METRIC

MIL-STD-1427A
14 December 1988
SUPERSEDING
MIL-STD-1427
24 September 1969

MILITARY STANDARD

ACTIVATED DESICCANTS (METRIC)

AMSC N/A

FSC 6850

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FOREWORD

1. This military 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-SPT-S, 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.

3. 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.

MIL-STD-1427A

CONTENTS

MIL-STD-1427A

TABLES

1. SCOPE

1.1 Scope. This standard is a presentation of nomenclature, formulas, physical and chemical properties, specification requirements, military and typical commercial uses, safety information, storage information and disposal information for activated desiccants. This standard does not 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 activated desiccants for application by the Department of Defense.

1.2 Application. Activated desiccants have military use in static and dynamic dehumidification of air and other gases, liquids, refrigerants, and in packaging of materials for protection from the deleterious effects of moisture. Commercial applications include the above, and also the purification of gases and liquids, the separation of compounds in gaseous and liquid mixtures, and in protective coating formulations to prevent reactions with moisture that cause gas formation.

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation (see 6.2).

SPECIFICATIONS

FEDERAL

O-D-210 - Desiccant, Activated, Calcium Sulfate, Anhydrous
PPP-C-2020 - Chemicals, Liquid, Dry and Paste, Packaging of

MILITARY

MIL-P-116 - Preservation, Method of
MIL-D-3263 - Desiccant Containers, Dehumidifier
MIL-D-3464 - Desiccants, Activated, Bagged, Packaging Use and Static Dehumidification
MIL-D-3716 - Desiccants, Activated for Dynamic Dehumidification
MIL-S-14374 - Silica Gel, Iron Free
DOD-D-87934 - Desiccant, Molecular Sieve (Impregnated) (Metric)

STANDARDS

FEDERAL

FED-STD-313 - Material Safety Data Sheets, Preparation and the Submission of

MILITARY

MS16188 - Chart, Humidity Indicator Color Comparison

(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Naval Publications and Forms Center, (ATTN: NPODS), 5801 Tabor Avenue, Philadelphia, PA 19120-5099.)

2.1.2 Other Government documents, drawings, and publications. The following other Government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues are those cited in the solicitation.

CODE OF FEDERAL REGULATIONS (CFR)

Title 29, Chapter XVII - 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 (DLAM 1000.2)	- Occupational And Environmental Health Respiratory Protection Program
TB MED 506	- Occupational And Environmental Health Occupational Vision
TM 38-250	- Packaging, Materials Handling - Preparation Of Hazardous Materials For Military Air Shipment

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH (NIOSH)

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 Non-Government publications. The following document(s) form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DOD adopted are those listed in the issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation (see 6.2).

AMERICAN CONFERENCE OF GOVERNMENT INDUSTRIAL HYGIENISTS (ACGIH)

TLVs® Threshold Limit Values and Biological Exposure Indices Adopted by American Conference of Governmental Industrial Hygienists (ACGIH).

(Application for copies should be addressed to American Conference of Governmental Industrial Hygienists, 6500 Glenway Avenue, Bldg D-7, Cincinnati, OH 45211-4438.)

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM E 11 - Wire-Cloth Sieves for Testing Purposes

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

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.)

(Non-Government standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

2.3 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. DEFINITIONS

3.1 Adsorption. The retention of gases, liquids or dissolved substances on the surface of a solid in a monomolecular layer; and by capillary condensation where the solid is porous and of high capillarity.

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

3.3 Relative humidity (RH). The ratio of the quantity of water vapor present in the atmosphere to the quantity which would saturate the atmosphere at the same temperature. It is also the ratio of the partial pressure of water vapor present in the atmosphere at any temperature to the vapor pressure of water at the same temperature. Relative humidity is usually expressed as a percentage.

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 applicable procurement documents. 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, nonroutine exposure (i.e., not exceeding 1 hour/day for 1 day/week), when the installation medical authority determines that there are no feasible engineering or work practice controls, during interim periods when engineering controls are being designed and/or installed, during emergencies, or for supplementing other control measures (refer to TB MED 502 or DLAM 1000.2). Ventilation containment, process controls, or other feasible engineering controls shall be adequate to remove hazardous concentrations. Respiratory protection shall not be used in place of feasible engineering controls.

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 MSDSs 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.

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 Incompatible materials. Materials that are chemically incompatible shall be segregated in the storage of both serviceable and unserviceable items. 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 and Biological Exposure Indices, 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. The identity of sources establishing if a chemical is a carcinogen or potential carcinogen, for hazard communication purposes, is shown in 29 CFR 1910.1200 (d)(4). The more stringent standard shall apply when there is a conflict between standards.

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.

4.4.3 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.

5. DETAILED REQUIREMENTS

5.1 Name. Desiccant, Activated, Alumina Al_2O_3 FW: 101.96

5.1.1 Specification. Manufacturer's specifications. (No Government specifications).

5.1.2 Technical description. Activated alumina desiccant is available from several manufacturers in several forms. The predominant form is spherical with the typical chemical analyses from two manufacturers shown in Table I. The typical physical properties are shown in Table II.

TABLE I. Typical analyses of spherical activated alumina.

	Source 1 (wt %)	Source 2 (wt %)
Al_2O_3	93.1	93.6
SiO_2	0.02	0.02
Na_2O	0.30	0.35
Fe_2O_3	0.02	0.02
Loss on ignition	6.5	6.0

TABLE II. Typical physical properties of spherical activated alumina.

	Source 1 For 1/8 in (3.2 mm)	Source 2
Surface area, m^2/g	355	300 to 380
Pore volume, cm^3/g	0.5	0.5
Static adsorption		
At 60% RH, wt %	21	20
At 100% RH, wt %	42	41
Bulk density, lbs/ft^3 (g/cm^3)	48 (0.77)	48 (0.77)
Crushing strength, lbs (kg)	30 (14)	35 (15.9) (for 4.0 mm spheres)

Spherical activated alumina is available from the first source as uniformly sized spheres with the following nominal sizes:

1/4 inch (6.4 mm)
3/16 inch (4.8 mm)
1/8 inch (3.2 mm)
1/16 inch (1.6 mm)

Spherical activated alumina is available from the second source with the following Tyler screen sizes:

TABLE III. Spherical activated alumina - Tyler screen sizes.

Pass through	Retained on
1/2 inch (12.7 mm)	1/4 inch (6.4 mm)
No. 3 (6.7 mm)	No. 6 (3.3 mm)
No. 5 (4.0 mm)	No. 8 (2.4 mm)
No. 7 (2.8 mm)	No. 12 (1.4 mm)

Activated alumina desiccant from the second source is also available in granular form in the following Tyler screen size:

Pass through No. 8 (2.36 mm), retained on No 14 (1.18 mm)

A special grade of activated alumina, with a silica content of 9.9 percent, is available from the first source with increased moisture capacities at high and low relative humidities. Activated alumina can be regenerated after adsorption of moisture by the use of either heated dry outlet gas or from an adsorption unit heated wet inlet gas at 400°F (204°C). After regeneration by each method, reactivated alumina can produce effluent gas at dew points of -150°F (-101°C) and -70°F (-57°C). Therefore alumina, reactivated by wet-gas regeneration, requires a higher temperature to effect the same effluent dew point that can be obtained by dry-gas regeneration.

5.1.3 Use. Activated alumina desiccant is intended for military use for the drying of gases and liquids. Other applications include use as a scavenger for undesirable impurities in various gas and liquid process streams; and for the removal of acid impurities from transformer oils, lubrication oils, and refrigerants resulting from degradation. Special grades of activated alumina are used for removal of hydrogen fluoride and hydrogen chloride, for catalyst supports and as catalyst carriers.

5.1.4 Safety. Activated alumina dust is a nuisance particulate and can be irritating to the eyes and respiratory tract. In case of contact with the eyes, flush with water for at least 20 minutes and obtain medical attention.

5.1.5 Storage. Activated alumina desiccant shall be stored in original sealed containers in a dry place.

5.1.6 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.

Activated alumina does not have an EPA Hazardous Waste Classification.

5.2 Name. Desiccant, Activated, Calcium Sulfate, Anhydrous
Soluble anhydrite $CaSO_4$ FW: 136.14

5.2.1 Specification. O-D-210, Desiccant Activated, Calcium Sulfate, Anhydrous.

5.2.2 Technical description. Calcium sulfate ($CaSO_4$) has a theoretical composition of 41.2 percent calcium oxide (CaO) and 58.8 percent sulfur trioxide (SO_3). Anhydrous calcium sulfate is a stable compound that is chemically inert except with water. It is insoluble in organic liquids and refrigerants. It reacts with water to form the hemihydrate, $(CaSO_4)_2 \cdot H_2O$, with a water content of 6.6 percent by weight of the anhydrite. This is the total capacity when drying liquids. When drying gases, it can adsorb 10 to 14 percent by weight of moisture, above 6.6 percent, by means of combined chemical and capillary action. The additional capacity, above the 6.6 percent, varies directly with the pressure and partial pressure of water vapor and inversely with temperature. The activated granules have 38 percent pore space which provides the additional capacity for gas drying. The anhydrite can be impregnated with

cobalt (II) chloride which will turn from blue to pink upon adsorption of moisture. After adsorption of moisture, the exhausted desiccant can be regenerated by heating at 200° to 225°C for 1 to 2 hours. Small quantities can be reactivated by treating in a microwave oven at 500 to 1000 watts for 10 to 20 minutes.

5.2.2.1 Specification requirements. The desiccant shall of the following types and classes.

Type I - Non-indicating
Class 1 - Nominal 8 mesh
Class 2 - Nominal 6 mesh
Type II - Indicating (nominal 8 mesh)

The material shall be anhydrous calcium sulfate which is free-flowing and non-caking. Type I material shall contain not less than 38.5 percent by weight of CaO, and not less than 56.0 percent by weight of SO_3 when tested as specified. Type II material shall contain not less than 37.0 percent by weight of CaO, and not less than 54.5 percent by weight of SO_3 when tested as specified. Type I and type II material shall adsorb not less than 9.0 percent by weight of water when stored over water for 24 hours at a temperature of 20° to 30°C in a sealed desiccator (100 percent relative humidity). Type II material shall be impregnated with not less than 3.0 and not more than 5.0 percent by weight of anhydrous cobaltous chloride ($CoCl_2$). The type II material shall be blue in color and shall change to pink or rose when tested for water adsorption. Type I material shall be noncorrosive to aluminum alloy, magnesium alloy, and steel when tested as specified, and when required by the contract or order. Type I, Class 1 material and type II material shall conform to the particle size characteristics shown in Table IV. Type I, Class 2 material shall conform to the particle size characteristics shown in Table V.

TABLE IV. Particle size characteristics - calcium sulfate, anhydrous - type I, class 1 and type II material.

U.S. Standard Sieves 1/	% by wt
Retained on No.4 (4.75 mm), max	1
Passing No.4 and retained on No.6 (3.35 mm), max	25
Passing No.6 and retained on No.14 (1.40 mm), min	72
Passing No.30 (600 µm), max	2

TABLE V. Particle size characteristics - calcium sulfate, anhydrous - type I, class 2 material.

U.S. Standard Sieves 1/	% by wt
Retained on No.3-1/2 (5.6 mm), max	10
Passing No.3-1/2 and retained on No.6 (3.35 mm), min	90
Passing No.30 (600 µm), max	2

1/ U.S. Standard Sieve dimensions are in accordance with ASTM E 11.

5.2.3 Use. Anhydrous calcium sulfate desiccant, type I, Class 1 material is intended for military use in laboratory units for drying air and other gases. Type I, Class 2 material is intended for general use such as in large drying units, and drying liquids either in the liquid or vapor phase. Type II material is intended for use in maintaining dew points at or below -65°F (-53.9°C) in a closed system.

5.2.4 Safety. Anhydrous calcium sulfate dust is a nuisance particulate and can be irritating to the eyes and respiratory tract. In case of contact with the eyes, flush with water for at least 20 minutes and obtain medical attention.

5.2.5 Storage. Anhydrous calcium sulfate desiccant shall be stored in original sealed containers in a dry place.

5.2.6 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.

Anhydrous calcium sulfate does not have an EPA Hazardous Waste Classification.

5.3 Name. Desiccant, Activated, Clay

5.3.1 Specification. Manufacturer's specifications. (No Government specifications).

5.3.2 Technical description. Activated clay desiccant is derived from montmorillonite, a sub-bentonite type. It consists of hydrous magnesium aluminum silicate which is activated by controlled drying. It is dehydrated to a volatile content of 5.5 to 7.0 percent, which is slightly higher than the theoretical hydroxyl water content of pure montmorillonite. Removal of free water at a moderate rate yields the most efficient adsorbent at low relative humidity. It can be regenerated repeatedly without deterioration. A typical analysis after ignition of montmorillonite clay desiccant is shown in Table VI

TABLE VI. Montmorillonite clay desiccant - typical analysis.

	% by wt
Silicon dioxide (SiO_2)	67.3
Aluminum oxide (Al_2O_3)	19.5
Magnesium oxide (MgO)	6.9
Other metal oxides	6.5

The moisture adsorption capacity of montmorillonite clay desiccant is shown in Table VII.

TABLE VII. Montmorillonite clay desiccant - moisture adsorption capacity at 77°F (25°C).

Relative humidity (%)	g H_2O/100 g desiccant
10	8.5
20	13.5
30	16.8
40	19.0
60	22.3
80	25.0

Typical physical and chemical properties of montmorillonite clay desiccant are shown in Table VIII.

TABLE VIII. Montmorillonite clay desiccant - typical physical and chemical properties.

Structure	Crystalline
Apparent density, g/cm^3	0.88
Void volume, cm^3/g	0.4
Total volatiles, loss on ignition at 1750°F (954.4°C), %	5.5 to 7.0
pH of water slurry	6.8 to 7.2

5.3.3 Use. Clay desiccants are intended for military use as chemically inert dehydrating agents for adsorption of moisture from enclosed spaces and packages in order to prevent corrosion and mildew.

5.3.4 Safety. Montmorillonite clay dust is a nuisance particulate, and can be irritating to the eyes and respiratory tract. In case of contact with the eyes, flush with water for at least 20 minutes and obtain medical attention.

5.3.5 Storage. Clay desiccant shall be stored in original sealed containers in a dry place.

5.3.6 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.

Clay desiccant does not have an EPA Hazardous Waste Classification.

5.4 Name. Desiccant, Activated, Molecular Sieves
General Formula: $M_{2/n}O \cdot Al_2O_3 \cdot xSiO_2 \cdot yH2O$ (where M is a cation of n valence)

5.4.1 Specification. DOD-D-87934, Desiccant Molecular Sieve (Impregnated) (Metric).

5.4.2 Technical description. Molecular sieve desiccants are synthetically produced crystalline metal alumino-silicates that are activated for adsorption by removal of their water of hydration. Because little or no change of structure occurs during dehydration, highly porous adsorbents are formed that have strong affinity for water and certain other gases and liquids. The pores of molecular sieves are of molecular dimensions and uniform in size. Depending on pore size, molecules can be readily adsorbed, slowly adsorbed, or completely excluded. Molecular sieves also show a selective preference for polar or polarizable molecules, and unsaturated molecules. Molecular sieves retain adsorbates by strong physical forces rather than by chemisorption. Desorption of the adsorbed molecules leaves the crystals in the same chemical state as before adsorption. The external surface area of the molecular sieve crystals is available for adsorption of molecules of all sizes, whereas the internal area is available only to molecules small enough to enter the pores. The external surface area is about 1 percent of the total surface area. Molecules which are too large to be adsorbed internally can be adsorbed externally to the extent of 0.2 to 1 weight percent.

The two main types of molecular sieves are type A and type X, based on crystal structure. The basic structure for type A molecular sieves is represented by the type 4A sodium cation form, $Na_{12}[(AlO_2)_{12}(SiO_2)_{12}] \cdot 27H_2O$ with openings of

about 4A° diameter into the interior. Type 3A substitutes potassium cations for the sodium cations, resulting in openings of about 3A° in diameter. Type 5A substitutes calcium cations for the sodium cations, resulting in openings of about 5A° in diameter. The basic structure for type X molecular sieves is represented by the type 13X sodium cation form, $Na_{86}[AlO_2)_{86}(SiO_2)_{106}]\cdot 276H_2O$, with openings of about 10A° into the interior. The water of hydration, in the saturated formula for type X, is 35 percent of the weight of the anhydrous form. The water of hydration is loosely bound and can be removed by heating. The voids can be refilled by adsorbing a variety of other gases and liquids.

Type 3A adsorbs molecules with an effective diameter of less than 3A°, including H_2O and NH_3, and excludes molecules greater than 3A°. Type 4A adsorbs molecules with an effective diameter of less than 4A° including CO_2, H_2S, SO_2, C_2H_4, C_2H_6, and C_2H_5OH, and excludes molecules greater than 4A°. Type 5A° adsorbs molecules with an effective diameter of less than 5A°, including normal paraffins from C_3H_8 to $C_{22}H_{46}$, and excludes molecules greater than 5A° including cyclic and branched chain hydrocarbons. Type 13A adsorbs molecules with an effective diameter of less than 10A° and excludes molecules greater than 10A°. Each type can adsorb molecules adsorbed by the preceding type.

Molecular sieves are commercially available in powder, pellet, and bead forms as types 3A, 4A, 5A, and 13X, and variations of these types.

5.4.2.1 Specification requirements. The desiccant shall be a sodium alumina-silcate molecular sieve type impregnated with an inorganic metal salt moisture indicator, and having a free aperture pore size of 3.5A° in diameter.

5.4.2.1.1 Sieve analysis. The desiccant shall be a spherical bead form, with a nominal 4 to 8 mesh size (U.S. Standard Sieves), conforming to the sieve analysis shown in Table IX.

TABLE IX. Desiccant, molecular sieve- sieve analysis.

U.S. Sieve No. 1/	% by wt, max
Retained on 0.265 in (6.7 mm)	5
Through No.8 (2.36 mm)	10
Through No.20 (850 μ m)	0.2

1/ Standard sieve designations are in accordance with ASTM E 11.

5.4.2.1.2 Crushing strength. The desiccant beads shall have a crushing strength of 10 pounds (4.54 kg) when a bead is compressed at a steady load rate of approximately 60 pounds per minute (27.2 kg/min).

5.4.2.1.3 Moisture indicator. The desiccant moisture indicator shall be an inorganic metal salt which will indicate moisture saturation by changing from a blue color to a beige or buff color.

5.4.2.1.4 Moisture content. The packaged desiccant shall contain a maximum of 5 percent by weight of adsorbed water, when tested for loss of weight by heating for 2 hours at 315° ± 5°C.

NOTE: $1A° = 10^{-10}$ meter = 10^{-7} mm.

5.4.2.1.5 Water adsorption capacity. The water vapor adsorption capacity of the desiccant shall conform to the minimum weight percent increase, when tested in equilibrium with air over glycerol-water solutions, at 25° ± 2°C, as shown in Table X.

TABLE X. Desiccant, molecular sieve - equilibrium water adsorption capacity at 25°C.

Relative Humidity, %	Increase above initial moisture content % by wt, min
10	17
20	18
40	19
60	20

5.4.2.1.6 Regeneration. Desorption by three heating cycles for two hours at 180° ± 5°C shall reactivate the desiccant to the as remanufactured adsorption capacity, as shown in Table X, and restore the blue color for moisture indicator.

5.4.3 Use. The specified molecular sieve is intended for military use in a dehydrator for a special application. Molecular sieves are in compliance with MIL-D-3464 type I requirements and are approved for method II packaging of MIL-P-116. Other military and commercial applications for molecular sieves include use in static and dynamic dehumidification of gases at elevated temperatures (above 50°C), and at low relative humidities (below 40%); the drying of liquids; the purification of gases; the separation of straight chain hydrocarbons from branch chain and cyclic hydrocarbons in both gas and liquid phases; as a carrier for premixed catalysts and accelerators for rubber and plastics; and in nonregenerable drying and moisture scavenging applications.

5.4.4 Safety. Molecular sieve desiccant dust is a nuisance particulate, and can be irritating to the eyes and respiratory tract. In case of contact with the eyes, flush with water for at least 20 minutes and obtain medical attention.

5.4.5 Storage. Molecular sieve desiccant shall be stored in original sealed containers in a dry place.

5.4.6 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.

Molecular sieves (metal alumino-silicates) do not have an EPA Hazardous Waste Classification.

5.5 Name. Desiccant, Activated, Silica Gel
Silicon dioxide SiO_2 FW: 60:08

5.5.1 Specification. MIL-S-14374, Silica Gel, Iron Free.

5.5.2 Technical description. Silica gel is prepared from silicic acid that is formed by the reaction of sodium silicate with sulfuric acid:

$$Na_2SiO_3 + H_2SO_4 \rightarrow Na_2SO_4 + H_2SiO_3$$

The silicic acid is washed and dried to form silica gel, containing some chemically bound water:

$$H_2SiO_3 \rightarrow SiO_2 \cdot xH_2O + (1-x)H_2O$$

where x is about 0.16 $\pm$ 0.02, which corresponds to a water content of about 4.6 percent. Silica gel is a granular, amorphous form of silica, with a vast network of interconnected microscopic pores which attract and hold water, alcohols, and other compounds by physical adsorption and capillary condensation.

When used as a desiccant silica gel can adsorb 40 percent of its own weight of water. Silica gel appears and feels dry even when saturated with water. Silica gel adsorption characteristics result from its large internal surface area.

Silica gel functions as an adsorbent in both the gas phase and liquid phase. The amount of vapor that silica gel will adsorb from a given gas mixture depends on the relative saturation (equivalent to relative humidity) of the vapor in the system. In selective adsorption from the liquid phase, highly polar liquids are readily adsorbed by silica gel. Compounds with hydroxyl groups, such as alcohols and phenols, are strongly adsorbed, as well as oxygen containing compounds, such as aldehydes, ketones, esters, and organic acids. The relative order of adsorbability for several types of compounds is as follows: water, alcohols, aromatics, diolefins, olefins, and paraffins.

Silica gel is non-corrosive, non-deliquescent, non-toxic, and dimensionally stable. It is chemically inert except with strong alkalies and hydrofluoric acid.

The purities of commercially available regular and intermediate grades of silica gel are shown in Table XI.

TABLE XI. Silica gel, chemical purity.

	Intermediate Density (wt %)	Regular Density (wt %)
Silica, as SiO_2	99.68	99.71
Iron, as Fe_2O_3	0.01	0.03
Aluminum, as Al_2O_3	0.10	0.10
Titanium, as TiO_2	0.02	0.09
Calcium, as CaO	0.07	0.01
Sodium, as Na_2O	0.06	0.02
Zirconium, as ZrO_2	0.03	0.01
Trace elements	0.03	0.03
Total volatiles, at 1750°F (954.4°C)	4.5	5 to 6.5

The physical properties and characteristics of commercially available intermediate density and regular density silica gel are shown in Table XII.

TABLE XII. Silica gel, regular and intermediate density grades - physical properties and characteristics.

	Regular Density	Intermediate Density
Pore volume, cm^3/g	0.43	1.15
Pore diameter, average, A° 1/	22	140
Surface area, m^2/g	750 to 800	340
Specific heat, J/(kg·°K)	920	920
(BTU/lb/°F)	0.22	0.22
True density (no porosity) g/cm^3	2.19	2.19
Apparent bulk density, g/cm^3	0.72	0.40
Thermal conductivity, $W/(m^2)(°K/cm)$	5.7	5.74
$(BTU/ft^2/hr/°F/in)$	1	1

1/ $1A° = 10^{-10}$ meter = 10^{-7} mm

The regular density silica gel has a typical equilibrium moisture adsorption capacity shown in Table XIII.

TABLE XIII. Silica gel, regular density - typical equilibrium moisture adsorption capacity.

Relative humidity (%)	Moisture adsorption (wt %)
10	7.7
20	14.7
40	27.4
60	33.0
80	35.3
100	37.0

Regular density silica gel can be reactivated for reuse by heating at 300° to 600°F (149° to 316°C). Small quantities can be reactivated by treating in a microwave oven at 500 to 1000 watts for 10 to 20 minutes.

Silica gel is also available in the form of beads.

5.5.2.1 Specification requirements. This specification covers one iron-free type of silica gel with the chemical and physical characteristics shown in Table XIV, and the particle size distribution shown in Table XV.

TABLE XIV. Silica gel, iron-free - chemical and physical characteristics - specification requirements.

Silicon dioxide, wt %, min	99.7
Iron, ppm, max	20
Chloride, ppm, max	2
Moisture, wt %, max	3.0
Contamination (NaOH solution test)	Pass test
pH	6 to 7
Apparent density, g/cm^3	0.59 to 0.69

TABLE XV. Silica gel, iron-free - particle size distribution - specification requirements.

U.S. Standard Sieves 1/	% by wt
Retained on No.30 (600 μ m) max	0
Pass No.30, retained on No.40 (425 μ m), max	2
Pass No.40, retained on No.60 (250 μ m), min	80
Pass No.60, retained on No.80 (180 μ m), max	20
Pass No.80, retained on No.100 (150 μ m), max	3
Pass No.100, max	3

1/ U.S. Standard Sieves are in accordance with ASTM E 11.

5.5.3 Use. Silica gel, iron-free, is intended for military use in the preparation of impregnated gels and in the manufacture of sampling tubes. Silica gels are also intended for military use as activated desiccants for dynamic dehumidification in accordance with MIL-D-3716. Silica gels also qualify as activated desiccants, bagged, for packaging use and static dehumidification in accordance with MIL-D-3464. In addition to the above uses, commercial applications include use in drying natural gas, refinery gases, hydrocarbon fuels and solvents; low dew point drying of gases such as hydrogen, nitrogen, hydrogen sulfide, hydrogen chloride, sulfur dioxide, and liquids such as carbon tetrachloride and refrigerants.

5.5.4 Safety. Silica gel dust is a nuisance particulate and can be irritating to the eyes and respiratory tract. In case of contact with the eyes, flush with water for at least 20 minutes and obtain medical attention.

5.5.5 Storage. Silica gel desiccant shall be stored in original sealed containers in a dry place.

5.5.6 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.

Silica gel does not have an EPA Hazardous Waste Classification.

5.6 Name. Desiccant, Activated, Dynamic Dehumidification

5.6.1 Specification. MIL-D-3716, Desiccants, Activated for Dynamic Dehumidification.

5.6.1.1 Specification requirements. This specification covers silica gel desiccants that remove moisture from air and other gases, and from liquids by dynamic means; and that offer an approximate indication of the relative humidity of an enclosed space.

Desiccants shall be of the following types and grades.

Type I - Large particle size.
Grade H - High adsorption capacity
Grade M - Medium adsorption capacity
Grade L - Low adsorption capacity

Type II - Medium particle size.
  Grade H - High adsorption capacity
  Grade M - Medium adsorption capacity

Type IV - Medium particle size impregnated with a humidity indicator.
  Grade H - High adsorption capacity

Types I and II shall not be impregnated. Type IV shall be impregnated with an indicator for the purpose of providing for a visual approximation of the degree of saturation of the desiccant. The impregnated desiccant shall have characteristic colors when in equilibrium with atmospheres of varying relative humidities, and shall coincide with the colors in accordance with MS16188.

The apparent density of the 3 grades of desiccant shall be as shown in Table XVI.

TABLE XVI. Dynamic dehumidification desiccants - specification requirements for apparent density.

Grade	lb/ft^3	g/cm^3
H and M, not less than	45	0.72
L, not less than	50	0.80

The water vapor adsorption capacity of the desiccants shall be as shown in Table XVII.

TABLE XVII. Dynamic dehumidification desiccants - specification requirements for minimum water vapor adsorption capacity.

Nominal Relative Humidity	Grade H (% of dry wt)	Grade M (% of dry wt)	Grade L (% of dry wt)
10	5.5	14.7	3.3
20	10.0	15.6	5.0
40	19.0	16.9	7.5
60	28.0	18.2	11.7
80	33.0	19.2	15.0

The particle size of types I, II, and IV shall be as shown in Table XVIII.

TABLE XVIII. Dynamic dehumidification desiccants - specification requirements for particle size.

U.S. Standard Sieves 1/	wt %
Type I:	
Retained on 0.265 in (6.7 mm), max	0.5
Through 0.265 in, retained on No.5, (4.00 mm) min	35.0
Through No.5, retained on No.6 (3.35 mm), min	36.5
Through No.6, retained on No.10 (2.00 mm), max	50.0
Through No.10, retained on No.18 (1.00 mm), max	2.5
Through No.18, max	0.5

TABLE XVIII. Dynamic dehumidification desiccants - specification requirements for particle size (Continued).

Type II:	
Retained on No.6 (3.35 mm), max	2.0
Through No.6, retained on No.14 (1.40 mm), min	93.0
Through No.14, retained on No.18 (1.00 mm), max	4.0
Through No.18, retained on No.20 (850 μ m), max	2.5
Through No.20, max	0.5
Type IV:	
Retained on No.6 (3.35 mm), max	2.0
Through No.6, retained on No.12 (1.70 mm), min	55.0
Through No.12, retained on No.18 (1.00 mm), min	19.0
Through No.18, max	3.5
Through No.20 (850 μ m), max	0.5

1/ U.S. Standard Sieves are in accordance with ASTM E 11.

The particle strength shall be as shown in Table XIX, as determined by attrition on a No. 18 sieve, and measuring the percentage passing a No. 30 sieve.

TABLE XIX. Dynamic dehumidification desiccants - specification requirements for particle strength.

Type	Grade	Passing through U.S. Sieve No. 30 (600 μ m) (% by wt, max)
I	H	0.2
I	M	1.5
I	L	2.5
II	H, M	1.5
IV	H	1.5

The loss on ignition shall be as shown in Table XX, as determined by heating at 960° ± 20°C for 1/2 to 3/4 hour.

TABLE XX. Dynamic dehumidification desiccants - Loss on ignition at 960°C.

Type	Grade	Loss (% by wt, max)
I	H	6.50
I	M	4.00
I	L	10.00
II	H	6.50
II	M	4.00
IV	H	5.75

5.6.1.1.1 Corrosiveness. Type I and type II desiccant samples, ground to pass a U.S. No.40 sieve (425 μ m) and retained on a U.S. No.80 sieve (180 μ m), are pretreated at 25°C and 60 percent relative humidity for a minimum of 24 hours. The ground pretreated desiccant sample shall be tested for corrosiveness in contact with polished test specimens of steel, magnesium alloy, brass, and aluminum held in a desiccator at 60 percent relative humidity, and which is placed in an oven at a temperature of 38°C for 72 hours. The metal specimens in contact with the desiccant samples shall not be more corroded than the bare metal surfaces exposed under the same test conditions.

5.6.2 Use. Activated desiccants for dynamic dehumidification are intended for military use in removing moisture from gases and liquids as follows:

> Types I and II desiccants are adaptable for use in mechanical dehumidification machines of the regenerative type, and are furnished in desiccant containers complete with desiccant in accordance with MIL-D-3263.
>
> Type IV desiccant is intended for use in indicator cards or humiplugs, when approximate indication of the relative humidity in the surrounding atmosphere is desired.

Commercial applications are the same.

5.6.3 Safety. Silica gel dust is a nuisance particulate and can be irritating to the eyes and respiratory tract. In case of contact with the eyes, flush with water for at least 20 minutes and obtain medical attention.

5.6.4 Storage. Silica gel desiccant for dynamic dehumidification shall be stored in original sealed containers in a dry place.

5.6.5 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.

Silica gel does not have an EPA Hazardous Waste Classification.

5.7 Name. Desiccant, Activated, Static Dehumidification

5.7.1 Specification. MIL-D-3464, Desiccants, Activated, Bagged, Packaging Use and Static Dehumidification.

5.7.1.1 Specification requirements. This specification covers bagged, chemically inert dehydrating agents. The bagged desiccants shall be the following types:

> Type I - General purpose
> Type II - Non-dusting
> Type III - For specific conditions (8 and 16 units only)

The desiccants shall be nondeliquescent. A desiccant unit shall be defined on the basis of adsorption capacity. A desiccant unit is that quantity of desiccant, in equilibrium with air at 25°C, which will adsorb at least the following quantities of water vapor:

> 3.00 grams at 20 percent relative humidity; and 6.00 grams at 40 percent relative humidity.

The weight of desiccant constituting a desiccant unit is defined as the unit weight. The unit weight shall not exceed 50.0 grams. The unit adsorption capacity is defined as the actual weight of water vapor adsorbed by a unit

weight of desiccant in equilibrium with air at 25°C determined at a flow rate of 4 liters per minute. The unit adsorption capacity shall be at least:

3.00 grams at 20 percent relative humidity; and 6.00 grams at 40 percent relative humidity.

For bagged desiccant, the unit adsorption capacity shall be at least:

2.85 grams at 20 percent relative humidity; and 5.70 grams at 40 percent relative humidity.

The volume of desiccant constituting a desiccant unit is defined as the unit volume. The unit volume shall not be greater than 45.0 mL.

The unit adsorption rate for bagged desiccant, containing 16 or less units, shall be determined at an air flow rate of 4 liters per minute. A unit weight of desiccant shall adsorb in 7 hours the minimum weight of water vapor per gram of desiccant as follows:

0.25 grams at 40 percent relative humidity; and 0.70 grams at 80 percent relative humidity.

5.7.1.1.1 Humidity control. A unit of desiccant shall prevent the humidified atmosphere in a closed metal box (10 in x 10 in x 10 in = 1000 in^3 or 0.0164 m^3 interior) from exceeding 60 percent relative humidity when tested as specified.

5.7.1.1.2 Adsorption capacity and rate after reactivation. After exposure to an enclosed atmosphere over an open container of water for 16 hours at 25°C, and reactivation at the manufacturers recommended temperature at not less than 245°F (118.3°C) for a period not exceeding 24 hours, and with this procedure repeated; the bagged desiccant shall retain at least 90 percent of the original unit adsorption capacity at 40 percent relative humidity, and at least 80 percent of the original unit adsorption capacity at 80 percent relative humidity.

5.7.1.1.3 Dusting. Types I and III desiccants shall conform to the dusting requirements shown in Table XXI when tested as specified.

TABLE XXI. Desiccants, activated, bagged, types I and III - dusting requirements.

Bag size, units	16	8	4 and smaller
Number of bags tested	12	12	12
At least six of the dust values shall not exceed, mg	5.0	2.5	---
At least eight of the dust values shall not exceed, mg	---	---	0.5
No more than two dust values shall be in the range, mg	60.0 to 200.0	60.0 to 200.0	60.0 to 200.0
No more than one dust value shall exceed, mg	200	200	200

Type II desiccant shall produce not more than 0.5 mg of dust.

5.7.1.1.4 Corrosiveness. Desiccant samples, ground to pass a U.S. No.40 sieve (425 μ m) and retained on a U.S. No. 80 sieve (180 μ m), are pretreated at 25°C and 60 percent relative humidity for a minimum of 24 hours. Four bags of desiccant are also pretreated at 25°C and 60 percent relative humidity for at least 24 hours. The ground pretreated desiccant and desiccant in bags shall be tested for corrosiveness in contact with polished test specimens of steel, brass, magnesium alloy, and aluminum held in a desiccator at 60 percent relative humidity, and which is placed in an oven at a temperature of 38°C for 72 hours. The metal specimens, in contact with the desiccant or the bagged desiccant, shall not be more corroded than the bare metal surfaces exposed under the same test conditions.

5.7.1.1.5 Particle size. The particle size distribution shall be as shown in Table XXII.

TABLE XXII. Desiccants, activated, bagged - particle size distribution.

U.S. Standard Sieves 1/	Retained, % by wt
1/2 in (12.5 mm)	0.0 max
No. 80 (180 μ m)	96.0 min

1/ U.S. Standard Sieve designations are in accordance with ASTM E 11.

5.7.2 Use. Bagged desiccants are intended for military use in removing moisture from gases, including air, and from liquids, as follows:

a. Generally applicable for static dehumidification of packages and closed spaces in order to prevent corrosion, mold, or mildew.

b. Method II packaging of MIL-P-116, which also specifies formulas for computing the proper quantity of desiccant to be used.

c. Type III desiccant in 8 and 16 unit bags for use in areas where a danger exists of accidental flooding by water (200°F or 93.3°C) maximum.

d. Type II desiccant is intended for use in critical packaging applications where dusting cannot be tolerated.

Commercial applications are the same.

5.7.3 Safety. Activated desiccant dust is a nuisance particulate and can be irritating to the eyes and respiratory tract. In case of contact with the eyes, flush with water for at least 20 minutes and obtain medical attention.

5.7.4 Storage. Activated desiccant, for static dehumidification, shall be stored in original sealed containers in a dry place.

5.7.5 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.

Desiccant for static dehumidification does not have an EPA Hazardous Waste Classification.

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. This standard is intended to cite nomenclature, formulas, physical and chemical properties, specification requirements, military and typical commercial uses, safety information, storage information, and disposal information for activated desiccants preferred for application by the Department of Defense.

6.2 Issue of DODISS. When this standard is used in acquisition, the applicable issue of the DODISS must be cited in the solicitation (see 2.1.1, and 2.2).

6.3 Subject term (key word) listing.

Activated desiccants
Adsorbents
Alumina, activated
Calcium sulfate
Clay, activated
Dehumidification
Dehydrating agents
Desiccants
Metal alumino-silicates
Molecular sieves
Montmorillonite clay
Silica gel, activated
Sodium alumino-silicate
Soluble anhydrite

6.4 Changes from previous issue. Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the changes.

6.5 Abbreviations. The use of abbreviations are in accordance with MIL-STD-12 where applicable. Metric system abbreviations and symbols are in accordance with ASTM E 380.

Custodians:
Army - EA
Navy - SH
Air Force - 68

Review activities:
DLA - GS
Army - AR, AT, MD, MI, SM
Navy - AS, OS, SA
Air Force - 11

User activities:
Army - AR, ER, ME
Navy - CG, MC, YD

Preparing activity: Army - EA

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STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

(See Instructions – Reverse Side)

1. DOCUMENT NUMBER	2. DOCUMENT TITLE
MIL-STD-1427A	ACTIVATED DESICCANTS (METRIC)

3a. NAME OF SUBMITTING ORGANIZATION

b. ADDRESS *(Street, City, State, ZIP Code)*

4. TYPE OF ORGANIZATION *(Mark one)*

- ☐ VENDOR
- ☐ USER
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- ☐ OTHER *(Specify)*: _____

5. PROBLEM AREAS

a. Paragraph Number and Wording:

b. Recommended Wording:

c. Reason/Rationale for Recommendation:

6. REMARKS

7a. NAME OF SUBMITTER *(Last, First, MI)* – Optional	b. WORK TELEPHONE NUMBER *(Include Area Code)* – Optional
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