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January 29, 1965
DMIC Memorandum 201

COMPATIBILITY OF MATERIALS WITH ROCKET PROPELLANTS AND OXIDIZERS

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AD-613 553

COMPATIBILITY OF MATERIALS WITH ROCKET PROPELLANTS AND OXIDIZERS

W. K. Boyd, et al

Battelle Memorial Institute
Columbus, Ohio

January 1965

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13. ABSTRACT

Compatibility data are summarized for the storage and handling of metals and nonmetals in the following rocket propellants and oxidizers: ammonia, HiCal-3, pentaborane, trialkyl boranes, fluorine, FLOX, oxygen difluoride, ozone difluoride, chlorine trifluoride, bromine trifluoride, bromine pentafluoride, iodine pentafluoride, perchloryl fluoride, halogenated hydrocarbons, hydrazine, monomethyl hydrazine, unsymmetrical dimethyl hydrazine, Aerozine-50 hydrogen, hydrogen peroxide, methylene chloride, red fuming nitric acid, white fuming nitric acid, concentrated acid, nitrogen tetroxide, oxygen, ozone, nitronium perchlorate, and solid propellant ANP-2639 AF. (Author)

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14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Fuels Oxidizers Compatibility Light metals Refractory metals High-strength steels Stainless steels Superalloys Other specific metals Metals (in general) Nonmetallics						

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ERRATA:

In Table 6 on page 12, several entries are in error. The corrections are listed below. In table 29, a rating for Monel is supplied that was inadvertently omitted during copying from the worksheets.

ERRATA FOR TABLE 6

Material	Temperature, F: Gas Class 1	Gas Class 2	Gas Class 3	Gas Class 4	Liquid Class 1	Liquid Class 2	Liquid Class 3	Liquid Class 4	References
309 Stainless Steel	500			570					7,207
309 Cb Stainless Steel	500			570					7,207
310 Stainless Steel	500			660					7,207
347 Stainless Steel	390			500	-310		-320		7,120,207, 274
430 Stainless Steel		400	390	600					7,207,211
Armco Iron	390	500	167						7,159,160, 207
Iron (0.004 Si)		200	400	390					82,159,160
Iron (0.79 Si)		100	300	390					82,159,160
Sheet Steel	390	660		500					7,207
SAE 1010	100	200	400	>400					82,160
SAE 10[illegible]				570					7,207
SAE 1020				390					7,207
SAE 1030	665		390	500					7,207
Music Wire				570					7,207
A-Nickel		1000	750	>1200					7,73,82,120, 143,153,159, 160,211,274
Monel		1000	750	>1200					7,73,82,120, 143,153,159, 160,211,274
Inconel		1000		<750					7,207,211
Deoxidised copper				<400					7,207
Brass 70-30		200		400					82,159,160
Magnesium MA (1.2% Mn)	140	200							82,159,160
Magnesium FS-1A	140	200							82,159,160

ERRATUM FOR TABLE 29

Material	Gas Class 1	Gas Class 2	Gas Class 3	Gas Class 4	Liquid Class 1	Liquid Class 2	Liquid Class 3	Liquid Class 4	References
Monel		75	125			100	75		211

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COMPATIBILITY OF MATERIALS WITH ROCKET PROPELLANTS AND OXIDIZERS

W. K. Boyd, W. E. Berry, and E. L. White*

GENERAL CONSIDERATIONS

An important consideration in rocket technology is the compatibility of each propellant with the container material. Serious problems arise because many propellants are extremely reactive and their containment is possible only with a few materials of construction. The resistance of many alloys to fuels and oxidizers is dependent entirely on the formation of an inert, corrosion-resistant film or barrier coating. In addition to corrosion problems, the presence of some metals tends to promote decomposition of the propellant. Also, certain metal/oxidizer combinations may ignite if subjected to impact.

Four years ago DMIC Memorandum 65 was issued and included all information available at that time on compatibility of materials of construction with rocket propellants and oxidizers. Since that time additional information on compatibility has been generated for new, as well as the more established, fuels and oxidizers. This report contains these new data combined with the information presented in DMIC Memorandum 65. In order to expand the usefulness of the report, the source of the data is referenced for each material.

This memorandum summarizes the available information on the compatibility of liquid rocket propellants with prominent materials of construction. It is pointed out that compatibility data for materials not ordinarily covered by the Defense Metals Information Center are included. These data were found during the search for information on materials that are within the scope of the DMIC, and are included for convenience. Fuels and oxidizers of current interest are discussed. The corrosion data which are presented will apply to storing, handling, and control equipment outside of missiles and to missile components excluding combustion chamber. The compatibility of materials with reaction products in combustion chambers, nozzles, etc., have not been considered. Included in the summary are data for many nonmetallic materials. These data were collected in conjunction with those obtained for metals but no concerted effort was made to secure compatibility data for nonmetals.

The memorandum is subdivided into sections according to the propellant. Each material of construction is rated for a given medium as belonging to one of four classes, based primarily upon corrosion resistance. Consideration also is given to such factors as catalytic decomposition and sensitivity to impact.

CLASSIFICATION OF MATERIALS OF CONSTRUCTION

Metals

Class 1

The Class 1 materials are those which exhibit a corrosion rate of less than 1 mil per year. The material does not promote decomposition of the propellant or oxidizer and is free from impact sensitivity.

Class 2

The materials falling in Class 2 are similar to those in Class 1, except that the corrosion rate may be as great as 5 mils per year.

Class 3

A material in Class 3 shows only fair corrosion resistance; rates of attack may be of the order of 5 to 50 mils per year. The material may also cause a moderate breakdown of the propellant, but it is not shock sensitive under conditions likely to be encountered in service.

Class 4

Materials in this class are not considered usable for containing the propellant; they have corrosion rates greater than 50 mils per year, cause extensive decomposition of the propellant, cause spontaneous ignition, or react on impact.

These classifications are summarized in Table 1.

TABLE 1. COMPATIBILITY CLASSIFICATIONS FOR METALS[a]

Class	Corrosion Resistance: Rating	Corrosion Resistance: Penetration Rate, mils/year	Decomposition of Propellant	Shock Sensitivity
1	Excellent	<1	No	No
2	Good	<5	No	No
3	Fair	5 to 50	Some	No
4	Poor	>50	Extensive	Yes

(a) The classification of a material is based on the lowest rating of any one of the three properties.

Nonmetals

Ratings for nonmetals are also somewhat arbitrary but wherever possible they follow those described in the Titan II Storable Propellant Handbook.(169) The classifications are summarized in Table 2.

TABLE 2. COMPATIBILITY CLASSIFICATIONS FOR NONMETALS

	Class 1	Class 2	Class 3	Class 4
Volume Change, percent	0 to +25	-10 to +25	-10 to +25	<-10 or >+25
Durometer Reading Change	±3	±10	±10	<-10 or >+10
Effect on Propellant	None	Slight change	Moderate change	Severe
Visual Examination	No change	Slight change	Moderate change	Severely blistered, or cracked, dissolved
General Usage	Satisfactory, general use	Satisfactory for repeated short term use	Satisfactory for short time use	Unsatisfactory

*Chief, Associate Chief, and Research Chemical Engineer, Corrosion Research Division, Battelle Memorial Institute, Columbus, Ohio.

The compatibility data have been tabulated according to the maximum temperature permissible for a given material in Classes 1, 2, and 3. The minimum temperature at which a given material becomes Class 4 (noncompatible) also is listed. For example, a notation of RT under Class 1 means that the material would fall into this classification up to room temperature. It will be noted, in many instances, that no temperature is listed for one of the more resistant classifications. This does not necessarily mean that the material does not fall in Class 1 or 2 at some temperature, but rather that insufficient data are available to assign a temperature limit.

Occasional entries indicate that a material has a higher rating at higher temperatures, e.g., Class 1 at 160 F and Class 2 at 80 F. These entries reflect a conflict in reported data. In many of these cases, it is recommended that the original references be consulted where possible, to determine which results were obtained under conditions most nearly simulating the application in question.

In many cases, a material does not fit into a classification because (1) there is a scarcity of numerical data, or (2) the decomposition effects on the propellant are of primary concern. Hydrogen peroxide is a good example of a propellant for which it is difficult to classify construction materials. In such a case, the classification used in the table is described in detail for the material in question. Many materials are listed by trade names. Similar materials marketed under other trade names probably would be given the same classification. However, only materials for which actual data are available are listed.

SOURCES OF INFORMATION

The information on which this memorandum is based came from a variety of sources. A list of references is given at the end of the text. Appropriate references for a particular propellant material are listed at the beginning of each section. References are also included for each individual entry. In addition to reference material obtained from published literature, specialists in companies active in the development of rocket propellants were contacted either by letter, by telephone, or in person. The cooperating companies are listed below.

Aerojet-General Corporation
Food Machinery and Chemical Corporation
    Becco Chemical Division
Belmont Smelting and Refining Works, Inc.
General Dynamics Corporation
    Convair Astronautics Division
Callery Chemical Company
    Research and Development Division
Celanese Corporation of America
Columbia-Southern Chemical Corporation
Commercial Solvents Corporation
Douglas Aircraft Company, Inc.
Diamond Alkali Company
The Dow Chemical Company
    Texas Division
E. I. du Pont de Nemours and Company, Inc.
Foote Mineral Company
Allied Chemical Corporation
    General Chemical Division
Hughes Tool Company
HEF, Inc. - Hooker Chemical Corporation and
    Foote Mineral Company
Hercules Powder Company
California Institute of Technology
    Jet Propulsion Laboratory
Lockheed Aircraft Corporation
    Missile Systems Division
Lithium Corporation of America
Menasco Manufacturing Company
Metal Hydrides, Inc.
Monsanto Chemical Company
    Research and Engineering Division
Chemetron Corporation
    National Cylinder Gas Division
Union Carbide Corporation
    Linde Company
    Union Carbide Metals Company
    National Carbon Company
Olin-Mathieson Chemical Corporation
Pennsalt Chemicals Corporation
Thiokol Chemical Corporation
    Reaction Motors Division
North American Aviation, Inc.
    Rocketdyne Division
Rohm & Haas Company
Stanford Research Institute
Solar Aircraft Company
Sinclair Research Laboratories, Inc.
Titanium Metals Corporation of America
Virginia-Carolina Chemical Corporation
Wyandotte Chemicals Corporation.

General information on compatibility and properties of large groups of propellants are contained in References 3, 23, 81, 102, 110, 151, 196, 198, 211, and 237. Information on handling, safety, and toxicity is included in References 81, 195, 291, and 302.

AMMONIA (NH_3)*

Ammonia is a pungent colorless gas that is alkaline in nature. It can be liquified at room temperature at pressures above 100 psia. The vapor irritates the eyes and respiratory tract. The threshold-limit value of toxicity in the atmosphere is 50 ppm.

Stainless steel, carbon steel, nickel alloys, silver, platinum, gold, and tantalum are sufficiently resistant to anhydrous ammonia to be placed in Class 1, as shown in Table 3. Inconel, gold, platinum, and tantalum are Class 1 materials in moist ammonia. Carbon steel and cast iron are also quite resistant and are normal materials of construction for ammonia service.

The copper alloys are less resistant than steel and have the disadvantage of being susceptible to cracking in ammonia atmosphere.

The upper temperature limit of many metals is related to the initiation of the nitriding process. Inconel is more resistant to nitriding than other nickel alloys, mild steel, or stainless steel.

Many organic materials are suitable for ammonia service. Plastics and elastomers usually resist attack up to their softening point.

Most inorganic construction materials are not attacked by ammonia. Graphitic materials are considered best for handling ammonia gas at very high temperatures.

*Ammonia: see References 80, 81, 82, 94, 102, 109, 110, 127, 128, 151, 181, 199, 211, 214, 217, 221, 287, and 295.

Hi-Cal-3*

The composition and properties of Hi-Cal-3 are classified.

Many of the common construction materials are compatible with Hi-Cal-3. Mild steels, stainless steels, copper alloys, nickel alloys, aluminum, titanium, tantalum, and lead can all be used up to 120 F and are listed as Class 1 in Table 4. Above this temperature, no data are available. Organic materials which are compatible with Hi-Cal-3 are listed in Table 4 as Class 2.

Pentaborane (B_5H_9)**

Pure pentaborane is a clear colorless liquid that possesses an odor similar to that of rotten pumpkin. It is pyrophoric and highly toxic. Maximum allowable exposure is less than 1.0 ppm. It has a vapor pressure of 77 mm at 77 F and boils at 137 F.

Most of the metals used in rocket construction are compatible with pentaborane, including iron, steel, stainless steel, aluminum, copper, brass, magnesium, titanium, etc. Data are presented in Table 5. Teflon, Viton, Kel-F, and fluorosilicon rubber are included among the plastics and elastomers that are compatible with pentaborane. Pentaborane forms shock-sensitive mixtures with most of the chlorinated hydrocarbons that are used as degreasers or solvents.

Trialkyl Boranes***

Materials which have withstood 1 month's exposure in triethylborane [$(C_2H_5)_3B$] (a colorless liquid that boils at 203 F) at 160 F with no apparent attack include:

Metals	Nonmetals
Mild steel	Teflon
Stainless steel	Phenolite
Aluminum	Garlock 900 packing
Brass	Garlock red rubber
Nickel	Koppers 6200
Monel	Super Dylan polyethylene
Inconel	
Lead	
Copper (pitted)	

Materials which have withstood 2 weeks' exposure in tri-n-butyl borane [$(C_4H_9)_3B$](a colorless liquid that exerts a vapor pressure of 20 mm at 228 F) at 122 F with no apparent attack include:

Metals	Nonmetals
Mild steel	Teflon gasket
Stainless steel	Palmetto gasket
Aluminum	Koroseal
Brass	Kel-F
Nickel	Hycar
Copper	Nylon gasket

*Hi-Cal-3: see Reference 103.
**Pentaborane: see References 56 and 294.
***Trialkyl boranes: See Reference 57.

A number of fluorine compounds are being considered as oxidizers for rocket-propulsion systems. These include fluorine, chlorine trifluoride, bromine trifluoride, bromine pentafluoride, iodine pentafluoride, oxygen difluoride, oxygen difluoride-oxygen mixtures, perchloryl fluoride, perchloryl fluoride-tetrafluoro-hydrazine mixtures, and fluorine-oxygen mixtures (FLOX). All of these materials are extremely active chemically. Under the proper conditions, they will react with almost every known element; hence, they present severe corrosion and compatibility problems. These oxidizers, however, are not for the most part susceptible to thermal and catalytic breakdown and present little or no problem in this respect. Therefore, compatibility ratings are based primarily on the reaction of the medium with the material in question.

Fluorine (F_2)*

Fluorine is a yellowish gas that has a pungent odor and is irritating to the respiratory tract. The threshold limit of toxicity of fluorine in the atmosphere is 0.1 ppm. It is normally handled as a liquid at -310 to -320 F.

Many metals perform well in liquid and gaseous fluorine as can be seen from the data in Table 6. It is believed that a protective fluoride film which forms on the surface of most metals imparts corrosion resistance. On the other hand, some experiments have revealed no increased corrosion on specimens immersed in liquid fluorine and wire brushed to remove any film, suggesting no passivating effect from metal fluorides.(275)

Traces of water in the system react with fluorine to form hydrofluoric acid. This acid tends to attack some of the materials which are resistant to uncontaminated fluorine. Since moisture may be present in many systems, Monel is usually chosen as a construction material because, in addition to being resistant to fluorine, it also is resistant to hydrofluoric acid.

Titanium ignites** in liquid fluorine if subjected to impact or rupture. However, ignition does not propagate as it does in liquid oxygen. Although ignition has occurred in at least one specimen of aluminum alloys, aluminum is not considered to be impact sensitive in liquid fluorine.(275) Dynamite cap explosions against tubes filled with liquid fluorine have failed to cause ignition in Monel, nickel, copper, brass, 304 stainless steel, 316 stainless steel, 347 stainless steel, and 1100 aluminum.(275) Tensile tests to fracture in liquid fluorine have not caused ignition of AM350, 304L stainless steel, 301 stainless steel, ASM 6434, 2014-T6 and 7075-T6 aluminum, Inconel X, and Ti-6Al-4V.(233)

*Fluorine: see References 7, 14, 15, 16, 20, 40, 52, 58, 73, 81, 82, 83, 86, 90, 91, 93, 94, 99, 100, 102, 110, 120, 121, 122, 123, 132, 134, 143, 146, 151, 152, 153, 159, 160, 161, 162, 163, 175, 184, 191, 194, 197, 199, 201, 202, 203, 204, 207, 211, 212, 214, 215, 217, 221, 224, 225, 226, 233, 237, 243, 251, 252, 253, 259, 261, 263, 264, 265, 266, 268, 269, 270, 271, 272, 273, 274, 275, 276, 277, 278, 290, 297, and 299.
**Ignition - fluorine: see References 141, 233, 274, 275, and 276.

Because of its strong oxidizing properties, fluorine reacts readily and often violently with most organic materials. Only the highly fluorinated hydrocarbons such as Teflon and Kel-F withstand continued service.

Cleanliness is essential for fluorine systems. If the metal surfaces in contact with fluorine or for that matter almost any strong oxidizer are contaminated with organic materials, such as traces of oil or grease, local hot spots may form which in turn may cause the violent burning of the encasing material.

It is recommended that equipment to handle fluorine be first thoroughly cleaned to remove all contaminants, e.g., organic matter, and then passivated with fluorine diluted with an inert gas.

FLOX*

Mixtures of liquid fluorine and liquid oxygen (called FLOX) have received some consideration as oxidizers. Typical ratios are 40:60 and 20:80 fluorine:oxygen. The limited compatibility data that are available for FLOX are summarized in Table 7. In general, it appears that any material which performs well in liquid fluorine also performs well in FLOX.

Oxygen Difluoride (OF_2)**

Oxygen difluoride is a colorless gas and a brownish yellow liquid. It boils at -220 F. It is toxic and possesses about the same lethal characteristics as phosgene.

The limited data on the compatibility of materials with oxygen difluoride and oxygen difluoride-oxygen mixtures are summarized in Tables 8 and 9. In general, the materials behave as well as, or better than, in fluorine. No detonation has been observed in steel cylinders when filled with OF_2 liquid or gas and struck by 0.22-caliber long rifle bullets fired from 50 feet.(124)

Ozone Difluoride (O_3F_2)

Ozone difluoride is a viscous blood-red liquid at -297 F. At -250 F it decomposes into oxygen and oxygen difluoride.

There is little published information on O_3F_2. The corrosive effect of 0.05 percent O_3F_2-LOX on stainless steel is reported to be about the same order of magnitude as that of fluorine.(83) Compatibility data are summarized in Table 10.

Chlorine Trifluoride (CTF)(ClF_3)***

Like fluorine, chlorine trifluoride is among the most active chemicals known. It is a nearly colorless gas at atmospheric pressure and room temperature, but can be liquified by the application of slight pressures. CTF reacts violently with water and many organic compounds. It attacks the respiratory tract. The threshold-limit value of toxicity for CTF in air is 0.1 ppm.

Chlorine trifluoride can be handled in many of the common metals shown in Table 11. As with fluorine, a coating is formed on metals, which provides protection from corrosive attack. Among the metals which are resistant to CTF are copper, brass, steel, Monel, and nickel. Of these, Monel and nickel are preferred because of their resistance to hydrogen fluoride and hydrogen chloride, which are formed by reaction of CTF with water. The organic materials that are compatible are limited to Teflon and Kel-F.

Although some surface staining has occurred in tests employing impact, shock, and perforation, there has been no ignition of low-carbon steel, stainless steel, aluminum, copper, magnesium, or titanium in liquid or gaseous CTF.(114, 115)

Cleaning and passivating treatments similar to those described for metals that are used to contain fluorine must be used for CTF systems to reduce the possibility of rapid reactions.

Bromine Trifluoride (BTF)(BrF_3)*

Bromine trifluoride is a colorless liquid that boils at 275 F. Its vapor pressure at 70 F is 0.15 psia. It is toxic and has a threshold limit value for toxicity in the atmosphere of 0.1 ppm.

Bromine trifluoride reacts violently with many organic compounds and vigorously with water. BTF, like CTF, appears to react with some metals to form a protective coating of the metal fluoride. As shown in Table 4, this coating permits the use of nickel up to about 1300 F, copper to 750 F, and steel to 480 F. The data are not sufficiently detailed to permit a more extensive classification than that shown in Table 12.

Metals which do not form protective coatings are vigorously attacked. Examples of this type of condition are molybdenum and tungsten, either as the pure metal or in an alloy. Titanium is also attacked by BTF. Boron, silicon, columbium, and sulfur all burn in BTF (liquid).

Materials of construction, equipment design, cleaning, passivation, and general handling practice for bromine trifluoride are the same as for chlorine trifluoride.

Bromine Pentafluoride (BPF)(BrF_5)**

Bromine pentafluoride is a colorless liquid that boils at 105 F. Its vapor pressure at 70 F is 7 psia. The toxicity threshold-limit value of BrF_5 in the atmosphere is 0.1 ppm.

Bromine pentafluoride reacts with most of the known elements except nitrogen, oxygen, and the rare gases. Under the proper conditions, it will react with most inorganic compounds except those containing fluorine in their highest valence state. Most organic compounds react violently with BPF at room temperature and atmospheric pressure. Detailed corrosion data for metals are not available.

Recommended materials of construction for BPF are the same as those for chlorine trifluoride. The same precautions for cleaning and passivation must be followed.

*FLOX: see References 224, 266, and 267.
**Oxygen difluoride: see References 83, 124, 224, 238, 282, and 283.
***Chlorine trifluoride: see References 17, 23, 40, 81, 82, 106, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 151, 158, 200, 211, 243, 244, 269, and 286.

*Bromine trifluoride: see References 82, 94, 106, 151, 211, 243, and 269.
**Bromine pentafluoride: see References 243 and 269.

Iodine Pentafluoride (IPF)(IF_5)*

Iodine pentafluoride is a colorless liquid. It boils at 207 F and has a vapor pressure of 0.4 psia at 70 F. Its toxicity threshold-limit value is 0.1 ppm.

Iodine pentafluoride is the least reactive of the halogen fluorides. Very few quantitative corrosion data for common materials of construction in IPF are available. However, it is reported that most metals are only slightly attacked by it at ordinary temperatures. The recommended materials of construction are the same as those for chlorine trifluoride.

IPF reacts violently with water. It also reacts with most organic compounds. Those rich in hydrogen will yield hydrogen fluoride and tend to ignite. Reaction with chlorine-containing compounds tends to release free iodine.

Perchloryl Fluoride (PF)(ClO_3F)**

Perchloryl fluoride is a colorless gas with a sweet odor. It can be liquified at room temperature at pressures in excess of 150 psia. PF affects the respiratory tract and causes "burns" if the liquid is splashed onto the body. The toxicity threshold-limit for PF in air is 3 ppm.

Anhydrous PF is normally shipped in liquid form in steel containers. Table 13 shows other materials which resist PF quite well.

Reactions of PF with water are very slow up to temperatures of about 575 F. However, in the presence of water, PF becomes more corrosive as indicated in Table 14. Under moist conditions, Types 304, 310, and 314 stainless steels have shown relatively good resistance at room temperatures. Short-time tests also have shown the nickel alloys, Hastelloy C, titanium, and tantalum to have good resistance.

Grenade or cylinder-perforation tests resulted in detonation of titanium in liquid and gaseous perchloryl fluoride.(114,115) Titanium also ignited under impact in perchloryl fluoride but the burning was not sustained. Other metals which underwent these same tests but did not ignite were: steel, stainless steel, copper, magnesium, and aluminum.(114,115)

Teflon and Kel-F are very resistant to attack by PF. Other plastics which are suitable are unmodified phenolic resins and epoxy resins. Rubbers which are compounded with carbon black tend to be inflammable, while those with iron oxide fillers are not inflammable. The large surface areas of sponge rubbers make them inflammable. Ordinary oils, greases, and waxes should never be used with PF, however, fluorocarbon compounds are compatible. Many organic materials do not react with PF at room temperature, but if ignited will burn violently. Some inorganic materials react rapidly, e.g., mercury and "Indicating" Drierite.

Mixtures With Perchloryl Fluoride

Compatibility data for materials in 25 percent perchloryl fluoride-75 percent chlorine trifluoride are summarized in Table 15. With the exception of columbium, molybdenum, and titanium, most metals perform well.

Compatibility data for materials in 50 percent perchloryl fluoride-50 percent tetrafluorohydrazine are presented in Table 16. All of the usual metals of rocket construction appear compatible in both the liquid and gas at -109 F. (Tetrafluorohydrazine boils at -100 F. It can be liquified at room temperature at pressures greater than 600 psi.)

Halogenated Hydrocarbon Propellants*

Halogenated hydrocarbon propellants are chiefly fluorinated and chlorinated methane and ethane. Many are well known as refrigerants under the trade names of Freon, Genetron, etc. They range from gases to liquids at room temperature with boiling points of about -200 F to about +200 F.

Compatibility data for some five propellants are summarized in Tables 17 to 21. Most of the common structural materials can be used satisfactorily with the halogenated hydrocarbons. At high temperatures, some metals promote catalytic breakdown of the propellants. The general order of this tendency is: Inconel<18-8 stainless steel<nickel<copper<1340 steel<aluminum<bronze<brass<silver.(68) Aluminum alloys containing more than 2 percent magnesium and magnesium alloys are not recommended for use in halogenated hydrocarbons containing water.

Impact tests at 70 ft-lb in Propellants 113 and 114B2 have not caused ignition of aluminum, aluminum plus alumina sand, titanium, titanium plus titanium filings, or titanium plus alumina sand.

Tetrafluoroethylene and chlorotetrafluoroethylene plastics and orlon acrylic are generally suitable for use in halogenated hydrocarbon propellants. Polyvinyl alcohol resists these propellants but is sensitive to water. Phenolics, Delrin acetal resin, nylon, polyethylene and vinyls are suitable for use in many applications, but the behavior of different types may vary in different propellants, and thus should be thoroughly tested before use. Methacrylates and polystyrene are generally not suitable. No single elastomer has been found to be compatible in all halogenated hydrocarbon propellants, but a satisfactory combination can usually be found.(68)

HYDRAZINES

Hydrazine (N_2H_4)**

Hydrazine is a clear oily liquid with an odor similar to that of ammonia. Its vapor pressure at 80 F is 0.31 psia and it boils at 236 F. Hydrazine vapors affect the respiratory tract, nervous system, liver, and kidney, and cause "burns" when spilled on the skin. The toxicity threshold-limit value in the atmosphere is 1 ppm.

The information regarding the compatibility of various metals and nonmetals with hydrazine and

*Iodine pentafluoride: see References 243 and 269.
**Perchloryl fluoride: see References 81, 82, 83, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 151, 211, 219, and 224.

*Halogenated hydrocarbon propellants: see References 51, 53, 68, 84, 136, 214, and 279.
**Hydrazine: see References 3, 4, 7, 23, 70, 81, 82, 102, 110, 135, 145, 149, 151, 170, 171, 172, 173, 174, 183, 196, 211, and 216.

hydrazine-water mixtures is not completely consistent. These differences appear to be related to the specific application. For example, a metal may be satisfactory if air oxidation of the surface can be prevented. On the other hand, this same metal may be unacceptable for service in which prolonged exposure to air cannot be avoided.

In assessing the compatibility of a material with hydrazine, two major factors must be considered for any given exposure condition. They are:

(1) The corrosion behavior of the material in contact with hydrazine

(2) The effect of the material and/or corrosion products on the rate of decomposition of hydrazine.

This is particularly true for carbon and low-alloy steels, copper alloys, and molybdenum. From the corrosion standpoint, they are satisfactory. On the other hand, these metals and/or their corrosion products catalyze hydrazine decomposition at elevated temperatures. Explosions may occur. At one time, it was believed that Type 316 stainless steel (containing molybdenum) caused explosions when contacted by hydrazine at elevated temperature. However, it is now generally agreed that the hazard from misoperation in hydrazine and unsymmetrical hydrazine is no greater with 316 stainless steel than with any of the other 300 series stainless steels.[254]

Most metallic materials of construction are compatible with hydrazine. Data are summarized in Table 22.

Many plastics and rubbers are compatible with hydrazine at room temperature. Graphite and Graphitar are not suitable, since they tend to promote decomposition.

Monomethyl Hydrazine (CH_3NHNH_2)*

Monomethyl hydrazine is a clear liquid with the odor of ammonia. It has a vapor pressure of 1 psia at 80 F and boils at 189.5 F. Its toxic properties are somewhat similar to those of hydrazine. The recommended threshold limit is 0.5 ppm in the atmosphere.

The following materials can be used in the storage and handling of monomethyl hydrazine:

Metals

303 stainless steels
304 stainless steels
321 stainless steels
347 stainless steels
4130 steel
Aluminum alloys to 160 F
Aerobraze-I

Nonmetals

Tetrafluoroethylene resins
High-density polyethylene
Some silicone rubbers
Some unplasticized trichlorofluorethylene

*Monomethyl hydrazine: see Reference 154.

Copper, lead, zinc, and alloys containing more than 0.5 wt% molybdenum are not compatible with monomethyl hydrazine.

Unsymmetrical Dimethyl Hydrazine (UDMH) [$(CH_3)_2NNH_2$]*

UDMH is a clear liquid with the odor of ammonia. Its vapor pressure at 80 F is 8.4 psia and it boils at 146 F. Its toxicity is similar to that of hydrazine but not so severe. The toxicity threshold-limit value of UDMH is 0.5 ppm.

In general, unsymmetrical dimethyl hydrazine affects materials in much the same manner as hydrazine. Of the metals, low-alloy steels, aluminum, and stainless steels are commonly used to contain UDMH. Aluminum is attacked by UDMH if water is present with the attack being in direct proportion to the amount of water. Teflon, Kel-F (unplasticized), nylon, polyethylene, and Haveg 60 are among the plastic materials which are not attacked by UDMH.

Lubricants such as APS C-407, Parkerlube 6 PB, Molykote, and Peraline 12-4 may cause decomposition On the other hand, litharge and glycerine paste, X-Pando, and Q-seal are compatible and can be used for thread compounds and other similar applications. Petroleum and silicone greases do not react, but are dissolved by the UDMH. Data for all materials are summarized in Table 23.

Hydrazine-Unsymmetrical Dimethyl Hydrazine Mixtures**

Much of the information on properties and compatibility of 50:50 N_2H_4:UDMH (Aerozine 50) is summarized in the Titan II Storable Propellant Handbook.[167,168,169] Most of the common metallic materials of construction are compatible with N_2H_4:UDMH at room temperature, including aluminum alloys, steel, stainless steel, nickel alloys, and titanium alloys. As described under "Hydrazine", Type 316 and molybdenum-containing stainless steels are no longer believed to pose an explosion hazard with 50:50 N_2H_4:UDMH.[254] Of the plastic materials only some of the fluorocarbons, polyethylene, polypropylene and polyolefins are Class 1 materials. Compatibility data are summarized in Tables 24 and 25.

HYDROGEN***

Liquid hydrogen boils at -423 F. Hydrogen is not toxic in the usual sense but will cause "burns" if the cold liquid contacts the skin. Hydrogen is readily ignited in air at concentrations of 4 to 74 vol%.

Liquid hydrogen and gaseous hydrogen at low temperatures are both considered to be noncorrosive. Embrittlement of metals by the low temperature of the liquid or gas is a more important factor. As can be seen in Table 26, a number of metals can be

*Unsymmetrical dimethyl hydrazine: see References 3, 7, 23, 24, 54, 60, 61, 62, 63, 79, 81, 82, 92, 102, 110, 145, 151, 155, 156, 157, 164, 171, 172, 173, 174, 182, 196, 198, 211, 227, 228, 281, and 296.

**Hydrazine-unsymmetrical dimethyl hydrazine mixtures: see References 4, 31, 47, 48, 49, 50, 165, 166, 167, 168, 169, 170, 198, 205, and 254.

***Hydrogen: see References 34, 46, 74, 80, 81, 82, 93, 151, 181, 199, 211, and 221.

rated compatible (Class 2) with liquid hydrogen; among these are the 300 series stainless steels, Type 410 stainless steel, aluminum and most of its alloys, some nickel alloys, cobalt alloys, and molybdenum. The use of organic materials is limited because of the effect of the low temperature on their physical properties. To avoid this temperature effect, "warm joints" are used, in which the gasket material is kept at a higher temperature so that only hydrogen gas contacts a joint. Table 26 lists some of the organic materials that can be used with liquid hydrogen.

HYDROGEN PEROXIDE (H_2O_2)*

Hydrogen peroxide is a colorless liquid that boils at 303 F. Its toxicity threshold-limit value in the atmosphere is 1 ppm.

When considering materials of construction for handling and containing concentrated hydrogen peroxide, both the effect of the H_2O_2 on the construction material and the effect of the construction material on the H_2O_2 must receive equal attention. If corrosion of the material takes place, usually the H_2O_2 will also decompose, although the reverse is not true, for some materials catalytically decompose H_2O_2 without much corrosive attack occurring.

One means of reducing the decomposition is to passivate the construction material before use.

Aluminum Passivation

An accepted passivation procedure for aluminum consists of several steps.

Step 1, thoroughly clean the metal. This step consists of degreasing with trichlorethylene, perchlorethylene, or a detergent wash, or both, depending upon the type of contaminating dirt, followed by thorough rinsing with clean water.

Step 2, treat with 5 percent nitric acid for 1 or 2 days. Rinse with tap water. Spots or areas which are not passivated can be readily identified. These spots will not have the uniform dull, velvety finish characteristic of passivated aluminum.

Step 3, reclean unpassivated areas and dig out areas containing iron or other inclusions in the aluminum.

Step 4, repeat the cleaning and nitric acid treatments until the aluminum is satisfactorily passivated.

Step 5, treat with stabilized 35 percent H_2O_2 for 1 to 3 days. The passivity of the aluminum can be checked by the amount of decomposition of the 35 percent H_2O_2, by gas bubbles, and by the warming of the solution.

Step 6, rinse with distilled or deionized water.

Step 7, expose to 90 percent H_2O_2. During the first 16 to 24 hours of exposure to strong H_2O_2, equipment must be carefully watched to be sure that the H_2O_2 is not decomposing.

*Hydrogen peroxide: see References 23, 28, 35, 36, 37, 38 41, 44, 75, 76, 77, 81, 82, 94, 101, 102, 105, 108, 110, 129, 144, 147, 148, 149, 151, 186, 187, 198, 206, 208, 210, 211, 213, 221, 229, 230, 234, 245, 246, 249, 250, 258, and 293.

Modifications of the procedure and other treatments which produce the same result may be used.

Stainless Steel Passivation

The passivating procedure for the 300 series stainless steels is similar to that for aluminum.

Step 1, clean with appropriate solvents and detergent solutions to remove dirt, grease, and other contamination and rinse with tap water.

Step 2, treat with 70 percent nitric acid for 4 or 5 hours and rinse with distilled water. An alternative treatment for 17-7PH steel uses a 2 percent $Na_2Cr_2O_7 \cdot 2H_2O$-20 percent HNO_3 solution for 1/2 hour at 120-130 F.

Step 3, condition the stainless steel in H_2O_2 of the concentration it will be required to handle. This operation should be observed closely to determine whether decomposition is taking place.

Step 4, if decomposition takes place, repeat the cleaning and passivating steps.

Some stainless steels may not respond to passivating treatments without prior cleaning by pickling in a 3% HF-10% HNO_3 solution.

Pretreatment of Plastics

Plastic materials must be cleaned with the appropriate solvents or detergent solutions and rinsed. Next, they should be pre-exposed for 16 to 24 hours in the H_2O_2 solution in which they will be used.

Discussion

Another method which effectively reduces the decomposition is the addition of sodium stannate to H_2O_2 in about 2.0 ppm concentration. This treatment is effective in reducing decomposition after refilling a container with fresh stannate-free H_2O_2.

In general, the acceptability of a material for H_2O_2 service is based mostly upon the amount of active oxygen that is lost by decomposition rather than upon a corrosion rate of the construction material. Accordingly, the "class" ratings used for materials for H_2O_2 have been based on decomposition limits. Table 27 describes these limits in detail for four classes of materials. The table lists the material in each class immediately under the description.

Aluminum, some of its alloys, tantalum, and zirconium are the only metals included in Class 1.

Many aluminum alloys, stainless steel alloys, silicon, and tin fall into Class 2.

Class 3 contains other aluminum alloys, a variety of stainless steel alloys, Inconel X, Alloy H-075, and Refractalloys 26 and 70.

In general, the presence of copper in an aluminum alloy greatly reduces its compatibility with H_2O_2. The 1060 alloy is most widely used in 90 percent H_2O_2 service; however, several other alloys are considered to be Class 1 materials.

The attack of an aluminum alloy is usually of the smooth overall type, but pitting occurs occasionally. Pitting is usually attributed to the presence of impurities which cause local breakdown of the H_2O_2. Chloride ions also accelerate the pitting attack. The addition of small amounts of nitrate ion, such as sodium nitrate, tends to reduce the action of the chloride ion. However, the presence of 10 mg Cl^- per liter causes accelerated attack even with nitrate present. Anodizing of the metal also reduces the attack by H_2O_2 with chloride, but damage of the anodic coating localizes the pitting in the damaged area. The addition of compounds to H_2O_2 which change the pH in either direction from the neutral point may accelerate attack.

Galvanic coupling of aluminum to stainless steel results in increased attack on the aluminum. Chloride ions in turn increase the galvanic effect.

Many of the higher strength aluminum alloys are not compatible with H_2O_2; therefore, one alternative is to use a strong alloy clad with a compatible grade. Of course, special attention must be given to welds, to insure complete covering of the base alloy.

Many cases of decomposition of H_2O_2 in aluminum or other compatible metals is traced to soluble or suspended contamination of the H_2O_2 and not to an effect of the container material.

The table shows that the 300 series stainless steels cannot be rated as Class 1, but give very good Class 2 service. The 300 series steels are used for high-pressure flowing systems and may be welded. Chloride contamination, at the 10-mg-per-liter level, does not appear to cause pitting in stainless steels. The galvanic effect in aluminum-stainless steel couples tends to protect the steel. The 17-7PH grades of stainless steel are satisfactory with H_2O_2, but the 400 series is not. A 120-grit finish on the 17-7PH steels improved their service.

Lower concentrations of H_2O_2 (52 to 90 percent) require the same materials of construction as 90 percent H_2O_2. Higher strength peroxide (98 percent) is, in general, more stable than 90 percent H_2O_2 in contact with metals. Aluminum alloys 1060, 5052, and 7072 are rated Class 1. Stainless steels Types 304, 316, and 347, and aluminum alloys 6061 and 356 are rated Class 2.

In the transporting of high-strength H_2O_2, 1060 aluminum has been used in tank cars and 43 aluminum or 300 series stainless steels in self-priming centrifugal pumps, while valves, fittings, and instruments are usually made of 300 series stainless steel.[208]

Of the plastics and rubbers, molded Teflon, Kel-F, and Mylar B are rated Class 1 (unrestricted use). Koroseal 700 has been used extensively as gasketing material. Many lubricants exhibit impact sensitivity in H_2O_2. The fluorinated and chlorinated lubricants appear most promising with a Class 2 rating and no impact sensitivity. Compatibility data for nonmetals in H_2O_2 are presented in Table 28.

METHYLENE CHLORIDE (CH_2Cl_2)*

Methylene chloride is a colorless liquid. It boils at 104 F and exerts a vapor pressure of 380 mm at 72 F. The toxicity threshold limit for CH_2Cl_2 in the atmosphere is 500 .

*Methylene chloride: see References 127, 128, and 211.

Liquid methylene chloride is compatible with copper, steel, austenitic stainless steels, Hastelloy B, Hastelloy C, asbestos, and graphite. Gaseous methylene chloride is more corrosive, being compatible with Worthite and Durimet 20. Compatibility data are summarized in Table 29.

NITRIC ACID (HNO_3)*

The nitric acid used for propellants is usually in the concentrated form referred to as "fuming nitric acid". In general, the fuming acids contain less than 5 percent water. If the acid contains dissolved oxides of nitrogen, it is known as "red fuming nitric acid" or "RFNA". The NO_2 content normally varies from 7 to 30 percent.

Nitrogen dioxide is not present in "white fuming nitric acid" or "WFNA", which contains a minimum of 97 percent HNO_3.

Hydrofluoric acid may be added to either RFNA or WFNA as a corrosion inhibitor. Listed below are the Military Specification compositions of inhibited and noninhibited acid (MIL-N-7254 C, July 19, 1956):

	White Fuming Nitric Acid	
	Type 1	Type 1 A (IWFNA)
Nitric acid (HNO_3)	97.5% min.	96.8% min.
Nitrogen dioxide (NO_2)	0.0 + 0.5%	0.0 + 0.5%
Water (H_2O)	2.0% max.	2.0% max.
Hydrofluoric acid (HF)	0.0	0.6 ± 0.1%
	Red Fuming Nitric Acid	
	Type III	Type III A (IRFNA)
Nitric acid (HNO_3)	82.0 - 85%	81.3-84.5%
Nitrogen dioxide (NO_2)	14.0 ± 1.0%	14.0 ± 1.0%
Water (H_2O)	2.5 ± 0.5%	2.5 ± 0.5%
Hydrofluoric acid (HF)	0.0	0.6 ± 0.1%

Red Fuming Nitric Acid

Red fuming nitric acid is a highly corrosive material; therefore, the choice of construction materials is based upon the corrosion resistance of the material rather than on the catalytic decomposition of the acid. Aluminum and stainless steel alloys are usually used to handle RFNA. The compatibility data in Table 30 indicate that at room temperature, the corrosion rate for aluminum alloys is slightly higher than for the 300 series stainless steels. It should be noted that at 160 F, aluminum alloys are more resistant than stainless steels. Stainless steels and aluminum alloys are usually attacked in a uniform manner. However, selective attack in the heat-affected zone near welds is sometimes produced. Knife-line attack at welds may occur in aluminum alloys above 120 F. The 1060 alloy appears to be free from this attack to higher temperatures. The low-carbon grades of the 300 series stainless steels and those containing columbium or titanium are less susceptible to attack at welds than are the regular grades. Aluminum, when coupled to stainless steel, acts as a sacrificial anode to protect the steel.

*Nitric acid: see References 18, 19, 29, 30, 32, 39, 64, 69, 81, 82, 87, 89, 93, 95, 96, 97, 102, 104, 110, 127, 128, 130, 133, 135, 150, 151, 179, 181, 185, 188, 189, 190, 192, 193, 198, 204, 211, 214, 221, 222, 223, 239, 240, 241, 242, 248, 260, 287, 298, and 300.

As little as 0.1 percent HF added to RFNA greatly reduces the corrosion rate of both aluminum and stainless steel. If this change from RFNA to IRFNA is made in stainless steel equipment and selective attack has already started, the inhibitors are not effective. The HF inhibitor reduces the selective attack at welds, permitting use at higher temperatures.

Titanium and tantalum are both resistant to RFNA; however, caution must be used with the titanium alloys. A pyrophoric reaction may occur with titanium alloys in RFNA which contains less than 1.5 to 2.0 percent H_2O. Both titanium and tantalum are attacked much more rapidly by IRFNA than by the acid without the HF addition.

A number of other alloys are compatible with red fuming nitric acid. These include cobalt alloys, Types 430 and 446 stainless steels, chromium, and for some applications, nickel and some nickel alloys. Platinum, gold, tin, and zirconium may be used. Low-alloy steels, lead, copper, and magnesium are rapidly attacked by either RFNA or IRFNA.

White Fuming Nitric Acid

White fuming nitric acid is similar to red fuming nitric acid with respect to compatibility with construction materials. It is not so stable as RFNA, but compatibility is largely dependent upon corrosion properties rather than on decomposition.

The corrosion behavior of metals in white fuming nitric acid is much the same as that in RFNA. The same materials are resistant and the same materials are severely attacked. However, Table 31 shows that the temperature limits are somewhat lower in the white fuming nitric acid.

Concentrated Nitric Acid

Table 32 has been included to show the compatibility of materials in somewhat less concentrated acids than the fuming grades. It can be seen that acids from 80 percent up to the fuming range are much more corrosive than the more concentrated ones. Stainless steels are the best materials of construction for these acids.

NITROGEN TETROXIDE (N_2O_4)*

Nitrogen tetroxide is an equilibrium mixture of dinitrogen tetroxide and nitrogen dioxide (N_2O_4<--->$2NO_2$). It is a heavy brown liquid that boils at 70.1 F. The liquid causes severe burns on body tissue. The toxicity threshold-limit value in the atmosphere is 5 ppm as NO_2 or 2.5 ppm as N_2O_4.

Much of the information on properties and compatibility of N_2O_4 is summarized in the *Titan II Storable Propellant Handbook*.(167,168,169)

Dry (less than 0.2 percent H_2O) nitrogen tetroxide can readily be contained by several metals and their alloys. It is normally handled in aluminum, mild steel, cast iron, or stainless steel, although there have been reported instances of intergranular attack in welded 2014-T6 aluminum. Compatibility data are summarized in Table 33.

*Nitrogen tetroxide: see References 3, 9, 10, 11, 12, 13, 23, 31, 47, 48, 49, 50, 59, 72, 81, 82, 88, 102, 110, 126, 131, 137, 145, 151, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 181, 196, 198, 205, 211, 220, 221, 245, 256, 257, 287, 288, and 292.

Titanium is resistant to N_2O_4 except under impact. It has been found that titanium impacts sporadically under reasonably well controlled test conditions; the ignition frequency is increased markedly by titanium filings or glass particles on the impact surface; increasing the impact-energy level increases the ignition frequency; and increasing the water content of the N_2O_4 to 2 to 5 percent lowers the ignition frequency.(256,257,292) The ignitions do not spread beyond the impact area.

Moist N_2O_4 is, in general, more corrosive because of the nitric acid formed. As shown in Table 34, at levels of up to 1 percent moisture in N_2O_4, most common metals are still Class 1 at room temperature. With 3.2 percent moisture in N_2O_4 the corrosion resistance of steel and aluminum alloys drops off markedly even at slight increases in temperature. Data for the latter are summarized in Table 35.

Limited data on the compatibility of materials with flowing N_2O_4 are presented in Table 36.

The most resistant plastic materials are polymerized fluorinated hydrocarbons such as Teflon and unplasticized Kel-F. Other plastics such as Koroseal, Saran, polyethylene, and Tygon are suitable for short-time exposures. Vinyl plastics, in general, do not hold up well in N_2O_4.

Asbestos and graphite are satisfactory for packing materials and graphite-waterglass for thread compound.

Impact tests at 60 ft-lb in liquid N_2O_4 have resulted in detonations of polydimethylsiloxane. Similar tests at 70 ft-lb did not cause detonation in polychloroprene, branched or linear polyethylene, polypropylene, polyvinylidene fluoride, and vinylidene fluoride-hexafluoropropylene copolymer.(126)

OXYGEN*

Oxygen is a light blue transparent liquid at -297.4 F. In the liquid state it can cause "burns" if spilled on the skin. Oxygen supports combustion and accidental contact should be avoided with oxidizable materials.

Of the elemental materials, oxygen is next to fluorine in reactivity. It will form compounds with all elements except the rare gases. However, the reactivity of liquid oxygen is very low compared with that of gaseous oxygen.

Liquid oxygen is considered to be noncorrosive to most metals. In particular, nickel, Monel, Inconel, copper, aluminum, the 300 series of stainless steels, brass, and silver solder are used in liquid-oxygen-handling equipment.

Several instances have been reported of violent reactions of titanium and liquid oxygen which appeared to be related to impact. The impact sensitivity of titanium in LOX has been investigated rather extensively.** It appears that the ignition of titanium under impact occurs in the following sequence:(139,140)

* Oxygen: see References 1, 5, 6, 7, 8, 21, 22, 25, 26, 27, 33, 42, 43, 45, 65, 66, 67, 71, 78, 80, 81, 82, 98, 102, 107, 125, 126, 138, 139, 140, 141, 142, 151, 176, 177, 180, 181, 195, 198, 209, 211, 218, 231, 232, 235, 236, 255, 259, 262, 284, and 285.

** Ignition in LOX: see References 7, 22, 27, 42, 43, 65, 66, 71, 78, 126, 138, 139, 140, 141, 142, 176, 177, 180, 198, 218, 235, and 236.

(1) The impact exposes fresh metal and results in some gaseous oxygen being formed at the point of impact.

(2) The gaseous oxygen reacts with the fresh metal in an exothermic reaction.

(3) The heat generated raises the metal temperature sufficiently to result in localized dissolution of any TiO_2 film that might form.

(4) Thus a protective oxide film does not build up and the reaction proceeds rapidly between the base metal and oxygen.

Ignition of massive titanium is observed in gaseous oxygen at liquid-oxygen temperatures at pressures of about 100 psi and above. This critical pressure limit is lowered only slightly as the temperature of the oxygen is raised to ambient temperature.

Massive aluminum exhibits ignition under severe detonation in LOX. The frequency is not so great nor is the propagation so severe as it is with titanium under the same conditions. Magnesium also ignites under detonation at shock levels higher than those for titanium but lower than those for aluminum.

Organic materials should be avoided with both liquid and gaseous oxygen because of possibilities of explosions. Currently, there is no single test or group of tests which gives a reliable compatibility rating for organic materials in liquid oxygen service. It is recommended that organic materials be avoided wherever possible and used only with caution. No completely compatible lubricants have been found. Thread antiseize sealants of graphite in chlorinated organic carrier and halogen paraffin oils with pour points as low as -100 F have been used in LOX systems. Teflon, Mylar, and certain chloroprene and Buna-N compounds have been used as static seals while Kel-F-300, Kel-F-500, Kel-F-240, Fluorothene FYTD, Fluorothene FYTS, and certain chloroprene and Buna-N compounds have been used in dynamic seals.[284,285]

Many organic and plastic materials exhibit impact sensitivity in LOX including:[71,126]

(1) Synthetic elastomers and Thiokols

(2) Cellulose-based papers

(3) Silicone- and silicate-based oils and greases

(4) Thermoplastics such as nylon and phenolics

(5) Thermo-setting resins (phenolics, silicones, epoxies, etc.)

(6) Petroleum-based oils and greases.

The fluorocarbon plastics are probably the best choice with respect to impact sensitivity. These, however, should not be used with aluminum. A number of other organic materials might be used, but specific conditions should be carefully studied. The list of references on ignition in LOX contains the results of many impact tests on organic materials, which can be used as a guide to selection.

OZONE

Ozone is colorless in gaseous and liquid state. It boils at -168 F. The toxicity threshold-limit value for ozone in the atmosphere is 0.1 ppm.

There are few data on the compatibility of materials with ozone. It has been shown that 100 percent gaseous ozone can be stored up to 50 days at 5 atm pressure and dry ice temperature (-109 F) in stainless steel, aluminum, and glass with no decomposition of the ozone.[280]

SOLID PROPELLANTS

ANP-2639AF

There are few or no data published in the open literature on the compatibility of materials with solid propellants. Bent beam specimens of the following materials bonded to propellant ANP-2639AF and stressed to 75 percent of the 0.2 percent offset yield strength have survived over 100 days' exposure at room temperature and 180 F:[289]

Ladish D6AC
300 M
Vascojet 1000
AM-355 (longitudinal)
PH 15-7Mo
B120VCA titanium
(longitudinal and transverse)

Nitronium Perchlorate (NO_2ClO_4)

Nitronium perchlorate is a white crystalline powder at room temperature which has a faint odor of chlorine and nitrogen oxide. Its vapor pressure is less than 0.05 mm at 68 F. It melts and decomposes at 250 to 285 F.

The following materials are reported to be compatible with nitronium perchlorate:[55]

Metals:	stainless steel (mild steel if system is dry)
Nonmetals:	glass, Teflon, unplasticized polyvinyl chloride, polyethylene
Lubricants:	Hooker Fluorolube Grease GR-54 Hooker Fluorolube Oil X-30 3M Kel-F Polymer Oil, Grade No. 1 Halocarbon Oil Series B-21.

TABLE 3. COMPATIBILITY OF MATERIALS WITH AMMONIA

Material	Temperature, F — Gas, Class 1	Gas, Class 2	Gas, Class 3	Gas, Class 4	Liquid, Class 1	Liquid, Class 2	Liquid, Class 3	Liquid, Class 4	References
Metals									
Aluminum	212	100	175	>175			175	175	211,224,287
302 Stainless Steel	75			<900					82
304 Stainless Steel	600			<900					58,73,109,217,221
316 Stainless Steel	600			<900					58,73,217,221
347 Stainless Steel			75						109
410 Stainless Steel	600			850					58,73,221
430 Stainless Steel	600			<900					58,73,217,221
Worthite	75			<900					82
Durimet 20	75			<900					221
Carpenter 20	600								58
Mild Steel	600			<900		75			211,221,287
Cast Iron	600			<900		75			211,221,287
Si-Iron	212	75					75		211,287
Ni-Cast Irons, Low Cu	75					160			211,287
Ni-Cast Irons, High Cu	75							All	211,287
Nickel	500		500	<1100				75	211,287
Inconel	700		1100	>1100		75			211,221,287
Monel	500		500	<1100				75	211,287
Hastelloy B	600	600		>1000					58,127,126,211
Hastelloy C	600	600		>1000					58,127,128,211
Hastelloy D	500	600		>1000					58,127,128,211
Hastelloy F		600		>1000					127,128
Chlorimet 2-3	75								221
Nickel-Copper	75								82
Copper		75		High				Low	127,217,221,287
Yellow Brass		75		High				Low	127,221,287
Red Brass		75		High				Low	127,221,287
Tin Bronze		75		High				Low	127,221,287
Al Bronze		75		High				Low	127,221,287
Si Bronze		75		High				Low	127,221,287
Cu-Nickel		75		High				Low	80,127,221,287
Gold	212				High				211,221
Lead		75		>260		75			211
Dow Metal C		Low							82
Dow Metal FS1		Low							82
Dow Metal H		Low							82
Dow Metal J-1		Low							82
Dow Metal M		Low							82
Platinum	212				High				211,221
Ir-Platinum	High				High				221
Rh-Platinum	High				High				221
Silver	75							Hot	211
Ag-Cu				All				All	82
Titanium	175								211
Tantalum	212			High	212		High		221
Zinc	75								217
Zirconium	175								211
Organic Materials									
Rubber, Hard Linings				75			75		82
Rubber, Soft Linings				75				75	82
Rubber, Natural		75		Hot					211
GRS		75		Hot					82
Neoprene		75		Hot					82
Butyl Rubber		75		Hot					82
Thiokol			Cold						82
Glass Fabric and Silicone Elastomer*		Hot							82
Silicone Greases		Hot							82
Haveg 41 Epon	212								211
Silicone Elastomer		75							82
Silicone Resins			75						82
Teflon	Hot								82
Cork				75					82
Vinyl Copolymers		Hot				Hot			82
Phenolics		Hot				Hot			82
Furans		Hot				Hot			82
Polyethylene		Hot				Hot			82
Kel-F		Hot				Hot			82
Vinylidene Chloride			Cold				Cold		82
Sulfur Cement			Cold				Cold		82
Bituminous Composition			Cold				Cold		82
Polystyrene				75					259
Polyesters				75					259
Phenol Formaldehyde				75					259
Nonmetals									
Glass	212								211
Stoneware	212								211
Karbate	>2000								82
Carbon	>2000								82
Graphite	>2000								211

* Glass Fabric and Silicone Rubber

TABLE 4. COMPATIBILITY OF MATERIALS WITH Hi-Cal-3 (82)

Material	Remarks
Class 1	
Mild steel	Below 120 F, probably higher
40/50 carbon steel	Below 120 F, probably higher
Hot-rolled primer steel	Below 120 F, probably higher
Type 304 stainless steel	Below 120 F, probably higher
Beryllium copper	Below 120 F, probably higher
Cupro-nickel	Below 120 F, probably higher
Naval brass	Below 120 F, probably higher
Phosphor-bronze	Below 120 F, probably higher
Phosphorized copper	Below 120 F, probably higher
Nickel	Below 120 F, probably higher
Inconel	Below 120 F, probably higher
Monel	Below 120 F, probably higher
Nionel	Below 120 F, probably higher
Incoloy	Below 120 F, probably higher
Aluminum	Below 120 F, probably higher
Lead	Class 2 at 120 F
Titanium	Below 120 F, probably higher
Tantalum	Below 120 F, probably higher
Class 2	
Organics	
Bakelite	No change at 120 F
Easton PVC plastic pipe	No change at 120 F
Epoxy resin	No change at 120 F
Graphite bearing	No change at 120 F
Kel-F 300	No change at 120 F
Kel-F 500	No change at 120 F
Teflon	No change at 120 F
Hycar 1001-520-39-5-4	No change at 120 F
Viton 4411A-58	No change at 120 F
Hycar 1000x88-520-39-20-3	No change at 120 F
Hycar 1001-520-37-83-1	No change at 120 F
IF4 Fluororubber	No change at 120 F
LS-53 Fluorosilicone rubber	Slightly less resilient at 120 F
Hycar 1001-520-37-83-5	No change at 120 F
X-Pando pipe dope	No change at 120 F
Nylon Zytel 101-NC-10	No change at 120 F
Class 3	
Organics	
Hycar 1001-520-39-5-2	120 F, Slightly stiffened
Polyethylene tubing	120 F, Turns yellow
Garlock 8748 (Buna-N binder)	120 F, Stiffened
Garlock 7021 (GRS - high sulfur binder)	120 F, Stiffened and roughened
Garlock 900 (GRS binder)	120 F, Stiffened
African Blue Asbestos packing	120 F, Darkened
Teflon asbestos packing	120 F, Weight gain
Class 4	
Organics	
Hycar 1001-520-39-5-5	120 F, Blistered
Compressed asbestos gasket	120 F, Fibers loosened
Garlock 7228 (neoprene binder)	120 F, Blistered
Hycar 1042-520-24-144-1	120 F, Brittle, crazed
Tygon tubing	120 F, Hardened
Garlock 7705 (GRS - blue asbestos)	120 F, Stiffened
Plexiglas	120 F, Became soft and sticky
Fairprene 5051 (neoprene on duck)	77 F, Stiffened
Fairprene 5039 (neoprene on nylon)	77 F, Became brittle
Natural rubber	120 F, Softened, easily torn
National 846, O-ring	120 F, Stiffened
Neoprene	120 F, Softened
Hycar 1001-520-39-5-1	120 F, Stiffened
Hycar 1001-520-39-5-3	120 F, Stiffened
Silicone rubber	120 F, Deteriorated to a powder

TABLE 5. COMPATIBILITY OF MATERIALS WITH PENTABORANE[294]

Material	Temperature, F: Gas Class 1	Gas Class 2	Gas Class 3	Gas Class 4	Liquid Class 1	Liquid Class 2	Liquid Class 3	Liquid Class 4	References
Metals									
Aluminum, 2024 T-3					75				
Aluminum, 3003 H-14					75				
Aluminum, 5052-0					75				
Aluminum, 6061 ST-6					75				
Aluminum, 7075 T-6					75				
Aluminum, 356 T-6					75				
Aluminum, Chromated					75				
Cadmium-Plated Steel					75				
Cadmium-Coated Aluminum					75				
Copper					75				
Brass					75				
Iron					75				
Steel					75				
302 Stainless Steel					75				
304 Stainless Steel					75				
321 Stainless Steel					75				
347 Stainless Steel					75				
Magnesium Alloy, Fed QQ					75				
Nichrome V					75				
Hastelloy No. X1258					75				
Titanium, C-110M					75				
Titanium, C-130AM					75				
Nonmetals									
Asbestos, Graphite Impregnated					75				
Asbestos, Hercules No. 571 K					75				
Pure Carbons					75				
Graphitar No. 39					75				
Teflon					75				
Viton					75				
Viton A					75				
Kel-F No. 5500					75				
Kel-F and Glass Cloth					75				
Fluoroplex [illegible]					75				
Fluorosilicon Rubber					75				
Foamglass								75	
Dow Corning R-7002 Foam								75	
Dow Corning R-7003 Foam								75	
Mopco F 10 Foam								75	
Mopco B 49								75	
Natural Rubber								75	
Nitrile Rubber on Nylon								75	
Dow Corning 9383 Rubber								75	
Swedlow Plastic X5G 156-101								75	
Saran								75	
Nylon								75	
Mylar								75	
Tygon								75	
Rubatex G-2027N								75	
Rubatex R-1C3J								75	
Fiberfrax, No. XSR								75	
Fiberfrax, No. SIF								75	
Dow Corning Silastic No. 80-24-480								75	
Garlock Silastic No. 2[illegible]C								75	
Lubricants									
Rockwell Nordstrom Lube No. 921					75				
Molybdenum Disulfide					75				
Rockwell Nordstrom Lube No. 833								75	
Rockwell Nordstrom Lube No. P-21								75	
Rockwell Nordstrom Lube No. 860								75	
Rockwell Nordstrom Lube No. 356								75	
Rockwell Nordstrom Lube No. 852-S								75	
Rockwell Nordstrom Lube No. P-55								75	
Rockwell Nordstrom Lube No. 942-B								75	
Water-Based Lubricants								75	

TABLE 6. COMPATIBILITY OF MATERIALS WITH FLUORINE

Material	Temperature, F: Gas Class 1	Gas Class 2	Gas Class 3	Gas Class 4	Liquid Class 1	Liquid Class 2	Liquid Class 3	Liquid Class 4	References
Metals									
Aluminum 1100	500	600	>600	<673	-320			-310	7,73,132, 143,153,159, 207,211,274
Aluminum 2017						-320			274
Aluminum 2024	700	>1000	1000	>1000				-310	143
Aluminum 3003	700	700	1000	>1000		-320		-310	120,143
Aluminum 5052						-320		-310	120,274
Aluminum 5154	700	>1000	1000	>1000				-310	143,274
Aluminum 6061					-320				153
Aluminum 7079					-320				274
Beryllium				75					269
304 Stainless Steel	400	400	500	>500	-320	-320	-310		58,211,274
304 L Stainless Steel	>70		>400						143
309 Stainless Steel	570		750						7
309 Cb Stainless Steel	500			>500					207
310 Stainless Steel	570	660	750						7,207
316 Stainless Steel	400				-320				58,211,274
321 Stainless Steel							-310		120
347 Stainless Steel	390	570	750		-320		-310		120,207,274
410 Stainless Steel				75	-320				58,153,211
420 Stainless Steel					-320				274
430 Stainless Steel	400	400	500	600					7,207,211
Carpenter 20	400				-320				58
PH15-7Mo					-320				153,274
AM-350-C					-320				274
AM-350-CX					-320				274
AM-350-D					-320				274
AM-350-DX					-320				274
Cast Iron				75					211
Armco Iron	750		500	>500					7,159,160,207
Silicon Iron				75					211
Iron (0.004Si)		200	400	>400					159,160
Iron (0.79Si)		100	300	>300					159,160
Sheet Steel	750	840		930					7
SAE 1010	100	200	400	>400			-310		207
SAE 1015	300	400	570	>300					7,159,160, 207,211
SAE 1020	390	840		930					7,207
SAE 1030	750		840	930					7,207
Carbon Steel	700			930					82
Music Wire		570							7
A Nickel	1290	900	1300	>1300	[illegible]		-310		7,73,120,143, 153,159,160, 211,274
D-Nickel		1200	1300	>1300					82
L-Nickel		800	1300	>1300			-310		82
Nickel (Low Carbon)	1100	1200	1300	>1300					82
Nickel (Electrolytic)	1150	1200	1300	>1300					82
Duranickel	1100	1200	1300	>1300					82
Monel	1000	1000	1200	>1200	-320	-320	-310		7,73,140, 153,159,160, 207,211,274
Cast Monel	400	800	1000	>1000			-310		82
K-Monel	600	800	1200	>1200					82
Inconel	930	1110	500	>500			-310		7,207,211
Hastelloy B		75	212						58,127,128, 211
Hastelloy C	95		212						58,127,128, 211
Hastelloy D			212						58, 211
Copper	200	400	800	>800	-320		-310		73,153,159, 207,211,274
Deoxidized Copper		930	1290						7
Copper ETP	200	400	800	>800					82
Brass (70-30)	200	400							159,160
Brass (Red)	200	400	600	>600				-310	73,211
Brass (243)	200		500	>500			-310		82
Brass (Low-leaded)								-310	120
Brass (Yellow)					-320				274
Brass (Cartridge)					-320				274
Brass (Casting)						-320			274
Bronze	200	400	700						73,159,160, 211
Copper-Nickel	200	400		>800					159
Copper-10% Nickel					-320				274
Copper-30% Nickel					-320				274
Everdur 1010					-320				274
Chromium Plate	400								159,160
Lead			100	>100					211
Magnesium		500	700						82
Magnesium M1A	653	<1000							143
Magnesium AZ81A-T6	691	<1000							143
Magnesium ZB1C-T6		400					-310		82
Magnesium AZ91C-T6	<1000								143
Magnesium HK-31					-320				274
Magnesium HK-31A-H24			1100				-310		82
Magnesium HK-31 (Coated with Dow-17)						-320			274
Magnesium HM-31					-320				153
Magnesium AZ-31					-320				153,274
Magnesium AZ-31 (Coated with Dow-17)					-320				274
Magnesium MA (1.2%Mn)		200							159,160
Magnesium FS-1A		200							159,160
Magnesium J-1H	140								159,160
Magnesium M-1A		600	1000				-310		82
Magnesium Dow Metal G	570	600							7,207

TABLE 6. (Continued)

Material	Gas Class 1	Gas Class 2	Gas Class 3	Gas Class 4	Liquid Class 1	Liquid Class 2	Liquid Class 3	Liquid Class 4	References
Molybdenum				75					94,199
Platinum	212								211
Gold	212								211
Silver	700								211
Silver Solder (Fluxed)		400							82
Tantalum	212		100	>100			-310		211
Tin	212		100	>100					211
Titanium A-55	212	100		>350				-310	211
Titanium A-70								-320	145
Titanium Alloy 6Al-4V		250			-320(a)	-320(c)		-310	86
Titanium A-110AT					-320(a)	-320(c)			153,274
Titanium Alloy B-120VCA		350		>350					86,153,274
Titanium Alloy 16V-2.5Al		300							86
Titanium Alloy 8Mn		300						-310	86
Titanium 75A								-310	86
Columbium				75					93
Zirconium		100	400	>700				-310	82
Zircaloy-2			400	>700			-310		82
Inorganic Materials									
Ruby (Al_2O_3)	75	1400							225,226
Alumina	392	1400							159,160
Alundum		1400							82
Sintered Corundum		1400							82
Recrystallized Alumina		1400							82
Activated Alumina		400		>400					82
Soda Glass	212	300		>300(b)					211
Pyrex	212	400		>400					211
Silica		480		>480					82
Transite		100							159,160
Asbestos		100							82
Amorphous Carbon		212		>212					159,160
Metal Fluorides		No limit							82
CaF_2-Ad-SiO_2 Baked	400	400		>400					159,160
Sulfur Cements				>32					82
Organic Materials									
Liquids									
Kel F No. 10			<RT						225,226
N-43 $(C_4H_9)_3N$			<RT						225,226
Cenco Hyvac Oil				All temp					225,226
Glyptal				All temp					159,167,225,226
Dow Corning Fluid 200				All temp					225,226
Safety Solvent 178				All temp					225,226
Leak Tec				All temp					225,226
Carbon Tetrachloride				All temp					160,225,226
Greases and Pastes									
Kel F Med. Wax			<RT						225,226
Kel F No. 1 Grease			<RT						225,226
Fluorlube LG and MG			<RT						225,226
Permatex No. 3			<RT						225,226
Q-Seal			<RT						225,227
Blue Goop			<RT						225,226
Molylube			<RT						225,226
Plast-o-Seal			<RT						225,226
Permatex Nos. 1 and 2				All temp					225,226
White Lead				All temp					225,226
Solids									
Teflon	390(d)			>390					225,226
Kel F	RT			>RT					225,226
Neoprene (Glass Filled)				>RT					225,226
Neoprene				All temp					225,226
Rubber	75			All temp					159,160,167,211
GRS Rubber				All temp					82
PVC				>RT					225,226
Plexiglas				>RT					225,226
Tygon				>RT					225,226
Pennsalt PCC and PCI				>RT					225,226
Polystyrene				All temp					259
Polyethylene				All temp					225,226
Dow Corning Elastomer				All temp					225,226
Molylube No. 2				All temp					225,226
Litharge and Glycerine				All temp					225,226
Phenolic Plastic (Filled)				All temp					225,226
Phenolic Cement				All temp					225,226
Phenol Formaldehyde				75					259
Polyfurfuryl Alcohol				All temp					82
Polymethyl Methacrylate				All temp					82
Polyethers				All temp					82
Polyesters				All temp					259
Graphite	75			All temp					159,211,215
Pressed Carbon C-13						-320			274

(a) See Reference 82 also.
(b) Glass is Class 4 at all temperatures if fluorine is contaminated with hydrofluoric acid.
(c) Titanium alloys exhibit impact ignition but flame does not propagate.
(d) Material is pressure sensitive, Class 2 below 390 F and 15-psi pressure. Higher pressures can be tolerated at room temperature.

TABLE 7. COMPATIBILITY OF MATERIALS WITH FLOX

Material	Gas Class 1	Gas Class 2	Gas Class 3	Gas Class 4	Liquid Class 1	Liquid Class 2	Liquid Class 3	Liquid Class 4	References
FLOX-40 (40% F_2-60% O_2)									
Aluminum, 2014-T6					-320				224,266
Aluminum, 5052-H34					-320				266
Aluminum, 6061-T6					-320				266
4340 Steel					-320				266
301 Stainless Steel					-320				266
304 Stainless Steel					-320				266
347 Stainless Steel					-320				266
Monel					-320				266
Inconel X					-320				266
Teflon TFE	RT								267
Teflon FEP	RT								267
Kel-F 81	RT								267
Armalon FOX 7700				RT					267
Asbestos-Stainless Steel Gasket				RT					267
Oxylube 701 on 347 SS						-320			82
FLOX-20 (20% F_2-80% O_2)									
Aluminum, 2014					-320				224
Cadmium Plated 4037 Steel					-320				224
Oxylube 701 on 347 SS						-320			224

TABLE 8. COMPATIBILITY OF MATERIALS WITH OXYGEN DIFLUORIDE (OF_2)(224)

Material	Gas Class 1	Gas Class 2	Gas Class 3	Gas Class 4	Liquid Class 1	Liquid Class 2	Liquid Class 3	Liquid Class 4	References
Metals									
Aluminum, 1100-0	-109				-109				
Aluminum, 2014-T6	-109				-109				
Aluminum, 2024-T351	-109								
Aluminum, 2219-T6	-109				-109				
Aluminum, 5456-H343	-109								
Aluminum, 6061-T6	-109				-109				
Aluminum, 7075-T6	-109								
Aluminum, 7079-T6	-109				-109				
Stainless Steel, 301	-109				-109				
Stainless Steel, 316	-109				-109				
Stainless Steel, 347	-109				-109				
Stainless Steel, 410	-109				-109				
PH15-7Mo	-109				-109				
AM-350	-109				-109				
AM-355	-109								
Nickel 200	-109				-109				
Monel 400	-109								
Inconel X	-109				-109				
Rene 41	-109				-109				
Cufenloy 40	-109				-109				
Cufenloy 40 with Electroless Ni Plate	-109				-109				
Copper	-109				-109				
Brass 7030	-109				-109				
Titanium, A-110AT	-109				-109				
Titanium, 6Al-4V	-109								
Columbium	-109				-109				
Tantalum	-109				-109				
Magnesium	-109								
Teflon 100 FEP	-109				-109				
Teflon 827 TFE		-109							
Fluoroflex T Teflon			-109						
Kel-F 5409				-109					
Graphite AGKSP	-109								
Oxylube 701 on 347 SS				-109					

TABLE 9. COMPATIBILITY OF MATERIALS WITH 70 PERCENT OF_2–30 PERCENT O_2 (1 ATMOSPHERE)(124)

Material	Temperature, F: Gas Class 1	Gas Class 2	Gas Class 3	Gas Class 4	Liquid Class 1	Liquid Class 2	Liquid Class 3	Liquid Class 4	References
Metals									
Aluminum, 2024-T4	212								
Aluminum, 2017-ST	212								
Copper	212								
Brass	212								
Mild Steel	212								
303 Stainless Steel	212								
304 Stainless Steel	212								
316 Stainless Steel	212								
318 Stainless Steel	212								
Worthite	212								
Lead	212								
Magnesium, Dowmetal FSIH	212								
Magnesium, Dowmetal FSIA	212								
Magnesium, Dowmetal MA	212								
Nickel	212								
H Monel	212								
K Monel	212								
KR Monel	212								
S Monel	212								
R Monel	212								
CR Monel	212								
Inconel	212								
Hastelloy D	212								
Platinum	212								
Nonmetals									
Teflon	212								
Kel-F			212						

TABLE 10. COMPATIBILITY OF MATERIALS IN OZONE DIFLUORIDE–LIQUID OXYGEN (0.09% O_3F_2 – BALANCE LOX)(83)

Material	Temperature, F: Gas Class 1	Gas Class 2	Gas Class 3	Gas Class 4	Liquid Class 1	Liquid Class 2	Liquid Class 3	Liquid Class 4	References
301 Stainless Steel	-297				-297				
316 Stainless Steel	-297				-297				
347 Stainless Steel	-297				-297				
410 Stainless Steel		-297				-297			
PH15-7Mo	-297					-297			
AM-350	-297				-297				

TABLE 11. COMPATIBILITY OF MATERIALS WITH CHLORINE TRIFLUORIDE (ClF_3)

Material	Temperature, F: Gas Class 1	Gas Class 2	Gas Class 3	Gas Class 4	Liquid Class 1	Liquid Class 2	Liquid Class 3	Liquid Class 4	References
Metals									
Aluminum, 1060					85				111,115
Aluminum, 1100	85		644		85				17,82,111,115,211
Aluminum, 1100, Welded	85				85				117
Aluminum, 2014, Welded	85				85				117
Aluminum, 2024					85				111,115
Aluminum, 3003					85				111,115
Aluminum, 5052					85				111,115
Aluminum, 6061, Welded	85				85				117
Aluminum, 7079					85				111,115
Columbium								-105	111,115
Copper, ETP	85		590		85				17,111,115
Copper, DHP					85				111,115
Beryllium Copper, 2%					85				111,115
Phosphor Bronze, 5%					85				111,115
Aluminum Bronze, 8%	85				85				111,115,211
Yellow Brass	85				85				111,115,211
Rule Brass					85				111,115
Tin Bronze	75								211
1010 Steel	85		685		85				17,111,115,211
1010 Steel (Coated with Fosbond 40)					85				111,115
1010 Steel (Coated with Fosbond 27)					85				111,115
303 Stainless Steel	85				85				111,115
304 Stainless Steel					85				111,115,211
316 Stainless Steel	85				85				111,115
347 Stainless Steel					85				111,115
AM-350						75			82
A-286						75			82
Carpenter 20					85	75			82,111,115
PH15-7Mo (RH 950)					85				117
PH15-7Mo (TH 1050)					85				117
410 Stainless Steel (Welded)	85				85				117
347 Stainless Steel (Welded)	85				85				117
AM-350 (Welded)	85				85				117
PH15-7Mo (Welded)	85				85				117
Lead		75							17
Magnesium, AZ-31B	85				85				111,115
Magnesium, HM-21A					85				111,115
Magnesium, HK-31A					85				111,115
A-Nickel	85				85				17,111,115,211
Monel	85				85				17,111,115,211
Inconel					85				111,115
Inconel X							75		82
Incoloy					85				111,115
Hastelloy X							75		82
Rene 41						75			82
Cupro-Nickel, 30%					85				111,115
Nickel 200 (Welded)	85				85				117
Monel 400 (Welded)	85				85				117
Nickel-Silver, 18% (Alloy A)					85				111,115
Thorium		660							82
Titanium, 100A				75				75	82,111,115
Titanium, C-120AV								75	111,115
Titanium, A-110AT								75	111,115
Uranium				400					82
Zirconium				645					82
Nonmetals									
Glass	75								211
Pyrex Glass		75							82
Stoneware	75								211
Neoprene Rubber	75								211
Carbon, Karbate #15[a]								75	111,115
Graphite, Karbate #25[a]								75	111,115
Graphite Graphitar 39						75			111,115
Graphitar 67								75	111,115
Graphite ATJ-82[b]								75	111,115
Teflon	75				85				17,111,115,211
Kel-F		75				85			17,111,115
Polyvinylidene Fluoride (RC-2525)					85			130	111,115

(a) Epoxy filler.
(b) Phenolic filler.

TABLE 12. COMPATIBILITY OF MATERIALS WITH BROMINE TRIFLUORIDE (BrF_3)

Material	Temperature, F: Gas Class 1	Gas Class 2	Gas Class 3	Gas Class 4	Liquid Class 1	Liquid Class 2	Liquid Class 3	Liquid Class 4	References
Metals									
Aluminum		75							17
Boron								75	82
Columbium								75	82
Copper		400	750				75		17,211
Tin Bronze							75		211
Aluminum Bronze							75		211
Brass		75							17
Gold								75	211
Steel		200	400				75		211,17
410 Stainless Steel							75		211
430 Stainless Steel							75		211
304 Stainless Steel							75		211
316 Stainless Steel							75		211
Durimet 20							75		211
Worthite							75		211
Silicon-Iron							75		211
Lead		75							17
Magnesium	500		690						82
Molybdenum								75	82
Nickel		1000	1300				75		17,211
Monel		75					75		17,211
Inconel							75		211
Platinum								75	211
Tantalum								75	211
Thorium			320						82
Titanium								75	82
Tungsten								75	82
Zirconium							200	75	82,211
Nonmetals									
Glass								75	211
Stoneware								75	211
Asbestos							75		211
Wood								75	211
Haveg 41, Resin								75	211
Fluoroethane							200		82
Silicon								75	82
Sulphur								75	82
Kel-F		75							17
Teflon		75							17

TABLE 13. COMPATIBILITY OF MATERIALS WITH PERCHLORYL FLUORIDE (ClO_3F)

Material	Temperature, F: Gas, Class 1	Gas, Class 2	Gas, Class 3	Gas, Class 4	Liquid, Class 1	Liquid, Class 2	Liquid, Class 3	Liquid, Class 4	References
Metals									
Aluminum, 1060					85				111,115
Aluminum, 1100	160				85				111,115,219
Aluminum, 1100 (Welded)	85				85				117
Aluminum, 2014 (Welded)	85				85				117
Aluminum, 2024	160				85				111,115,219
Aluminum, 3003	160				85				111,115
Aluminum, 5052	160				85				111,115,219
Aluminum, 6061	160								219
Aluminum, 6061 (Welded)	85				85				117
Aluminum, 7075					85				111,115
Copper, ETP	85				85				111,115
Copper, DHP					85				111,115
Beryllium Copper, 2%					85				111,115
Phosphor Bronze, 5%					85				111,115
Aluminum Bronze, 8%	85				85				111,115
Yellow Brass	85				85				111,115
Rule Brass					85				111,115
1010 Steel	85				85				111,115
1010 Steel (coated with Fosbond 40)					85				111,115
1010 Steel (coated with Fosbond 27)					85				111,115
Carbon Steel	160								219
403 Stainless Steel	85				85				111,115
430 Stainless Steel	160								219
531 Stainless Steel	160								219
201 Stainless Steel	160								219
202 Stainless Steel	160								219
302 Stainless Steel	160								219
304 Stainless Steel	160				85				111,115,219
310 Stainless Steel	160								219
314 Stainless Steel	160								219
316 Stainless Steel	160				85				111,115,219
321 Stainless Steel	75	160							219
329 Stainless Steel	160								219
347 Stainless Steel	160				85				111,115
347 Stainless Steel (Welded)	85				85				117
410 Stainless Steel (Welded)	85				85				117
AM-350 (Welded)	85				85				117
PH15-7Mo (RH950)					85				111,115
PH15-7Mo (TH1050)					85				111,115
PH15-7Mo (Welded)	85				85				117
Carpenter 20-Cb					85				111,115
Lead	75	80							219
Magnesium AZ31B		85			85				111,115
Magnesium HM21A					85				111,115
Magnesium HM31A					85				111,115
A-Nickel	160				85				111,115,219
Monel	80	85			85				111,115,219
Inconel					85				111,115
Incoloy					85				111,115
Hastelloy B		160							219
Hastelloy C		80							219
Nickel 200 (Welded)	85				85				117
Monel 400 (Welded)	85				85				117
Cupro-Nickel, 30%					85				111,115
Silver Solder	75	80							219
Nickel Silver, 18%					85				111,115
Tin	75	80							219
Titanium-100A	95	80			85(a)				111,115,219
Titanium C-120AV	95				85(a)				111,115,219
Zinc	75								111,115,219
Organic Materials									
Teflon	75	390							82,111,115
Kel-F	75	390							82,111,115
Phenolic Resins		390							82
Epoxy Resins		390							82
Saran	75	80							82
Fluorosilicone Rubber (Iron Oxide Filler)		390							82,219
GRS Rubber		390							82
Kel-F Elastomer		390							82
Silicone Rubber (On Glass Cloth)		390							82
Polychlorotrifluoroethylene		390							82
Oil or Grease				80					82
Cellulose				80					82
Cellulose Acetate				80					82
Ethyl Cellulose				80					82
Gum Arabic				80					82
Melamine Formaldehyde				80					82
Methyl Styrene				80					82
Nylon				80					82
Polyurethane				80					82
Polyvinyl Chloride				80					82
Polystyrene				80					82
Polymethyl Methacrylate				80					82
Polyacrylonitrile				80					82
Polyvinyl Pyrrolidone				80					82
Polyisobutylene				80					82
Polyethylene	75			80					82,219
Rulon				80					82
Xylylene Glycol Polyether				80					82
Cotton	75								82,219
Rayon	75			390					82,219
Plexiglas	75			390					82,219
Dacron				390					82
Orlon				390					82
Wool				390					82
Silk				390					82
Alkyl Resins				390					82
Alkyl Enamel				390					82
Modified Phenolic Resin				390					82
Silicone Glass Cloth				390					82
Varnished Glass Cloth				390					82
Varnished Paper				390					82

TABLE 13. (Continued)

Material	Temperature, F: Gas, Class 1	Gas, Class 2	Gas, Class 3	Gas, Class 4	Liquid, Class 1	Liquid, Class 2	Liquid, Class 3	Liquid, Class 4	References
Butyl Rubber with Carbon				390					82
Natural Rubber				390					82
Foam Rubber				390					82
Hypalon Carbon Filled				390					82
Neoprene Carbon Filled				390					82
Okonite Tape				390					82
Perfluorobutyl Acrylate				390					82
(Carbon Filled)				390					82
Reclaimed Rubber				390					82
(Carbon Filled)				390					82
Silicone Rubber				390					82
Beeswax				390					82
Carnauba Wax				390					82
Lubricant Grease				390					82
Silicone Stopcock Grease	75			390					82,219
Transformer Oil				390					82
Chlorinated Naphthalene				390					82
Fluorolube	75								82,219
Other Materials									
Kaoline Clay				390					82
Mercury				390					82
Drierite (Indicating)				390					82
Masonite Board				390					82
Kraft Board				390					82
Leather	75			390					82,219
White Lead Pipe Dope				390					82
Permatex Pipe Dope				390					82
Chemlon Pipe Dope				390					82
Leak Lock Pipe Dope				390					82
Paper	75			390					82,219
Plywood				390					82
Alumina		390							82
Activated Silica		390							82
Sodium Metasilicate		390							82
Graphite	75	80							82,219
Glass		390							82
Asbestos Paper		390							82
Transite Board		390							82
Cork	75	80							82,219

(a) Ignites under impact, but burning is not sustained.

TABLE 14. COMPATIBILITY OF MATERIALS WITH PERCHLORYL FLUORIDE CONTAINING UP TO 1% MOISTURE

Material	Temperature, F: Gas, Class 1	Gas, Class 2	Gas, Class 3	Gas, Class 4	Liquid, Class 1	Liquid, Class 2	Liquid, Class 3	Liquid, Class 4	References
Metals									
Aluminum, 1100		85		75					115,219
Aluminum, 2024				75					219
Aluminum, 3003				75					219
Aluminum, 5052				75					219
Aluminum, 6061				75					219
Copper		75		80		85			115,219
Brass		75		80					219
Aluminum Bronze, 8%		85				85			115
Yellow Brass		85					85		115
1010 Steel			85(a)				85		115
Carbon Steel				75					219
403 Stainless Steel				85			85(a)		115
201 Stainless Steel				75					219
202 Stainless Steel				75					219
302 Stainless Steel		75		160					219
304 Stainless Steel		85(a)			85(a)				115,219
310 Stainless Steel		75		160					219
314 Stainless Steel	75								219
316 Stainless Steel		85(a)			85				115,219
321 Stainless Steel	75								219
347 Stainless Steel			85(a)			85			115,219
Carpenter 20-Cb	85(a)				85				115
Duriron D				75					219
Durichlor				75					219
Durimet 20	85			80	85				115,219
Durimet T	75			160					219
Chlorimet 3			85				85		115
Lead		75		80					219
Mg AZ 31B		85(a)		75		85			115,219
A-Nickel		85				85			115
Monel		75	85(a)	80		85			115,219
Inconel	85(a)				85				115
Incoloy	85				85				115
Ni-O-Nel	85				85				115
Hastelloy A				75					219
Hastelloy B		75		160					219
Hastelloy C (cast)	85	160		160	85				115
Hastelloy C (wrought)	160	85				85			115,219
Hastelloy D		75		160					219
Illium G	85				85				115
Illium R	85				85				115
Illium 98	85					85			115
Illium G-134	160								219
Illium G-13B	160								219
Cupro-nickel, 30%		85				85			115
Gold	85				85				115
Platinum	85				85				115
Silver	85				85				115
Nickel Silver, 18%			85				85		115
Tantalum	160								219
Tin		75		80					219
Titanium C-120AY	85			160			85		115,219
Zinc	75								219

(a) Pits.

TABLE 15. COMPATIBILITY OF MATERIALS WITH [illegible] ClO_3F - [illegible] ClF_3

Material	Gas Class 1	Gas Class 2	Gas Class 3	Gas Class 4	Liquid Class 1	Liquid Class 2	Liquid Class 3	Liquid Class 4	References
Metals									
Aluminum, 1060					85				115
Aluminum, 1100					85				115
Aluminum, 1100 (Welded)	85				85				119
Aluminum, 2014 (Welded)	85				85				119
Aluminum, 2024					85				115
Aluminum, 3003					85				115
Aluminum, 5052					85				115
Aluminum, 6061 (Welded)	85				85				119
Aluminum, 7079					85				115
Columbium								85	111,115
Copper, ETP					85				115
Copper, DHP					85				115
Beryllium Copper, 2%					85				115
Phosphor Bronze, 5%					85				115
Aluminum Bronze, 8%					85				115
Yellow Brass					85				115
Mule Brass					85				115
1010 Steel					85				115
1010 Steel (Coated with Fosbond 49)					85				115
1010 Steel (Coated with Fosbond 27)					85				115
403 Stainless Steel					85				115
410 Stainless Steel (Welded)	85				85				119
304 Stainless Steel					85				115
316 Stainless Steel					75				115
347 Stainless Steel					85				115
347 Stainless Steel (Welded)	85				85				119
Carpenter 20-Cb					85				115
PH15-7Mo (RH950)					85				115
PH15-7Mo (TH1050)					85				115
PH15-7Mo (Welded)	85				85				119
AM-350 (Welded)	85				85				119
Magnesium, AZ31B					85				115
Magnesium, HK31A					85				115
Magnesium, HM21A					85				115
Molybdenum								85	111,115
A-Nickel					85				115
Nickel 200 (Welded)	85				85				119
Monel					85				115
Monel 400 (Welded)	85				85				119
Inconel					85				115
Incoloy					85				115
Titanium C-120AV								85	111,115
Nonmetals									
Graphite, Spectroscopic Grade								85	111,115
Teflon							85		115
Teflon, CaF_2 filled					85				115
Kel-F							85		115

TABLE 17. COMPATIBILITY OF MATERIALS WITH DICHLORODIFLUOROMETHANE (CCl_2F_2) (FREON 12)[211]

Material	Gas Class 1	Gas Class 2	Gas Class 3	Gas Class 4	Liquid Class 1	Liquid Class 2	Liquid Class 3	Liquid Class 4	References
Metals									
Mild Steel	75								
Cast Iron			75						
410 Stainless Steel			75						
430 Stainless Steel			75						
304 Stainless Steel	75								
316 Stainless Steel	75								
Worthite	75								
Durimet 20	75								
Copper	75								
Sn Bronze	75								
Al Bronze	75								
Si Bronze	75								
Red Brass	75								
Yellow Brass	75								
A-Nickel			75						
Monel			75						
Inconel			75						
Aluminum, 1100			75						
Lead									
Gold	75								
Platinum	75								
Tantalum	75								
Nonmetals									
Glass	75								
Stoneware	75								
Rubber				75					
Asbestos	75								

TABLE 18. COMPATIBILITY OF MATERIALS WITH MONOCHLOROTRIFLUOROMETHANE ($CClF_3$) (FREON 13)[211]

Material	Gas Class 1	Gas Class 2	Gas Class 3	Gas Class 4	Liquid Class 1	Liquid Class 2	Liquid Class 3	Liquid Class 4	References
Metals									
Mild Steel			75						
304 Stainless Steel	75	70							
316 Stainless Steel	75	70							
Worthite	75								
Durimet 20	75								
Gold	75								
Platinum	75								
Tantalum	75								
Ni-O-Nel		70							
Nonmetals									
Glass	75								
Stoneware	75								

TABLE 16. COMPATIBILITY OF MATERIALS WITH [illegible] (83,224)

Material	Gas Class 1	Gas Class 2	Gas Class 3	Gas Class 4	Liquid Class 1	Liquid Class 2	Liquid Class 3	Liquid Class 4	References
Metals									
Aluminum, 1100-0	-109				-109				
Aluminum, 2014-T6	-109				-109				
Aluminum, 2024-T351	-109				-109				
Aluminum, 2219-T6	-109				-109				
Aluminum, 5456-H343	-109				-109				
Aluminum, 6061-T6	-109				-109				
Aluminum, 7075-T6	-109				-109				
Aluminum, 7079-T6	-109				-109				
Columbium	-109				-109				
Cufenloy 40					-109				
Copper	-109				-109				
Brass 7030	-109				-109				
301 Stainless Steel	-109				-109				
316 Stainless Steel	-109				-109				
347 Stainless Steel	-109				-109				
410 Stainless Steel	-109				-109				
PH15-7Mo	-109				-109				
AM-350	-109				-109				
AM-355	-109								
Magnesium	-109				-109				
Nickel 200	-109				-109				
Monel 400	-109				-109				
Inconel X	-109				-109				
René 41	-109				-109				
Tantalum	-109				-109				
Titanium, A-110AT	-109				-109				
Titanium, 6Al-4V	-109				-109				
Teflon 100 FEP	-109								
Teflon 8277FE			-109						
Fluoroflex T Teflon			-109						
Kel-F 5500 Elastomer		-109							
Graphite AGKSP	-109							-109	

TABLE 19. COMPATIBILITY OF MATERIALS WITH TRICHLOROMONOFLUOROMETHANE (FREON 11)[211]

Material	Gas Class 1	Gas Class 2	Gas Class 3	Gas Class 4	Liquid Class 1	Liquid Class 2	Liquid Class 3	Liquid Class 4	References
Metals									
Mild Steel	75								
Cast Iron	75								
304 Stainless Steel	75								
316 Stainless Steel	75								
Worthite	75								
Durimet 20	75								
Copper	75								
Sn-Bronze	75								
Al Bronze	75								
Red Brass	75								
Yellow Brass	75								
Aluminum, 1100	75								
Gold	75								
Platinum	75								
Tantalum	75								
Nonmetals									
Glass	75								
Stoneware	75								

TABLE 20. COMPATIBILITY OF MATERIALS WITH TRICHLOROTRIFLUOROETHANE (CCl_2F-$CClF_2$) (FREON 113)

Material	Temperature, F								References
	Gas				Liquid				
	Class 1	Class 2	Class 3	Class 4	Class 1	Class 2	Class 3	Class 4	
Metals									
Aluminum, 1100	392								136,211
Aluminum, 6061	75								136
Copper	75		392						136,211
Sn Bronze	75								211
Al Bronze	75								211
Si Bronze	75								211
Red Brass	75								211
Yellow Brass	75								211
Mild Steel	392								136,211
Cast Iron	75								211
Ni-Resist	75								211
17-7PH	75								136
410 Stainless Steel	75								211
430 Stainless Steel	75								211
304 Stainless Steel	75								211
316 Stainless Steel	75								211
4130 Steel	75								136
Worthite	75								211
Durimet 20	75								211
A-Nickel	75								211
Monel	75								211
Inconel	75								211
Gold	75								211
Platinum	75								211
Tantalum	75								[illegible]
Magnesium		200							136
Titanium 75A	75								136
Titanium, 6Al-4V	75								136
Nonmetals									
Glass	75								211
Stoneware	75								[illegible]

TABLE 21. COMPATIBILITY OF MATERIALS WITH DIBROMOTETRAFLUOROETHANE ($CBrF_2$-$CBrF_2$) (FREON 114B2)(136)

Material	Temperature, F								References
	Gas				Liquid				
	Class 1	Class 2	Class 3	Class 4	Class 1	Class 2	Class 3	Class 4	
Metals									
Aluminum	248			392					
Aluminum, 6061	75								
Copper	200		392						
Brass	248	248							
Steel	248	248							
4130 Steel	75								
17-7PH	75								
Magnesium	75								
Titanium 75A	75								
Titanium, 6Al-4V	75								

TABLE 22. COMPATIBILITY OF MATERIALS WITH HYDRAZINE (N_2H_4)

Material	Temperature, F								References
	Gas				Liquid				
	Class 1	Class 2	Class 3	Class 4	Class 1	Class 2	Class 3	Class 4	
Metals									
Aluminum, 1100	140				140		140		7,149,174,211,216
Aluminum, 2020							160		82
Aluminum, 2014					80			160	174
Aluminum, 2017					160				174
Aluminum, 2024					66			80	7,174,216
Aluminum, 3003					80		140		174,211
Aluminum, 4043					160				174
Aluminum, 5052					80				7,174
Aluminum, 5456	140				140				174
Aluminum, 6061	140				160				7,174
Aluminum, 6066					80				174
Aluminum, 7075							160	75	7,174
Aluminum, 408					75		160		149,174
Aluminum, 356					160				174
Aluminum, 716					140		160		174
Cadmium								RT	174
Chromium Plating					RT				174
Cobalt								73	[illegible]
Stellite							77		143
Stellite 21					75				174
Copper					68	80		140	7,174,216
Brass					80	140		140	7,174,216
Bronze								RT	174
Gold					75			212	211
Pure Iron								80	7
Mild Steel								80	7,149,211,216
1020 Steel								73	174
410 Stainless Steel					80	77			7,174
416 Stainless Steel				200 (pits)	200 (pits)				7

TABLE 22. (Continued)

Material	Temperature, F								References
	Gas				Liquid				
	Class 1	Class 2	Class 3	Class 4	Class 1	Class 2	Class 3	Class 4	
430 Stainless Steel					68			68	7,174,210
440 C Stainless Steel					80			75	7
302 Stainless Steel					80	140			174,216
303 Stainless Steel						75			7
304 Stainless Steel	140				140				7,174
316 Stainless Steel	200				200			160	7,174
317 Stainless Steel					80				174
321 Stainless Steel	140				140			68	7,174,216
347 Stainless Steel	200				200				7,174
Stainless W					75		160		149,174
17-4PH	140				140			160	174
17-7PH					75				174
AM-350					160				174
AM-355					160				174
Worthite	75								211
Durimet 20	75								211
Lead					68				149,211,216
90Pb-10Sn			77		75			77	149,174
Magnesium								80	7,174
Magnesium, AM100A				140					174
Molybdenum					75			80	7,149,174
Nickel				140				140	7,149,174,211,216
Electroless Nickel								68	174
Monel					80			80	211,216
K-Monel				200	140				174
Inconel				200	200		140		7,149,174,211,216
Inconel X					80		140		149,174
Nichrome					80				149,174
Chromel A					80			80	149,174
Hastelloy C					125				211
Silver					80			75	7,174,211
Silver Solder					75		140		149,174
Tantalum					80			212	7,211
Tin					80		140		7
Titanium, 6Al-4V					160				82
Titanium, A110AT	140				140				174
Tungsten						75			7
Zinc								RT	7,174
Zirconium					75				211
Nonmetals									
Teflon					140				7,149,174,211,216
Kel-F					80			160	7,82
Kel-B-1								140	174
Kel-B-5								140	174
Kel-F-300 (15% Glass Filled)								140	174
Polyethylene					80			160	7,149
Saran								68	216
Lucite						80			149
Epon							75		7
Nylon							75		7
Tygon								68	7,216
Polyvinyl Chloride							75		7
Polyvinyl Alcohol								75	7
Vinylite						75			82
Polyester								75	7
Cellulose Acetate								75	7
Ethyl Cellulose							75		7
Lactoprene								75	7
Phenolic							75		7
Mylar, Type A								140	174
Buna N Rubber						80	120		82
Neoprene Rubber						75	75	68	174,216
Natural Rubber						80		75	7,211,216
Silicone Rubber						75			2
U.S. Rubber L7825						77			149
Butyl Rubber Compound 805-70					140				174
U.S. Rubber M-20995						77			149
SBR					75	160			23
Polybutadiene						75		160	23
Hycropol						160			23
Silastic 167						75			149
Silastic LS-53								140	174
Silicone DC-710							70		143
Korotseal							77		82
Haveg 61							200		174
Delanium					140				174
Garlock Gasket 900							200		174
Ardex C							75		174
Carum 200							75		174
Dapon 35								140	174
Oxyseal							75		7
AN-C-63							75		7
Glass					80		140		7,211
Graphite					68	75			7,149,216
Graphitar 2 and 50					[illegible]		73		7,82,174
Asbestos					80		75	80	7,211,216

TABLE 23. COMPATIBILITY OF MATERIALS WITH UNSYMMETRICAL DIMETHYL HYDRAZINE (UDMH)

Material	Temperature, F								References
	Gas				Liquid				
	Class 1	Class 2	Class 3	Class 4	Class 1	Class 2	Class 3	Class 4	
Metals									
Aluminum, 1100					160				174,296
Aluminum, 1100-H14					145				7,92,227
Aluminum, 1060-H14					145				92,227
Aluminum, 2014	140		160		140				174,296
Aluminum, 2017	75	140			75	160			174,296
Aluminum, 2024	75	160			75	160			174,296
Aluminum, 2024-T3					145				7,92,227
Aluminum, 2024-T3 (Iridited)					80				174
Aluminum, 3003	75	160			80	160			174,296
Aluminum, 3003-H14					145				92,227
Aluminum, 3004-H34					145				92,227
Aluminum, 5052	140				160				92,174,227, 296
Aluminum, 5052-H34					145				92,227
Aluminum, 5086					85				174
Aluminum, 5086-H34					145				7
Aluminum, 5154-H34					145				92,227
Aluminum, 5456	140	160			140	160			174
Aluminum, 6061	75	160			160	160			174,296
Aluminum, 6061-T6					145				7,92,227
Aluminum, 6063-T6					145				92,227
Aluminum, 7075	160				160				174,296
Aluminum, 7075-T6					145				7,92,227
Aluminum, 43					145				7,92,227
Aluminum, 356	75	140	160		160	140			174, 296
Aluminum, 356-T6					85	145			7,92,227
Aluminum, 3003 (Anodized)	75	160			75	160			296
Aluminum, 5052 (Welded to 356)	75	160			75	160			296
Aluminum, 5052 Welded to 6061	75	160			75	160			296
Cadmium Plate								75	174
Haynes Alloy 25					145				92,227
Copper					145			75	7,92,174, 211,227
Brass					75		160	75	174,211,296
Bronze							160	75	174,211
Mild Steel					145				7,92,174, 211,227,296
4130	75	160			85	160			7,92,227
Chromium Steel	75	160			75	160			82
302 Stainless Steel					160				7,92,174,227
303 Stainless Steel	140				160				92,174,227, 296
304 Stainless Steel	140				160				92,174,227, 296
316 Stainless Steel	140				140				92,174,211, 227,296
321 Stainless Steel	140				160				92,174,227, 296
347 Stainless Steel	160				160				92,174,227, 296
410 Stainless Steel	160				160				82
416 Stainless Steel					250				7,92,174,227
422 Stainless Steel					145				7,92,227
17-7PH	160				160				92,174,227
PH15-7Mo					55				7,92,174,227
A-286					85				92,227
Carpenter 20	140				140				82
AM-355 CRT					160				145
Magnesium, Dowmetal 032					75				82
Magnesium, AZ92F					85				92,227
Magnesium, AZ31BO					85				92,227
Magnesium, AZ31B					130				174
Magnesium, AZ61A					130				174
Magnesium, AZ91C					130				174
Magnesium, AZ92A					130				174
Magnesium, ZK60A					130				174
Magnesium, AM100A	140				140				174
Magnesium, Dowmetal					145				174
Molybdenum						85			174
Nickel					140				174,211,296
Monel	140				140				174,211,296
Inconel	140				140				174,211
Hastelloy B					145				92,227
Hastelloy C					145				92,174,227
Hastelloy F					145				92,227
Hastelloy X					145				92,227
Rene 41					85				227
Tantalum	140				140				174
Tin Plate								75	296
Titanium, A55					145				7,92,227
Titanium, A110AT					130				174
Titanium, B120VCA					145				7,92,227
Titanium, C120AV	140				160				7,92,174,227
Zinc								75	174

TABLE 23. (Continued)

Material	Temperature, F								References
	Gas				Liquid				
	Class 1	Class 2	Class 3	Class 4	Class 1	Class 2	Class 3	Class 4	
Nonmetals									
Alathon					80				82
Buna N Rubber				75				32	7
Acid Seal Rubber								75	296
Butyl Rubber			75	130	140		75	130	82,174
Buna S								75	82
DC-152								75	82
Dioxyrin								<140	82
Fluororubber								75	296
Garlock Red Rubber								75	296
Hydropol V							160		296
Hydropol *						85			7
Kel-F-z300				<140				<140	174
Kel-F-5500								80	7
Kel-F-3700								80	82
Neoprene								32	296
Poly FBA								80	82
Silicone Rubber				32				32	296
Thiokol C 55935						85			7
Vinylite				32				32	82
Firestone C-432						85			7
Parker 37-014						85			7
Precision 925-70						85			7
Stillman 613-75						85			7
Chicago Rawhide 2C316-70								85	7
Silicone 201*								85	7
Butyl 218						75		160	23
Butyl 325								75	23
Butyl 035								75	23
Precision Butyl								160	23
MC551								75	23
Polybutadiene						75		160	23
Hydropol						160			23
Hycar 2202								75	23
SBR						75			23
Nylon					130				82
Polyvinyl Chloride								85	7
Polyethylene					80			160	296
Polyvinyl acetate								75	296
Teflon FEP, TFE	160				140				7,174,296
Furan Resin					75				296
Phenolic Resin								75	296
Kel-F 300-25				140				140	82
Kel-F Unplasticized	140				140				296
Kel-E-1								140	174
Kel-E-5								140	174
Dylat								75	174,296
Teflite								75	82
Tygon								75	82
Vistanex								80	82
Isocyanate polyester								75	296
Acrylonitrile Butadiene Copolymer								75	296
PVC-PVD Copolymer								75	296
Butadiene-styrene Copolymer								75	296
PVC-PVA Copolymer								75	296
Cellulose Acetate Butyrate								75	296
Polyfluorochloroethylene								75	296
Polyvinyl alcohol polymer								75	7,296
Epon 815								140	174
Carum 200							75		174
Carum 325								75	174
Genetron HL							140		174
Genetron GCX-3R								140	174
Rathene N							140		174
Ander C							75		174
Garlock Gasket #900							140		174
Organic Polysulfide								75	296
Diallylphthalate								75	296
Delanium					75				296
Johns-Manville Svc #60							140		174
Dapon 35							140		174
Silastic LS-53								75	174
Glass Pyrex	160				160				82
Fiberglas Polyester Binder								75	296
Graphitar #2					140				174
Graphitar #50							140		174

TABLE 24. COMPATIBILITY OF MATERIALS WITH 50:50 HYDRAZINE-UNSYMMETRICAL DIMETHYL HYDRAZINE (N_2H_4-UDMH)

Material	Temperature, F								References
	Gas				Liquid				
	Class 1	Class 2	Class 3	Class 4	Class 1	Class 2	Class 3	Class 4	
Metals									
Aluminum, 1100					60				31,165,169
Aluminum, 1100-0					60				50
Aluminum, 2014-T4					60				50,169
Aluminum, 2014-T6	160				160				50,165
Aluminum, 2014-T6 (Welded)	160	60			160	60			169
Aluminum, 2014-T6 (Spot Welded)								60	169
Aluminum, 2014-T6 (Extrusion)	160				160				50,169
Aluminum, 2014-T6 (Extrusion Stressed to 30,000 psi)					60				169
Aluminum, 2014-T6 (Welded and Stressed to 30,000 psi)					60				169
Aluminum, 2014-T6 (Hardas Anodize)					60				50,169
Aluminum, 2014-T6 (H_2SO_4 Anodize)	160				160				169
Aluminum, 2014-T6 (Iridite)					60				50,169
Aluminum, 2014-T6 (Alodine)		160				160			169
Aluminum, 2014-T6 (Fluoride)					80				169
Aluminum, 2024-T6	160				160				169
Aluminum, 2219-T81					60				50,165,169
Aluminum, 2219-T81 (Welded)					60				169
Aluminum, 3003-H14	150				150				169
Aluminum, 5086-H36	160				160				169
Aluminum, 5086-H36 (Welded)					160				169
Aluminum, 5254-F	160				160				169
Aluminum, 5456-H24					60				50,169
Aluminum, 5456-H24 (Welded)					60				169
Aluminum, 5456-H321	160				160				169
Aluminum, 5456-H321 (Stressed 30,000 psi)					60				169
Aluminum, 5456-H321 (Welded)	60				60				169
Aluminum, 5456-H321 (Welded and Stressed to 30,000 psi)	60				60				169
Aluminum, 6061-T6	160				160				50,165,169
Aluminum, 6061-T6 (Welded)					160				169
Aluminum, 6061-T6 (H_2SO_4 Anodize)	160				160				169
Aluminum, 6061-T6 (Alodine)	160				150				169
Aluminum, 6066	160				160				169
Aluminum, 7075-T6	160				160				165,169
Aluminum, 7075-T6 (Stressed to 80% of Yield)					160				169
Aluminum, 356	160				160				165,169
Aluminum, 356-T6	60								50
Aluminum, Tens 50	160				160				169
Berylco 25	160				160				165,169
Cadmium Plate								60	169
Chromium Plate					60				169
Stellite 25	160				160				169
Stellite 6K	160				160				[illegible]
Stellite 21	160				160				169
Copper Plate								60	169
718 Filler Braze of 6061-T6 Al					160				169
AMS 4775 Microbraze of 347 Stainless Steel					160				169
C-62 Braze (Mn-Ni-Co) of 347 Stainless Steel					160				169
Gold Plate	160				160				169
1020 Steel					60				50,169
4130 Steel					60				50,169
303 Stainless Steel	160				160				169
304 L Stainless Steel	160				160				50,[illegible],169
304 L Stainless Steel (Welded)					160				169
316 Stainless Steel	160				160				165,169
321 Stainless Steel	160				160				50,169
321 Stainless Steel (Welded)					160				31,169
347 Stainless Steel	160				160				50,165,169
347 Stainless Steel (Welded)					160				169
410 Stainless Steel	160				160				169
410 Stainless Steel (Welded)					160				169
440C Stainless Steel	160				160				165,169
A-286					60				50,169
PH15-7Mo (Cond. A)	160				160				169
17-4PH	160				160				169
17-7PH (Cond.)	160				150				165,169
AM-350 SCT	160				160				169
AM-355 (Cond. H)	160				160				165,169

TABLE 24. (Continued)

Material	Temperature, F								References
	Gas				Liquid				
	Class 1	Class 2	Class 3	Class 4	Class 1	Class 2	Class 3	Class 4	
Magnesium, AZ31								150	169
Magnesium, HM21A-T8								60	31,50,165,169
Microseal 100-1 on AM100A, Mg				160				160	169
Microseal 100-100 on AZ31C, Mg				160				160	169
Nickel	160				160				165,169
Mt Span C					60				165,169
Nilvar					60				50,169
Nickel Electroplate					60				169
Nickel, Electroless Plate	160				160				169
Silver Solder					60				50,165,169
Easy Flo 45						100			169
Easy Flo Silver Braze of 347 Stainless Steel					160				169
Silver Plate					60				169
Tin Plate					60				169
Pure Tin Solder of 303 Stainless Steel					160				169
Titanium, B120VCA	160				160				50,165,169
Titanium, A110-AT	160				160				169
Titanium, C120AV	160				160				165,169
Titanium Carbide (Nickel Binder)	160				160				169
Tungsten Carbide	150				160				169
Zinc Plate								50	169
Plastics									
Teflon (TFE)					80	150			50,92,165,169
Teflon filled with Graphite					60				50,169
Teflon filled with MoS_2					60				50,169
Teflon filled with Asbestos					60				50,169
Armalon 7700 with Teflon Fibers							60		50,165,169
Armalon 7700B with Teflon Fibers							60		50,165,169
Fluorobestos filled with Asbestos					60				169
TFE-Felt 7250						60			50,169
Fluorogreen					60				50,169
Teflon (FEP)					60			160	50,165,169
Kel-F 300 Unplasticized						60		80	165,169
Kel-F 300 Annealed							60		50,169
Kel-F 300 (15% Glass Filled)					75				92
Kel-F 300 (Unfilled)					75				92
Kel-F 800								75	92
Low-Density Polyethylene					60				50,169
High-Density Polyethylene						60		160	169
Marlex 50 Polyethylene					60				50,169
Polyethylene 7028						80			92
Polyolefin, White Insulation					160				169
Polyolefin, Black Insulation							160		169
Polypropylene					160	60			50,169
Zytel 31								90	169
Zytel 63								80	169
Zytel 101					60			90	169
Mylar								60	50,169,165
Mylar A						75			92
Silicone-Glass Laminate							60		50,169
Phenolic-Glass Laminate								60	50,165,169
Epoxy-Glass Laminate								60	50,165,169
Polyester-Glass Laminate								60	169
Saran							80		50,169
Delrin								60	50,169
Lexan								60	50,169
Tedlar						60			50,169
Kynar						80		160	169
Plexiglas CR 39								60	50,169
Plexiglas II								80	169
Opalon 1219								60	169
Nylon 1220								60	169
Opalon 1444								60	169
Opalon 81222								60	169
Amerplate								160	169
Tygon								80	169
Rigid PVC								60	169
Epon VI								60	169
Epon 828								60	169
Epon 103 (with PMDA)								80	169
BC 1469 Epoxy								60	169
Hypalon 20								80	169
Phenolic Asbestos								60	169
F120-55								60	169
Silicone R-700								60	169
Narmco XJ160								60	169
P-4010					60				169
30000					60				169
H-Film								160	169
Depon 35 (Glass Filled)						75			92
Depon 35 (Unfilled)						75			92

TABLE 24. (Continued)

Material	Gas Class 1	Gas Class 2	Gas Class 3	Gas Class 4	Liquid Class 1	Liquid Class 2	Liquid Class 3	Liquid Class 4	References
Rubbers									
Chicago Rawhide-Sirvene 9623								145	92
Chicago Rawhide-Sirvene 9694								145	92
Chicago Rawhide-Sirvene 9617								85	92
Chicago Rawhide-Sirvene 20316								85	92
Connecticut Hard Rubber Company 3601								85	92
Enjay 035					80	75		80	92
Enjay 218						140		160	92
Enjay 268								60	50,169
Enjay 551							60		169
Enjay CR617						85			92
Firestone Rubber D-404								85	92
Firestone Rubber D-430								85	92
Firestone Rubber D-431								85	92
Firestone Rubber D-432								85	92
Firestone Rubber D-406								145	92
Firestone Rubber D-405								145	92
Firestone Rubber D-408								145	92
Firestone Rubber D-409								145	92
Firestone Rubber D-410								145	92
Parker Appliance 37-C14						85			92
Parker Appliance 37-C24						85			92
Plastics and Rubber Products 805-70								85	92
Plastics and Rubber Products 805-90								85	92
Precision Rubber Products 907-90								85	92
Precision Rubber Products 925-70								85	92
Stillman SR 613-75						80	160	85	92,169
Stoner Rubber BB-55								85	92
Synthetic Rubber Products 50XB656								85	92
Synthetic Rubber Products 50223								85	92
Thiokol C 42986-1						85		145	92
Thiokol C 55938								85	92
Du Pont Neoprene (1158)								100	92
B.F. Goodrich Neoprene 091						100			92
Neoprene								60	50,169
Hycar 2202							60	85	50,92,169
Hycar 520-41-125-1								85	92
Hycar 1043 Std. No. 1								85	92
Hycar 1001								85	92
Hycar G41								100	92
Chemigum N6 12								100	92
Chemigum SL								75	92
Kel-F 3700								75	92
Kel-F 5500								75	92
Fluorubber 1F4								60	50,92,169
Fluorel								60	50,92,169
Viton A								60	92,165,169
Viton A-247M								85	92
Viton A-44-11 A-35								85	92
Viton B								60	165,169
Stillman Fluororubber								60	50,169
EX 821-A70								80	169
Precision Rubber 18007, 18057								160	169
Hydropol Y						140		160	92
Hydropol T						145			92
Tyson X3603								75	92
Saran Rubber								75	92
Saran Rubber 300 Uncured								100	92
Saran Rubber 300 Cured								100	92
Dow Silicone LS-63								100	92
Dow Silicone DC-152								75	92
G.E. Nitrile Silicone NSR035602								85	92
G.E. Nitrile Silicone SE750								130	92
Nichols Teflon and Silicone LS-63								85	92
Parco 823-70							80		165,169
Parco 805-70								80	165,169
Precision Rubber 9357								80	165,169
Precision 214-407-9								80	169
Precision Rubber 9407								80	165,169
940 X 559					80			160	169
Parker B480-7								80	169
Parker B496-7							60		169
Parker 318-7							160		169
Gusman 1357							80		169
Linear 7806-70								80	169
Hadbar XB800-71					160				169
Formula 120 (Resin Cured)							160		169
Formula 121 (Resin Cured)							160		169
Acushnet SBR-442							160		165,169
Acushnet SBR-849							160		169
Acushnet SBR-850							160		169
Acushnet SBR-851						160			169
Stillman EX 904-90								160	165,169
LB53								60	165,169
Hadbar 58789-230T								80	165,169
Thiokol 3000 St.								130	92
Garlock 900								60	169
Garlock 22								60	50,169
Cohrlastic 500								60	50,169
Parco B318-7								60	169
Adiprene B1156								100	92
Adiprene B1157								100	92

TABLE 24. (Continued)

Material	Gas Class 1	Gas Class 2	Gas Class 3	Gas Class 4	Liquid Class 1	Liquid Class 2	Liquid Class 3	Liquid Class 4	References
Lubricants and Sealants									
[illegible] Lube						80			169
S No. 58-M						80			169
LOX Safe						80			169
Andok C						80			169
DC-11		80				80			169
Microseal 100-1 (Dry Lube)					80				169
Rockwell Nordstrom 147						75			92
Rockwell Nordstrom 421								75	92
Rockwell Nordstrom 551								75	92
Rockwell Nordstrom 921								75	92
Rockwell Nordstrom 950							80		169
Nordcoseal DC-234-8								75	92
Valve Seal A						80			169
Flake Graphite					80				169
DC-55		80				80			169
DC-41 Vacuum		80				60			169
Molykote Z								60	165,169
Kel-F 40								75	92
Kel-F 90						75		60	92,165,169
Kel-F 200								75	92
Drilube 703								60	165,169
Rayco-32								60	169
Electrofilm 66-C							60		169
Polyglycol Oils						[illegible]			169
FX-45							80		169
Apiezon L						80			92,169
NC 150						80			169
Fluorolube MG-600							80		169
Fluorolube Hg-1200								75	92
Fluorethene G								80	169
Anderol L237								75	92
Carum 200							75		92
Fluoropack								75	92
Lubriseal						75			92
Nonaq Stopcock Grease								75	92
Rectorseal 15								75	92
Silicone DC 11							75		92
Reddy Lube 100					80				169
Reddy Lube 200					80				169
Water Glass Graphite					80				169
Drylube Sealant						80			169
Vydax A						80			169
Teflon Tape					80				169
Potting Compounds									
PR 1422								60	169
RTV 20								60	169
Paraplex P-43								60	169
Proseal 793								60	169
Pairprene 5159								60	169
Crystal MHCP								60	50,169
Adhesives									
Armstrong A-6								60	169
EC 847								60	169
MT 424								60	50,169
Epon 422					80				169
Epon 4-3								80	169
Ceramics									
Temporell 1500					60				50,169
Sauereisen P-1					60				50,169
Sauereisen 31					60				50,169
Sauereisen 47							75		169
Rockflux					75				169
Coatings									
Epoxy No. 1								60	169
Modified Epoxy No. 2								60	169
Epoxy No. 7								60	169
Epoxy No. 9								60	169
Epoxy No. 6809								60	169
Alkyd No. 4								60	169
Polyurethane								60	169
Acrylic Nitrocellulose								60	169
Vinyl								60	169
Primer MIL-P-6889								60	169
Catalac								160	169
Tygon K								160	169
Copolymer P-2000								160	169
CA 9747 Primer								160	169
Corrosite Clear 581								160	169
Proseal 333							80		169
Markal DA-8								80	169
Aluminous								80	169
Graphites									
Graphitar 14								160	169
Graphitar 39					80			160	169
Graphitar 84					80				169
Graphitar 86					160				169
National Carbon CCP-72					160				169
Purebon P3N					160				169
Purebon P5N						160			169
Gasket and Packing Material									
Vistex KS-NBS (with Teflon)						75			92
Delenium						75			92
Neoprene								75	92
Garlock 900						130			92
Du Verre 22								75	92
Naveg 30								75	92
Naveg 41								75	92
Naveg 50								75	92
Naveg 60						100			92
Melbestos 031						100			92

TABLE 25. COMPATIBILITY OF MATERIALS WITH 50:50 HYDRAZINE-UNSYMMETRICAL DIMETHYL HYDRAZINE PLUS UP TO 3% WATER(50)

Material	Temperature, F								References
	Gas				Liquid				
	Class 1	Class 2	Class 3	Class 4	Class 1	Class 2	Class 3	Class 4	
Metals									
Aluminum, 1100-0					>60				
Aluminum, 5456-H321					>60				
Aluminum, 7075-T6					>60				
Aluminum, 356-T6	>60								
Ni-Span-C					>60				
Titanium, 5Al-4V					>60				

TABLE 26. COMPATIBILITY OF MATERIALS WITH LIQUID HYDROGEN(82,211,221)

Class 1 or 2 Materials		Class 4 Materials
Aluminum, 1100	Inconel	Aluminum, 40 E
Aluminum, 5052	Low-Carbon Steel	Magnesium
Aluminum, 4043	High-Nickel Steels	Lead
Aluminum, 2024-T	Titanium	Zinc
Aluminum, 1100-T	Nitrile Rubber	Iron
300 Series Stainless Steel	Silicone Rubber	High-Carbon Steel
410 Stainless Steel	Teflon	Natural Rubber
Haynes 21	Garlock Packing	Neoprene Rubber
Molybdenum	Bakelite	Cork
Nickel	Micarta	Wood
Monel	Lucite	Polyvinyl Chloride
	Graphite	Saran
		Polyvinyl Alcohol

TABLE 27. COMPATIBILITY OF METALS WITH 90 PERCENT HYDROGEN PEROXIDE

Class 1 Metals

Maximum per cent of active oxygen loss (AOL) by H_2O_2 in 1 week: at 30 C (76 F) - 0.2%, at 66 C (150 F) - 5.0%
Minimum stability of H_2O_2 after test - 95% stable in 24-hour test at 212 F in glass
No other effect on H_2O_2 or metal

Aluminum Alloys	Stainless Steel Alloys	Nickel Alloys	Cobalt Alloys	Other Alloys	Other Pure Metals	Reference
1060	None	None	None	None	Tantalum	35,36,37, 38,149,210
1100					Zirconium	35,36,132, 149,210
1160						35,210
1260						35,210
7072						35,36,37, 38,210
B-356						35,36,38, 210

Class 2 Metals

Maximum per cent of active oxygen loss (AOL) by H_2O_2 in 1 week: at 30 C (76 F) - 6.0%, at 66 C (150 F) - 80%
Minimum stability of H_2O_2 after test - 90% stable in 24-hour test at 212 F in glass
No other effect on H_2O_2; slight bronzing of the metal allowable but no corrosion

Aluminum Alloys	Stainless Steel Alloys	Nickel Alloys	Cobalt Alloys	Other Alloys	Other Pure Metals	Reference
3003	Type 202	None	None	None	Silicon	35,36,210
4043	Type 302				Tin (cp)	35,36,149, 210
5052	Type 304					35,36,37, 38,149,210
5054	Type 304 ELC					35,210
5056	Type 309					35,210
5652-0	Type 310					35,36,210
5254-0	Type 316					35,36,37, 38,210
6061	Type 316 ELC					35,36,37, 38,210
3063	Type 317					35,210
6363	Type 318					35,36,210
150	Type 321					35,210
214E	Type 322					35,36,37, 38,210
214F	Type 347					35,36,210
356F	17-7PH, 37-45 R_c					35,36,37, 210
5052 (anodized)	17-7PH, 45 R_c (buffed)					35,210
6061 (anodized)	17-7PH (unhardened)					35,210
6061 (HNO_3 Pass.)	Hasco-O-Seven					35,210
6061 (detergent wash)	Malin-Wilslabrite					35,36,210
6061 (WFNA Pass.)						35

Table 27. (Continued)

Aluminum Alloys	Stainless Steel Alloys	Nickel Alloys	Cobalt Alloys	Other Alloys	Other Pure Metals	Reference
			Class 3 Metals			
	Maximum per cent of active oxygen loss (AOL) by H_2O_2 in 1 week: at 30 C (76 F) – 11.0%, at 66 C (150 F) – 100% in 24 hours. Minimum stability of H_2O_2 after test – 15% after 30 C (76 F) test. Bronzing and staining, but no rusting or other corrosion products; slight attack may be allowed.					
2024	329	Inconel X	None	H-975	None	35,37,38, 210
B214F	AM 350			Refractalloy 26		35,210
A360	17-7PH, 45 Rc			Refractalloy 70		35,210
6061 (anodized)	17-7PH, 45 Rc (electropolished)					35
2017 (anodized)	17-4PH					35
2024 (anodized)	Carpenter 20					35,36,210
6061 (hard coat)	Durimet 20					35,210
	AM 355					35,210
	19-9DL					35,210
	16-25-6					35
	Proloy Type 302 porous wire					35,210
	Worthite					35,210
			Class 4 Metals			
	Maximum per cent of active oxygen loss (AOL) by H_2O_2 in 1 week – not specified. Minimum stability of H_2O_2 after test – not specified. Pitting or corroding during or after test					
2014	AM 350	Nickel	Cobalt	Mild steel	Copper	35,36,149, 210
2017	410	Inconel	Haynes 25	Be-bronze	Zinc	35,36,149, 210
7075	416	Monel	Star "J"	Chromaloy H-3	Tungsten	35,149,206, 210
40E	420	Hastelloy "B"	Haynes 3	Duriron (cast)	Titanium	35,36,210
218	430		Haynes 6		Sodium	35,36,210
355F	431	Hastelloy "C"	Haynes 12	Fanweld "O"	Magnesium	35,38,149, 210
A750	440		S-588	Ni-Resist	Beryllium	35,210
B750	443	Hastelloy "D"	S-590	Tantung	Cadmium	35,149,210
2024 (anodized)	446			Dow metal JIA	Chromium	35,149,210
	Rigimesh J SS porous wire	Be-nickel		Dow metal MA	Gold	35,210
		Illium "G"		Kennametal K-138	Iron	35,36,210
		Chlorimet			Lead	35,36,210
	300 series SS powder compact			Kennametal K-3H	Manganese	35,210
					Mercury	35,210
	Type 302 powder compact			Kennametal K-501	Molybdenum	35,94,149, 210
					Platinum	35,210
	Type 316 powder compact			Kennametal K-M	Silver	35,36,210
	Type 302B powder compact			Multimet N-155		35,210
	Type 316 + Cb powder compact					35
	Utiloy 3					35,210
	Utiloy 20					35,210
	Utiloy H					35,210
	Utiloy NH					35,210
	Elgiloy					35,210

TABLE 28. COMPATIBILITY OF NONMETALS WITH 90 PERCENT HYDROGEN PEROXIDE AT 150 F[35]

Material	Classification
Plastics - Polyethylene and Halogenated Polyethylene Type	
Fluoroflex T-TP1001	1
Fluoroflex T-TP1000 (black)	2
Fluran B-4100	3
Halgene	2
Hypalon S-2	4
Hypalon Gasket	4
Hypalon V-54-B (gray)	4
Hypalon V-56-A (gray)	4
Hypalon V-163-4 (black)	4
Hyplon "O" Ring (GRC 90-5)	3
Irrathene 101 (irradiated polyethylene)	2
Kel-F (unplasticized)	1
Kel-F 800 (Lot 5649)	1
Kel-F 820 (G4028)	2
Kel-F 3700 gum	3
50% Kel-F 3700-50% Kel F 800	2
Kel-F 5500 (unpigmented)	2
Kel-F 5500 gum	3
Kel-F 5500-121	2
Kel-F 5500-61	2
50% Kel-F 5500-50% Kel-F 800	1
75% Kel-F 5500-25% Kel-F 800	
Kel-F O-Ring (CPD. 7761-70)	2
Polyethylene	2
Rulon (Teflon Base)	2
Teflon (white)	1
Viton A (411A4) (black)	3
Plastics - Polyvinylchloride and Copolymers	
Alanol tubing	3
Boltron 6200 (gray)	2
Geon 118	4
Geon 404 (yellow)	3
Koroseal 116	3
Koroseal 117 (molded)	3
Koroseal 700	2
Lucoflex (translucent)	3
Lucoflex (white)	3
Marvinol 218-200	4
Marvinol 218-201	4
Marvinol NG-3005	4
Marvinol NR-6010	4
Saran	2
Saran Rubber Q-187	4
Transflex Tubing	4
Tygon B-20	3
Tygon B-32	3
Tygon B-63	3
Tygon B-71	3
Tygon B-72	3
Tygon B-136	3
Tygon S-22-1	4
Tygon TL-103	4
Tygon 2807	4
Tygon 3400	4
Tygon 3603	4
Tygon 3604A	2(a)
Tygon 3604B	2(a)
Vinyl 79139	2
Vinylite VG 1914	2
Vinylite VU 1940	2
Vinylite VS 1310	3
Vinylite VU 1900	3
Vinylite UE 1907	3
Vinylite VU 1920	3

TABLE 28. (Continued)

Material	Classification
Plastics - Polyvinylchloride and Copolymers	
Vinylite VU 1930	3
Vinylite VU 1940	3
Plastics - Silicone Rubber Compounds	
Fluorosilicone LS-53	2
GE 407B-217-1	4
GE 1240	2
GE 81223	2
GE 12601	4
GE 12602	3
GE 12650 (unpigmented)	2
GE 12650 (pigmented red)	3
GE 12670	4
GE 12670 (pigmented brown)	4
GE 15060 (pigmented)	3
GE 15080	3
GE X-7181	3
Parkone White 467-1 O-ring	4
SE 450 (unpigmented)	2
Silastic 152	3
Silastic 160	3
Silastic 160 O-ring	4
Silastic 161	3
Silastic 181	3
Silastic 240	2
Silastic 250	4
Silastic 261	3
Silastic 675	3
Silastic 6-128	2
Silastic 7-180	3
Silastic 9711	2
Silastic HR-9711	2
Silastic 9711 welded with S-2200	2
Silastic S-2000-4-480	2
Silicone 407-B-217-1	3
Silicone 407-B-437-1	2
Silicone HT 656	3
Silicone SR 5550	2
Silicone SR 5570	2
SR 5550	2
SR 5570	2
X-7181	3
Silicone Y-1749	2
Rubbers and Plastics - General	
Acrylon Rubber BA-12	4
Acrylon EA-5	4
Adiprene C	4
Bisilon No. 50	2
Buna N	4
Butyl Rubber A 3405	4
Butyl Rubber SR-384	4
Cycolac (natural color)	4
Garlock No. 5681 (Teflon-impregnated asbestos)	4
Hycar PA 478-1-1 (black)	4
Haveg 41 (Asbestos filled phenolic)	4
Haveg 60 (phenolic)	4
Hysol 4-77C (clear)	4
Hysol 4-77D (amber)	4
Hysol 4-77E	4
Hysol 4-77F	4
Hysol 4-78A (white)	4
Hysol 4-78B (brown)	4
Hysol 4-78C (amber)	4
Hysol 4-78D (amber)	4
Hysol 6000 B (amber)	4

TABLE 28. (Continued)

Material	Classification
Rubbers and Plastics - General (continued)	
Kralite	3
Melmac No. 1077	4
Mylar A	1
Mylar B	1
Neoprene Pure Gum	4
Neoprene SR 365-B	4
Nylon	4
Phenol-Formaldehyde	4
Plexiglas	4
Polystyrene (Polyflex)	2
Thiokol EC-801-LP2	4
Thiokol 3000 FA	4
Thiokol 3000 ST	4
Thiokol 1620 AH	4
Plastics - Laminates, Diaphragm Materials and Adhesives	
Chemelic MI-411 (Teflon Fiberglas)	2(b)
Duroid 5600 (fiber-reinforced Teflon)	3
Fairprene PS57-167 (Viton A, 116 Glass)	3
Fairprene PS57-168 (Viton A, Dacron)	2
Fairprene (Viton A)	
5806	2
5807	2
5809	2
Kel-F-Dacron Diaphragm-VL-1101m4	4
Kel-F 5160 Diaphragm	2
Kel-F 5500 (gray) Diaphragm	2
Kel-F 5500 (gray) on Dacron diaphragm	2
Korda Flex (Teflon-coated glass fabric)	2
Silastic DC-9711 on Dacron diaphragm	3
Vinyl coated Fiberglas (gray-green)	3
9711 Silicone seal washer DC A 4094 adhesive (Dow Corning Silicate base) on aluminum	3
9711 Silicone seal washer DC Chemloc 607 adhesive on aluminum	3
Porous Materials	
Al-Si-Mag, Porous Ceramic No. 393	3
Aluminum Oxide, Porous-RA-98	2
Armalon-Teflon Felt (impregnated)	3
Armalon-	3
Dacron Cloth	2
Dac-2100	
Dac-2101	2
Dac-2102	2
Filtros C Stone (55 Micron)	2
Glass Cloth G-206-C	2
Poroloy--302SS Wire	3
Porous Kel-F (15-Micron Pore)	2
Porous Porcelain (1.4 Micron)	2
Porous Teflon (9-Micron Pore)	2
Rigimesh J SS. Wire	4
Sintered 300 Series SS Powder Compact	4
Sintered 302 SS Powder Compact	4
Sintered 316 SS Powder Compact	4
Sintered 302B SS Powder Compact	4
Sintered 316 and Cb SS Powder Compact	4
Teflon Cloth (25 Grade)	3
Teflon Cloth-Repeat (25 Grade)	2
Teflon Cloth (40 Grade)	3
Teflon Felt (impregnated)	
Teflon Cloth T-2300	3
Teflon Cloth T-2305	2

TABLE 28. (Continued)

Material	Classification	Impact Sensitive
Lubricants		
Alkaterge C	4	Yes
Amino Silane Oil and Grease	4	Yes
Apiezon Hardwax W	4	
Arochlor 1221	4	Yes
Arochlor 1232	4	Yes
Arochlor 1242	4	Yes
Arochlor 1248	4	Yes
Arochlor 1254	4	Yes
Bardahl	4	Yes
Carum 200	4	Yes
Ceresin Wax	4	Yes
CFE-1	4	Yes
Dichloro-bis-tri-fluoromethyl benzene	3	No(c)
Dichlorohexafluorobutene	3	No(c)
Fluorolube FS	2	No(c)
Fluorolube FS plus 5% fluorolube light grease	2	No(c)
Fluorolube heavy grease 10214	2	No(c)
Fluorolube oil 10213	2	No(c)
Fluorolube S	2	No(c)
Fluorolube T	2	No(c)
Fluorolube Oil, S-30	2	No(d)
Fluorolube Grease, Hg-1200	2	No(d)
Fluorolube Grease, GR-660	2	No(d)
Formulation		Yes
F-9	4	
OS-16	4	Yes
OS-22	4	Yes
OS-23	4	Yes
OS-27	4	Yes
OS-28	4	Yes
OS-30	4	Yes
OS-32	4	Yes
OS-33	4	Yes
OS-34	4	Yes
OS-35	4	Yes
OS-37	4	Yes
CP-3898-2	4	Yes
Skydrol (uncolored)	4	Yes
Halocarbon Oil 8-25 AV	2	No(c)
Halocarbon Grease, Series 25-10	2	No(d)
Halocarbon Hi-Temp Stopcock Grease	2	No(d)
Halocarbon Oil 10-21	2	No(c)
Halocarbon Oil 11-14	2	No(c)
Halocarbon Stopcock Grease	2	No(d)
Hexachlorobutadiene	3	No(c)
Hexachloropropylene	4	
Hydraulic fluid RPM	4	Yes
Hydraulic Oil Houghton Safe 620	3	
Kel-F Alkane	2	No(d)
Kel-F Oil Cut No. 1	2	No(c)
Kel-F Oil No. 10	2	No(c)
Kel-F No. 90 Grease	2	No(c)
Lindol HF (tricresyl phosphate)	4	Yes
Lindol HFX	4	Yes
Liqui-Moly Concentrate	4	Yes
Lubriseal	4	Yes
Mineral Oil	4	Yes
Paraffin	4	Yes
Perfluorolube Grease FCD-759	2	No(c)
Perfluorolube Oil FC-331	2	No(c)
FC-332	2	No(c)
FC-333	2	No(c)
FC-334	2	No(c)
FC-335	2	No(c)
Petrolatum	4	Yes
Polychloropentane (stabilized)	4	Yes
Renex	4	Yes
Silicone XF 224	4	Yes
Silicone Oil DC-7	4	Yes
DC-44	4	Yes
DC-200	4	Yes
DC-550	4	Yes
DC-701	4	Yes
DC-702	4	Yes
DC-710	4	Yes
Silicone Oil GE 2V3733	4	Yes
GE 51346	4	Yes
Tectyl	4	Yes
1,1,2,2, tetrafluoroethyl dodecylether	4	Yes
Tributyl Phosphate	4	Yes
Ucon Hydrolube U-4	4	

TABLE 28. (Continued)

Material	Classification
Ceramics, Refractories, and Miscellaneous	
Agate (natural)	3
Agate (polished)	3
Al-Si-Mag (porcelain)	2
Alundum LA 116	2
Boron Nitride	4
Carboloy 44-A	4
Carboloy 55-A	4
Carboloy 78	4
Carboloy 999	4
Ceramic AB-2	2
Ceramic Al-200	2
Charcoal	4
Crystalon (Silicon Carbide)	4
Graphitar No. 30	4
Graphite P5A6 Silver impregnated	4
Graphite P-55 Copper impregnated	4
Graphite P-59L Copper impregnated	4
Graphite P-692	4
Karbate	4
Norbide	2
Synthetic Sapphire (polished)	1
Protective Coatings	
(A. Recommended for Long-Time Contact and Splash Resistance)	
Teflon	1(e)
Kel-F	1(e)
Kel-F on 1060 Aluminum	1
Kel-F on 5254 Aluminum	1
Kel-F on 5652 Aluminum	1
Glass-lining (Clear) Light-Gray	1
Glass-lining (Cobalt) Cobalt-Colored Glass	1
(B. Recommended for Splash Resistance Service Only)	
Tygon Paint 7286 TP-81-Clear	3(e)
Tygon Paint 71253 TP-107B	3(e)
Corrosite No. 521	3(e)
Corrosite No. 551	3(e)
Corrosite No. 581	3(e)
Plastic Metal No. 22	3(e)
Saran Rubber Q-1875	3(e)
Mv-Type No. 150	3(e)
Amercoat No. 1262	3(e)
Heilex	3(e)
P-5, Copolymer	3(e)
Neolac Gray No. 8588	3(e)
Steelcote Stainless Steel	3(e)
(C. Not Recommended for 90% H_2O_2 Service)	
Geon Latex 31X	4(e)
Flexcoat No. 1 Black	4(e)
Lithgow LC-600 (Gray)	4(e)
Amercoat Red	4(e)
Prufcoat Medium Gray	4(e)
Lithgow LC (600) (Brown)	4(e)
Veloform F-10 CPP304	4(e)
Cordo .-255A	4(e)
Cordo Plastic Coating (E-1 Resin + H-26 Activator)	4(e)
Chromalloy	4(e)
Unichrome Drum Lining B-124-17	4(e)
Ucilon, System E Coating	4(e)
EX63B Paint	4(e)
Sealer EC801 With Accelerator	4(e)

TABLE 28. (Continued)

Material	Formulation	Classification	Impact Sensitive(f)
Joint Sealing Compounds			
"Althon" E	Polyethylene resin	1(e)	Non-impact sensitive
Dispersite 1920-?	Butyl rubber in alkaline dispersion	2(e)	Non-impact sensitive
Duxseal	Teflon	1(e)	Non-sensitive
Calbar CB Pipe Seal		4(e)	Impact sensitive
Crane Thread Lub.	Oxidizable Oil	4(e)	1 doubtful impact from 11 trials
Fel-Pro, C-5	Colloidal Copper	4(e)	Impact sensitive 1 of 4 trials
Graphite Paste	Graphite dispersion	4(e)	Non-impact sensitive
Goop (Blue)		4(e)	Positive
Goop (Silver)		4(e)	Positive
Cyl-Seal		4(e)	Non-impact sensitive
Molybdenite Pipe Dope		4(e)	Not tested
Permatex, Aviation Form A Gasket No. 3		4	Not tested
OS-18 Lubricant	Skydrol + 30% Benton 34	4(e)	Impact sensitive
Pecora Cpd.		4(e)	Impact sensitive
Plastic Metal	No. 22-aluminum filler, latex base. No. 333-SS filler, latex base	4(e)	Impact sensitive when wet
Rutland Pipe Dope		4(e)	Sensitive 2 of 3 trials
Skydrol	Mixture Skydrol (P-601) and talc	4(e)	Impact sensitive
T-Film	Teflon-water dispersion	4(e)	
Weco No-Gal.	No. 50 metallic zinc base	4(e)	Impact sensitive
X-Pando		4(e)	Non-impact sensitive
Kel-F Grease No. 90	Polychlorotrifluoro-ethylene		Non-sensitive
Tin Plating On Aluminum 6061		4(e)	
Alcoa Thread Lubricant		4(e)	Not tested
Rectorseal No. 15		4	Not tested

(a) Based on service experience.

(b) After 24-hour screening at 66 C (150 F).

(c) Non-impact sensitive to 1 kg at room temperature.

(d) Non-impact sensitive to 3 kg at room temperature.

(e) Tested at room temperature.

(f) One-kg impact at room temperature.

TABLE 29. COMPATIBILITY OF MATERIALS WITH METHYLENE CHLORIDE (CH_2Cl_2)

Material	Temperature, F								References
	Gas				Liquid				
	Class 1	Class 2	Class 3	Class 4	Class 1	Class 2	Class 3	Class 4	
Metals									
1100 Aluminum			125				75	100	211
Copper			125		100		75		211
Sn Bronze			125				75		211
Al Bronze			125				75		211
Si Bronze					125		75		211
Red Brass			125				75		211
Yellow Brass			125				75		211
Mild Steel			125		75				211
Cast Iron							75		211
Ni-Resist							75		211
Si-Iron									211
410 Stainless Steel									211
430 Stainless Steel					100		75		211
304 Stainless Steel					75		75		211
316 Stainless Steel					75		75		211
Worthite	175		212						211
Durimet 20	175		212						211
Carpenter 20					100				211
A-Nickel			75			100	75		211
Monel			125			100	75		211
Inconel			75				75		211
Hastelloy B					100				127,128,211
Hastelloy C					100	100			127,128,211
Ni-O-Nel					70				211
Lead							75		211
Gold							75		211
Platinum							75		211
Tantalum							75		211
Silver							75		211
Nonmetals									
Glass							75		211
Stoneware							75		211
Rubber								75	211
Asbestos					75				211
Graphite					75				211

TABLE 30. COMPATIBILITY OF MATERIALS WITH RED FUMING NITRIC ACID

Material	Temperature, F: RFNA (Type III) Class 1	RFNA (Type III) Class 2	RFNA (Type III) Class 3	RFNA (Type III) Class 4	IRFNA (Type IIIA) Class 1	IRFNA (Type IIIA) Class 2	IRFNA (Type IIIA) Class 3	IRFNA (Type IIIA) Class 4	References
Metals									
Aluminum 1060	80		160						82,
Aluminum 1100	125	80	150	300	160				18,29,95,181, 193,211
Aluminum 2014		100	130	150	130				29,193
Aluminum 2017		100	130	<250	130				18,149,193
Aluminum 2024	80	80	150	<200	130	160			18,29,149,193
Aluminum 2024, Anodized						160			82
Aluminum 3003		80	150						29
Aluminum 3004		80							82
Aluminum 4043		80	160						18
Aluminum 5052		80	160	>160					29,192,
Aluminum 6061		80	160	160	160				18,29,30,95, 149,179,189, 192
Aluminum 6063		80	160	>160					29
Aluminum 7[illegible]		80	130	160	130				29,193
Aluminum [illegible]		80		160					18,29
Aluminum [illegible]		80							18
Aluminum [illegible]			80						18
Aluminum [illegible]		80							18
Aluminum [illegible]		80	130	160	130				18,29,149,189
301 Stain[illegible]	80	80		122					29
302 Stainles[s]	80	125	130	<212		122	160		18,193
303 Stainless Steel				<130		130	160		18,192,193
304 Stainless Steel	125		130	150		130	160		18,29,58,149, 179,193,211
304 ELC Stainless Steel	80	120	130	160		120	130		29,30
309 Stainless Steel	80		122	160					29
310 Stainless Steel	80		122	160					5,29
316 Stainless Steel	125			120					18,29,58, 149,211
316 ELC Stainless Steel	80			<160					29
318 Stainless Steel	80			160					29
321 Stainless Steel	80		130	>130		130	160		18,29,193
322 Stainless Steel	80								29
347 Stainless Steel	80	80	130	>130	80	160	160		18,58,149,182, 189,192,193
Stainless W	75			<2[illegible]					149
410 Stainless Steel	80			130			130	130	18,29,58, 149,192,193, 211
414 Stainless Steel		80		<250					18,149
416 Stainless Steel		80		<250					18,149
420 Stainless Steel				<250					149
430 Stainless Steel	80	130		160		130			18,29,58, 193,211
440 Stainless Steel			130						18,149
446 Stainless Steel		130					130		149,193
Worthite	125	125		<250					18,149,211
Carpenter 20	80	125	160	300					58
Aloyco 20	80	125							82
Durimet 20	125	125		<300					82
17-7PH annealed 1900 F			130	>130		130			193,211
17-7PH hardened		120		<130		130			30,179
19-9DL				<130	130				192,193
19-9DX			130	>130		130			193
Mild Steel			7[illegible]	200					193,2[illegible]
1020 Steel			80	120				130	18,29
Cast Iron				80					18,211
Duriron	75	75	300						18,211
Ni-Resist				75					211
4130				130				130	192,193
Inconel			75	300					211
Illium G	125	125		175					82
Hastelloy B				75					211
Hastelloy C	75		75	<300					211
A Nickel			130	75			130		193,211
Monel				75					211
Invar				75					149
Copper				All					211
Sn Bronze				All					211
Al Bronze				All					211
Si Bronze				All					211
Yellow Brass				All					211
Red Brass				All					211
Chromium	80	130		<250	130				18, 93,149
Stellite No. 1	80			<250					18,149
Stellite No. 6	80			<250					18,149
Haynes 25		160							29
Gold	80	<250	300						18,149
Platinum	300	300							211
Magnesium				All					87
Columbium	75								93
Tantalum	300	300					130		18,149,193, 211
Tin	80	250	275						18,149
Tin Babbit			250	300					18,149
Titanium 75A	160							130	29,31,193, 211,240,241
Titanium Alloy C110M	130		85						39,240,241
Titanium Alloy 130A		130						130	193
Titanium A70		75							39
Zirconium	75	160							211,131
Hafnium	75								87
Lead				130				130	193
Inorganics									
Glass	300								211
Stoneware	300								211

TABLE 30. (Continued)

Material	Temperature, F: RFNA (Type III) Class 1	RFNA (Type III) Class 2	RFNA (Type III) Class 3	RFNA (Type III) Class 4	IRFNA (Type IIIA) Class 1	IRFNA (Type IIIA) Class 2	IRFNA (Type IIIA) Class 3	IRFNA (Type IIIA) Class 4	References
Lubricants									
Standard Servo Oil No. [illegible]		75		212					149
Nujol				212					149
Aroclor 1254				330					149
Aroclor 1242				300					149
Dow Corning Fluid				75					149
Crane No. 5	75			250					149
Cresan No. 32				75					149
Carballoy								160	149
Plastics									
Teflon					75				23
Teslar 30								75	23
Teslar 40								75	23
Hi Styrene Sheet								75	23
Lexan								75	23
Kydepar 11								75	23
S[illegible]te								75	23
Mylar								75	23
Zytel								75	23
KFE 5500								75	23
KFE 2140								75	23
Viton A-HV								75	23
LD-234								75	23
Phenol-Formaldehydes				75					222
Phenol-Furfurals				75					222
Furan Resins				75					222
Urea-Formaldehydes				75					222
Melamine-Formaldehydes				75					222
Aniline-Formaldehyde				75					222
Glyceryl-Phthalate				75					222
Epoxy Resins				75					222
Cellulose Compounds				75					222
Casein Compounds				75					222
Shellac				75					222
Inorganic Plastics				75					222
Vinyl Chloride-Acetate Copolymers			75						222
Vinyl Chloride Resins			75						222
Vinylidene Chloride Resins			75						222
Vinyl Formal Resins				75					222
Vinyl Butyral Resins				75					222
Vinyl Alcohol Resins				75					222
Polyvinyl Carbazole Resins				75					222
Allyl Resins				75					222
Polyester Resins				75					222
Polyacrylic Ester Resins				75					222
Methyl Methacrylic Resins				75					222
Polystyrenes				75					222
Polyethylene				75					222
Polytrifluorochloro-ethylene			75						222
Polytetrafluoroethylene			75						222
Nylon				75					222
Silicone			75						222
Diallylphthalate				75					222
Modified Styrene				75					222
Acrylonitrile Rubber				75					222
Chlorinated Rubber			75						222
Hard Rubber				75					222
Protective Coatings for Metals									
Hycar				75					222
Hycar 2202				75					222
Nukem No. 40				75					222
Neoprene				75					222
Pliogard				75					222
Saranco[illegible]e				75					222
Bitumastic No. 50				75					222
Epon YB-100				75					222
Novelon B-100-10				75					222
Epoxy				75					222
Modified Epoxy				75					222
Vinylidene Chloride				75					222
Vinyl Chloride				75					222
Exon 400 XR61	75								222
Porcelon	75								222
Fluorline 100	75								222
XR-2710		75							222
Kel-F	75								222
Teflon	75								222
Vinyl Mastic	75								222
DEL Series A			75						222
Prufcoat A	75								222
Lankote Fluoro B	75								222
Nerva-Kote Fluorinax	75								222
Coatings for Nonmetals									
Silicate Cement				75					222
Kel-F				75					222
Kotol 102-C	75								222
Phenoline 315		75							222
Corocrete			75						222
Lankote Fluoro B	75								222
Nerva-Kote Fluorinax	75								222
Vinyl Mastic	75								222
Exon 400 XR61	75								222

TABLE 31. COMPATIBILITY OF MATERIALS WITH WHITE FUMING NITRIC ACID

Material	Temperature, F: Gas Class 1	Gas Class 2	Gas Class 3	Gas Class 4	Liquid Class 1	Liquid Class 2	Liquid Class 3	Liquid Class 4	References
Metals									
Aluminum 1060						130			248
Aluminum 1085						85	185		82
Aluminum 1100					75	85	160		29,149,211, 298
Aluminum 2014					110	75	100		29,298
Aluminum 2017							100		82
Aluminum 2024					110	75		160	29, 298
Aluminum 3003					110	75	130		29,248,298
Aluminum 5052					110	75	160		29,298
Aluminum 6061					110	75	120	160	30,298
Aluminum 6061 (Welded)					75	100	125	140	97
Aluminum 6063					110	75	160		29,298
Aluminum 7075					110	75		160	29,298
Aluminum 43								160	29,149
Aluminum 356								160	29
301 Stainless Steel					75			<120	29
302 Stainless Steel					75				149
304 Stainless Steel					75	70	85	120	21,29,30, 58,149,248
304 ELC Stainless Steel					75		120	<160	29,30
304 ELC Stainless Steel (Welded)						120	140		150
309 Stainless Steel					75		120	<160	29,149,248
310 Stainless Steel					75		120	<160	29,149,248
316 Stainless Steel					75		85	120	29,56,149, 211
316 ELC Stainless Steel						75		<160	29
318 Stainless Steel						75		<160	29
321 Stainless Steel						75		<120	29
322 Stainless Steel					75			<160	29
347 Stainless Steel						75	120	120	149,248,298
347 Stainless Steel (Welded)						120	140		150
410 Stainless Steel					75			75	29,58,149, 211
410 Stainless Steel (Welded)							75	100	150
420 Stainless Steel								All	82
430 Stainless Steel					75		[illegible]	[illegible]	29,56,149, 211,248
440 Stainless Steel								All	82
446 Stainless Steel							85	130	149,248
Carpenter 20					75			125	58
SAE 1020						75		75	29,149,239
Mild Steel								All	149,211
Cast Iron								All	149,211
Ni-Irons								All	149,211
Cr-Irons								All	82
Si-Irons						75			149,211
Si-Mo Irons						185			82
Inconel					75		125	130	149,211
Nickel								All	149,211
Ni-Mo-Fe Alloys								All	149
Ni-Cu Alloys								All	82
Ni-Si Alloys								All	82
Monel								75	149,211
Ni-O-Nel					70		160		149
Copper								All	211
Cu-Ni Alloys								All	221
Other Copper Alloys								All	211
Bronzes								All	211
17-7PH								120	30
Worthite							125		211
Durimet 20							125		211
Stainless W						75		130	149
Haynes 25						160			29
Gold						175			211
Lead								All	82
Soft Solder						75			149
Platinum						175			211
Silver Alloys								All	82
Silver Solder								75	149
Tantalum						175			211
Molybdenum								75	149
Titanium					160	160			29,211,240
Titanium A70					75				39
Titanium C-110M					75				39
Zirconium					160				29,211
Organics									
Teflon						80			149
Furan Resins								All	82
Phenolic Resins								All	82
Rubbers								All	149
Kel-F Dispersion Coating						75			82
3M-WFNA Sealer						75			82
Uclon System E								All	82
Epon 470								All	82
Epon 471								All	82
Vinyl Mastic								All	82
DEL Series A								All	82
Prufcoat A								All	82
Stoneware R9A					75(a)				82
Lankote-KB					75(a)				82
Fluorline 100					75(a)				82
Phenoline 315 Plus					75(a)				82

TABLE 31. (Continued)

Material	Temperature, F: Gas Class 1	Gas Class 2	Gas Class 3	Gas Class 4	Liquid Class 1	Liquid Class 2	Liquid Class 3	Liquid Class 4	References
Navelon B-400-10								All	82
Marvelite Industrial								All	82
Sevapon 84 Series								All	82
Lankote Fluoro B								All	82
Cellcote N-605								All	82
EX 2710								All	82
Sarankote A-1098								All	82
Prufcoat Standard								All	82
Pennsalt Acid Proof Cement								All	82
Inorganic Nonmetallics									
Concrete								All	82
Carbon								All	82
Graphite								All	82
Glass					300	185			211
Porcelain						185			82
Chemical Stoneware					300	185			211
Organic Materials									
Koroseal								75	149
Polyethylene								75	149
Saran								75	149
Silastic-167,-180,-181								75	149
Tygon								75	149
Vinylite								75	149
Garlock-230,-233								75	149
Graphitar-2,-50								75	149
Silicone Lubricants								75	149
Dow Corning 710 Fluid								75	149

(a) Intermittent contact, such as spillage.

TABLE 32. COMPATIBILITY OF MATERIALS WITH 80 TO 95 PERCENT NITRIC ACID

Material	Temperature, F: 90 to 95% HNO_3 Class 1	90 to 95% Class 2	90 to 95% Class 3	90 to 95% Class 4	80 to 90% HNO_3 Class 1	80 to 90% Class 2	80 to 90% Class 3	80 to 90% Class 4	References
Metals									
Aluminum 1060		130							248
Aluminum 1085		85	185			85	140	140	287
Aluminum 1100	75	85	185	175		85	75	140	211,221,287
Aluminum 3003		130	185			85	140	140	248,287
Aluminum 6061		85	185			85	140	140	248
304 Stainless Steel	75	130	125	212	75	120	160	160	58,211,248, 287
309 Stainless Steel		130	160			120	160	160	248,287
310 Stainless Steel		130	160			120	160	160	248,287
316 Stainless Steel	75	120	160	160	75	120	160	160	58,287
321 Stainless Steel	75		125	212	75		125	212	211,221
347 Stainless Steel	75	130	125	212	75		125	212	211,248
410 Stainless Steel				All			75	125	58,211,287
420 Stainless Steel								All	82
430 Stainless Steel		130	75	120			75	120	58,211,248, 287
446 Stainless Steel		130	160	160		120	160	160	248
Carpenter 20	75		212		75		212		58
Mild Steel				All				All	211,287
Cast Iron				All				All	211,287
Ni-Irons				All				All	211,287
Cr-Irons				All				All	287
Si-Irons	212				212	185			211,287
Si-Mo Irons						185			287
Nickel			120	All				All	211,287
Hastelloy B				75					82
Hastelloy C	75								82
Copper				All				All	211,221,287
All Copper Alloys				All				All	211,221,287
Gold	212	185			212	185			211,221
Lead				All				All	211,287
All Lead Alloys				All				All	287
Platinum	212	185			212	185			211
Magnesium				All				All	287
All Magnesium Alloys				All				All	287
Silver				All				All	287
Zirconium	75								214
Tantalum	212	185			212	185			211
Titanium	75								214
Columbium	75				75				93
Nonmetals									
Glass	212				212				211
Stoneware	212				212				211
Rubber				75				75	211
Graphite				75				75	211

TABLE 33. COMPATIBILITY OF MATERIALS WITH NITROGEN TETROXIDE (N_2O_4) (<0.2% MOISTURE)

Material	Temperature, F — Gas Class 1	Gas Class 2	Gas Class 3	Gas Class 4	Liquid Class 1	Liquid Class 2	Liquid Class 3	Liquid Class 4	References
Metals									
Aluminum, 1060					80				82
Aluminum, 1100					80				174,220
Aluminum, 1100-0					60				50,169
Aluminum, 2014-T6	60				60				50,169
Aluminum, 2014-T6 (Hardas Anodize)					60				50,169
Aluminum, 2014-T6 (H_2SO_4 Anodize)					65				169
Aluminum, 2014-T6 (Iridite)					60				50,169
Aluminum, 2014-T6 Welded	50	60			60	60			169
Aluminum, 2014-T6 Spot welded		60				60			169
Aluminum, 2014-T6 Extruded					50				50,169
Aluminum, 2014-T6 Extrusion (Welded)					50				169
Aluminum, 2014-T6 Extrusion (Stressed to 50,000 psi)					60				169
Aluminum, 2014 (Sanfordize Hard Coat)						100			169
Aluminum, 2024	60				140				174,220
Aluminum, 2024-0	150				150	150			169
Aluminum, 2219-T6 (Iridite)					60				169
Aluminum, 2219-T81	60				60				50,169
Aluminum, 2219-T81 (Welded)					50				169
Aluminum, 3003-H14	150				150				169
Aluminum, 4043					80				174
Aluminum, 5052					130				82
Aluminum, 5052-0					100	140			169
Aluminum, 5086-H34					165	120			169
Aluminum, 5086-H34 (Welded)					165				12,169
Aluminum, 5086-H36	65				65				169
Aluminum, 5086-H36 (Welded)					65				169
Aluminum, 5254-F	65				65				169
Aluminum, 5456	60				60				174
Aluminum, 5456 H-24					60				50,169
Aluminum, 5456-H24 (Welded)					60				169
Aluminum, 5456-H24 (Iridite)					50				169
Aluminum, 5456-H321					65				50,169
Aluminum, 5456-H321 (Welded)					60				169
Aluminum, 5456-H321 (Stressed to 20,000 psi)					60				169
Aluminum, 5456-H321 (Welded and Stressed to 20,000 psi)					50				169
Aluminum, 6061					130				50,174,220
Aluminum, 6061-T6	150				150				50,169
Aluminum, 6061-T6 Welded					65				169
Aluminum, 6061-T6 (Iridite)					60				169
Aluminum, 6066	65				65				169
Aluminum, 7075	60				60		160		174,220
Aluminum, 7075-0	150				150				169
Aluminum, 7075-T6					150				50,169
Aluminum, 7075 (Sanfordize Hard Coat)						100			169
Aluminum, 7075-0 (H_2SO_4 Anodize)						100			169
Aluminum, 356	60				80				174,245
Aluminum, 356 (H_2SO_4 Anodize)						100			169
Aluminum, 356 (Sanfordize Hard Coat)					100				169
Aluminum, 356-T6	65				65				169
Aluminum, Tens 50	65				65				169
Beryllco 25		65				65			169
Cadmium								75	174
Cadmium Plate								60	169
Chromium Plate					60				169,174
Haynes Stellite 1					100				169
Haynes Stellite 12					100				169
Haynes Stellite 6K					65				169,174
Haynes Stellite 21					65				169
Haynes Stellite 25					65				169
Haynes Stellite 93					100				169
Copper plate								60	169
Copper		80	80	80					88,174,220
Yellow Brass			75						82
Red Brass			75						174
Al-Bronze			75						82
Si-Bronze			75						82
Sn-Bronze			75						174
Gold					75	75			169,211
Gold Plate		65			60	65			169
82 Gold - 18 Ni-Braze						75			(a)
Pure Iron				K1286					88
Cast Iron					80				82
Carbon Steel					80				12
Mild Steel					140				82
[illegible] Steel					130				50,169
ASTM A-285, Grade C					165				169
[illegible] Steel					140				169,174
410 Stainless Steel	65				150				169,174
410 Stainless Steel (Welded)					65				169
416 Stainless Steel	65				65				169,174
440C Stainless Steel					100				169,245
302 Stainless Steel					100				169
303 Stainless Steel					100				169,174
304 Stainless Steel	65			K2155	140				88,169,174, 220
304L Stainless Steel					165				12,50,169
304L Stainless Steel (Welded)					65				169
316 Stainless Steel	65				65				169
321 Stainless Steel	65				65				50,169
321 Stainless Steel (Welded)					65				169
347 Stainless Steel	65				130				50,169,174
347 Stainless Steel (Welded)					65				169
A-286 (Annealed)					100				50,169
A-286 (Aged)					60				50
AM-350 (Annealed)					60				169
AM-355 (Condition H)					150				169
17-4PH (Condition A)					65				169
17-4PH (H1000)					100				169
17-7PH (TH950)	60				100				169,174
17-7PH (RH950)					100				169
PH15-7 Mo (Condition A)					165				12
16-25-6					80				174
Lead						80	80	80	174,220
Molybdenum				K2112					98
Magnesium, 100A	65	65			60	65			169,174
Magnesium, AZ31C	65	65			60	65	150		169,174
Magnesium, HM21A-T8					60				50,169
A-Nickel	60				65			75	169,174
Nickel Electroplate					60				165
Electroless Nickel Plate	65				100				169,174
A-Nickel (Welded)					65				169
Inconel	65				65			75	169,174
Monel	65				65			75	169,174
K-Monel								75	174
Ni-Span-C					60				169
Inconel X					75				174
Hastelloy Alloys					75				174
Nilvar					60				50,169
Platinum					75	75			211
Silver								75	174,211
Silver Plate								60	169
Silver Solder								60	50,169
Easy Flo 45								80	169,245
Sil Fos (80Cu, 15Ag, 5P)								80	245
Metco Hard Facing Alloy M								100	169
Metco Hard Facing Alloy 120								100	169
Metco Hard Facing Alloy 310								100	169
TE Spec Braze								80	245
Microseal 100-1 on AM100A Mg				100				100	169
Microseal 100-1 CG on AZ31C Mg				75				75	169
Microseal 100-1 on 2014-T6 Al	100				100			100	169
718 Braze 6061-T6 Al					65				169
Pure Tin Solder on 303 SS					65				169
Easy Flo Braze on 347 SS					55				169
AMS 4775 Microbraze on 347 SS					65				169
C-62 Braze (Mo-Ni-Co) on 347 SS						100			169
Tantalum	65			K2026	75				88,169,174, 211,220
Tin					80				174,220
Tin Plate					60				169
Titanium, 65A					100 (b)				169
Titanium, 75A					165 (b)				12,169,220
Titanium, A110AT	65 (b)				65 (b)				169,174
Titanium, B120VCA					60 (b)				50,169
Titanium, C120AV					165 (b)				169,174
Titanium, RC130AM	150 (b)				150 (b)				169
Titanium, 6Al-4V									12,50
Tungsten Carbide		65				65			169
Zinc								80	174,220
Zinc Plate								60	169
Zirconium								75	220
Plastics									
Teflon					75				50
Teflon TFE					75	60			169
Teflon FEP					160	60		60	23,169
Teflon, Graphite					75	50			23,50,169
Teflon MoS_2					75	50			50,169
Teflon Asbestos					75				50,169
Teflon Filled With Glass					80				23,169
Teflon Filled With CaF_2					80				23,169
Teflon (Silica Primed)								75	23
TFE-Felt					75			60	50,169
Armalon 7700					75	60			50,169
Armalon 7700B					75	60			50,169
Fluorobestos					60				50,169
Fluorogreen					60				50,169

TABLE 33. (Continued)

Material	Gas Class 1	Gas Class 2	Gas Class 3	Gas Class 4	Liquid Class 1	Liquid Class 2	Liquid Class 3	Liquid Class 4	References
Kel-F								75	50
Kel-F 300 (unplasticized)								60	169
Kel-F 300 (Annealed)								60	169
Genetron GC						80		160	23,169
Genetron OCX-3B					65				169
Genetron III-2B					65				169
Trithene A						80		75	23,169
Alcar 191					67				169
Polyethylene								75	23,50
Polyethylene (low density)						60		60	169
Polyethylene (high density)						60		60	169
Polyethylene (irradiated)							60	60	50,169
Raythene N (irradiated)					65			65	169
Polypropylene						60		60	50,169
Nylon								65	50
Zytel 101								60	23,169
Capran 391								67	169
Mylar								60	23,50,169
Saran								80	50,169
Kynar					80				169
Delrin								60	50,169
Lexan								80	50,169
Tedlar					67			75	50,169
Marlex 50								75	50
Hi Fax								75	23
Spauldite								75	23
Kodapak II								75	23,169
Hypalon 20								65	169
H-Film								80	169
Epon 1031 (With PMDA)								80	169
Plexiglas II								75	50
Plexiglas CR-39								75	50,169
Plexiglas 55								75	50
Silicone Laminate								60	50,169
Phenolic Laminate						60		75	50,169
Epoxy Laminate								60	50,169
Polyester Laminate								60	50,169
[illegible]-1571 Laminate								75	50
Polyvinylchloride								75	50
Ultron						80		80	50,169
Opalon 1219							60		169
Opalon 1220								65	169
Opalon 1474								67	169
Opalon 81222								65	169
[illegible]plate								67	169
Elastomers									
Pelistarine 14 (Ethylene Propylene Rubber)							65		169
Formula 132 (Ethylene Propylene Rubber)								67	169
X105								65	169
E-612-2								65	169
E-622-1								65	169
X-7000-1 to 7 and 9 to 11								65	169
Parco 805-70								80	169
Parco 846-80								65	169
Parker B496-7								80	169
Parker XB-1235-10								80	169
Enjay 268								65	50,169
Enjay 551								65	50,169
Hycar 2202								65	50,169
Stillman SR613-75								65	169
Stillman 11092-3A								80	169
Stillman TC-419-9A								80	169
Precision 1330X20								70	169
Precision Formula 120								67	169
Precision Formula 121								67	169
Parker XV-1235-2								80	169
Parker XV-1235-5								80	169
Parker XB-1235-10								75	50,169
Trifluoronitrosomethane tetrafluoroethylene (TFNM-TFE)								80	169
Viton A								60	50,169
Viton B								60	50,169
Stillman EX774M-1								67	169
Omni X FBF-4								75	169
Parker V494-7								67	169
Parker 77-545								60	169
EX821-A70								80	169
Kel-F Elastomer								75	50,169
Kel-F-3700								60	169
Kel-F-5500								60	169
Stillman TH1057								65	169
Fluorel								60	50,169
LS 53								60	50,169
LS 63								80	169
Natural Rubber								80	50,169
Buna N								60	50,169
B-318-7								80	169
Cohrlastic 500 (Silicone)								60	50,169
Garlock 22								65	50,169
Garlock 900								65	50,169
Neoprene								80	50,169
Hypalon 20								75	50
Polyvistrenex								75	50
Tylac 1650								75	50
Tylac 16400								75	50
Tylac 16470								75	50
Fenton								75	50
Chloroprene								75	50

TABLE 33. (Continued)

Material	Gas Class 1	Gas Class 2	Gas Class 3	Gas Class 4	Liquid Class 1	Liquid Class 2	Liquid Class 3	Liquid Class 4	References
Lubricants									
DC 11		67				67			169
DC 55						80			169
DC F1 VAC		67				67			169
KG 150					65				169
Royco-30 Grease								60	169
Kel-F 90						60			169
Polyglycol Oils								67	169
FX 45						67			169
Molykote Z					60				169
Oxilube 703							60		169
Electrofilm 66-C							60		169
Royco-32 Grease								60	169
Halocarbon Grease						67			169
Nordcoseal 147S and 421						80			169
Microseal 100-1					67				169
PD-788								67	169
LOX Safe					80				169
Flake Graphite					80				169
Johns Manville No. 60								65	169
Graphitar 2,14,39,50, and 86					67				169
CCP-72					67				169
Purebor P3N and P5N						67			169
Valve Seal A						80			169
Apiezon L							80		169
Fluorolube MG600					80				169
Fluoroethene G					80				169
Sealants and Potting Compounds									
Reddy Lube 100	67				160				169
Reddy Lube 200	67				160				169
Waterglass-Graphite	67				67				169
Vydax A			67				67		169
Oxylube Sealant					80				169
Teflon Tape (Unsintered)					80				169
PR 1422								60	50,169
RTV 20								60	50,169
Epon 828								60	50,169
Fateplex P-43								60	50,169
Proseal 793								60	50,169
Fairprene 5159								60	50,169
Crystal M & CF					60			60	50,169
DC R-7001								75	50
Epon VI								[illegible]	50
Epon VIII								[illegible]	[illegible]
Epon 422								75	50
Epon 901								[illegible]	[illegible]
Epon 1001								[illegible]	[illegible]
Epon EX1469								75	50
EC 1595								75	50
EC 1596								75	50
Resinox SC1008								[illegible]	50
Resinox SC1013								75	50
Reinhold F120-55								75	50
US Polymeric [illegible]								75	50
Adhesives									
Armstrong A-6								60	50,169
EC 847								60	50,169
HT 424								60	50,169
3M-AF-40								60	169
4-5					60				169
Epon 422								60	50,169
Ceramics									
Temporel 1500						60			50,169
Sauereisen P-1					60	75			50,169
Sauereisen 31						60			50,169
Sauereisen 47								75	169
Coatings									
Rockflux							75		169
Rexilad 1,2, and 3								60	169
Aluminous								80	169
Epoxy No. 1								60	169
Epoxy No. 5								60	169
Epoxy No. 7								60	169
Epoxy No. 9								60	169
Epoxy 6809								60	169
Modified Epoxy No. 5								60	169
Alkyd No. 4								60	169
Polyurethane								60	169
Catalac Primer and Finish on Steel								67	169
Catalac Improved								67	169
Acrylic Nitrocellulose								60	169
Vinyl								60	169
Primer MIL-P-6889								60	169
Tygon K								75	169
Co-Polymer P-2000								75	169
CA 9747 Primer								75	169
Corrosite Clear 581								75	169
Proseal 333					60				169
Markal DA8, DA9, DA9 (Gray)								80	169

(a) Personal communication.
(b) Titanium ignites under impact, but ignition does not spread.

TABLE 34. COMPATIBILITY OF MATERIALS WITH NITROGEN TETROXIDE CONTAINING FROM 0.2 TO 1.0 PERCENT WATER

Material	Temperature, F								References
	Gas				Liquid				
	Class 1	Class 2	Class 3	Class 4	Class 1	Class 2	Class 3	Class 4	
Metals									
Aluminum, 1060					80				82
Aluminum, 1100-0					60				50
Aluminum, 2014-T6					60				50
Aluminum, 2024					140				82
Aluminum, 2219-T81					60				50
Aluminum, 5052					130	140			50
Aluminum, 5086-H34					70	15	165		12
Aluminum, 5086 (Welded)						15	165		12
Aluminum, 5456-H24					60				50
Aluminum, 5456-H321					60				50
Aluminum, 6061-T6					130				50
Aluminum, 7075-T6					60		160		50
Aluminum, 356-T6					80				50
Copper						80			88
Yellow Brass								80	82
Red Brass								80	82
1020 Steel					130				50
Carbon Steel ASTM-A285, Grade C					70	165			12
Carbon Steel						80	170		82
Mild Steel					130	140			82
4130 Steel					140				82
303 Stainless Steel					80				82
304 Stainless Steel					140				82
304L Stainless Steel					165				12,50
347 Stainless Steel					130				82
440C Stainless Steel					80				82
A-286 (Annealed)					60				50
PH15-7Mo					165				12
Ni-Span-C					60				50
Tin						80			82
Titanium, 75A					165				12
Titanium, 6Al-4V					165				12,50
Nonmetals									
Silicone Rubber							80		82
Kel-F (unplasticized)					160				82
Kel-F (plasticized)								160	82
Koroseal							80		82
Polyethylene							80		82
Saran							80		82
Teflon					160				82
Tygon						80			82
U. S. No. 20995								80	82
Graphite Waterglass						80			82

TABLE 35. COMPATIBILITY OF MATERIALS WITH NITROGEN TETROXIDE CONTAINING 3.2% WATER[12]

Material	Temperature, F								References
	Gas				Liquid				
	Class 1	Class 2	Class 3	Class 4	Class 1	Class 2	Class 3	Class 4	
Metals									
Aluminum, 5086-H34						15	70	120	
Aluminum, 5086, Welded						15	70	120	
Carbon Steel, ASTM-A285, Grade C					15	70	120		
304L Stainless Steel					165				
PH15-7Mo					155				
Titanium, 75A					165				
Titanium, 6Al-4V					165				

TABLE 36. COMPATIBILITY OF MATERIALS WITH NITROGEN TETROXIDE FLOWING AT 10 FEET PER SECOND N_2O_4 (12.5 gal/min.)[12]

Material	Temperature, F								References
	Gas				Liquid				
	Class 1	Class 2	Class 3	Class 4	Class 1	Class 2	Class 3	Class 4	
Metals									
Aluminum, 5086					90				
Carbon Steel, ASTM-A285, Grade C					90				
304L Stainless Steel					90				
PH15-7Mo					90				
Nonmetals									
Kel-F								90	
Teflon								90	
Koroseal								90	
Alathon								90	
PVC								90	
Johns-Mansville Service Asbestos								90	
African Blue Asbestos					90				
Teflon Impregnated Asbestos - Palmetto 1330					90				

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