Cl ₂ | FW 126.96 |
| | Aluminum ethyl dichloride | | |

5.4.3.5.1 Technical description. Ethylaluminum dichloride is a colorless liquid, above its freezing point, with a density of 1.227 g/cm³ at 35°C, and its density as a solid at 25°C is 1.232 g/cm³. It has a freezing point of 30.9°C and an extrapolated boiling point of 194°C at 760 mm Hg. It is miscible with most liquid hydrocarbons. It is decomposed by water, and is reactive with polar compounds including halogenated hydrocarbons. The theoretical composition is 21.3% Al and 55.9% Cl, and the compound is dimeric.

5.4.3.5.2 Specification. Manufacturer's requirements. (No Government specification)

5.4.3.5.2.1 Requirements. Ethylaluminum dichloride is available from two manufacturers with the requirements and the typical analyses shown in Table L and LI.

DOD-STD-1445

TABLE L. Ethylaluminum dichloride - commercial analysis range.

| | Theoretical | Analysis Range |
|----------------|-------------|----------------|
| Aluminum, wt % | 21.3 | 20.3-21.5 |
| Chlorine, wt % | 55.9 | 55.2-56.3 |

TABLE LI. Ethylaluminum dichloride - requirements and typical analysis.

| | Requirement | Analysis |
|-----------------------------------|--------------|----------|
| Product composition, wt % | | |
| Aluminum | 20.3 to 21.5 | 20.9 |
| Chloride | 55.2 to 56.3 | 56.0 |
| Hydrolysis gas composition, mol % | | |
| Ethane | 98.0 min | 99.2 |
| Isobutane | 1.0 max | 0.0 |
| n-Butane | 1.5 max | 0.8 |
| Hydrogen | nil | 0.0 |

5.4.3.5.3 Use. Ethylaluminum dichloride is used as a catalyst component for polymerization and other reactions.

5.4.3.5.4 Safety. Ethylaluminum dichloride, above 31°C, is a pyrophoric liquid that flames spontaneously and gives off dense smoke on exposure to air. It is reactive with water with the release of flammable and explosive vapors that can be ignited by the heat of reaction. Hydrocarbon solutions of ethylaluminum dichloride may not be pyrophoric depending on concentration and temperature. The burning liquid can release irritating and toxic fumes and smoke. There is no PEL or TLV referenced for ethylaluminum dichloride, but the TLV, as Al, is 2 mg/m³ for aluminum alkyls not otherwise classified. Inhalation of fumes from burning liquid shall be avoided. Ethylaluminum dichloride produces severe burns, predominantly thermal, on contact with skin or eyes by reaction with body moisture, so contact shall be avoided. (Refer to 4.3.1)

5.4.3.5.5 Storage. Ethylaluminum dichloride shall be stored in special containers, blanketed with dry nitrogen under a slight positive pressure, in a cool dry place. (Refer to 4.3.2)

5.4.3.5.6 Disposal. Spills of ethylaluminum dichloride will ignite spontaneously. Small spill fires can be controlled with dry powder extinguishers, absorbed by nonreactive dry powders and placed in sealed containers. In case of large liquid solution spills, the burning liquid shall be isolated by use of sandbags to prevent spreading. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

Ethylaluminum dichloride has an EPA Hazardous Waste Classification - Ignitable, Waste No. D001; and Reactive, Waste No. D003.

5.4.3.6 Name. Ethylaluminum Sesquichloride $Al_2(C_2H_5)_3Cl_3$ FW 247.52
 $(C_2H_5)_2AlCl \cdot Cl_2AlC_2H_5$
 Aluminum ethyl sesquichloride
 Triethylaluminum trichloride

5.4.3.6.1 Technical description. Ethylaluminum sesquichloride is a clear liquid with a density of 1.092 g/cm³ at 25°C. It has a freezing point of -20°C

DOD-STD-1445

and a boiling point of 204°C (extrapolated) at 760 mm Hg. It is miscible with most liquid hydrocarbons. It is decomposed by water, and is reactive with polar compounds including halogenated hydrocarbons. The theoretical composition is 21.8% Al and 43.0% Cl, and the compound is a 1:1 complex of ethylaluminum dichloride and diethylaluminum chloride.

5.4.3.6.2 Specification. Manufacturer's requirements. (No Government specification)

5.4.3.6.2.1 Requirements. Ethylaluminum sesquichloride is available from two manufacturers with the requirements and typical analyses shown in Table LII and LIII.

TABLE LII. Ethylaluminum sesquichloride - commercial analysis range.

| | Theoretical | Analysis Range |
|----------------|-------------|----------------|
| Aluminum, wt % | 21.8 | 21.4 to 22.0 |
| Chlorine, wt % | 43.0 | 42.1 to 43.3 |

TABLE LIII. Ethylaluminum sesquichloride - requirements and typical analysis.

| | Requirement | Analysis |
|-----------------------------------|--------------|----------|
| Product composition, wt % | | |
| Aluminum | 21.1 to 21.8 | 21.5 |
| Chloride | 42.0 to 43.5 | 42.9 |
| Hydrolysis gas composition, mol % | | |
| Ethane | 98.5 min | 99.5 |
| Methane | 0.2 max | 0.1 |
| Propane | 0.1 max | Trace |
| Isobutane | 0.3 max | 0.1 |
| n-Butane | 1.2 max | 0.2 |
| Hydrogen | 0.4 max | 0.1 |

5.4.3.6.3 Use. Ethylaluminum sesquichloride is used as a catalyst for polymerization of olefins and for hydrogenation of aromatics.

5.4.3.6.4 Safety. Ethylaluminum sesquichloride is a pyrophoric liquid that flames spontaneously and gives off dense smoke on exposure to air. It is reactive with water with the release of flammable and explosive vapors that can be ignited by the heat of reaction. Hydrocarbon solutions of ethylaluminum sesquichloride may not be pyrophoric depending on concentration and temperature. The burning liquid can release irritating and toxic fumes and smoke. There is no PEL or TLV referenced for ethylaluminum sesquichloride, but the TLV, as Al, is 2 mg/m³ for aluminum alkyls not otherwise classified. Inhalation of fumes from burning liquid shall be avoided. Ethylaluminum sesquichloride produces severe burns, predominantly thermal, on contact with skin or eyes by reaction with body moisture, so contact shall be avoided. (Refer to 4.3.1)

5.4.3.6.5 Storage. Ethylaluminum sesquichloride shall be stored in special containers, blanketed with dry nitrogen under a slight positive pressure, in a cool dry place. (Refer to 4.3.2)

5.4.3.6.6 Disposal. Spills of ethylaluminum sesquichloride will ignite spontaneously. Small spill fires can be controlled with dry powder extinguishers, absorbed by nonreactive dry powders and placed in sealed containers. In

DOD-STD-1445

case of large liquid spills, the burning liquid shall be isolated by use of sandbags to prevent spreading. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

Ethylaluminum sesquichloride has an EPA Hazardous Waste Classification - Ignitable, Waste No. D001; and Reactive, Waste No. D003.

5.4.3.7 Name. Isobutylaluminum Dichloride $\text{Al}[\text{CH}_2\text{CH}(\text{CH}_3)_2]\text{Cl}_2$ FW 155.00
Aluminum isobutyl dichloride

5.4.3.7.1 Technical description. Isobutylaluminum dichloride is a clear liquid with a density of 1.121 g/cm^3 at 30°C . It has a freezing point of -30°C . It is miscible with most liquid hydrocarbons. It is decomposed by water, and is reactive with polar compounds including halogenated hydrocarbons. The theoretical composition is 17.4% Al and 45.8% Cl, and the compound is dimeric.

5.4.3.7.2 Specification. Manufacturer's requirements. (No Government specification)

5.4.3.7.2.1 Requirements. Isobutylaluminum dichloride is available from a manufacturer with the requirements and typical analysis shown in Table LIV.

TABLE LIV. Isobutylaluminum dichloride - commercial analysis range.

| | Theoretical | Analysis Range |
|----------------|-------------|----------------|
| Aluminum, wt % | 17.4 | 17.2 to 17.6 |
| Chlorine, wt % | 45.8 | 45.5 to 46.2 |

5.4.3.7.3 Use. Isobutylaluminum dichloride is used as a catalyst component for polymerization of olefins and dienes.

5.4.3.7.4 Safety. Isobutylaluminum dichloride is a pyrophoric liquid that flames spontaneously and gives off dense smoke on exposure to air. It is reactive with water with the release of flammable and explosive vapors that can be ignited by the heat of reaction. Hydrocarbon solutions of isobutylaluminum dichloride may not be pyrophoric depending on concentration and temperature. The burning liquid can release irritating and toxic fumes and smoke. There is no PEL or TLV referenced for isobutylaluminum dichloride but the TLV, as Al, is 2 mg/m^3 for aluminum alkyls not otherwise classified. Inhalation of fumes from burning liquid shall be avoided. Isobutylaluminum dichloride produces severe burns, predominantly thermal, on contact with skin or eyes by reaction with body moisture, so contact shall be avoided. (Refer to 4.3.1)

5.4.3.7.5 Storage. Isobutylaluminum dichloride shall be stored in special containers, blanketed with dry nitrogen under a slight positive pressure, in a cool dry place. (Refer to 4.3.2)

5.4.3.7.6 Disposal. Spills of isobutylaluminum dichloride will ignite spontaneously. Small spill fires can be controlled with dry powder extinguishers, absorbed by nonreactive dry powders and placed in sealed containers. In case of large liquid spills, the burning liquid shall be isolated by use of sandbags to prevent spreading. For appropriate procedures, contact the Instal-

DOD-STD-1445

lation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

Isobutylaluminum dichloride has an EPA Hazardous Waste Classification - Ignitable, Waste No. D001; and Reactive, Waste No. D003.

5.4.3.8 Name. Isobutylaluminum Sesquichloride

$Al_2[CH_2CH(CH_3)_2]_3Cl_3$ FW 331.67

$[(CH_3)_2CHCH_2]_2AlCl \cdot Cl_2Al[CH_2CH(CH_3)_2]$

Aluminum isobutyl sesquichloride
Triisobutyldialuminum trichloride

5.4.3.8.1 Technical description. Isobutylaluminum sesquichloride is a clear liquid with a density of 0.998 g/cm³ at 23°C. It has a freezing point of -93°C and a boiling point range of 120 to 150°C at 10 mm Hg. It is miscible with most liquid hydrocarbons. It is decomposed by water, and is reactive with polar compounds including halogenated hydrocarbons. The theoretical composition is 16.3% Al and 32.00% Cl, and the compound is a 1:1 complex of isobutylaluminum dichloride and diisobutylaluminum chloride.

5.4.3.8.2 Specification. Manufacturer's requirements. (No Government specification)

5.4.3.8.2.1 Requirements. Isobutylaluminum sesquichloride is available from a manufacturer with requirements and typical analysis shown in Table LV.

TABLE LV. Isobutylaluminum sesquichloride - requirements and typical analysis.

| | Requirement | Analysis |
|-----------------------------------|--------------|----------|
| Product composition, wt % | | |
| Aluminum | 15.8 to 16.5 | 16.2 |
| Chloride | 31.2 to 32.6 | 32.0 |
| Hydrolysis gas composition, mol % | | |
| Isobutane | 96.0 min | 98.7 |
| n-Butane | 0.6 max | 0.3 |
| Propane | 0.6 max | 0.2 |
| Ethane | 1.5 max | 0.5 |
| Methane | 0.4 max | 0.2 |
| Isobutylene | 0.5 max | 0.0 |
| Hydrogen | 0.8 max | 0.1 |

5.4.3.8.3 Use. Isobutylaluminum sesquichloride is used as a catalyst component for polymerization of olefins and dienes.

5.4.3.8.4 Safety. Isobutylaluminum sesquichloride is a pyrophoric liquid that flames spontaneously and gives off dense smoke on exposure to air. It is reactive with water with the release of flammable and explosive vapors that can be ignited by the heat of reaction. Hydrocarbon solutions of isobutylaluminum sesquichloride may not be pyrophoric depending on concentration and temperature. The burning liquid can release irritating and toxic fumes and smoke. There is no PEL or TLV referenced for isobutylaluminum sesquichloride but the TLV, as Al, is 2 mg/m³ for aluminum alkyls not otherwise classified. Inhalation of fumes from burning liquid shall be avoided. Isobutylaluminum sesquichloride produces severe burns, predominantly thermal, on contact with skin or

DOD -STD-1445

eyes by reaction with body moisture, so contact shall be avoided. (Refer to 4.3.1)

5.4.3.8.5 Storage. Isobutylaluminum sesquichloride shall be stored in special containers, blanketed with dry nitrogen under a slight positive pressure, in a cool dry place. (Refer to 4.3.2)

5.4.3.8.6 Disposal. Spills of isobutylaluminum sesquichloride will ignite spontaneously. Small spill fires can be controlled with dry powder extinguishers, absorbed by nonreactive dry powders and placed in sealed containers. In case of large liquid spills, the burning liquid shall be isolated by use of sandbags to prevent spreading. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

Isobutylaluminum sesquichloride has an EPA Hazardous Waste Classification - Ignitable, Waste No. D001; and Reactive, Waste No. D003.

5.4.3.9 Name. Methylaluminum Dichloride $AlCH_3Cl_2$ FW 112.92
Aluminum methyl dichloride

5.4.3.9.1 Technical description. Methylaluminum dichloride is a white crystalline solid with a density of 1.00 g/cm^3 at 22°C . It has a melting point of 73.6°C and a boiling point of 152°C at 760 mm Hg. It is soluble in most liquid hydrocarbons. It is decomposed by water, and is reactive with polar compounds including halogenated hydrocarbons. The theoretical composition is 23.9% Al and 62.8% Cl, and the compound is dimeric.

5.4.3.9.2 Specification. Manufacturer's requirements. (No Government specification)

5.4.3.9.2.1 Requirements. Methylaluminum dichloride is available from two manufacturers without specification requirements.

5.4.3.9.3 Use. Methylaluminum dichloride is used as a catalyst component for polymerization reactions, and as a methylating agent.

5.4.3.9.4 Safety. Methylaluminum dichloride is a pyrophoric solid that flames spontaneously and gives off dense smoke on exposure to air. It is reactive with water with the release of flammable and explosive vapors that can be ignited by the heat of reaction. Hydrocarbon solutions of methylaluminum dichloride may not be pyrophoric depending on concentration and temperature. The burning liquid can release irritating and toxic fumes and smoke. There is no PEL or TLV referenced for methylaluminum dichloride but the TLV, as Al, is 2 mg/m^3 for aluminum alkyls not otherwise classified. Inhalation of fumes from burning material shall be avoided. Methylaluminum dichloride produces severe burns, predominantly thermal, on contact with skin or eyes by reaction with body moisture, so contact shall be avoided. (Refer to 4.3.1)

5.4.3.9.5 Storage. Methylaluminum dichloride, solid or solution, shall be stored in special containers, blanketed with dry nitrogen under a slight positive pressure, in a cool dry place. (Refer to 4.3.2)

5.4.3.9.6 Disposal. Spills of methylaluminum dichloride will ignite spontaneously. Small spill fires can be controlled with dry powder extinguishers,

absorbed by nonreactive dry powders and placed in sealed containers. In case of large liquid solution spills, the burning liquid shall be isolated by use of sandbags to prevent spreading. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

Methylaluminum dichloride has an EPA Hazardous Waste Classification - Ignitable, Waste No. D001; and Reactive, Waste No. D003.

5.4.3.10 Name. Methylaluminum Sesquichloride

$\text{Al}_2(\text{CH}_3)_3\text{Cl}_3$ or $(\text{CH}_3)_2\text{AlCl} \cdot \text{Cl}_2\text{AlCH}_3$ FW 205.43

Aluminum methyl sesquichloride
Trimethyldialuminum trichloride

5.4.3.10.1 Technical description. Methylaluminum sesquichloride is a colorless liquid above its freezing point with a density of 1.163 g/cm³ at 25°C. It has a freezing point of 22.8°C and an extrapolated boiling point of 143.7°C at 760 mm Hg. It is miscible with most liquid hydrocarbons. It is decomposed by water, and is reactive with polar compounds including halogenated compounds. The theoretical composition is 26.3% Al and 51.9% Cl, and the compound is a 1:1 complex of methylaluminum dichloride and dimethylaluminum chloride.

5.4.3.10.2 Specification. Manufacturer's requirements. (No Government specification)

5.4.3.10.2.1 Requirements. Methylaluminum sesquichloride is available from two manufacturers with the requirements and typical analyses shown in Table LVI and LVII.

TABLE LVI. Methylaluminum sesquichloride - commercial analysis range.

| | Theoretical | Analysis Range |
|----------------|-------------|----------------|
| Aluminum, wt % | 26.3 | 25.5 to 27.1 |
| Chlorine, wt % | 51.9 | 48.0 to 52.0 |

TABLE LVII. Methylaluminum sesquichloride - requirements and typical analysis.

| | Requirement | Analysis |
|-----------------------------------|--------------|----------|
| Product composition, wt % | | |
| Aluminum | 24.8 to 26.4 | 25.8 |
| Chloride | 49.5 to 52.5 | 51.5 |
| Hydrolysis gas composition, mol % | | |
| Methane | 98.0 min | 99.4 |
| Ethane | 2.0 max | 0.4 |
| Propane | 0.3 max | 0.1 |
| Isobutane | 0.5 max | 0.1 |
| n-Butane | 0.3 max | 0.0 |
| Hydrogen | 0.3 max | 0.0 |

5.4.3.10.3 Use. Methylaluminum sesquichloride is used as a catalyst for polymerization of olefins and for hydrogenation of aromatics.

DOD-STD-1445

5.4.3.10.4 Safety. Methylaluminum sesquichloride, above 23°C, is a pyrophoric liquid that flames spontaneously and gives off dense smoke on exposure to air. It is reactive with water with the release of flammable and explosive vapors that can be ignited by the heat of reaction. Hydrocarbon solutions of methylaluminum sesquichloride may not be pyrophoric depending on concentration and temperature. The burning liquid can release irritating and toxic fumes and smoke. There is no PEL or TLV referenced for methylaluminum sesquichloride but the TLV, as Al, is 2 mg/m³ for aluminum alkyls not otherwise classified. Inhalation of fumes from burning liquid shall be avoided. Methylaluminum sesquichloride produces severe burns, predominantly thermal, on contact with skin or eyes by reaction with body moisture, so contact shall be avoided. (Refer to 4.3.1)

5.4.3.10.5 Storage. Methylaluminum sesquichloride shall be stored in special containers, blanketed with dry nitrogen under a slight positive pressure, in a cool dry place. (Refer to 4.3.2)

5.4.3.10.6 Disposal. Spills of methylaluminum sesquichloride will ignite spontaneously. Small spill fires can be controlled with dry powder extinguishers, absorbed by nonreactive dry powders and placed in sealed containers. In case of large liquid solution spills, the burning liquid shall be isolated by use of sandbags to prevent spreading. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

Methylaluminum sesquichloride has an EPA Hazardous Waste Classification - Ignitable, Waste No. D001; and Reactive, Waste No. D003.

5.4.4 Aluminum Alkyl Hydrides

5.4.4.1 Name. Diisobutylaluminum Hydride AlH[CH₂CH(CH₃)₂]₂ FW 142.22
Aluminum diisobutylhydride

5.4.4.1.1 Technical description. Diisobutylaluminum hydride is a colorless liquid with a density of 0.799 g/cm³ at 25°C. It has a freezing point of -80°C and a boiling point of 275°C at 760 mm Hg. As a dialkylaluminum hydride, it is trimerically associated. Diisobutylaluminum hydride is miscible with liquid hydrocarbons. It is decomposed by water and is reactive with polar compounds including halogenated hydrocarbons. The theoretical aluminum content is 19.0%.

5.4.4.1.2 Specification. Manufacturer's requirements. (No Government specification)

5.4.4.1.2.1 Requirements. Diisobutylaluminum hydride is available from two manufacturers with the requirements and typical analyses shown in Table LVIII and LIX.

TABLE LVIII. Diisobutylaluminum hydride - commercial specification requirements.

| | Percent by weight | |
|---|-------------------|------------------|
| | Requirement | Typical Analysis |
| Aluminum, as Al | 18.5 min | 18.9 |
| Triisobutylaluminum | 5.5 max | 3.0 |
| Purity, as AlH(1-C ₄ H ₉) ₂ | 93.0 min | 97 |

DOD-STD-1445

TABLE LIX. Diisobutylaluminum hydride - commercial specification requirements.

| | Percent by weight | |
|----------------------------|-------------------|------------------|
| | Requirement | Typical Analysis |
| Diisobutylaluminum hydride | 93.0 min | 95.0 |
| Triisobutylaluminum | 5.5 max | 3.5 |
| Tri-n-butylaluminum | 0.6 max | 0.4 |
| Tri-n-propylaluminum | 1.5 max | 0.8 |
| Triethylaluminum | 0.5 max | Trace |
| Methane | 0.5 max | 0.3 |
| Aluminum | 18.5 min | 18.8 |

5.4.4.1.3 Use. Diisobutylaluminum hydride is used as a component of catalyst systems for olefin and diene polymerization, and as a reducing agent in organic reduction reactions.

5.4.4.1.4 Safety. Diisobutylaluminum hydride is a pyrophoric liquid that flames spontaneously and gives off dense smoke on exposure to air. It is reactive with water with the release of flammable and explosive vapors that can be ignited by the heat of reaction. Hydrocarbon solutions of diisobutylaluminum hydride may not be pyrophoric depending on concentration and temperature. The burning liquid can release irritating and toxic fumes and smoke. There is no PEL or TLV referenced for diisobutylaluminum hydride, but the TLV, as Al, is 2 mg/m³ for aluminum alkyls not otherwise classified. Inhalation of fumes from burning liquid shall be avoided. Diisobutylaluminum hydride produces severe burns, predominantly thermal, on contact with skin or eyes by reaction with body moisture, so contact shall be avoided. (Refer to 4.3.1)

5.4.4.1.5 Storage. Diisobutylaluminum hydride shall be stored in special containers, blanketed with dry nitrogen under a slight positive pressure, in a cool dry place. (Refer to 4.3.2)

5.4.4.1.6 Disposal. Liquid spills of diisobutylaluminum hydride will ignite spontaneously. Small liquid spill fires can be controlled with dry powder extinguishers, absorbed by nonreactive dry powders and placed in sealed containers. In case of large liquid spills, the burning liquid shall be isolated by use of sandbags to prevent spreading. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

Diisobutylaluminum hydride has an EPA Hazardous Waste Classification - Ignitable, Waste No. D001; and Reactive, Waste No. D003.

5.4.4.2 Name. Sodium Aluminum Diethyl Dihydride NaAl(C₂H₅)₂H₂ FW 110.11
Sodium diethyldihydroaluminum
Sodium diethyldihydroaluminate

5.4.4.2.1 Technical description. Sodium aluminum diethyl dihydride is a solid. It is soluble in aromatic hydrocarbons and ethers. It is insoluble in paraffinic hydrocarbons. It is decomposed by water and is reactive with active hydrogen or hydroxylated solvents. It does not attack halogenated compounds unless they are activated or exposed at elevated temperatures for prolonged time periods.

DOD -STD-1445

5.4.4.2.2 Specification. Manufacturer's requirements. (No Government specification)

5.4.4.2.2.1 Requirements. Sodium aluminum diethyl dihydride is available from a manufacturer as a 25 wt percent solution in toluene containing 4 wt percent tetrahydrofuran, with the typical analysis shown in Table LX.

TABLE LX. Sodium aluminum diethyl dihydride solution - typical analysis.

| | |
|-------------------------------------|-------|
| Al, wt % | 5.9 |
| Active hydride, meqs/g soln | 4.4 |
| Total gas evolution, mmols/g soln | 8.8 |
| Density, at 20°C, g/cm ³ | 0.879 |
| Viscosity at 20°C, cp | 2.08 |

5.4.4.2.3 Use. Sodium aluminum diethyl dihydride is used as a reducing agent for a variety of functional groups requiring an active hydrogen reducing agent, such as ketones, aldehydes, acids, esters, amides, nitriles, and nitro compounds.

5.4.4.2.4 Safety. Sodium aluminum diethyl dihydride solutions, containing concentrations of over 10 wt percent, are pyrophoric and flame spontaneously on exposure to air, giving off dense smoke. It is explosively reactive with water with the release of flammable and explosive vapors that can be ignited by the heat of reaction. The burning liquid can release irritating and toxic fumes and smoke. There is no PEL or TLV referenced for sodium aluminum diethyl dihydride, but the TLV, as Al, is 2 mg/m³ for aluminum alkyls not otherwise classified. Inhalation of fumes from burning liquid solution shall be avoided. Sodium aluminum diethyl dihydride solution produces severe burns, predominantly thermal, on contact with skin or eyes by reaction with body moisture, so contact shall be avoided. (Refer to 4.3.1)

5.4.4.2.5 Storage. Sodium aluminum diethyl dihydride solution shall be stored in special containers, blanketed with dry nitrogen under a slight positive pressure, in a cool dry place. (Refer to 4.3.2)

5.4.4.2.6 Disposal. Spills of sodium aluminum diethyl dihydride solutions will ignite spontaneously. Small liquid spill fires can be controlled with dry powder extinguishers, absorbed by nonreactive dry powders and placed in sealed containers for disposal. In case of large liquid spills, the burning liquid shall be isolated by use of sandbags to prevent spreading. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

Sodium aluminum diethyl dihydride has an EPA Hazardous Waste Classification - Ignitable, Waste No. D001; and Reactive, Waste No. D003.

5.4.5 Magnesium Alkyl

5.4.5.1 Name. Di-n-Hexylmagnesium $Mg[CH_2(CH_2)_4CH_3]_2$ FW 194.65
Magnesium di-n-hexyl

5.4.5.1.1 Technical description. Di-n-hexylmagnesium is a light green or yellow solid. It is soluble in liquid hydrocarbons. It is decomposed by

DOD-STD-1445

water, and is reactive with compounds containing active hydrogen. It reacts with oxygen to form the alkoxide. It complexes with ethers and tertiary amines.

5.4.5.1.2 Specification. Manufacturer's requirements. (No Government specification)

5.4.5.1.2.1 Requirements. Di-n-hexylmagnesium is available from a manufacturer with the typical analysis shown in Table LXI.

TABLE LXI. Di-n-hexylmagnesium solution - typical analysis.

| | |
|---|----------|
| (C ₆ H ₁₃) ₂ Mg, wt % | 15 to 20 |
| Al, wt % of contained Mg | 4 |
| Cl, wt % of contained Mg | 7 |

5.4.5.1.3 Use. Di-n-hexylmagnesium is used as a component of catalyst systems for olefin and diene polymerization, and as an alkylating agent.

5.4.5.1.4 Safety. Di-n-hexylmagnesium solution is not pyrophoric. Its flash point is dependent on the hydrocarbon solvent, and it is either flammable, combustible or burnable. It is reactive with water with the release of flammable and explosive vapors that can be ignited by the heat of reaction. The burning liquid can release irritating and toxic fumes and smoke. There is no PEL or TLV referenced for di-n-hexylmagnesium but the PEL for magnesium oxide fumes is 15 mg/m³ and the TLV is 10 mg/m³, so inhalation of fumes from burning liquid shall be avoided. Di-n-hexylmagnesium produces severe burns, predominantly thermal, on contact with skin or eyes by reaction with body moisture, so contact shall be avoided. (Refer to 4.3.1)

5.4.5.1.5 Storage. Di-n-hexylmagnesium shall be stored in special containers, blanketed with dry nitrogen under a slight positive pressure, in a cool dry place. (Refer to 4.3.2)

5.4.5.1.6 Disposal. Spills of di-n-hexylmagnesium solution will not ignite spontaneously, and ignition shall be avoided. Small spills can be absorbed by nonreactive dry powders and placed in sealed containers for disposal. Large liquid spills shall be diked to prevent spreading. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

Di-n-hexylmagnesium has an EPA Hazardous Waste Classification - Ignitable, Waste No. D001; and Reactive, Waste No. D003.

5.4.6 Metallocenes

5.4.6.1 Name. 2,2-Bis(Ethylferrocenyl) Propane
 $(CH_3)_2C(C_5H_4FeC_5H_4C_2H_5)_2$ FW 468.248

5.4.6.1.1 Technical description. 2,2-Bis(ethylferrocenyl) propane is in the form of a liquid at 25°C. It is miscible with liquid hydrocarbons. The theoretical iron content is 23.85 percent.

DOD-STD-1445

5.4.6.1.2 Specification. Military, MIL-C-85493, Catalyst, Burn-Rate 2,2-Bis(Ethylferrocenyl) Propane.

5.4.6.1.2.1 Requirements. This specification covers one type of 2,2-bis(ethylferrocenyl) propane with the chemical and physical properties conforming to the requirements shown in Table LXII.

TABLE LXII. 2,2-Bis(Ethylferrocenyl) Propane - chemical and physical requirements.

| | |
|--|-------|
| Viscosity (25°C), centistokes, (mm ² ·s), max | 2.200 |
| Iron content, %, min | 23.3 |
| max | 24.3 |
| Moisture, %, max | 0.10 |
| Acidity, milliequivalent/gram, max | 0.023 |
| Insolubility in chloroform, %, max | 0.1 |
| Evaporation loss (80°C, 15 mm Hg, 22 hrs), %, max | 4.0 |
| Assay (by titration), %, min | 97.5 |

5.4.6.1.3 Use. 2,2-Bis(ethylferrocenyl) propane is intended for military use as a burn-rate catalyst in solid rocket propellants.

5.4.6.1.4 Safety. 2,2-Bis(ethylferrocenyl) propane is a burnable liquid, and can emit irritating and toxic fumes if heated to decomposition. There is no PEL or TLV referenced for this compound; but the TLV for the parent compound, dicyclopentadienyl iron, is 10 mg/m³, so breathing of fumes shall be avoided. It can be irritating to the eyes, skin and mucous membranes, so contact shall be avoided. (Refer to 4.3.1)

5.4.6.1.5 Storage. 2,2-Bis(ethylferrocenyl) propane shall be stored in approved tightly sealed containers in a cool dry place. (Refer to 4.3.2)

5.4.6.1.6 Disposal. In case of small liquid spills, absorb with nonre-active absorbent and place in containers for disposal. In case of large liquid spills, dike to prevent spreading. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

An EPA Hazardous Waste Classification is not listed in 40 CFR.

5.4.6.2 Name. Ferrocene C5H5FeC5H5 FW 186.04
Dicyclopentadienyliron

5.4.6.2.1 Technical description. Ferrocene is in the form of monoclinic crystalline yellow-orange needles with a melting point of 172.5 to 173°C. It is insoluble in water. It is soluble in methyl and ethyl alcohols, ether and benzene. The theoretical composition is 30.1% Fe, and the molecule is neutral. Ferrocene is a "sandwich"-bonded compound in which the C₅H₅⁻ anions are planar symmetrical pentagons in shape and are staggered in configuration relative to each other. The compound is thermally stable to about 500°C. It is reactive with oxidizing agents.

DOD-STD-1445

5.4.6.2.2 Specification. Manufacturer's requirements. (No Government specification)

5.4.6.2.2.1 Requirements. Ferrocene is available from a manufacturer with the requirements shown in Table LXIII.

TABLE LXIII. Ferrocene (dicyclopentadienyliron) - commercial requirements.

| | |
|---------------------------|-------------------|
| Appearance | Orange |
| Color | Crystalline solid |
| Form | 173 to 174 |
| Melting point, °C | 249 |
| Boiling point, °C | 29 to 30 |
| Iron content, as Fe, | 0.2 |
| Toluene insolubles, % max | |

5.4.6.2.3 Use. Ferrocene is intended for military use, in the form of a 10% by weight solution in xylene, as a smoke abatement additive for fuel oils. Ferrocene is also used as an intermediate for the preparation of high temperature polymers, and in the preparation of metallocenes.

5.4.6.2.4 Safety. Ferrocene is a burnable solid that emits irritating and toxic fumes if heated to decomposition. The TLV for dicyclopentadienyliron is 10 mg/m³, so breathing of dust and fumes shall be avoided. Ferrocene can be irritating to the eyes, skin and mucous membranes, so contact shall be avoided. (Refer to 4.3.1)

5.4.6.2.5 Storage. Ferrocene shall be stored in tightly sealed containers in a cool dry place. (Refer to 4.3.2)

5.4.6.2.6 Disposal. In case of dry spills, gather up and place in containers. In case of small solution spills, absorb with nonreactive absorbents and place in containers for disposal. In case of large solution spills, dike to prevent spreading. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

An EPA Hazardous Waste Classification is not listed in 40 CFR.

5.4.6.3 Name. Methylcyclopentadienylmanganese Tricarbonyl
 $\text{CH}_3\text{C}_5\text{H}_4\text{Mn}(\text{CO})_3$ FW 218.095

5.4.6.3.1 Technical description. Methylcyclopentadienylmanganese tricarbonyl is a liquid with a density of 1.3884 g/cm³ at 20°C, a freezing point of about 1°C and a boiling point of 233°C. It is miscible with liquid hydrocarbons. It is stable in the presence of air and water. The theoretical Mn content is 25.2 percent.

5.4.6.3.2 Specification. Manufacturer's requirements. (No Government specification)

5.4.6.3.2.1 Requirements. Methylcyclopentadienylmanganese tricarbonyl is available from a manufacturer as a clear straw colored liquid. The product shall have a minimum Mn content of 24.7 wt percent.

DOD-STD-1445

5.4.6.3.3 Use. Methylcyclopentadienylmanganese tricarbonyl is intended for military use as an additive for fuel oils to improve combustion efficiency. It is also used as an additive for unleaded gasoline.

5.4.6.3.4 Safety. Methylcyclopentadienylmanganese tricarbonyl is a burnable liquid, and can emit irritating and toxic fumes if heated to decomposition. The compound is toxic by inhalation and skin absorption. The TLV is 0.2 mg/m^3 including skin. Contact with eyes, skin and clothing shall be avoided. (Refer to 4.3.1)

5.4.6.3.5 Storage. Methylcyclopentadienylmanganese tricarbonyl shall be stored in approved tightly sealed containers in a cool dry place. (Refer to 4.3.2)

5.4.6.3.6 Disposal. In case of small liquid spills, absorb with nonreactive absorbent and place in containers for disposal. In case of large liquid spills, dike to prevent spreading. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

An EPA Hazardous Waste Classification is not listed in 40 CFR.

5.4.7 Zinc Alkyl

5.4.7.1 Name. Diethylzinc $\text{Zn}(\text{C}_2\text{H}_5)_2$ FW 123.49
Zinc diethyl

5.4.7.1.1 Technical description. Diethylzinc is a colorless liquid with a density of 1.182 g/cm^3 at 18°C . It has a freezing point of -28°C and a boiling point of 124°C at 760 mm Hg. It is miscible with liquid hydrocarbons. It is decomposed by water, and is reactive with polar compounds including halogenated hydrocarbons.

5.4.7.1.2 Specification. Manufacturer's requirements. (No Government specification)

5.4.7.1.2.1 Requirements. Diethylzinc is available from a manufacturer with a minimum purity of 95 percent.

5.4.7.1.3 Use. Diethylzinc is used as a component of catalyst systems for polymerization, and also as an alkylation agent and reducing agent.

5.4.7.1.4 Safety. Diethylzinc is a pyrophoric liquid that flames spontaneously and gives off dense smoke on exposure to air. It decomposes on heating above 200°C . It is reactive with water with the release of flammable and explosive vapors that can be ignited by the heat of reaction. Hydrocarbon solutions of diethylzinc may not be pyrophoric depending on concentration and temperature. The burning liquid can release irritating and toxic fumes and smoke. There is no PEL or TLV referenced for diethylzinc but the PEL and TLV for zinc oxide fumes is 5 mg/m^3 , so inhalation of fumes from burning liquid shall be avoided. Diethylzinc produces severe chemical and thermal burns on contact with skin or eyes by reaction with body moisture, so contact shall be avoided. (Refer to 4.3.1)

DOD-STD-1445

5.4.7.1.5 Storage. Diethylzinc shall be stored in special containers, blanketed with dry nitrogen under a slight positive pressure, in a cool dry place. (Refer to 4.3.2)

5.4.7.1.6 Disposal. Liquid spills of diethylzinc will ignite spontaneously. Small liquid spill fires can be controlled with dry powder extinguishers, absorbed by nonreactive dry powders and placed in sealed containers. In case of large liquid spills, the burning liquid shall be isolated by use of sandbags to prevent spreading. For appropriate procedures, contact the Installation Environmental Office, the DRMO, or Safety and Health Offices. (Refer to 4.4)

Diethylzinc has an EPA Hazardous Waste Classification - Ignitable, Waste No. D001; and Reactive, Waste No. D003.

DOD-STD-1445

6. NOTES

6.1 Abbreviations. The use of abbreviations in this military standard are in accordance with MIL-STD-12 where applicable. Metric system abbreviations and symbols are in accordance with ASTM E 380.

6.2 Subject term (key word) listing.

Aluminum acetylacetonate
 Aluminum alkoxides
 Aluminum alkyl alkoxide
 Aluminum alkyl halides
 Aluminum alkyl hydrides
 Aluminum alkyls
 Aluminum butoxide (n-, sec-, tert-)
 Aluminum ethoxide
 Aluminum isopropoxide
 Aluminum stearate
 Antimony alkoxides
 Antimony butoxide (n-)
 Antimony ethoxide
 Antimony methoxide
 Barium oxalate
 Barium stearate
 2,2-Bis(ethylferrocenyl) propane
 Boron alkoxides
 Boron butoxide (n-)
 Boron ethoxide
 Boron methoxide
 Boron octoxide (n-)
 Boron propoxide (n-)
 Calcium oxalate
 Calcium resinate
 Calcium stearate
 Catalyst, burn-rate
 Chelate ligands
 Chromic acetylacetonate
 Chromium 2-ethylhexanoate
 Cobaltic acetylacetonate
 Cobaltous acetylacetonate
 Copper acetylacetonate
 Copper naphthenate
 Copper 8-quinolinolate
 Dibutyl tin acetylacetonate
 Diethylaluminum chloride
 Diethylaluminum ethoxide
 Diethylaluminum iodide
 Diethylzinc
 Di-n-hexylmagnesium
 Diisobutylaluminum chloride
 Diisobutylaluminum hydride
 Dimethylaluminum chloride
 Disposal, hazardous chemicals
 Ethylaluminum dichloride
 Ethylaluminum sesquichloride

DOD-STD-1445

Exposure limits, hazardous chemicals
 Ferric acetylacetonate
 Ferrocene
 Germanium alkoxides
 Germanium butoxide (n-)
 Germanium ethoxide
 Germanium isopropoxide
 Germanium methoxide
 Isobutylaluminum dichloride
 Isobutylaluminum sesquichloride
 Lead 2-ethylhexanoate
 Lead salicylate
 Lead stearate
 Lithium stearate
 Magnesium acetylacetonate
 Magnesium alkyl
 Magnesium stearate
 Manganic acetylacetonate
 Manganous acetylacetonate
 Metal alkoxides
 Metal alkyls
 Metal carboxylates
 Metal chelates
 Metallic soaps
 Metallocene
 Methylaluminum dichloride
 Methylaluminum sesquichloride
 Methylcyclopentadienylmanganese tricarbonyl
 Nickel acetylacetonate
 Organometallic compounds
 Ruthenium acetylacetonate
 Safety, hazardous chemicals
 Sodium acetate
 Sodium alkoxides
 Sodium aluminum diethyl dihydride
 Sodium butoxide (n-)
 Sodium ethoxide
 Sodium gluconate
 Sodium methoxide
 Sodium oxalate
 Sodium resinate
 Storage, hazardous chemicals
 Strontium oxalate
 Titanium alkoxides
 Titanium ammonium dihydroxy lactate
 Titanium butoxide (n-)
 Titanium diisopropoxide acetylacetonate
 Titanium diisopropoxide bis(triethanolamine)
 Titanium diisopropoxide ethylacetoacetate
 Titanium ethoxide
 Titanium 2-ethylhexoxide
 Titanium isobutoxide
 Titanium isopropoxide
 Titanium methoxide
 Titanium potassium oxalate

DOD-STD-1445

Tri-n-butylaluminum
Triethylaluminum
Tri-n-hexylaluminum
Triisobutylaluminum
Trimethylaluminum
Tri-n-propylaluminum
Vanadyl acetylacetonate
Zinc acetylacetonate
Zinc alkyl
Zinc 8-quinolinolate
Zinc stearate
Zirconium acetylacetonate
Zirconium alkoxides
Zirconium butoxide (n-)
Zirconium ethoxide
Zirconium isopropoxide
Zirconium n-propoxide

DOD-STD-1445

INDEX

| | <u>Paragraph</u> | <u>Page</u> |
|--|------------------|-------------|
| Abbreviations | 6.1 | 87 |
| Aluminum acetylacetonate | 5.3.1 | 42 |
| Aluminum alkoxides | 5.1.1 | 11 |
| Aluminum alkyl alkoxide | 5.4.2 | 67 |
| Aluminum alkyl halides | 5.4.3 | 68 |
| Aluminum alkyl hydrides | 5.4.4 | 79 |
| Aluminum alkyls | 5.4.1 | 61 |
| Aluminum n-butoxide | 5.1.1.1 | 11 |
| Aluminum sec-butoxide | 5.1.1.2 | 11 |
| Aluminum tert-butoxide | 5.1.1.3 | 12 |
| Aluminum ethoxide | 5.1.1.4 | 12 |
| Aluminum isopropoxide | 5.1.1.5 | 12 |
| Aluminum stearate | 5.2.1 | 25 |
| Antimony alkoxides | 5.1.2. | 13 |
| Antimony n-butoxide | 5.1.2.1 | 13 |
| Antimony ethoxide | 5.1.2.2 | 13 |
| Antimony methoxide | 5.1.2.3 | 14 |
| Application | 1.2 | 1 |
| Barium oxalate | 5.3.2 | 43 |
| Barium oxalate - chemical and physical requirements. . . . | TABLE XXVI | 43 |
| Barium stearate | 5.2.2 | 26 |
| Barium stearate - chemical and physical requirements. . . | TABLE X | 26 |
| 2,2-Bis(ethylferrocenyl) propane | 5.4.6.1 | 82 |
| 2,2-Bis(ethylferrocenyl) propane - chemical and physical requirements | TABLE LXII | 83 |
| Boron alkoxides | 5.1.3. | 14 |
| Boron n-butoxide | 5.1.3.1 | 14 |
| Boron ethoxide | 5.1.3.2 | 15 |
| Boron methoxide | 5.1.3.3 | 15 |
| Boron n-octoxide | 5.1.3.4 | 15 |
| Boron n-propoxide | 5.1.3.5 | 16 |
| Calcium oxalate | 5.3.3 | 44 |
| Calcium oxalate - chemical and physical requirements. . . | TABLE XXVII | 44 |
| Calcium resinate | 5.2.3 | 27 |
| Calcium resinate - chemical and physical requirements. . . | TABLE XI | 27 |
| Calcium stearate | 5.2.4 | 28 |
| Calcium stearate - chemical and physical requirements. . . | TABLE XII | 28 |
| Chemical hazardous exposure limits | 4.3.3 | 8 |
| Chromic acetylacetonate | 5.3.4 | 45 |
| Chromium 2-ethylhexanoate | 5.2.5 | 29 |
| Chromium 2-ethylhexoate-chemical and physical requirements | TABLE XIII | 29 |
| Cleanup of liquid spills | 4.4.3.1 | 9 |
| Cobaltic acetylacetonate | 5.3.5 | 46 |
| Cobaltous acetylacetonate | 5.3.6 | 46 |
| Copper acetylacetonate | 5.3.7 | 47 |
| Copper naphthenate | 5.2.6 | 30 |
| Copper 8-quinolinolate | 5.3.8 | 48 |
| Copper 8-quinolinolate - commercial specification require- ments | TABLE XXVIII | 48 |
| Definitions | 3. | 5 |
| Detailed requirements | 5. | 11 |
| Dibutyl tin acetylacetonate | 5.3.16 | 54 |
| Diethylaluminum chloride | 5.4.3.1 | 68 |

DOD-STD-1445

INDEX (Continued)

| | <u>Paragraph</u> | <u>Page</u> |
|---|------------------|-------------|
| Diethylaluminum chloride - commercial specification requirements. | TABLE XLV | 68 |
| Diethylaluminum chloride - requirements and typical analysis. | TABLE XLVI | 68 |
| Diethylaluminum ethoxide | 5.4.2.1 | 67 |
| Diethylaluminum ethoxide - commercial specification requirements. | TABLE XLIII | 67 |
| Diethylaluminum ethoxide - commercial specification requirements. | TABLE XLIV | 67 |
| Diethylaluminum iodide | 5.4.3.2 | 69 |
| Diethylaluminum iodide - requirements and typical analysis | TABLE XLVII | 69 |
| Diethylzinc | 5.4.7.1 | 85 |
| Di-n-hexylmagnesium | 5.4.5.1 | 81 |
| Di-n-hexylmagnesium solution - typical analysis. | TABLE LXI | 82 |
| Diisobutylaluminum chloride | 5.4.3.3 | 70 |
| Diisobutylaluminum chloride - requirements and typical analysis. | TABLE XLIX | 71 |
| Diisobutylaluminum chloride - requirements and typical analysis. | TABLE XLVIII | 70 |
| Diisobutylaluminum hydride | 5.4.4.1 | 79 |
| Diisobutylaluminum hydride - commercial specification requirements. | TABLE LIX | 80 |
| Diisobutylaluminum hydride - commercial specification requirements. | TABLE LVIII | 79 |
| Dimethylaluminum chloride | 5.4.3.4 | 71 |
| Disclaimer | 4.4.4 | 10 |
| Disposal and storage of hazardous wastes | 4.4.3 | 9 |
| Disposal for aluminum alkoxides. | 5.1.1.9 | 13 |
| Disposal for aluminum alkyls | 5.4.1.9 | 66 |
| Disposal for antimony alkoxides. | 5.1.2.7 | 14 |
| Disposal for boron alkoxides | 5.1.3.9 | 16 |
| Disposal for germanium alkoxides | 5.1.4.8 | 17 |
| Disposal for sodium alkoxides. | 5.1.5.7 | 20 |
| Disposal for titanium alkoxides | 5.1.6.10 | 23 |
| Disposal for zirconium alkoxides | 5.1.7.8 | 24 |
| Disposal of excess or unserviceable material | 4.4.2 | 8 |
| EPA Acute Hazardous Toxicity (H) | 4.3.4.2 | 8 |
| EPA Toxic (T) | 4.3.4.1 | 8 |
| Ethylaluminum dichloride | 5.4.3.5 | 72 |
| Ethylaluminum dichloride - commercial analysis range. . . | TABLE L | 73 |
| Ethylaluminum dichloride - requirements and typical analysis. | TABLE LI | 73 |
| Ethylaluminum sesquichloride | 5.4.3.6 | 73 |
| Ethylaluminum sesquichloride - commercial analysis range . | TABLE LII | 74 |
| Ethylaluminum sesquichloride - requirements and typical analysis. | TABLE LIII | 74 |
| Exercises | 4.3.1.5 | 7 |
| Face and eye protection | 4.3.1.3 | 6 |
| Ferric acetylacetonate | 5.3.9 | 49 |
| Ferrocene | 5.4.6.1 | 83 |

DOD-STD-1445

INDEX (Continued)

| | <u>Paragraph</u> | <u>Page</u> |
|--|------------------|-------------|
| Ferrocene (dicyclopentadienyliron) - commercial requirements | TABLE LXIII | 84 |
| Flammable, combustible, pyrophoric and ignitable materials | 4.3.2.1 | 7 |
| General Requirements | 4. | 6 |
| Germanium alkoxides | 5.1.4. | 16 |
| Germanium n-butoxide | 5.1.4.1 | 16 |
| Germanium ethoxide | 5.1.4.2 | 17 |
| Germanium isopropoxide | 5.1.4.3 | 17 |
| Germanium methoxide | 5.1.4.4 | 17 |
| Government documents | 2.1 | 2 |
| Hazardous materials information | 4.2 | 6 |
| Hazardous toxic constituents | 4.3.4.3 | 8 |
| Incompatible materials | 4.3.2.3 | 7 |
| Isobutylaluminum dichloride | 5.4.3.7 | 75 |
| Isobutylaluminum dichloride - commercial analysis range. . | TABLE LIV | 75 |
| Isobutylaluminum sesquichloride | 5.4.3.8 | 76 |
| Isobutylaluminum sesquichloride - requirements and typical analysis. | TABLE LV | 76 |
| Lead 2-ethylhexanoate | 5.2.7 | 31 |
| Lead 2-ethylhexoate - chemical and physical requirements . | TABLE XIV | 31 |
| Lead salicylate | 5.2.8 | 32 |
| Lead salicylate - chemical and physical requirements (MIL-L-13788). | TABLE XV | 32 |
| Lead salicylate - chemical and physical requirements (MIL-L-17700). | TABLE XVI | 33 |
| Lead stearate | 5.2.9 | 33 |
| Lead stearate - chemical and physical requirements. . . . | TABLE XVII | 34 |
| Lithium stearate | 5.2.10 | 34 |
| Lithium stearate - chemical and physical requirements. . . | TABLE XVIII | 35 |
| Magnesium acetylacetonate | 5.3.10 | 49 |
| Magnesium alkyl | 5.4.5 | 81 |
| Magnesium stearate | 5.2.11 | 36 |
| Magnesium stearate - chemical and physical requirements. . | TABLE XIX | 36 |
| Manganic acetylacetonate | 5.3.11 | 50 |
| Manganous acetylacetonate | 5.3.12 | 51 |
| Metal alkoxides | 5.1 | 11 |
| Metal carboxylates | 5.2 | 24 |
| Metal chelates | 5.3 | 41 |
| Metallocenes | 5.4.6 | 82 |
| Methylaluminum dichloride | 5.4.3.9 | 77 |
| Methylaluminum sesquichloride | 5.4.3.10 | 78 |
| Methylaluminum sesquichloride - commercial analysis range. | TABLE LVI | 78 |
| Methylaluminum sesquichloride - requirements and typical analysis. | TABLE LVII | 78 |
| Methylcyclopentadienylmanganese tricarbonyl | 5.4.6.2 | 84 |
| Nickel acetylacetonate | 5.3.13 | 51 |
| Notes | 6. | 87 |
| Order of precedence | 2.3 | 4 |
| Organometallic compounds | 5.4 | 61 |
| Other Government documents, drawings, and publications . . | 2.1.2 | 2 |

DOD-STD-1445

INDEX (Continued)

| | <u>Paragraph</u> | <u>Page</u> |
|---|------------------|-------------|
| Other publications | 2.2 | 3 |
| Packaging data and labeling | 4.1 | 6 |
| Personal protective measures | 4.3.1 | 6 |
| Pollution and disposal | 4.4 | 8 |
| Pollution potential | 4.4.1 | 8 |
| Polydentate chelate ligands. | TABLE XXV | 41 |
| Purpose | 1.1 | 1 |
| Referenced documents | 2. | 2 |
| Respiratory protection | 4.3.1.1 | 6 |
| Ruthenium acetylacetonate | 5.3.14 | 52 |
| Safety | 4.3 | 6 |
| Safety for aluminum alkoxides | 5.1.1.7 | 13 |
| Safety for aluminum alkyls | 5.4.1.7 | 66 |
| Safety for antimony alkoxides | 5.1.2.5 | 14 |
| Safety for boron alkoxides | 5.1.3.7 | 16 |
| Safety for germanium alkoxides | 5.1.4.6 | 17 |
| Safety for sodium alkoxides | 5.1.5.5 | 20 |
| Safety for titanium alkoxides | 5.1.6.8 | 22 |
| Safety for zirconium alkoxides | 5.1.7.6 | 24 |
| Scope. | 1. | 1 |
| Skin protection | 4.3.1.2 | 6 |
| Sodium acetate, anhydrous. | 5.2.12 | 37 |
| Sodium acetate, anhydrous - specification requirements. | TABLE XX | 37 |
| Sodium alkoxides | 5.1.5. | 18 |
| Sodium aluminum diethyl dihydride | 5.4.4.2 | 80 |
| Sodium aluminum diethyl dihydride solution - typical analysis. | TABLE LX | 81 |
| Sodium n-butoxide | 5.1.5.1 | 18 |
| Sodium n-butoxide solution in butanol-physical properties. | TABLE I | 18 |
| Sodium n-butoxide solution in butanol - typical chemical analysis. | TABLE II | 18 |
| Sodium ethoxide | 5.1.5.2 | 18 |
| Sodium ethoxide, anhydrous - requirements and properties | TABLE III | 18 |
| Sodium ethoxide solution in ethanol - physical properties. | TABLE IV | 19 |
| Sodium ethoxide solution in ethanol - typical chemical analysis. | TABLE V | 19 |
| Sodium gluconate | 5.2.13 | 38 |
| Sodium gluconate - chemical and physical requirements. | TABLE XXI | 38 |
| Sodium methoxide | 5.1.5.3 | 19 |
| Sodium methoxide, anhydrous - chemical and physical requirements. | TABLE VI | 19 |
| Sodium methoxide solution in methanol - physical properties | TABLE VII | 19 |
| Sodium methoxide solution in methanol - requirements. | TABLE IX | 20 |
| Sodium methoxide solution in methanol - requirements and typical chemical analysis. | TABLE VIII | 20 |
| Sodium oxalate | 5.2.14 | 38 |
| Sodium oxalate, technical - chemical requirements. | TABLE XXII | 39 |
| Sodium oxalate, technical - granulation requirements. | TABLE XXIII | 39 |
| Sodium resinate | 5.2.15 | 39 |
| Sodium resinate - chemical and physical requirements. | TABLE XXIV | 40 |

DOD-STD-1445

INDEX (Continued)

| | <u>Paragraph</u> | <u>Page</u> |
|---|------------------|-------------|
| Specifications, standards, and handbooks | 2.1.1 | 2 |
| Storage conditions | 4.3.2 | 7 |
| Storage for aluminum alkoxides | 5.1.1.8 | 13 |
| Storage for aluminum alkyls. | 5.4.1.8 | 66 |
| Storage for antimony alkoxides | 5.1.2.6 | 14 |
| Storage for boron alkoxides | 5.1.3.8 | 16 |
| Storage for germanium alkoxides. | 5.1.4.7 | 17 |
| Storage for sodium alkoxides | 5.1.5.6 | 20 |
| Storage for titanium alkoxides | 5.1.6.9 | 23 |
| Storage for zirconium alkoxides | 5.1.7.7 | 24 |
| Strontium oxalate | 5.3.15 | 53 |
| Strontium oxalate - chemical and physical requirements. . | TABLE XXIX | 53 |
| Subject term (key word) listing | 6.2 | 87 |
| TEA - chemical requirements. | TABLE XXXIII | 63 |
| Titanium alkoxides | 5.1.6. | 21 |
| Titanium ammonium dihydroxy lactate | 5.3.17 | 54 |
| Titanium n-butoxide | 5.1.6.1 | 21 |
| Titanium diisopropoxide acetylacetonate | 5.3.18 | 55 |
| Titanium diisopropoxide bis(triethanolamine) | 5.3.19 | 56 |
| Titanium diisopropoxide ethylacetoacetate | 5.3.20 | 57 |
| Titanium ethoxide | 5.1.6.2 | 21 |
| Titanium 2-ethylhexoxide | 5.1.6.3 | 21 |
| Titanium isobutoxide | 5.1.6.4 | 22 |
| Titanium isopropoxide | 5.1.6.5 | 22 |
| Titanium methoxide | 5.1.6.6 | 22 |
| Titanium potassium oxalate, dihydrate | 5.3.21 | 58 |
| Toxicity | 4.3.4 | 8 |
| Training | 4.3.1.4 | 6 |
| Tri-n-butylaluminum | 5.4.1.1 | 61 |
| Tri-n-butylaluminum-commercial specification requirements. | TABLE XXXI | 62 |
| Tri-n-butylaluminum-commercial specification requirements. | TABLE XXXII | 62 |
| Triethylaluminum | 5.4.1.2 | 62 |
| Triethylaluminum - commercial specification requirements . | TABLE XXXIV | 63 |
| Triethylaluminum - commercial specification requirements . | TABLE XXXV | 63 |
| Tri-n-hexylaluminum | 5.4.1.4 | 64 |
| Tri-n-hexylaluminum-commercial specification requirements. | TABLE XXXVIII | 64 |
| Trisobutylaluminum | 5.4.1.3 | 63 |
| Trisobutylaluminum - commercial specification requirements. . | TABLE XXXVI | 64 |
| Trisobutylaluminum-commercial specification requirements. | TABLE XXXVII | 64 |
| Trimethylaluminum | 5.4.1.5 | 65 |
| Trimethylaluminum - commercial specification requirements. | TABLE XL | 65 |
| Trimethylaluminum - commercial specification requirements. | TABLE XXXIX | 65 |
| Tri-n-propylaluminum | 5.4.1.6 | 65 |
| Tri-n-propylaluminum-commercial specification requirements | TABLE XLI | 66 |
| Tri-n-propylaluminum-commercial specification requirements | TABLE XLII | 66 |
| Ultimate disposal | 4.4.3.2 | 10 |
| Use for aluminum alkoxides | 5.1.1.6 | 12 |
| Use for antimony alkoxides | 5.1.2.4 | 14 |
| Use for boron alkoxides. | 5.1.3.6 | 16 |

DOD-STD-1445

INDEX (Continued)

| | <u>Paragraph</u> | <u>Page</u> |
|--|------------------|-------------|
| Use for germanium alkoxides | 5.1.4.5 | 17 |
| Use for sodium alkoxides | 5.1.5.4 | 20 |
| Use for titanium alkoxides | 5.1.6.7 | 22 |
| Use for zirconium alkoxides | 5.1.7.5 | 24 |
| Vanadyl acetylacetonate | 5.3.22 | 58 |
| Water-sensitive fire and explosive hazardous materials . . | 4.3.2.2 | 7 |
| Zinc acetylacetonate | 5.3.23 | 59 |
| Zinc alkyl | 5.4.7 | 85 |
| Zinc 8-quinolinolate | 5.3.24 | 60 |
| Zinc 8-quinolinolate - commercial chemical and physical requirements. | TABLE XXX | 60 |
| Zinc stearate | 5.2.16 | 40 |
| Zirconium acetylacetonate | 5.3.25 | 60 |
| Zirconium alkoxides | 5.1.7. | 23 |
| Zirconium <i>n</i> -butoxide | 5.1.7.1 | 23 |
| Zirconium ethoxide | 5.1.7.2 | 23 |
| Zirconium isopropoxide | 5.1.7.3 | 23 |
| Zirconium <i>n</i> -propoxide | 5.1.7.4 | 24 |

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