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TITAN II STORABLE PROPELLANT HANDBOOK

Final Handbook

Revision B

Prepared by

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Contract Number AF04(694)-72

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AIR FORCE BALLISTIC SYSTEMS DIVISION
Air Force Systems Command
Los Angeles 45, California

FOREWORD

This is the second revision to the "Titan II Storable Propellant Handbook." The work of developing data for this revision was accomplished by the Bell Aerosystems Company under Contract AF04(694)-72. The effort was concluded on 31 March 1963.

Captain C.D. James of AFBSD was the Project Officer and Mr. Glen W. Howell of the Space Technology Laboratories, Inc., Los Angeles, California, was the Technical Director. Mr. Ralph R. Liberto, Project Engineer, directed the study effort at the Bell Aerosystems Company.

The following technical personnel at Bell Aerosystems Company made major contributions to this handbook:

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NOTICES

Qualified requestors may obtain copies of this report from the Armed Services Technical Information Agency (ASTIA), Arlington Hall Station, Arlington 12, Virginia.

This report has been released to the Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C., for sale to the general public.

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ABSTRACT

Summarized are the physical properties, materials compatibility, handling techniques, flammability and explosivity hazards, and procedures for storing, cleaning, and flushing of the Titan II propellants, N_2O_4 as the oxidizer and a nominal 50/50 blend of UDMH and N_2H_4 as the fuel. The data presented was derived both from a literature survey and from a test program conducted at Bell Aerosystems Company and at the U. S. Bureau of Mines.

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SYMBOLS AND ABBREVIATIONS USED IN THE TEXT

AFBMD	Air Force Ballistic Missile Division
AFBSD	Air Force Ballistic Systems Division
AFFTC	Air Force Flight Test Center
ADL	Arthur D. Little, Inc.
JPL	Jet Propulsion Laboratory
STL	Space Technology Laboratories, Inc.
AEROZINE-50	Trade name adopted by Aerojet-General, Propellant, Hydrazine-Uns-Dimethylhydrazine (50% N_2H_4 -50% UDMH) MIL-P-27402 (USAF)
50/50 FUEL BLEND	Propellant, Hydrazine-Uns-Dimethylhydrazine (50% N_2H_4 - 50% UDMH) MIL-P-27402 (USAF)
NO_2	Nitrogen Dioxide
N_2H_4	Hydrazine, Specification Grade MIL-P-26536A (USAF)
N_2O_4	Nitrogen Tetroxide, Specification Grade MIL-P-26539 (USAF), an Equilibrium Mixture of NO_2 and N_2O_4
RFNA	Red Fuming Nitric Acid
UDMH	Unsymmetrical Dimethylhydrazine, Specification Grade MIL-D-25604B(ASG)
Calc	Calculated
cc	Cubic Centimeter(s)
Incl	Inclusive
M.A.C.	Maximum Allowable Concentration
MPY	Mils per Year
ppm	Parts per Million by Volume
SIT	Spontaneous Ignition Temperature (s)

Metal and alloy designations used in this handbook, such as type 304SS, are those established by the cognizant agencies and used in the trade.

SECTION 2.0
PHYSICAL PROPERTIES OF 50/50 FUEL BLEND

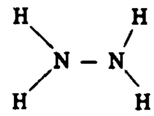
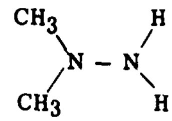
The fuel blend, comprising a 50/50 mixture of UDMH and N_2H_4, is a clear, colorless, hygroscopic (capable of absorbing moisture readily) liquid having a characteristic ammoniacal odor. When the blend is exposed to air, a distinct fishy odor is evident in addition to the ammonia odor; this is probably caused by the air oxidation of UDMH.

The UDMH and N_2H_4 are miscible in all proportions. When combined, there is an immediate tendency for each to dissolve in the other. However, because of their different densities, they are easily stratified; UDMH above the N_2H_4, especially when UDMH is poured into a vessel containing N_2H_4. Under these conditions, a distinct interface may form (Reference 1).

In the pages that follow, additional physical property data is presented for this fuel blend. The information was obtained from the literature or from laboratory tests conducted at Bell Aerosystems. Table 2.1 summarizes pertinent physical properties of the fuel blend.

TABLE 2.1

PHYSICAL PROPERTIES OF THE 50/50 FUEL BLEND

	N_2H_4	UDMH
Structural Formula of the Fuel		
Molecular Weight (ave)	45.0	
Melting Point[a]	18.8°F	
Boiling Point UDMH[c] at 14.7 psia	146°F	
Boiling Point N_2H_4[c] at 14.7 psia	235°F	
Physical State	Colorless Liquid	
Density of Liquid at 77°F and 14.7 psia[a]	56.1 lb/ft^3	
Viscosity of Liquid at 77°F[a]	54.9 x 10^{-5} lb/ft-sec	
Vapor Pressure at 77°F[b]	2.75 psia	
Critical Temperature (calc)	634°F	
Critical Pressure (calc)	1696 psia	
Heat of Vaporization (calc)	425.8 BTU/lb	
Heat of Formation at 77°F (calc)	527.6 BTU/lb	
Specific Heat at 77°F (calc)	0.694 BTU/lb-°F	
Thermal Conductivity at 77°F (calc)	0.151 BTU/ft-hr-°F	
Specific Resistance at 78°F[a]	142 to 161 ohm-cm[d]	

All data is from Reference 1 except as noted.

a - Measured on samples of the fuel blend of typical composition (51.0% N_2H_4, 48.2% UDMH, and 0.5% H_2O).

b - Fuel blend composition 51.0% N_2H_4, 48.4% UDMH, and 0.6% H_2O.

c - Fuel blend is not a constant boiling mixture (see Section 2.8).

d - Reference 68.

2.3 DENSITY

Figures 2.2 and 2.3 present density and specific gravity data for the fuel blend at various pressures as reported by Aerojet-General Corporation (References 1 and 35)! The specific gravity equation is

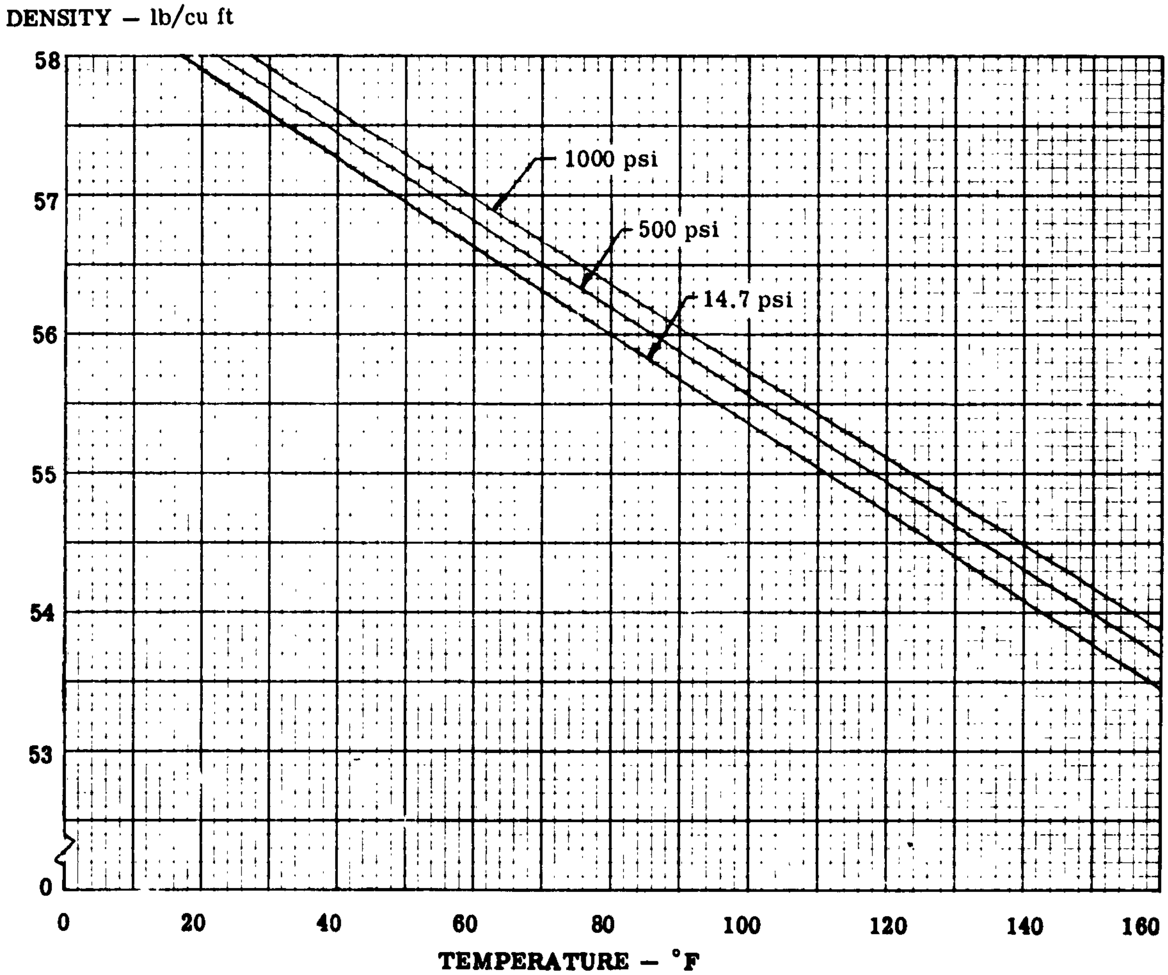
$$S.G. = \left[5.1 \times 10^{-4} (114 - T_F) + 0.880\right] + \left[\Delta P (5.9 \times 10^{-6})\right]$$

where:

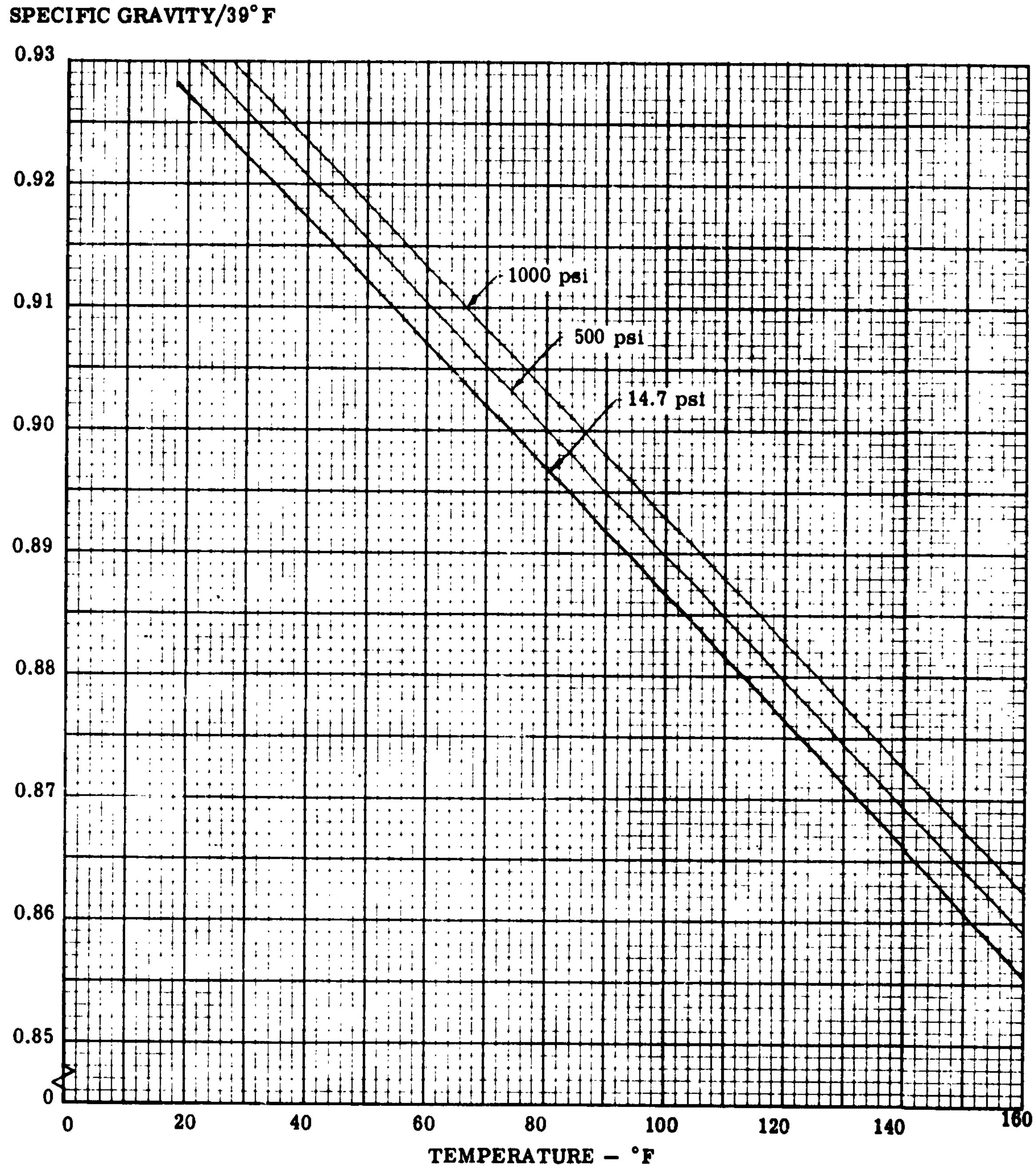
S.G. = Specific gravity of fuel blend.

T_F = Temperature of fuel blend, °F.

ΔP = Pressure difference between the desired point of measurement and atmospheric pressure, psi.



(References 1 and 35) Figure 2.2. Density of 50/50 Fuel Blend at Various Pressures



(References 1 and 35)

Figure 2.3. Specific Gravity of 50/50 Fuel Blend at Various Pressures

SECTION 3.0
PHYSICAL PROPERTIES OF N_2O_4

The compound N_2O_4 is an equilibrium mixture of nitrogen tetroxide and nitrogen dioxide ($N_2O_4 \rightleftharpoons 2NO_2$).

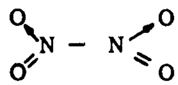
In the solid state, N_2O_4 is colorless; in the liquid state, the equilibrium mixture is yellow to red-brown; and in the gaseous state, it is red-brown. The fumes exhibit a characteristic pungent and irritating odor.

When exposed to water, N_2O_4 reacts to form nitric acid and nitrous acid. The nitrous acid decomposes immediately to form additional nitric acid and evolve nitric oxide (Reference 30). Also, N_2O_4 is hypergolic with fuels as UDMH, N_2H_4, and aniline.

This section of the handbook contains physical property data for N_2O_4 based upon information obtained from a literature survey. Table 3.1 summarizes the pertinent physical properties of N_2O_4.

TABLE 3.1

PHYSICAL PROPERTIES OF N_2O_4

		Reference
Empirical Formula	$N_2O_4 \rightleftharpoons 2NO_2$	5
Structural Formula		6
Molecular Weight	92.016	5
Melting Point	11.84°F	5
Boiling Point at 14.7 psia	70.07°F	5
Physical State	Red-brown liquid	5
Density of Liquid at 77°F and 18.0 psia	89.34 lb/ft^3	5
Viscosity of Liquid at 77°F	0 0002796 lb/ft-sec 0.410 centipoise	7 7
Vapor Pressure at 77°F	17.7 psia	5
Critical Temperature	316.8°F	5
Critical Pressure	1469 psia	5
Heat of Vaporization (equilibrium mixture at 70°F)	178 BTU/lb	5
Heat of Formation at 77°F (calc for liquid equilibrium mixture)	-87.62 BTU/lb	41
Specific Heat at 77°F	0.374 BTU/lb °F	8
Thermal Conductivity at 77°F and at the bubble point	0.0755 BTU/ft-hr-°F	5
Heat of Fusion	68.4 BTU/lb	5

3.1 N_2O_4 SPECIFICATION

The chemical requirements for procuring N_2O_4 were taken from Specification MIL-P-26539 (USAF) dated 18 July 1960. These requirements are presented in Table 3.2. The specification contains procedures for performing propellant analysis. The N_2O_4 assay is determined directly by titration. The water content is determined directly by evaporating N_2O_4 and weighing the nitric acid remaining. The water equivalent in this acidic non-volatile matter is based upon the assumption that it is 70% nitric acid. Nitrosyl chloride (NOCl) content is determined by colorimetric means. The non-volatile ash is determined by evaporating N_2O_4 to dryness and igniting the residue at high temperatures. The percentage of non-volatile ash is calculated from the ash that remains.

TABLE 3.2

PROPELLANT SPECIFICATION – N_2O_4

Chemical Requirements	Specification (wt %)
N_2O_4 Assay	99.5 (min)
H_2O Equivalent	0.1 (max)
Chloride as NOCl	0.08 (max)
Non-Volatile Ash	0.01 (max)

3.2 N_2O_4 DISSOCIATION

The compound N_2O_4 is an equilibrium mixture of nitrogen tetroxide and nitrogen dioxide ($N_2O_4 \rightleftharpoons 2NO_2$). At 68° F and at a pressure of one atmosphere, the vapor consists of 84.2% N_2O_4 in equilibrium with 15.8% NO_2 as shown in Table 3.3 and Figure 3.1.

TABLE 3.3

EQUILIBRIUM VALUES - PERCENT DISSOCIATION OF GASEOUS N_2O_4

$$N_2O_4 \rightleftharpoons 2NO_2$$

Temperature (°F)	Weight Percent NO_2		
	At 7.4 psia	At 14.7 psia	At 73.5 psia
68	19.5	15.8	7.2
104	38.7	31.0	15.1
140	66.0	50.4	28.2
176	85.0	73.8	46.7
212	93.7	88.0	66.5
(Reference 5)			

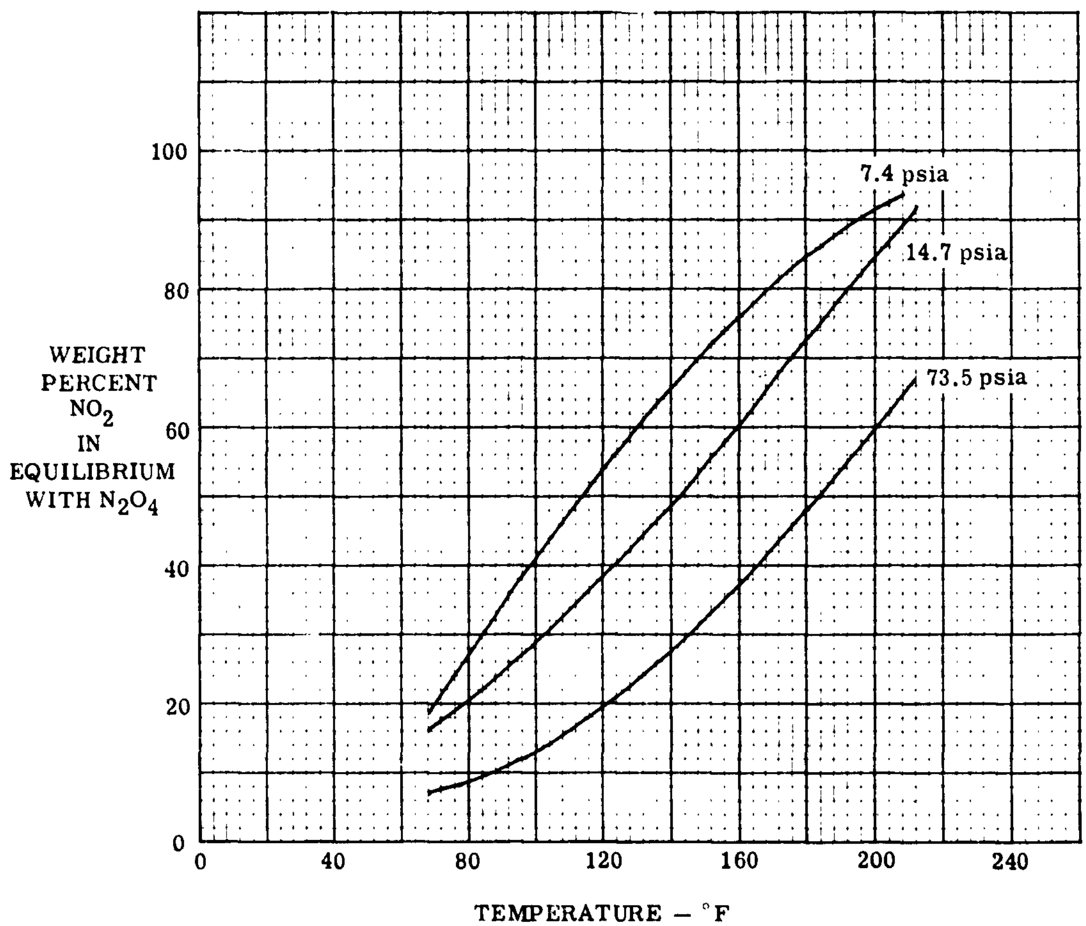


Figure 3.1. Equilibrium Values — Dissociation of Gaseous N_2O_4

3.3 VAPOR PRESSURE

Vapor pressure data, as a function of temperature, is presented in Table 3.4 and plotted in Figure 3.2.

TABLE 3.4

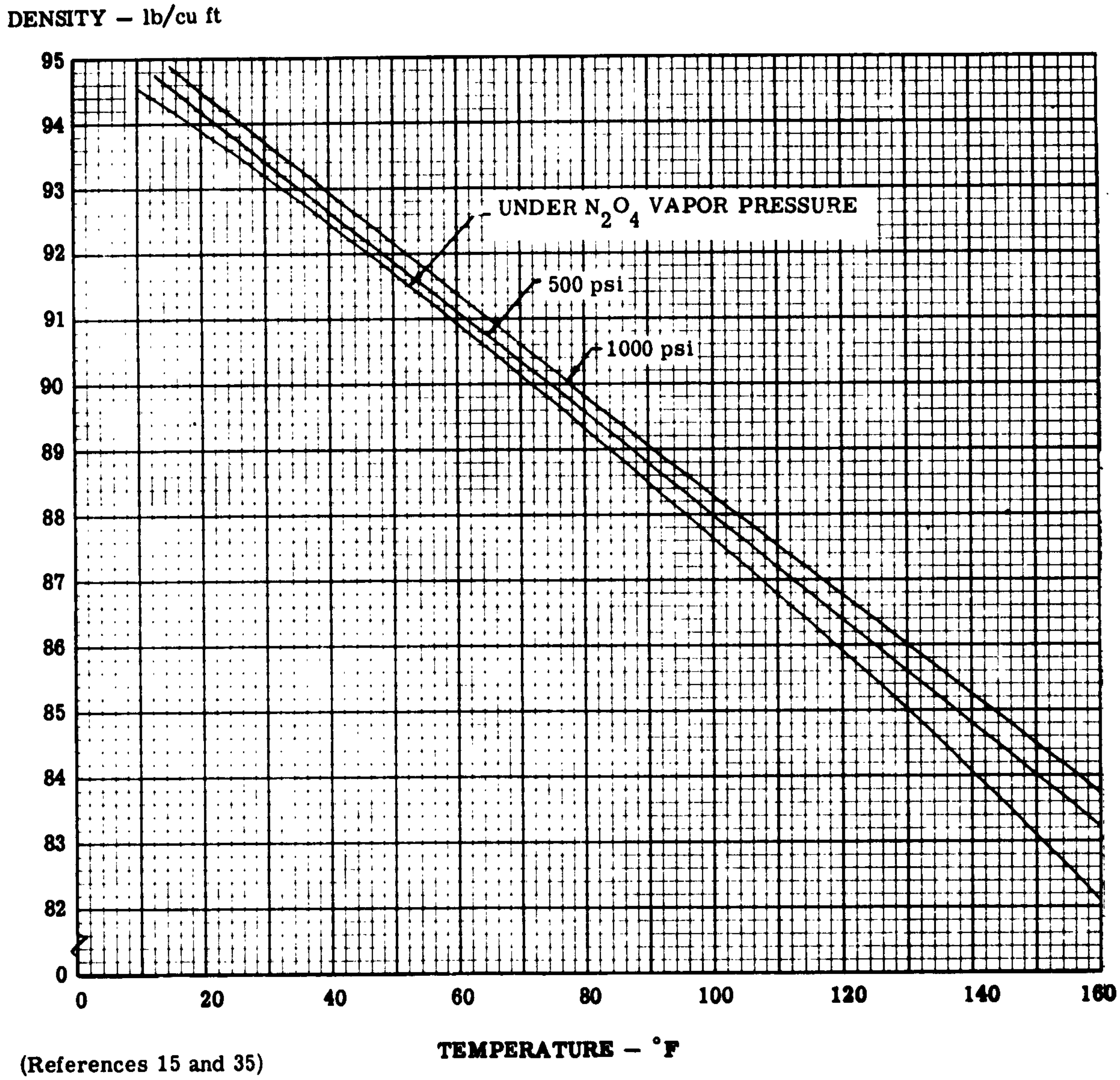
VAPOR PRESSURE OF N_2O_4

Temperature (°F)	Vapor Pressure (psia)	Temperature (°F)	Vapor Pressure (psia)
11.8	2.70	180	163.29
14	2.90	190	196.35
32	5.08	200	235.01
50	8.56	210	281.56
68	13.92	220	332.8
70	14.78	230	393.2
80	18.98	240	463.3
90	24.21	250	543.9
100	30.69	260	636.3
110	38.62	270	732.6
120	48.24	280	864.1
130	59.98	290	1000.5
140	74.12	300	1160.1
150	91.06	310	1336.5[a]
160	111.24	316.8[b]	1469.0[a]
170	135.14		

a - Value extrapolated.

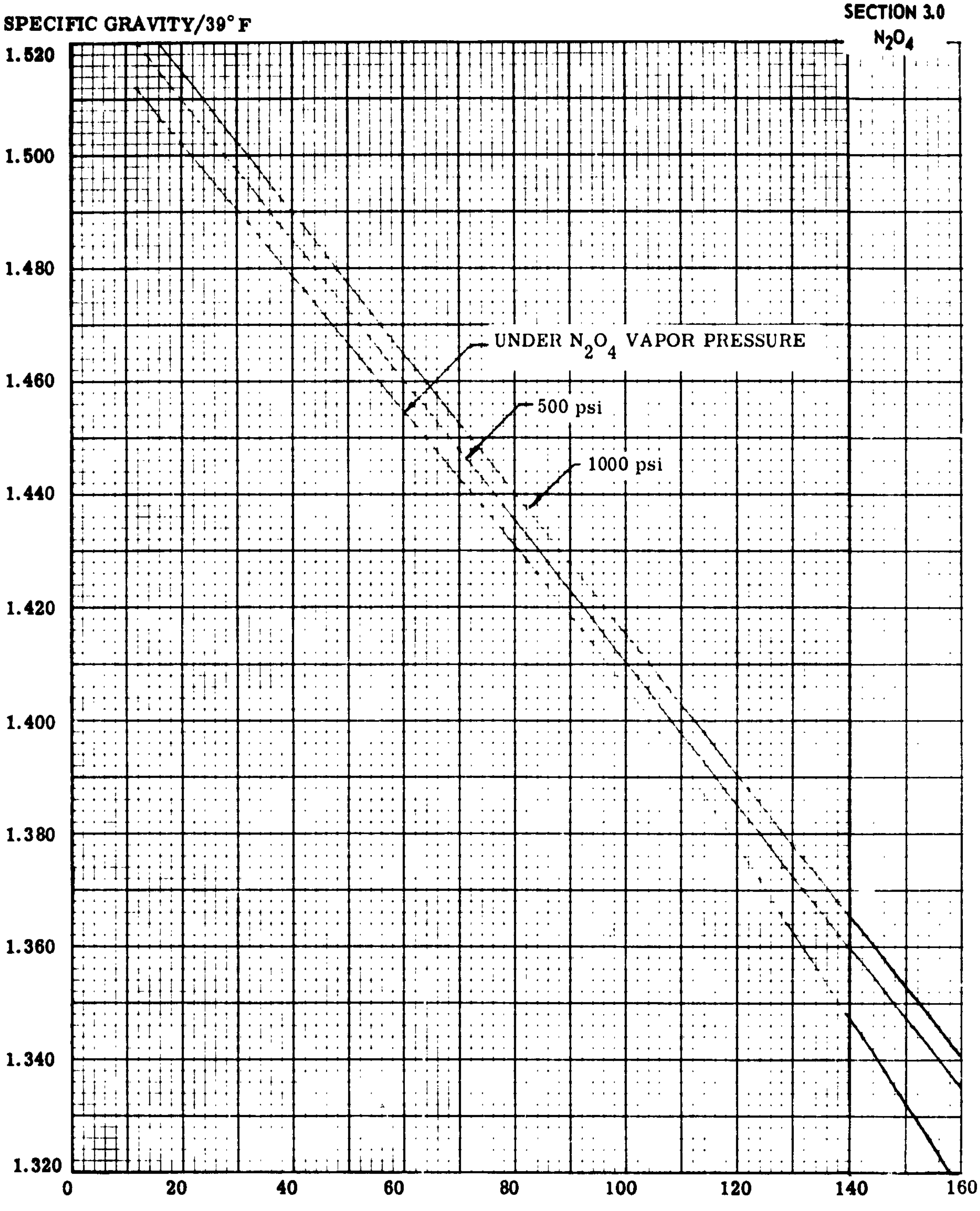
b - Critical pressure estimated from measured critical temperature.

(References 1 and 5)



(References 15 and 35)

Figure 3.3 Density of N_2O_4 at Various Pressures



(References 15 and 35)

Figure 3.4 Specific Gravity of N_2O_4 at Various Pressures

Fuel blend spread on a rusted iron surface in contact with air may generate enough heat to cause spontaneous ignition. Experiments at Aerojet show that the probability of such reactions is low at ambient temperatures. Drops of fuel blend placed on heavily rusted surfaces in an air atmosphere at 150° to 160°F did not ignite (Reference 1).

During a test at Bell Aerosystems, 50/50 fuel blend was dripped onto reagent-grade iron oxide and rusted steel (Reference 51). The fuel blend ignited when the reagent-grade iron oxide was heated to 115°F; the fuel blend ignited when the rusted steel band was heated to 180°F.

Rust oxidizes N_2H_4 and may be a decomposition catalyst under certain conditions. At Aerojet, a laboratory quantity of N_2H_4 was rapidly added to a few grams of ferric oxide at room temperature without evidence of gross effects (Reference 1). However, if two to three drops of N_2H_4 are allowed to drip onto a layer of ferric oxide spread on the bottom of a glass flask, ignition will occur in air at room temperature (Reference 44). The N_2H_4-air interface in the latter case is relatively large and the decomposition due to oxidation by both air and ferric oxide is so rapid that the N_2H_4 quickly ignites. In a nitrogen blanket, ignition did not occur.

These experiments indicate that the surface area of the rust, the volume of liquid N_2H_4, and the presence of air are important factors in the rapid decomposition of N_2H_4. Vapors of N_2H_4 near 235°F are especially susceptible to explosive decomposition and metal oxides such as rust undoubtedly contribute to this reaction.

4.1.4 Nickel Alloys

In general, nickel and nickel alloys are corrosion-resistant to the 50/50 fuel blend.

4.1.5 Titanium Alloys

Titanium alloys are resistant to 50/50 fuel blend corrosion. Titanium C120AV was tested with the 50/50 fuel blend containing as much as 16% water without adverse effects.

4.1.6 Magnesium Alloys

Magnesium alloys show poor resistance to the 50/50 fuel blend.

4.1.7 Cobalt Alloys

Haynes Stellites 6K, 21, and 25, which are cobalt-chrome alloys, exhibited good resistance to the fuel blend.

4.1.8 Copper and Copper Alloys

Because of the formation of copper oxide, a potential catalyst, the limited use of copper alloys is recommended. Berylco 25, a beryllium-copper alloy, darkened during exposure to the fuel blend, but exhibited good corrosion resistance.

4.1.9 Platings

Gold plating darkened during exposure to the fuel blend, but exhibited good corrosion resistance. Non-porous tin, silver, chromium, and nickel platings proved satisfactory; pore-free electroless nickel also was satisfactory.

4.1.10 Conversion Coatings

Sulfuric acid anodize, Hardas (hardcoat) anodize, iridite, and fluorine (Reference 45), are the most resistant conversion coatings used on aluminum alloys.

4.1.11 Brazing and Soldering

Tin and silver solder, nicrobrazing, and aluminum brazing (with aluminum-silicon alloy 718 filler) were resistant to the fuel blend at 160°F for 14 days. Also, a manganese brazing alloy (C-62) proved resistant to the fuel blend at 100°F for 7 days.

4.1.12 Miscellaneous

Titanium carbide with a nickel binder and tungsten carbide are resistant to the fuel blend.

4.1.13 Couples

Metal couples (aluminum-stainless steel, aluminum-titanium, copper-aluminum, and mercury-aluminum) including brazed joints showed no galvanic corrosion during exposure to the fuel blend.

TABLE 4.1 (CONT)

COMPATIBILITY OF METALS WITH 50/50 FUEL BLEND

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	LIQUID RATING[a]	LIQUID REFERENCE	VAPOR TIME IN DAYS	VAPOR RATING[a]	VAPOR REFERENCE	INTERFACE TIME IN DAYS	INTERFACE RATING[a]	INTERFACE REFERENCE	REMARKS
TITANIUM ALLOYS											
B120 VCA	55-60	270	A	46							
	160	90	A^b	4	90	A^b	4	90	A	4	
A110-AT	160	90	A^b	4	90	A^b	4	90	A	4	
C120 AV	55-60	270	A	46							2% H_2O
	160	90	A^b	4	90	A^b	4	90	A	4	Up to 16% H_2O incl
MAGNESIUM ALLOYS											
HM21A-T8	55-60	30	D	15							Grossly pitted
AZ31	150	7	D	73							Pitted
COBALT ALLOYS											
Haynes Stellite 25	160	90	A^b	4	90	A^b	4	90	A	4	
Stellite 6K	160	90	A^b	51	90	A^b	51	90	A	51	Slight stain at interface
Stellite 21	160	90	A^b	51	90	A^b	51	90	A	51	Slight stain at interface

a - Definitions of ratings are given on page 4-1
b - Predicted rating from interface data.

TABLE 4.1 (CONT)

COMPATIBILITY OF METALS WITH 50/50 FUEL BLEND

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	LIQUID RATING[a]	LIQUID REFERENCE	VAPOR TIME IN DAYS	VAPOR RATING[a]	VAPOR REFERENCE	INTERFACE TIME IN DAYS	INTERFACE RATING[a]	INTERFACE REFERENCE	REMARKS
COPPER ALLOYS											
Berylco 25	160	90	A[b]	4	90	A[b]	4	90	A	4	Darkened
PLATINGS											
Cadmium	55-60	360	D	36							
Chromium (non-porous)	55-60	360	A	36							0.0005 to 0.003 in. thick
Copper	55-60	360	D	36							
Gold on Berylco 25	160	90	A[b]	4	90	A[b]	4	90	A	4	Darkened
Nickel Electrolytic (non-porous)	55-60	-	A	15							
Electroless	160	46	A	51	46	A[b]	51	46	A	51	On 2014 aluminum
	160	133	A	51	133	A[b]	51	133	A	51	On 1018 steel
Silver	55-60	360	A	36							0.0001 to 0.0005 in. thick
Tin	55-60	360	A	36							0.001 to 0.003 in. thick
Zinc	55-60	360	D	36							

a - Definitions of ratings are given on page 4-1.
b - Predicted rating from interface data.

TABLE 4.1 (CONT)

COMPATIBILITY OF METALS WITH 50/50 FUEL BLEND

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	LIQUID RATING[a]	LIQUID REFERENCE	VAPOR TIME IN DAYS	VAPOR RATING[a]	VAPOR REFERENCE	INTERFACE TIME IN DAYS	INTERFACE RATING[a]	INTERFACE REFERENCE	REMARKS
<u>COATINGS ON ALUMINUM ALLOYS</u>											
Iridite 2014-T6	55-60	270	A	46							
Alodine 2014-T6	160							90	B	4	Lost weight; stain at interface; up to 16% H_2O incl
6061-T6	160	90	A[b]	4	90	A[b]	4	90	A	4	Gained weight; up to 16% H_2O incl
Hardas (Hardcoat) Anodize 2014-T6	55-60	270	A	46							
Sulfuric Acid Anodize 2014-T6	160	90	A[b]	4	90	A[b]	4	90	A	4	Lost weight; up to 16% H_2O incl; no deposit; some stain
6061-T6	160	90	A[b]	4	90	A[b]	4	90	A	4	Gained weight; up to 16% H_2O incl; stain at interface
Fluoride 2014-T6	70-80	9	A	45							"A" rating based on visual examination

a - Definitions of ratings are given on page 4-1.
b - Predicted rating from interface data.

TABLE 4.1 (CONT)

COMPATIBILITY OF METALS WITH 50/50 FUEL BLEND

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	LIQUID RATING[a]	LIQUID REFERENCE	VAPOR TIME IN DAYS	VAPOR RATING[a]	VAPOR REFERENCE	INTERFACE TIME IN DAYS	INTERFACE RATING[a]	INTERFACE REFERENCE	REMARKS
MISCELLANEOUS											
Titanium Carbide with Nickel binder	160	90	A[b]	4	90	A[b]	4	90	A	4	
Silver Solder	55-60	270	A	46							
Microseal 100-1 coating on AM 100A Magnesium	160							90	D	4	Coating porous, metal attacked
Microseal 100-1 CG Coating on AZ 31 C Magnesium	160							3	D	4	Coating porous, metal attacked
Tungsten Carbide	160	90	A[b]	79	90	A[b]	79	90	A	79	

a - Definitions of ratings are given on page 4-1.
b - Predicted rating from interface data.

TABLE 4.1 (CONT)

COMPATIBILITY OF METALS WITH 50/50 FUEL BLEND

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	RATING[a]	REFERENCE	VAPOR TIME IN DAYS	RATING[a]	REFERENCE	INTERFACE TIME IN DAYS	RATING[a]	REFERENCE	REMARKS
BRAZING AND SOLDERING											
6061-T6 Al Brazed with 718 Filler	160	14	A	4							
303 SS Soldered with Pure Tin	160	14	A	4							Tin solder darkened
347 Silver Brazed with Easy Flo per QQS-561 Class 4	160	14	A	4							
347 SS Ni-crobrazed AMS 4775	160	14	A	4							
347 SS Brazed with C-62 (Mn-Ni-Co)	100	7	A	61							
Easy Flo 45	100	7	B	61							Corrosion rate 2 to 3 MPY

a - Definitions of ratings are given on page 4-1.

TABLE 4.1 (CONT)

COMPATIBILITY OF METALS WITH 50/50 FUEL BLEND

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE: LIQUID TIME IN DAYS	LIQUID RATING[a]	LIQUID REFERENCE	VAPOR TIME IN DAYS	VAPOR RATING[a]	VAPOR REFERENCE	INTERFACE TIME IN DAYS	INTERFACE RATING[a]	INTERFACE REFERENCE	REMARKS
METAL COUPLES											
2014-T6 Al Bolted to 321 SS	55-60	270	A	46							
	55-60	30	A	46							2% H_2O
2014-T6 Al Bolted to 6A1 + 4V Titanium	55-60	180	A	46							2% H_2O
2014-T6 Al Welded to 6061-T6 Al	160	14	A	4							
6061-T6 Al Ultrasonic Welded to 321 SS	55-60	18	A	46							2% H_2O, "D" rating because of visible cracks in area of poor fusion
6061-T6 Al Bolted to 321 SS	55-60	270	A	46							
6061-T6 Al Spotwelded to 2014-T6 Al	55-60	180	B	46							2% H_2O, "B" rating because of cracks
2014-T6 Al Spotwelded to 2014-T4 Al (bare)	55-60	180	A	46							3% H_2O added
Copper/ 2014-T6 Al	160	90	A	79							
Mercury/ 2014-T6 Al	160	90	A	79							

a - Definitions of ratings are given on page 4-1.

TABLE 4.1 (CONT)

COMPATIBILITY OF METALS WITH 50/50 FUEL BLEND

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	LIQUID RATING[a]	LIQUID REFERENCE	VAPOR TIME IN DAYS	VAPOR RATING[a]	VAPOR REFERENCE	INTERFACE TIME IN DAYS	INTERFACE RATING[a]	INTERFACE REFERENCE	REMARKS
METAL COUPLES (CONT)											
2014-T6 Al Spotwelded to 2014-T4 Al (Clad)	55-60	180	A	46							1% H_2O added
304 SS/ Teflon bolted 321 SS	55-60	90	A	46							2% H_2O

a - Definitions of ratings are given on page 4-1.

4.2 EFFECTS OF FUEL BLEND ON NONMETALS

Government specifications[a] on rubbers and plastic fabricated parts intended for packings and seals show that the physical property effects to be minimized are volume change, durometer change, effect on media, and visual examination in terms of surface appearance. The specifications contain different values for volume change and durometer change. Using the ranges called for in the specifications, the following ratings were derived for the nonmetals:

	A	B	C	D
Volume Change, %	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	Dissolved, severely blistered, or cracked

Definitions for these ratings are as follows:

A: Satisfactory for service under conditions indicated.

B: Use with knowledge that the material will swell, shrink, and/or change in hardness; also, other slight changes may occur on the material and/or in the propellant.

C: Satisfactory for ground support where preventive maintenance can be scheduled. Also good for actual missile service where discoloration of propellant and/or extracted residue is tolerable.

D: Unsatisfactory for use except where otherwise noted (Volume changes to 50% and hardness change of 25 units are included in these exceptions).

Table 4.2 contains compatibility data, references, and ratings for many nonmetals exposed to the 50/50 fuel blend.

The fuel blend can dissolve, attack, or decompose nonmetals such as plastics, elastomers, lubricants, and coatings. These reactions usually cause degradation or complete destruction of the material. The fuel can extract components from the material or be absorbed by the material, thereby altering the physical properties. The nonmetals investigated embrace a wide variety of chemical and physical structures; as such, methods of fabrication and geometrical factors greatly influence the behavior of the material.

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a — Government Specifications:

MIL-R-2765A	Rubber, Synthetic, Oil Resistant (Sheet, Strip, and Molded Shapes).
MIL-R-3065B	Rubber Fabricated Parts.
MIL-R-8791A	Retainer Packing, Hydraulic and Pneumatic, Tetrafluorethylene.
HH-P-131C	Packing, Metallic and Nonmetallic, Plastic.
HH-P-166A	Packing, Nonmetallic.

For example, many materials can be used as gaskets or seals where a definite compression set limitation, and in all probability a volume change limitation, is required for sealing. The gasket or seal can be enclosed between two metal surfaces with only a small portion exposed to the fuel. The swelling characteristics of this type exposure are of less importance than the swelling obtained from complete immersion in the fuel where volume change is magnified. Tensile properties play a small role in the application of a material as a gasket. For this reason, use of the nonmetals must be weighed in terms of the physical properties desired.

4.2.1 Plastics

Teflon and Teflon products are chemically resistant to the 50/50 fuel blend.

Nylons 31, 63, and 101 vary in composition and are highly inert to most solvents; however, the resistance of these Nylons to the 50/50 fuel blend is limited to 90 to 120 days at 70° to 80°F (References 1 and 15). At 160°F, the nylons failed within 30 days (Reference 4).

High-density polyethylene is subject to stress cracking in the fuel blend (Reference 1). Of the polyethylenes tested, low density polyethylene was the most resistant. Irradiated and high-density polyethylene were "D"-rated because of shrinkage.

Kel-F 300 showed a stress cracking tendency (Reference 1) after 70 days at 70° to 80°F, and darkened and became brittle within 30 days at 160°F (Reference 4). Mylar dissolved in the fuel blend at 55° to 60°F after 30 days exposure.

4.2.2 Elastomers

Some butyl rubbers are compatible with the 50/50 fuel for up to 30 days at 160°F. The fluorosilicone and fluororubbers show poor resistance to the fuel blend.

Dynamic seal tests, constituting approximately 1000 cycles, were conducted at room temperature and standard pressure with Parco 805-70 butyl rubber O-rings and various lubricants as stated in section 4.2.3 of this report (Reference 4). No leakage was detected during these tests. Similar tests were conducted on O-rings from Parker B496-7 (a butyl rubber), Parco 805-70, and Resistazine 74 (an ethylene-propylene rubber) with the fuel at 100 and 500 psig (Reference 74). No visible liquid leakage was detected during these tests and no significant physical damage was noted in any of the O-rings tested. Also, Reaction Motors (Reference 57) conducted dynamic seal tests (10,000 cycles) at 160°F and 1000 psig with butyl formulation 34 and cis-4-polybutadiene formulation 35; no leakage was detected.

4.2.3 Lubricants and Sealants

Most lubricants dissolve or wash out to varying degrees when exposed to the 50/50 fuel blend; dry lubes, such as Microseal, do not wash out. Some of the lubricants in Table 4.2, such as UDMH Lube, Lox Safe, and DC High Vacuum grease, can be used for limited service. Section 4.6 of this handbook lists a number of lubricants satisfactory for short-term service. Reddy Lubes 100 and 200 and water glass/graphite blend are satisfactory sealants with the fuel blend. Fluorinated lubricants such as Kel-F 90 grease react with the fuel blend.

4.2.4 Potting Compounds and Ceramics

Crystal M & CF, a potting compound, is satisfactory for limited use with the fuel blend. Temporell, Sauereisen P-1, and Sauereisen 31 are ceramics satsifactory for service with the fuel blend.

4.2.5 Adhesives

The adhesives listed in Table 4.2 are not resistant to the fuel blend. Adhesives used on tapes and markings are compatible for short-term service (see Section 4.6).

4.2.6 Coatings

Most coatings are quickly removed by the fuel blend.

Proseal 333, a butyl rubber coating, exhibited slight blistering after 2 hours immersion in the fuel blend. This coating was resistant to splash and drip tests with fuel blend in Section 4.6.

4.2.7 Graphites

Of the graphites listed in Table 4.2, only Graphitar 14 was incompatible with the fuel blend.

TABLE 4.2

COMPATIBILITY OF NONMETALS WITH 50/50 FUEL BLEND

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	LIQUID RATING[a]	LIQUID REFERENCE	VAPOR TIME IN DAYS	VAPOR RATING[a]	VAPOR REFERENCE	REMARKS
PLASTICS								
POLYTETRA-FLUOR-ETHYLENE								
Teflon (TFE)	55-60	270	A	46				
	70-80	125	A	1				
	160	30	B	4				Shrinks 4.5%, 7% tensile loss
Teflon filled with graphite	55-60	360	A	46				
Teflon filled with molydisul-fide	55-60	360	A	46				
Teflon filled with asbestos	55-60	360	A	46				
Armalon 7700 im-pregnated with Teflon fibers	55-60	270	C	46				Fuel discolored
Armalon 7700B im-pregnated with Teflon fibers	55-60	270	C	46				Fuel discolored

a - Definitions of ratings are given on page 4-18

TABLE 4.2 (CONT)

COMPATIBILITY OF NONMETALS WITH 50/50 FUEL BLEND

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	LIQUID RATING[a]	LIQUID REFERENCE	VAPOR TIME IN DAYS	VAPOR RATING[a]	VAPOR REFERENCE	REMARKS
PLASTICS (CONT)								
Fluoro-bestos filled with asbestos	55-60	90	A	15				2% H_2O, "A" rating based on visual observation
TFE-felt 7550	55-60	270	B	46				Fuel discolored
Fluorogreen	55-60	180	A	46				
FLUORINATED ETHYLENE PROPYLENE CO-POLYMER								
Teflon (FEP)	55-60	180	A	46				Shore D increase 6 units
	55-60	270	B	46				
	70-80	60	A	1				
	160	30	D[b]	4				Shrinks 15.8%
POLYCHLOROTRIFLUOROETHYLENE								
Kel-F 300 Unplasticized	55-60	360	B	46				Slightly discolored, shrinks < 1%
	70-80	8	D	65				Stress cracks, surface attack

a - Definitions of ratings are given on page 4-18

b - Based on hardness and/or volume changes, otherwise satisfactory for use.

TABLE 4.2 (CONT)
COMPATIBILITY OF NONMETALS WITH 50/50 FUEL BLEND

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	RATING[a]	REFERENCE	VAPOR TIME IN DAYS	RATING[a]	REFERENCE	REMARKS
PLASTICS (CONT)								
	160	6	D	79				Blackened, became fragile
Annealed	55-60	30	B	46				Slightly discolored, shrinks < 1%
	55-60	270	C	46				Sample brown
POLYETHYLENE								
Low Density	55-60	360	A	46				
Hi-Density	160	30	D[b]	4				Shrinks 10.8%
Marlex 50	55-60	270	A	46				
Hi-Density	55-60	360	B	46				Shrinks < 1%
Irradiated	55-60	90	A	46				
	55-60	270	D[b]	46				Shrinks > 10%
	55-60	180	B	46				Shrinks 9%
POLYOLEFIN								
White insulation	160	30	A	4				
Black insulation	160	30	C	4				Fuel discolored in 1 hr

a - Definitions of ratings are given on page 4-18
b - Based upon hardness and/or volume changes, otherwise satisfactory for use.

TABLE 4.2 (CONT)

COMPATIBILITY OF NONMETALS WITH 50/50 FUEL BLEND

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	LIQUID RATING[a]	LIQUID REFERENCE	VAPOR TIME IN DAYS	VAPOR RATING[a]	VAPOR REFERENCE	REMARKS
PLASTICS (CONT)								
POLYPROPYLENE								
From Hercules	55-60	180	A	46				
	55-60	270	B	46				Shrinks 0.5%
From Chicago Molded Products	160	30	A	4				5.1% tensile loss
POLYAMIDE-NYLON								
Zytel 31	70-80	50	A	66,80				
	70-80	60	D	66,80				Crazed, cracked
	160	7	D	4				Crumbled
Zytel 63	70-80	–	D	1,80				Dissolved
Zytel 101	55-60	360	A	46				
	70-80	50	B	65				Shore D decrease 6 units
	70-80	55	D	65,80				Crazed, cracked
	160	7	D	4				Crumbled
POLYESTER								
Mylar	55-60	10	D	66				Dissolved
	70-80	1	D	69				Dissolved

a - Definitions of ratings are given on page 4-18

TABLE 4.2 (CONT)

COMPATIBILITY OF NONMETALS WITH 50/50 FUEL BLEND

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	STATIC EXPOSURE LIQUID RATING[a]	STATIC EXPOSURE LIQUID REFERENCE	STATIC EXPOSURE VAPOR TIME IN DAYS	STATIC EXPOSURE VAPOR RATING[a]	STATIC EXPOSURE VAPOR REFERENCE	REMARKS
PLASTICS (CONT)								
LAMINATES-GLASS								
Silicone (composition unknown)	55-60	30	A	46				
	55-60	90	C	46				Partly delaminated
Phenolic (composition unknown)	55-60	30	C	46				Fuel and sample discolored
	55-60	90	D	46				Fuel discolored, resin dissolving
Epoxy (composition unknown)	55-60	90	C	46				Partly delaminated
	55-60	180	D	46				Delaminated, 86% volume swell
Polyester (composition unknown)	55-60	30	D	11				Delaminated
POLYVINYLIDENE CHLORIDE								
Saran	55-60	10	D	66				Sample rubbery
	70-80	-	C	69,74				Discolored in 2 hr

a - Definitions of ratings are given on page 4-18.

TABLE 4.2 (CONT)
COMPATIBILITY OF NONMETALS WITH 50/50 FUEL BLEND

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	LIQUID RATING[a]	LIQUID REFERENCE	VAPOR TIME IN DAYS	VAPOR RATING[a]	VAPOR REFERENCE	REMARKS
PLASTICS (CONT)								
POLYFORMALDEHYDE								
Delrin	55-60	30	B	46				Shrinks 7%
	55-60	90	D[b]	46				Shrinks 29%, Shore D decrease 19 units
POLYCARBONATE								
Lexan	55-60	10	D	46				Dissolved
	70-80	-	D	79,80				Dissolved in 2 min
POLYVINYL FLUORIDE								
Tedlar	55-60	180	B	46				Shrinks 4.3% after 30 days, swells 9.3% after 180 days
POLYVINYLIDENE FLUORIDE								
Kynar	70-80	30	B	51				Sample discolored
	70-80	30	A	69				
	160	30	D	51				Swollen, cracked

a - Definitions of ratings are given on page 4-18.

b - Based upon hardness and/or volume changes, otherwise satisfactory for use.

TABLE 4.2 (CONT)
COMPATIBILITY OF NONMETALS WITH 50/50 FUEL BLEND

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	LIQUID RATING[a]	LIQUID REFERENCE	VAPOR TIME IN DAYS	VAPOR RATING[a]	VAPOR REFERENCE	REMARKS
PLASTICS (CONT)								
POLY-METHYL METHACRY-LATE								
Plexiglas								
CR 39	55-60	9	D	66				Completely dissolved
II	70-80	1	D	69,80				Disintegrating
POLYVINYL CHLORIDE								
Opalons								
1219	55-60	-	D	36				
1220	55-60	-	D	36				
1444	55-60	-	D	36				
81222	55-60	-	D	36				
Rigid PVC	55-60	-	D	36				
Amerplate	160	-	D	74				Dissolved overnight
Tygon	70-80	-	D[b]	80				Discolored, softened
EPOXY								
Epon								
VI	55-60	-	D	36				
828	55-60	1	D	69				Decomposing
1031 (with PMDA)	70-80	-	D	80				Disentegrating in 1 hr
EC 1469	55-60	-	D	36				

a - Definitions of ratings are given on page 4-18.
b - Based upon hardness and/or volume changes, otherwise satisfactory for use.

TABLE 4.2 (CONT)
COMPATIBILITY OF NONMETALS WITH 50/50 FUEL BLEND

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	RATING[a]	REFERENCE	VAPOR TIME IN DAYS	RATING[a]	REFERENCE	REMARKS
PLASTICS (CONT)								
MISCELLANEOUS								
Hypalon 20	70-80	7	D	79				Black particles in fuel
Phenolic-asbestos	55-60	-	D	36				
F120-55	55-60	-	D	36				
Silicone R-7001	55-60	-	D	36				
Narmco X3168	55-60	-	D	36				
P-4010	55-60		A	36				
30000	55-60	-	A	36				
H-Film	160	-	D	74				Dissolved immediately

a - Definitions of ratings are given on page 4-18.

TABLE 4.2 (CONT)

COMPATIBILITY OF NONMETALS WITH 50/50 FUEL BLEND

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	RATING[a]	REFERENCE	STATIC EXPOSURE VAPOR TIME IN DAYS	RATING[a]	REFERENCE	REMARKS
RUBBERS BUTYL								
Parco 823-70	70-80	1	B	80				Shore A decrease 8 units
	70-80	27	C	80				Precipitate extracted
Precision Rubber	70-80	1	B	1				
9357	70-80	3	D[b]	1				Shore A decrease 11 units
9257	70-80	1	D[b]	65				Shore A decrease 12 units
940 x 559	70-80	151	A	80				
	160	7	D	51				Blistered
Parker B480-7	70-80	2	A	65				
	70-80	30	C	65				Shore A decrease 10 units, precipitate extracted
	70-80	365	D[b]	65				Shore A decrease 17 units
	160	7	D	51				Tacky and flowed
Parco 805-70	70-80	1	B	1				
	70-80	16	C	1				Fuel dark amber
	70-80	31	D	80				Crystals, fuel dark
	160	2	C	4,79				Precipitate extracted, tensile loss 28.8% hardness not measured
Goshen 1357	70-80	5	B	1				Shore A decrease 10 units
	70-80	100	C	1,80				Shore A decrease 9 units, fuel dark amber
	160	2	C	4,79				Heavy precipitate extracted, tensile loss 28.5%

a - Definitions of ratings are given on page 4-18.
b - Based upon hardness and/or volume changes otherwise satisfactory for use.

TABLE 4.2 (CONT)

COMPATIBILITY OF NONMETALS WITH 50/50 FUEL BLEND

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	LIQUID RATING[a]	LIQUID REFERENCE	VAPOR TIME IN DAYS	VAPOR RATING[a]	VAPOR REFERENCE	REMARKS
Enjay 268	50-60	30	A	46				
	55-60	90	C	46				Fuel discolored
	50-60	180	D[b]	46				Fuel discolored; Shore A decrease 12 units
Enjay 551	55-60	90	C	46				Fuel discolored yellow with white precipitate
	55-60	30	B	46				Shore A decrease 6 units
Precision 214-907-9	160	1	D	4				Violent reaction
	70-80	7	D	4				Slight reaction
Hycar 2202	55-60	1	B	69				Fuel gassing
	55-60	270	C	46				Fuel discolored, 14% volume swell
	55-60	30	D[b]	46				43% volume swell
Linear 7806-70	160	30	D	4				Precipitate extracted, cracked
	70-80	7	D	80				Salts formed, Shore D decrease 13 units
Hadbar XB800-71	160	30	A	4				Tensile loss 6.8%
Parker B496-7	160	30	A	4				Tensile loss 11.4%
	55-60	90	C	46				White crystals
Parker 318-70	160	1	C	4,79				Heavy precipitate extracted, tensile loss 29.7%
Stillman SR 613-75	160	30	C	4				Heavy precipitate extracted, tensile loss 16%
	55-60	90	B	46				Shore A decrease 10 units
	70-80	540	B	63				Softened

a - Definitions of ratings are given on page 4-18.
b - Based upon hardness and/or volume changes, otherwise satisfactory for use.

TABLE 4.2 (CONT)

COMPATIBILITY OF NONMETALS WITH 50/50 FUEL BLEND

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	RATING[a]	REFERENCE	STATIC EXPOSURE VAPOR TIME IN DAYS	RATING[a]	REFERENCE	REMARKS
Formula 120 (resin cured)	160	5	C	79				Precipitate formed
Formula 121 (resin cured)	160	5	C	79				Precipitate formed
POLYBUTA-DIENE								
Acushnet BWK 442	160	17	A	4				
	160	30	C	4				Precipitate extracted, fuel discolored, tensile loss 8.3%
SWK 849	160	17	B	4				Slight turbidity
	160	30	C	4				Precipitate extracted, fuel discolored, tensile loss 41.9%
SWK 850	160	10	C	4				Precipitate extracted
	160	30	C	4				Precipitate extracted, fuel discolored tensile loss 23.6%
SWK 851	160	30	B	4				Slight precipitate extracted,no strength
Stillman EX 904-90 (Hydropol)	160	30	D[b]	4				29% volume swell, tensile loss 77.2% brittle
	160	1	C	79				Heavy precipitate extracted
FLUOROSIL-ICONE								
LS 53	55-60	30	D	15				Decomposed
	70-80	1	D	69				Blistered
Hadbar 58789-23GT	70-80	1	D[b]	77				Shore A decrease 25 units

a - Definitions of ratings are given on page 4-18.
b - Based upon hardness and/or volume changes, otherwise satisfactory for use.

TABLE 4.2 (CONT)

COMPATIBILITY OF NONMETALS WITH 50/50 FUEL BLEND

MATERIAL	TEMPERATURE DEGREES IN FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	LIQUID CLASSIFICATION	LIQUID REFERENCE	VAPOR TIME IN DAYS	VAPOR CLASSIFICATION	VAPOR REFERENCE	REMARKS
FLUORO RUBBERS								
Stillman	55-60	30	D	46				Broke up
EX 821-A70	70-80	-	D	69				Blistered in 4 hr
Viton A[a]	55-60	10	D	66				Broke up
	70-80	1	D	69				Dissolved
Viton B	55-60	30	D	11				Dissolved
	70-80	1	D	69				Dissolved
Kel-F 5500	55-60	-	D	46				Dissolved in minutes
Fluorel	55-60	30	D	46				Broken up less than 30 days
	70-80	-	D	69				Blistered in 1 hr
Precision Rubber 18007, 18057	160	1	D	51				Dissolved
ETHYLENE PROPYLENE RUBBER								
Formula 132	160	30	A	64				Volume swell not measured
MISCELLANEOUS RUBBERS								
Garlock 900	55-60	30	D[b]	46				Fuel yellow, crystals on specimen, Shore D decrease 12 units
	70-80	1	C	79				Heavy precipitate extracted
Garlock 22	55-60	30	A	46				
	55-60	180	B	46				Shore A decrease 10 units

a - Definitions of ratings are given on page 4-18.
b - Based upon hardness and/or volume changes, otherwise satisfactory for use.

TABLE 4.2 (CONT)

COMPATIBILITY OF NONMETALS WITH 50/50 FUEL BLEND

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	LIQUID RATING[a]	LIQUID REFERENCE	VAPOR TIME IN DAYS	VAPOR RATING[a]	VAPOR REFERENCE	REMARKS
MISCELLANEOUS RUBBERS (CONT)								
	55-60	270	D[b]	46				Fuel discolored yellow, Shore A decrease 21 units
	70-80	1	B	79				Fuel slightly discolored
Buna N	55-60	30	D	11				Sample blistered
	70-80	1	D	69				Crystals on specimen
Neoprene	55-60	30	D	46				Fuel discolored red, 38% volume swell
	70-80	2	B	77				Shore A decrease 9 units
	70-80	9	D[b]	77				Shore A decrease 12 units
Cohrlastic 500 (Silicone)	55-60	30	D[b]	46				Shore A increase 11 units
Parco B318-7	55-60	30	D[b]	46				Shore A decrease 14 units, fuel red
LUBRICANTS								
UDMH Lube	70-80	1[c]	B	4				Some washed off
S #58-M	70-80	1[c]	B	4				Some washed off
Lox Safe	70-80	1[c]	B	4				Some washed off
ANDOK-C	70-80	1[c]	B	4				Some washed off
DC-11	70-80	14	B	4	14	B	4	Washed off in liquid, partly in vapor

a - Definitions of ratings are given on page 4-18.
b - Based upon hardness and/or volume changes, otherwise satisfactory for us.
c - Dynamic tests with Parco 805-70 butyl rubber O-rings.

TABLE 4.2 (CONT)
COMPATIBILITY OF NONMETALS WITH 50/50 FUEL BLEND

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	LIQUID RATING[a]	LIQUID REFERENCE	STATIC EXPOSURE VAPOR TIME IN DAYS	VAPOR RATING[a]	VAPOR REFERENCE	REMARKS
LUBRICANTS (CONT)								
Microseal 100-1 (dry lube)	70-80	90	A	4				Compatible
Rockwell Nordstrom 950	70-80	1[c]	C	4				Some washed off
Valve Seal A	70-80	1	B	65				Some washed off
Flake Graphite	70-80	1	A	65				
DC-55	70-80	14	B	4	14	B	4	Washed off in liquid, partly in vapor
DC-Hi Vacuum	55-60	180	B	36				Some washed off
	70-80	14	B	4	14	B	4	Washed off in vapor, partly in vapor
Kel-F 90	55-60	30	D	11				Reacted
Molykote Z	55-60	30	D	11				Reacted and evolved gas immediately
Drilube 703	55-60	30	D	46				Broken up
Rayco-32	55-60	30	D	11				Decomposed
Electrofilm 66-C	55-60	180	C	46				Bond to glass broken loose otherwise compatible
Polyglycol Oils	70-80	14	B	1,4				Some washed off

a - Definitions of ratings are given on page 4-18.

b - Based upon hardware and/or volume changes, otherwise satisfactory for use.

c - Dynamic test with Parco 805-70 butyl rubber O-rings

TABLE 4.2 (CONT)
COMPATIBILITY OF NONMETALS WITH 50/50 FUEL BLEND

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	LIQUID RATING[a]	LIQUID REFERENCE	VAPOR TIME IN DAYS	VAPOR RATING[a]	VAPOR REFERENCE	REMARKS
FX 45	70-80	14	C	4				Two phases, fuel turned orange
Apiezon L	70-80	1	B	65				Some washed off
XC 150	70-80	1	B	65				Some washed off
Fluorolube MG-600	70-80	-	C	75				Material discolored in 1 hr
Fluorothene G	70-80	-	D	75				Material discolored, slight reaction in 1 hr
THREAD SEALANTS								
Reddy Lube								
100	70-80	14	A	4				Satisfactory
200	70-80	14	A	4				Satisfactory
Water Glass Graphite	70-80	14	A	4				Satisfactory
Oxylube Sealant	70-80	14	B	4				Material crusty in 1 hr
Vydax A	70-80	14	B	4				Some washed off
Teflon Tape (unsintered)	70-80	1	A	75				
POTTING COMPOUNDS								
PR 1422	55-60	30	D	11				Dissolved in few hours
RTV 20	55-60	30	D[b]	46				Shrinks 6.9%, Shore A decrease 13 units
	70-80	3	A	69				
Paraplex P-43	55-60	30	D	11				Decomposed
Proseal 793	55-60	30	D	11				Dissolved

a - Definitions of ratings are given on page 4-18

b - Based upon hardware and/or volume changes, otherwise satisfactory for use.

TABLE 4.2 (CONT)
COMPATIBILITY OF NONMETALS WITH 50/50 FUEL BLEND

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	RATING[a]	REFERENCE	VAPOR TIME IN DAYS	RATING[a]	REFERENCE	REMARKS
POTTING COMPOUNDS								
Fairprene 5159	55-60	30	D	11				Swollen; became brittle
Crystal M & CF	55-60	180	D	46				Brittle, appeared satisfactory after 30 days
	55-60	30	A	46				
ADHESIVES								
Armstrong A-6	55-60	30	D	11				Fell apart
EC 847	55-60	30	D	11				Fell apart
HT 424	55-60	-	D	46				Reacted
Epon 422	70-80	1	A	67				Blistered and
4-3	70-80	1	D	67				decomposed
CERAMICS								
Temporell 1500	55-60	270	A	46				Satisfactory
Sauereisen P-1	55-60	180	A	46				Satisfactory
Sauereisen 31	55-60	270	A	46				Satisfactory
Sauereisen 47	75	-	C	4				Partly removed within 7 hr, limited service
Rockflux	75	-	A	4				Satisfactory for 10.5 hr
COATINGS								
Epoxy No. 1	55-60	30	D	11				Dissolved

a - Definitions of ratings are given on page 4-18

TABLE 4.2 (CONT)

COMPATIBILITY OF NONMETALS WITH 50/50 FUEL BLEND

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	LIQUID RATING[a]	LIQUID REFERENCE	VAPOR TIME IN DAYS	VAPOR RATING[a]	VAPOR REFERENCE	REMARKS
COATINGS (CONT)								
Modified Epoxy No. 5	55-60	30	D	11				Edges swollen
Epoxy No. 7	55-60	30	D	11				Stripped off
Epoxy No. 9	55-60	30	D	11				Dissolved
Epoxy No. 6809	55-60	30	D	11				Peeled off
Alkyd No. 4	55-60	30	D	11				Stripped off
Polyurethane	55-60	30	D	11				Stripped off
Acrylic Nitrocellulose	55-60	30	D	11				Dissolved
Vinyl	55-60	30	D	11				Blistered
Primer MIL-P-6889	55-60	30	D	11				Stripped off
Catalac								
Primer and Finish	160	-	D	4				Coating lifted immediately
Improved	160	-	D	4				Coating lifted within 2 minutes
Tygon K	160	-	D	4				Coating blistered within 1 hr

a - Definitions of ratings are given on page 4-18

TABLE 4.2 (CONT)

COMPATIBILITY OF NONMETALS WITH 50/50 FUEL BLEND

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	LIQUID RATING[a]	LIQUID REFERENCE	VAPOR TIME IN DAYS	VAPOR RATING[a]	VAPOR REFERENCE	REMARKS
COATINGS (CONT)								
Co-Polymer P-200 G	160	-	D	4				Coating washed off within 3 min
CA 9747 Primer	160	-	D	4				Blistered and dis-solved within 10 min
Corrosite Clear 581	160	-	D	4				Blistered within 1 hr
Proseal 333	70-80	-	C	51				Slight blistering in 2 hr
Markal DA-8 DA-8 Gray, DA-9	70-80	-	D	51				Washed off
Aluminous	70-80	-	D	51				Blistered badly
GRAPHITES								
Graphitar								
14	160	30	D	51				Samples crumbled
39	160	30	D	51				
	70-80	6	A	37				Dynamic Test
84	70-80	10	A	37				Dynamic Test
86	160	30	A	51				

a - Definitions of ratings are given on page 4-18.

TABLE 4.2 (CONT)
COMPATIBILITY OF NONMETALS WITH 50/50 FUEL BLEND

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE						REMARKS
		LIQUID			VAPOR			
		TIME IN DAYS	RATING[a]	REFERENCE	TIME IN DAYS	RATING[a]	REFERENCE	
GRAPHITES (CONT)								
National Carbon CCP-72	160	30	A	50				
Purebon P3N	160	30	A	50				
Purebon P5N	160	30	B	50				Slight shrinkage

a - Definitions of ratings are given on page 4-18.

4.3 EFFECTS OF FUEL BLEND ON MATERIALS OF CONSTRUCTION

Table 4.3 is a list of construction materials showing the compatibility results of short exposure to fuel blend liquid spillage, fuel blend vapors, and watered fuel blend. Details of these tests are given in References 4 and 51. Coatings and/or surface treatments were applied to various materials to ascertain life expectancy. The resistance of the material was determined by dripping 50/50 fuel blend at an approximate rate of 1.5 cc/min on the specimen while partly immersed in water. The fuel was allowed to drip on the portion of the specimen exposed to the atmosphere. Of the coatings, Sauereisen 47 and Proseal 333 exhibited the best resistance. Rockflux, an inorganic concrete coating material having a viscous consistency when mixed with water, appeared to be resistant to the 50/50 fuel blend. However, bare concrete was unaffected by the fuel blend.

TABLE 4.3

COMPATIBILITY OF CONSTRUCTION MATERIALS WITH
50/50 FUEL BLEND AT 75°F

Material	Exposure Time	Remarks
Birch Wood	2 hr 30 min	Wood grain split
Concrete		
Bare	13 hr	No visual effect
Coated with water glass	1 hr 30 min	Water glass crystalized and powdered off
Coated with water glass and floor enamel (Esco Brand 41138)	1 hr 15 min	Paint blistered
Coated with water glass and Chex-Wear floor enamel	6 min	Paint blistered
Coated with Rockflux	10 hr 30 min	No visual effect
Mild Steel Coated with		
Tygon K paint	1 hr	Paint blistered
Catalac improved paint	1 hr 30 min	Grainy appearance; lifted when totally immersed
Co-Polymer P-200G	3 min	Paint was removed
Sauereisen 47 (4 coatings)	7 hr	First coating was removed in one hour; blistered but did not penetrate 4 coatings
CA 9747 Primer paint	10 min	Blistered and discolored
Corrosite Clear 581	1 hr 15 min	Blistered
Proseal 333	2 hr	Unaffected

4.4 EFFECTS OF METALS ON FUEL BLEND DECOMPOSITION

To determine the effects of materials on fuel decomposition, portions of unwelded, welded, brazed, and soldered metal specimens were sealed in Pyrex glass ampules with a small quantity of 50/50 fuel blend and placed in test for 14 days at 160°F. A surface area of 0.4 sq in. was exposed to 0.16 cu in. of fuel blend which corresponds to a surface-to-volume ratio of 2.5 $in.^{-1}$. Blanks containing only fuel blend also were included as controls. After test, a weight loss of the fuel blend was indicative of decomposition. Details of this test are presented in Reference 50. The metals tested and the results are shown in Table 4.4.

The average weight percent decomposition was used in determining the compatibility classification of the metal in the fuel under the test conditions stated in the foregoing paragraph. Three ratings were established as follows:

A: These metals are exceptionally good even for elevated temperature service and will cause negligible fuel decomposition. The weight percent decomposition values are less than 0.10%.

B: These metals are satisfactory for normal use and will cause only slight fuel decomposition. The weight percent decomposition range is 0.10% to 0.50%.

C: These metals are suitable for limited use, such as spillage and brief contact. The weight percent decomposition range is 0.50% to 1.00%.

D: These metals are not recommended because their decomposition percentages exceed 1.00%.

In general, the 50/50 fuel blend exhibited negligible to slight decomposition in the presence of aluminum alloy and stainless steel alloy.

One magnesium alloy (HK31A) caused sufficient pressure build-up to burst the glass ampules; the other magnesium alloy (AZ31BO) caused excessive fuel decomposition. A mild steel, and oxide coatings of molybdenum and copper, also exhibited excessive fuel decomposition. These metals were assigned "D" ratings.

4.5 EFFECTS OF METAL FILINGS AND LINT ON FUEL BLEND

Filings of 2014 aluminum alloy and types 304, 316, and 347 stainless steels were exposed to 50/50 fuel blend at 160°F for 14 days to determine the potential effects of contaminants on the fuel blend. The metal filings were sealed in Pyrex glass ampules with fuel blend; after test, the fuel blend weight loss indicated decomposition (Reference 50). The test results listed in Table 4.5 indicate higher decomposition rates with the filings than with the respective metals in massive form; this probably can be attributed to the greater surface area of the filings.

TABLE 4.4

EFFECTS OF METALS ON 50/50 FUEL BLEND DECOMPOSITION AFTER 14 DAYS EXPOSURE AT 160°F

Material	Decomposition Wt%[a] Welded	Decomposition Wt%[a] Unwelded	Other	Rating
CONTROLS - average of 10 = 0.03 (Fuel blend alone)				
ALUMINUM ALLOYS				
2014-T6 Manual Weld	0.03	0.04		A
2014-T6 Machine Weld	0.05			A
2014-6061 Manual Weld	0.02			A
2014 Nickel-Plated (Electrolytic)		0.48		B
5086 H-36	0.02	0.02		A
5456	0.07	0.04		A
6061-T6	0.06	0		A
6061-T6 Brazed			0.05	A
7075		0		A
STAINLESS STEELS				
301		0.06		A
302		0.20		B
303		0.07		A
303 Tin-Soldered		0.31		B
304L Annealed	0	0.03		A
304L Nichrome-Brazed			0.06	A
304L Lead/Tin-Soldered			0.04	A
316		0.21		B
321 Annealed	0.02	0.02		A
347 Annealed	0.09	0.09		A
347 Nichrome-Brazed			0.14	B
347 Silver-Brazed			0.06	A
347 Gold-Plated		1.87[b]		D
347 Silver-Plated		0		A
410 H&T	0.21	0.21		B
410 Rusted		0.06[c]		A
PH 15-7 Mo		0.04		A
PH 17-4		0.25		B
AM 355		0.02		A
A 286		0.67		C

a - Control value 0.03% was subtracted from decomposition values.
b - Test was repeated with same samples; 0.12% decomposition was obtained.
c - Also tested with N_2H_4. Result was 0.53% with 0.01% control for N_2H_4 subtracted.
d - All three samples burst in the bath during exposure period.

TABLE 4.4 (CONT)

EFFECTS OF METALS ON 50/50 FUEL BLEND DECOMPOSITION AFTER 14 DAYS EXPOSURE AT 160°F

Material	Decomposition Wt %[a] Welded	Decomposition Wt %[a] Unwelded	Other	Rating
MISCELLANEOUS ALLOYS				
Beryllium Copper		0		A
Brass		0		A
Bronze		0		A
Copper		0		A
Copper Oxide (Coating)		1.26		D
4130 Rusted		0.60		C
4140		1.26		D
Magnesium AZ 31BO		1.24		D
Magnesium HK 31A		d		D
Molybdenum		0.65		C
Molybdenum Oxide (Coating)		1.45		D
Nickel "A"	0.07	0.04		A
Stellite 21		0		A

a - Control value 0.03% was subtracted from decomposition values.
b - Test was repeated with same samples; 0.12% decomposition was obtained.
c - Also tested with N_2H_4. Result was 0.53% with 0.01% control for N_2H_4 subtracted.
d - All three samples burst in the bath during exposure period.

TABLE 4.5

EFFECTS OF METAL FILINGS ON 50/50 FUEL BLEND DECOMPOSITION AFTER 14 DAYS EXPOSURE AT 160°F

Material	% Decomposition[a]	Rating
2014 Aluminum Alloy Filings	0.16	B
316 Stainless Steel Filings	0.25	B
347 Stainless Steel Filings	0.15	B
304 Stainless Steel Filings	0.09	A
Controls (Fuel Blend alone)	0.03	-

a - Control value 0.03% was subtracted from decomposition values.

Tests were made with 6061 aluminum alloy, type 347 stainless steel shavings, and lint exposed to the 50/50 fuel blend contained in glass flasks fitted with reflux condensers (Reference 2). After one week at 160°F, no visual changes were detected in either the fuel or the metal, and spectral analyses of the fuel indicated no decomposition. With lint, the analysis of the fuel blend was hampered by the absorption of the lint dye; however, observations during test indicated no decomposition.

4.6 SHORT-TERM COMPATIBILITY

Components that are not designed to be in contact with propellants may be subjected to liquid or gaseous 50/50 fuel blend as a result of leakage or splashing during filling or storage periods. A number of these materials were exposed to fuel blend splash tests similar to a procedure outlined in Reference 47. Briefly, this procedure consists of wetting the surface of the material with fuel blend and air drying at 80°F for 24 hours at a relative humidity of less than 80%. Table 4.6 contains compatibility data for the various materials exposed to fuel blend splash tests.

4.6.1 Plastics

Of the plastics listed in Table 4.6,only Lexan (a polycarbonate) and Plexiglas CR-39 were incompatible for limited exposure to the fuel blend.

4.6.2 Elastomers

All the elastomers listed in Table 4.6 showed good resistance to the fuel blend.

4.6.3 Potting Compounds

Epon 828, PR 1422, and RTV 20 showed good resistance to the fuel blend.

4.6.4 Coatings

Of the coating materials listed in Table 4.6, Valdura, Swedlow RD101, Dimetcote, Proseal 333, and Magna Polyurethane NTH showed good resistance to the fuel blend.

4.6.5 Lubricants

All oils and greases listed in Table 4.6 washed off to varying degrees when exposed to the fuel blend splash test. All dry films listed in Table 4.6 are resistant to the fuel blend splash test.

4.6.6 Tapes and Markings

All the tapes and marking materials listed in Table 4.6 were resistant to the fuel blend splash test.

TABLE 4.6

COMPATIBILITY OF MATERIALS EXPOSED TO 50/50 FUEL BLEND
SPLASH TESTS

Material	Rating[a]	Reference	Remarks
PLASTICS			
Polytetrafluorethylene			
Teflon (TFE)	A	46	No visible change, swell < 1%, Shore D hardness unchanged
Teflon TFE-Asbestos	A	46	No visible change, swell 4%, Shore D increase 1 unit
Teflon-Graphite	A	46	No visible change, swell < 1%, Shore D hardness unchanged
Teflon-Molydisulfide	A	46	No visible change, swell < 1%, Shore D hardness 1 unit
Armalon 7700B impregnated with Teflon fibers	A	46	No visible change, shrinkage < 1%, Shore A hardness unchanged
Fluorobestos, asbestos-filled Teflon	B	46	No visible change, swell 1.3%, Shore D increase 4 units
Fluorogreen, ceramic-filled Teflon	A	46	No visible change, swell < 1%, Shore D increase unchanged
Fluorinated Ethylene Propylene Co-polymer			
Teflon 100X (FEP)	A	46	No visible change, swell < 1%, Shore D hardness unchanged
Polychlorotrifluorethylene			
Kel-F, annealed	A	46	No visible change, swell < 1%, Shore D hardness unchanged
Kel-F	A	46	No visible change, swell < 1%, Shore D hardness unchanged
Polyethylene			
Low-density	B	46	No visible change, shrinkage < 1%, Shore D decrease 5 units
High-density (Marlex 50)	A	46	No visible change, swell < 1%, Shore D decrease 1 unit
Polypropylene			
Hercules	A	46	No visible change, shrinkage < 1%, Shore D hardness unchanged
Polyamide			
Nylon	A	46	No visible change, shrinkage < 1%, Shore D hardness unchanged.

a - Definitions of ratings are given on page 4-18.

TABLE 4.6 (CONT)

COMPATIBILITY OF MATERIALS EXPOSED TO 50/50 FUEL BLEND
SPLASH TESTS

Material	Rating[a]	Reference	Remarks
PLASTICS (CONT)			
Laminate-Glass Silicone	A	46	No visible change, swell <1%
Polycarbonate Lexan	D	46	Surface sticky and cracked, shrinkage 4%, Shore D hardness unchanged
Polymethyl Methacrylate Plexiglas II UVA	B	46	Specimens brittle, swell <1%, Shore D hardness unchanged
Plexiglas CR-39	D	46	Surface sticky, swell <1 %, Shore D hardness unchanged
BUTYL RUBBERS			
Parker B496-7	A	46	No visible change, shrinkage <1%, Shore A hardness unchanged
Enjay 268	A	46	No visible change, shrinkage <1%, Shore A hardness unchanged
FLUORO RUBBERS			
Viton A	B	46	No visible change, swell <1%, Shore A increase 10 units
Viton B	B	46	No visible change, shrinkage <1%, Shore A decrease 4 units
MISCELLANEOUS RUBBERS			
Buna N	A	46	No visible change, shrinkage <1%, Shore A decrease 2 units
Cohrlastic 500	B	46	No visible change, shrinkage <1%, Shore A decrease 5 units
Garlock 22	A	46	No visible change, shrinkage <1%, Shore A decrease 2 units
Garlock 900	A	46	No visible change, swell 1.6%, Shore D hardness unchanged
Hypalon 20	A	46	No visible change, shrinkage <1%, Shore A increase 2 units

a - Definitions of ratings are given on page 4-18.

TABLE 4.6 (CONT)

COMPATIBILITY OF MATERIALS EXPOSED TO 50/50 FUEL BLEND
SPLASH TESTS

Material	Rating[a]	Reference	Remarks
Miscellaneous Rubbers (cont)			
Natural rubber	B	46	No visible change, shrinkage 1.2%, Shore A increase 1 unit
Neoprene	A	46	No visible change, swell <1%, Shore A hardness unchanged
B318-7	A	46	No visible change, swell <1%, Shore A hardness unchanged
POTTING COMPOUNDS			
Epon 828	A	46	No visible change, shrinkage <1%, Shore D hardness unchanged
Fairprene 5159	D	46	Surface dissolving and blistered, shrinkage 5.7%, Shore A increase 12 units
Paraplex P-43	B	46	Surface softened, swell 1.5%, Shore D decrease 1 unit
PR 1422	A	46	No visible change, shrinkage <1%, Shore A increase 1 unit
Proseal 793	D	46	Turned powder brown, swell 5.4%, Shore A hardness unchanged
RTV 20	A	46	No visible change, swell <1%, Shore A increase 3 units
COATINGS			
Proseal 333	A	51	No visible change even when fuel dripped on coating partly immersed in water (2 hours dripping)
Aluminous	D	51	Blistered
Markal			
DA8	D	51	Washed off
DA8-Grey	D	51	Washed off
DA8 Improved	D	51	Washed off
Magna Polyurethane NTH	D	79	Blistered
Chem Seal	A	60	No apparent effect
	D	60	Attacked

a - Definitions of ratings are given on page 4-18.

TABLE 4.6 (CONT)

COMPATIBILITY OF MATERIALS EXPOSED TO 50/50 FUEL BLEND
SLASH TESTS

Material	Rating[a]	Reference	Remarks
COATINGS (CONT)			
Hysol 1 C	A	78	
Valdura	A	79	
Swedlow RD 101	A	79	Fuel slightly discolored
Dimetcote 1731/1741	A	79	
LUBRICANTS			
Braycote 660 AMS (Rayco 60 AMS)	B	58	Oil component is soluble and will wash off
Drilube 822	B	58	Oil component is soluble and will wash off
Drilube 842	B	58	Oil component is soluble and will wash off
Drilube 7, Type A	A	76	See footnote b
Drilube 1, Type B	A	76	See footnote b
M8800, Type A	A	76	See footnote b
X106, Type B	A	76	
X15, Type C	A	76	
LOX Safe	A	75	See footnote b
Microsea	A	4	
TAPES AND MARKINGS			
Mylar			
Metallized	A	36	
Declar 956	A	36	
X9040 (Al backed)	A	36	
SL1-281011			
Al backed	A	36	
Tedlar backed	A	36	
Teflon backed	A	36	
Butyl Phenolic Adhesive			
Polyethylene	A	36	
Aluminum Fibreglass	A	36	
Y9050	A	36	
Polyplate Decal	A	36	
Black AX-Aero Metal Ink	A	36	
PD 455	A	36	

a - Definitions of ratings are given on page 4-18.

b - Not recommended for extended fuel exposure, particularly in a confined area, because of slow catalytic decomposition of the fuel.

4.8 EFFECTS OF FUEL BLEND VAPORS ON VARIOUS MATERIALS

Compatibility tests were conducted (Reference 79) with various materials exposed to 1200 ppm and 12,000 ppm fuel blend vapors in an atmosphere at a relative humidity of at least 80%. These materials were also exposed to the high humidity alone as controls. Table 4.8 summarizes the test results of the materials exposed to these environments for 30, 60, and 90 days at temperatures ranging from 70° to 77° F.

TABLE 4.8

COMPATIBILITY OF MATERIALS WITH FUEL BLEND VAPORS
IN AIR AT 80% RELATIVE HUMIDITY

	Rating	Remarks
12,000 ppm Fuel Blend Vapors		
2014-T6 Al	A	Slight weight increase, slight stain on specimen
Zytel 101 (Nylon)	A	2% weight increase in 90 days
7075 Al	A	Slight weight increase
1010 Mild Steel	C	Slight weight increase, rust film present
AZ-31A Mg	B	< 1 MPY, but many fine pit marks
Copper	D	Black deposits owing to catalylic reaction
1200 ppm Fuel Blend Vapors		
2014-T6 Al	A	< 1 MPY, localized superficial attack
Zytel 101 (Nylon)	A	4% weight increase in 90 days
7075 Al	A	< 1 MPY, slight superficial attack
1010 Mild Steel	C	< 1 MPY, but all rust not removed
AZ-31A Mg	B	Slight weight increase with dull gray appearance
Copper	D	Black deposits owing to catalylic reaction
Controls (In air only at 80% relative humidity)		
2014-T6 Al	A	< 1 MPY
Zytel 101 (Nylon)	A	3% weight increase in 90 days
7075 Al	A	< 1 MPY
1010 Mild Steel	B	Slight weight increase, few rust spots
AZ-31A Mg	B	Slight weight increase, some pitting
Copper	A	< 1 MPY

5.1.4 Nickel Alloys

In general, oxidizing conditions promote corrosion of nickel alloys. Nickel can protect itself against certain forms of attack by developing a passive oxide film; thus, oxidizing conditions do not always accelerate the corrosion of nickel. While these alloys show good resistance to dry N_2O_4, caution is advised in their use with moist N_2O_4. An exception to this is Inconel which has good corrosion resistance to oxidizing conditions.

5.1.5 Titanium Alloys

Commerically pure titanium is outstanding among structural materials in its resistance at ordinary temperatures to oxidizing conditions. Titanium, when passivated, is the noble metal in a galvanic couple with all structural alloys except Monel and stainless steels.

Because of a known tendency toward impact sensitivity with strong oxidizers such as RFNA, liquid oxygen, and fluorine (References 27 and 28), titanium must be studied carefully before using it with any strong oxidizer. Extensive impact testing by the Nitrogen Division of Allied Chemical Corporation, the Martin Company, and Bell Aerosystems Company has shown that, except under extreme impact conditions, titanium is a satisfactory material for use with N_2O_4 (Reference 22).

Allied Chemical (Reference 55) reported that titanium alloy C120AV (6 aluminum - 4 vanadium) soaked for 24 hours in N_2O_4 at 32°F had an impact sensitivity threshold value of 220 to 250 foot-pounds, using a flat-end pin. However, no propagation of the ignition was observed on any of the titanium specimens. Ignition was rarely accompanied by noise or sparks and was evidenced by small fused areas on the specimen surface. (See Propellant Handling, Section 6.4, for additional impact data with titanium soaked in N_2O_4.)

The data in Table 5.1 shows that the titanium alloys are virtually unaffected by N_2O_4 containing up to 25% water. No corrosion effects occur when titanium is coupled with 2014-T6 aluminum alloy in N_2O_4. All corrosion testing to date indicates that titanium alloys are satisfactory for use with N_2O_4.

5.1.6 Magnesium Alloys

In general, magnesium alloys are corroded in oxidizing media. While these alloys show fair resistance to dry N_2O_4, caution is advised in their use with moist N_2O_4.

5.1.7 Copper and Copper Alloys

Because of their poor resistance to nitric acid formed in moist N_2O_4, copper and copper alloys are not recommended for use. Although Berylco 25, a beryllium-copper alloy, exhibited good corrosion resistance to dry N_2O_4, caution is advised in its use with moist N_2O_4.

5.1.8 Cobalt Alloys

Haynes Stellites No. 6K, 21, and 25 exhibited good corrosion resistance with N_2O_4.

5.1.9 Platings

Gold-plating exhibited a corrosion rate less than 1 MPY; however, corrosion products formed on the surface. Non-porous chromium, nickel plating, and electroless nickel are satisfactory for N_2O_4 service; however, both nickel platings are susceptible to attack by nitric acid and should be used with caution with moist N_2O_4.

5.1.10 Conversion Coatings

There is evidence to show that sulfuric acid anodize, Hardas anodize, and iridite aluminum conversion coatings are resistant to N_2O_4 exposure.

5.1.11 Brazing and Soldering

Included in Table 5.1 are specimens prepared by means of acceptable brazing and soldering techniques. Aluminum brazing and nicrobrazing techniques proved resistant to N_2O_4. Tin solder and silver brazing (Easy Flo per QQS-561) were resistant to dry N_2O_4, but were readily attacked by dilute nitric acid; therefore, these techniques must be used with discretion. Silver solder, as reported in Reference 10, and Easy Flo 45 for silver brazing became badly pitted in N_2O_4.

5.1.12 Miscellaneous Metals

Tantalum and tungsten carbide exhibit good corrosion resistance to N_2O_4.

5.1.13 Couples

Various metal couples show no galvanic corrosion with N_2O_4 at 55° to 65°F; these couples are 2014-T6 Al and 321SS, 2014-T6 Al and titanium (6 Al + 4V), 2014-T6 Al and copper, 6061-T6 Al and 321SS, 356 Al and Nilvar (Nickel alloy), tin and 303SS, silver and 347SS, and nichrome and 347SS.

TABLE 5.1 (CONT)

COMPATIBILITY OF METALS WITH N_2O_4

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	LIQUID RATING[a]	LIQUID REFERENCE	VAPOR TIME IN DAYS	VAPOR RATING[a]	VAPOR REFERENCE	INTERFACE TIME IN DAYS	INTERFACE RATING[a]	INTERFACE REFERENCE	REMARKS
FERROUS ALLOYS											
ASTM A-285 (Grade C)	15	27	A	16							Up to 3.2% H_2O incl
	70	27	A	16							Up to 0.8% H_2O incl
	70	27	B	16							1.6 to 3.2% H_2O
	165	27	A	16							Up to 0.4% H_2O incl
	165	27	B	16							0.8% H_2O
	165	27	C	16							> 0.8% H_2O to 3.2% incl
1020	55-60	180	A	46							Up to 0.2% H_2O incl
	130	30	A	19							
8630	140	29	A	19							
NICKEL ALLOYS											
Inconel	55-65	33	A[b]	19	33	A[b]	19	33	A	19	
Monel[c]	55-65	63	A[b]	19	63	A[b]	19	63	A	19	
"A" Nickel[c] Welded and Unwelded	63-67	14	A	4							
Ni Span C	55-60	90	A	46							0.2% H_2O
Nilvar	55-60	30	A	10							

a - Definitions of ratings are given on page 4-1.
b - Predicted rating from interface data.
c - These alloys are highly susceptible to corrosion in nitric acid.

TABLE 5.1 (CONT)

COMPATIBILITY OF METALS WITH N_2O_4

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	LIQUID RATING[a]	LIQUID REFERENCE	VAPOR TIME IN DAYS	VAPOR RATING[a]	VAPOR REFERENCE	INTERFACE TIME IN DAYS	INTERFACE RATING[a]	INTERFACE REFERENCE	REMARKS
TITANIUM ALLOY											
B120 VCA[d]	55-60	180	A	46							
C120 AV[d] (6A1-4V)	55-60	180	A	46							Up to 0.2% H_2O incl
	70-165	27	A	16							Up to 3.2% H_2O
75A[d]	70-165	27	A	16							Up to 3.2% H_2O
Ti 65A[d]	100	14	A	18							Up to 25% H_2O
RC 130 AM[d]	100-150							14	A	18	3% H_2O, discoloration in vapor
A 110 AT[d]	55-65	7	A[b]	19	7	A[b]	19	7	A	19	
MAGNESIUM ALLOYS											
HM 21A T8[c]	55-60	30	A	15							
AZ 31C[c]	55-65	63	B[b]	19	63	B[b]	19	63	B	19	"B" rating because of slight corrosion products
	150	7	C	73							
AM 100A[c]	55-65	63	B[b]	19	63	B[b]	19	63	B	19	"B" rating because of slight corrosion products
COPPER AND COPPER ALLOYS											
Berylco 25[c]	63-67	90	B[b]	4	90	B[b]	4	90	B	4	Slight corrosion products

a - Definitions of ratings are given on page 4-1.
b - Predicted rating from interface data.
c - These alloys are highly susceptible to corrosion in nitric acid.
d - Before using these materials, see Section 5.1.5 of this handbook.

TABLE 5.1 (CONT)

COMPATIBILITY OF METALS WITH N_2O_4

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	LIQUID RATING[a]	LIQUID REFERENCE	VAPOR TIME IN DAYS	VAPOR RATING[a]	VAPOR REFERENCE	INTERFACE TIME IN DAYS	INTERFACE RATING[a]	INTERFACE REFERENCE	REMARKS
COBALT ALLOYS											
Haynes Stellite											
1	100	7	A	73							
6K	55-65	63	A[b]	19	63	A[b]	19	63	A	19	
12	100	7	A	73							
25	63-67	90	A[b]	4	90	A[b]	4	90	A	4	
21	63-67	145	A[b]	51	145	A[b]	51	145	A	51	
93	100	7	A	73							
PLATINGS											
Cadmium	55-60	-	D	36							
Chromium (non-porous)	55-60	-	A	36							0.0005 to 0.003 in. thick
Copper[c]	55-60	-	D	36							
Gold	63-67	30	B[b]	4	30	B[b]	4	30	B	4	Slight corrosion products
	55-60	-	A	36							0.0001 to 0.001 in. thick
Nickel[c]											
Electrolytic (non-porous)	55-60	-	A	15							
Electroless	100	7	A	18							Up to 0.3% H_2O
	63-67	46	A[b]	51	46	A[b]	51	46	A	51	Plate on 2014 aluminum
	63-67	30	A	51	30	A[b]	51	30	A	51	Plate on 1018 steel
Silver	55-60	-	D	15							
Zinc	55-60	-	D	15							
Tin[c]	55-60	-	A	36							0.001 to 0.003 in. thick

a - Definitions of ratings are given on page 4-1.
b - Predicted rating from interface data.
c - These alloys are highly susceptible to corrosion in nitric acid.

TABLE 5.1 (CONT)

COMPATIBILITY OF METALS WITH N_2O_4

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID			VAPOR			INTERFACE			REMARKS
		TIME IN DAYS	RATING[a]	REFERENCE	TIME IN DAYS	RATING[a]	REFERENCE	TIME IN DAYS	RATING[a]	REFERENCE	
COATINGS ON ALUMINUM ALLOYS											
Iridite											
2014-T6											
Welded	55-60	180	B	46							0.269% H_2O, "B" rating due to stress cracks
	55-60				180	A	46				
Unwelded	55-60	30	A	46							0.268% H_2O
2219-T81											
Welded	55-60	30	A	46							0.165% H_2O
5456-H24											
Welded	55-60	180	A	46							
6061-T6											
Welded	55-60	180	A	46							
Sulfuric Acid Anodize											
7075-0	100	7	B	18							
A 356	100	7	B	18							
2014-T6 Al	63-67	30	A[b]	4	30	A[b]	4	30	A	4	
Hardas Anodize											
2014-T6	55-60	30	A	46							0.327% H_2O

a - Definitions of ratings are given on page 4-1.
b - Predicted rating from interface data.
c - These alloys are highly susceptible to corrosion in nitric acid.

TABLE 5.1 (CONT)

COMPATIBILITY OF METALS WITH N_2O_4

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	LIQUID RATING[a]	LIQUID REFERENCE	VAPOR TIME IN DAYS	VAPOR RATING[a]	VAPOR REFERENCE	INTERFACE TIME IN DAYS	INTERFACE RATING[a]	INTERFACE REFERENCE	REMARKS
<u>COATINGS ON ALUMINUM ALLOYS (CONT)</u>											
Hard Coat (Sanfordize)											
2014	100	7	B	18							
A 356	100	7	A	18							
7075	100	7	B	18							
<u>MISCELLANEOUS</u>											
Microseal 100-1 on AM 100A Magnesium	63-67							100	D	4	Coating porous, metal attacked
Microseal 100-1 CG on AZ 31C Magnesium	63-67							75	D	4	Coating porous, metal attacked
Microseal 100-1 on 2014-T6 Al	63-67							100	A	4	Coating porous, see data above for coating on Magnesium
Silver Solder[c]	55-60	30	D	10							Pitting
Tantalum	55-65	30	A[b]	19	30	A[b]	19	30	A	19	
Metco Hard Facing Alloy											
H	100	7	B	73							
12C	100	7	B	73							
31C	100	7	B	73							
Tungsten Carbide	63-67	90	B[b]	79	90	B[b]	79	90	B	79	N_2O_4 darkened slightly

a - Definitions of ratings are given on page 4-1.
b - Predicted rating from interface data.
c - These alloys are highly susceptible to corrosion in nitric acid.

TABLE 5.1 (CONT)

COMPATIBILITY OF METALS WITH N_2O_4

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE									REMARKS
		LIQUID			VAPOR			INTERFACE			
		TIME IN DAYS	RATING[a]	REFERENCE	TIME IN DAYS	RATING[a]	REFERENCE	TIME IN DAYS	RATING[a]	REFERENCE	
<u>BRAZING AND SOLDERING</u>											
6061-T6 Al brazed with 718 filler	63-67	14	A	4							
303 SS soldered with pure Tin	63-67	14	A	4							Tin is attacked by nitric acid
347 SS silver brazed with Easy Flo per QQS-561 Class 4	63-67	14	A	4							Silver is attacked by nitric acid
Easy Flo 45	100	7	D	61							Heavy salting
347 SS nicrobrazed AMS 4775	63-67	14	A	4							
347 SS brazed with C-62 (Mn-Ni-Co)	100	7	B	61							Light salting
	100	7	B	61							0.3% H_2O, light salting

a - Definitions of ratings are given on page 4-1.

TABLE 5.1 (CONT)

COMPATIBILITY OF METALS WITH N_2O_4

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	RATING[a]	REFERENCE	VAPOR TIME IN DAYS	RATING[a]	REFERENCE	INTERFACE TIME IN DAYS	RATING[a]	REFERENCE	REMARKS
METAL COUPLES											
2014-T6 Al coupled to Teflon	63-67							30	A	4	Teflon in tape or bar form had no effects
2014-T6 Al bolted to 6A1-4V Titanium	55-60	90	A	15							0.2% H_2O
2014-T6 Al bolted to 321 SS	55-60	180	A	46							Up to 0.2% H_2O incl
2014-T6 Al welded to 6061-T6 Al	63-67	14	A	4							
2014-T6 Al spotwelded to 6061-T6 Al	55-60	180	A	46							0.2% H_2O
6061-T6 Al ultrasonic weld to 321 SS	55-60	90	A	46							0.2% H_2O, cracks in weld due to poor fusion not N_2O_4
356-T6 Al bolted to Nilvar	55-60	180	A	46							
304SS/Teflon/321 SS bolted	55-60	30	A	15							0.2% H_2O
Copper/2014-T6 Al	63-67	90	A	79							Copper tarnished slightly
Mercury/2014-T6 Al	63-67	1	D	74							Amalgamated

a - Definitions of ratings are given on page 4-1.

TABLE 5.1 (CONT)

COMPATIBILITY OF METALS WITH N_2O_4

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE: LIQUID TIME IN DAYS	LIQUID RATING[a]	LIQUID REFERENCE	VAPOR TIME IN DAYS	VAPOR RATING[a]	VAPOR REFERENCE	INTERFACE TIME IN DAYS	INTERFACE RATING[a]	INTERFACE REFERENCE	REMARKS
METAL COUPLES (CONT)											
304L coupled with Teflon	15	56	A	16							Up to 1.6% H_2O incl
	115	109	A	16							Up to 2.0% H_2O incl
	165	70	A	16							
	165	70	B	16							0.5% to 3.0% H_2O incl
	63-67							30	A	4	Tape or bar Teflon had no effect
347 with Teflon	100	14	A	73							0.6% H_2O

a - Definitions of ratings are given on page 4-1.

5.2 EFFECTS OF N_2O_4 ON NONMETALS

Table 5.2 contains compatibility data, references, and the ratings of several nonmetals exposed to N_2O_4. The ratings are identical with those described in Section 4.0, page 4-18, on the 50/50 fuel blend materials compatibility.

The N_2O_4 can act on nonmetals in several ways. The propellant can dissolve, attack, and decompose the material causing degradation, or it can completely destroy the material. Moreover, the propellant can extract some components, thereby altering physical properties, or it can be absorbed by the material and thus affect the strength. In addition, the chemical environment can affect the dimensional stability and finish appearance without seriously affecting the mechanical properties. The nonmetals tested embrace a wide variety of chemical and physical structures and, as such, geometrical factors, methods of fabrication, and similar variables can greatly influence the behavior of a part fabricated from any of the nonmetals shown in Table 5.2.

5.2.1 Plastics

Of all the pastics tested, Teflon and Teflon products exhibited the best resistance to N_2O_4; however, the N_2O_4 permeated and was absorbed by the Teflon. The important considerations from these tests were the retention of properties after outgassing the N_2O_4. Teflon swelled approximately 5% before outgassing and returned to its original volume after outgassing.

Omniseal[a], a Teflon seal with a stainless steel spring insert, showed promise as a dynamic seal in N_2O_4. Omniseals were exposed to N_2O_4 at 500 psig for 1000 cycles without leakage (Reference 79).

The polyethylenes absorbed N_2O_4 and embrittled with time. High-density polyethylene showed good resistance to N_2O_4 for periods up to 30 days.

Kynar, a vinylidene fluoride, showed good resistance to N_2O_4 at 65°F for 30 days.

5.2.2 Elastomers

The fluororubbers swelled considerably in N_2O_4 and had a negative volume change after outgassing.

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a - Trade name; manufactured by Reid Enterprises Inc., Long Beach, California.

Phenolic resin-cured butyls and fluorosilicone rubbers showed resistance to N_2O_4; the resin-cured butyls swelled approximately 45% as compared with 145% for the best fluorosilicone after being immersed in N_2O_4 at 65°F for 30 days.

Dynamic seal tests with N_2O_4 and resin-cured butyl rubber O-rings (Formulation 121), lubricated with Nordcoseal 147S, failed after 250 cycles (Reference 51).

None of the ethylene-propylene rubbers showed resistance to N_2O_4 at room temperature beyond 7 days.

5.2.3 Lubricants and Sealants

Reddy Lubes 100 and 200 unsintered Teflon tape, Oxylube Sealant, and water glass/graphite mixture proved to be satisfactory thread sealants. Most lubricants either reacted or washed off in N_2O_4; other lubricants were found satisfactory for short-term service. Dry lubricants Microseals, Molykote Z, Drilube 703, and Electrofilm 66C were satisfactory with N_2O_4.

5.2.4 Adhesives

The adhesives listed in Table 5.2 are not resistant to N_2O_4. Adhesives used on tapes and markings are compatible for short-term service (see Section 5.5).

5.2.5 Ceramics and Potting Compounds

Only Sauereisen P-1, a ceramic, exhibited satisfactory resistance to N_2O_4. Test results indicate that none of the potting compounds listed in Table 5.2 are compatible with N_2O_4.

5.2.6 Coatings

Most coatings were attacked by N_2O_4; however, Proseal 333, a butyl rubber coating, was satisfactory for service with N_2O_4 for 35 days.

5.2.7 Graphites

Of the graphite materials listed in Table 5.2, only the Graphitars and CCP-72 proved satisfactory for service with N_2O_4.

TABLE 5.2

COMPATIBILITY OF NONMETALS WITH N_2O_4

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	LIQUID RATING[a]	LIQUID REFERENCE	VAPOR TIME IN DAYS	VAPOR RATING[a]	VAPOR REFERENCE	REMARKS
PLASTICS								
POLYTETRA-FLUORO-ETHYLENE								
Teflon (TFE)	63-67	30	A	4				
	55-60	180	B	46				Shore D decrease 6 units, sample slightly yellow
Teflon filled with graphite	55-60	180	B	46				Shore D decrease 9 units
Teflon filled with molydisul-fide	55-60	180	B	46				Shore D decrease 7 units
Teflon filled with asbestos	55-60	180	A	46				
Teflon filled with glass	70-80	21	A	12				
Teflon filled with calcium fluoride	70-80	21	A	12				
Armalon 7700 im-pregnated with Teflon fibers	55-60	90	B	46				Shore A decrease 4 units, sample slightly yellow

a - Definitions of ratings are given on page 4-18.

TABLE 5.2 (CONT)

COMPATIBILITY OF NONMETALS WITH N_2O_4

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	LIQUID RATING[a]	LIQUID REFERENCE	VAPOR TIME IN DAYS	VAPOR RATING[a]	VAPOR REFERENCE	REMARKS
PLASTICS (CONT)								
Armalon 7700B impregnated with Teflon fibers	55-60	180	B	46				Shore A increase 5 units, 1.5% shrinkage
Fluorobestos-filled with asbestos	55-60	180	A	46				
TFE-felt 7550	55-60	30	D	11				Sample coming apart
Fluorogreen filled with ceramic	55-60	180	A	46				
FLUORINATED ETHYLENE PROPYLENE COPOLYMER								
Teflon (FEP)	63-67	30	A	4				Hardness data after outgassing
	160	7	A	12				
	55-60	30	B	46				Shore D decrease 8 units
	55-60	80	D[b]	46				Shore D decrease 11 units, sample yellow

a - Definitions of ratings are given on page 4-18.

b - Based upon hardness and/or volume changes, otherwise satisfactory for use.

TABLE 5.2 (CONT)

COMPATIBILITY OF NONMETALS WITH N_2O_4

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	RATING[a]	REFERENCE	VAPOR TIME IN DAYS	RATING[a]	REFERENCE	REMARKS
PLASTICS (CONT)								
POLYCHLORO TRIFLUORO ETHYLENE								
Kel-F 300 Unplastisized	55-60	30	D[b]	46				Shore D decrease 21 units, sample yellow
	70-80	1	D	1,80				Shore D decrease 29 units
Annealed	55-60	30	D	46				Shore D decrease 34 units, sample yellow
Genetron								
GC	70-80	90	B	12				Shore C increases 8 units
	160	7	D	12				Shredded, 16% loss in strength
GCX-3B	55-65	30	A	19				Hardness not measured
XE-2B	55-65	30	A	19				Hardness not measured
Trithene A	70-80	90	B	12				Shore C increase 10 units, loss in strength 25%
	160	7	D	12				Brittle
Aclar 191	63-67	30	A	51				Preliminary screening test

a - Definitions of ratings are given on page 4-18.
b - Based upon hardness and/or volume changes, otherwise satisfactory for use.

TABLE 5.2 (CONT)

COMPATIBILITY OF NONMETALS WITH N_2O_4

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	RATING[a]	REFERENCE	STATIC EXPOSURE VAPOR TIME IN DAYS	RATING[a]	REFERENCE	REMARKS
PLASTICS (CONT)								
POLYETHYLENE								
Low Density	55-60	30	B	46				Shore D decrease 9 units
	55-60	90	D	46				Fell apart
Irradiated	55-60	90	C	46				No visible change, "C" rating because of 48% loss in strength
	55-60	270	D	46				Fell apart
Hi Density (Marlex 50)	55-60	30	B	46				Shore D decrease 4 units, sample slightly yellow
	55-60	90	D	46				Brittle and broke during handling
	70-80	4	B	70,80				Shore D decrease 8 units
POLYOLEFIN								
Raythene N (irradiated)	55-65	48	A	19				Sample flexible
	55-65	63	D	19				Cracked
White and black insulation	63-67	30	A	4				Slight dimensional change
Polypropylene	55-60	30	B	46				Shrinks 3%
	55-60	90	D[b]	46				Shore D decrease 21 units
	70-80	2	B	77				Shore D decreases 9 units
	70-80	8	D	77				Blistered

a - Definitions of ratings are given on page 4-18.
b - Based upon hardness and/or volume changes, otherwise satisfactory for use.

TABLE 5.2 (CONT)

COMPATIBILITY OF NONMETALS WITH N_2O_4

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	LIQUID RATING[a]	LIQUID REFERENCE	VAPOR TIME IN DAYS	VAPOR RATING[a]	VAPOR REFERENCE	REMARKS
PLASTICS (CONT)								
POLYAMIDE-NYLON								
Zytel 101	55-60	-	D	46,80				Disolving in minutes
Capran 391	63-67	-	D	51				Dissolved on contact
POLYESTER								
Mylar	55-60	1	D	11,12				Dissolved
LAMINATES - GLASS								
Silicone (composition unknown)	55-60	30	D	11				Delaminated
Phenolic (composition unknown)	55-60	30	B	11				Sample was bleached
Epoxy (composition unknown)	55-60	30	D	11				Delaminated
Polyester (composition unknown)	55-60	30	D	11				Delaminated

a - Definitions of ratings are given on page 4-18.

TABLE 5.2 (CONT)

COMPATIBILITY OF NONMETALS WITH N_2O_4

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	LIQUID RATING[a]	LIQUID REFERENCE	VAPOR TIME IN DAYS	VAPOR RATING[a]	VAPOR REFERENCE	REMARKS
PLASTICS (CONT)								
POLYVINYLIDENE CHLORIDE								
Saran	70-80	-	D	69				Dissolving in 1 hr
VINYLIDENE FLUORIDE								
Kynar	70-80	90	A	65,80				
POLYFORMALDEHYDE								
Delrin	55-60	-	D	66,80				Reaction in 1 hr
POLYCARBONATE								
Lexan	70-80	-	D	69,80				Dissolved in 1 hr

a - Definitions of ratings are given on page 4-18.

TABLE 5.2 (CONT)

COMPATIBILITY OF NONMETALS WITH N_2O_4

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	LIQUID RATING[a]	LIQUID REFERENCE	VAPOR TIME IN DAYS	VAPOR RATING[a]	VAPOR REFERENCE	REMARKS
PLASTICS (CONT)								
POLYVINYL FLUORIDE								
Tedlar	63-67	30	A	4				8% volume swell before outgassing, (1% shrinkage after outgassing)
	160	7	D	12				Dissolved
POLYMETHYL METHACRYLATE								
Plexiglas CR-39	70-80	-	D	69,80				Dissolving in 1 hr
POLYVINYL CHLORIDE								
Ultron	70-80	42	B	12				Shore C increase 10 units
	70-80	90	D	12				Surface tacky
	160	1	A	12				
	160	7	D	12				Crumbled
Opalons 1219	55-60	30	C	46				Shrinks 7% Sample yellow
1220	55-60	30	D[b]	46				Shrinks 10% Sample yellow
1444	55-60	30	D[b]	46				Shrinks 14% Sample yellow
81222	55-60	30	D[b]	46				Shrinks 18% Sample bleached
Amerplate	63-67	-	D[b]	79				Shore D decreases 30 units in 2 hr

a - Definitions of ratings are given on page 4-18.
b - Based upon hardness and/or volume changes, otherwise satisfactory for use.

TABLE 5.2 (CONT)

COMPATIBILITY OF NONMETALS WITH N_2O_4

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	LIQUID RATING[a]	LIQUID REFERENCE	VAPOR TIME IN DAYS	VAPOR RATING[a]	VAPOR REFERENCE	REMARKS
Tygon	70-80	-	D[b]	80				Discolored, hardened
PLASTICS (CONT)								
CELLUOSE ACETATE BUTYRATE								
Kodapak II	70-80	1	D	12				Disintegrated
MISCEL-LANEOUS								
Hypalon 20	65	-	D	79				100% volume swell in 2 hours
H-Film	70-80	7	D	70				Crumbled
Epon 1031 (with PMDA)	70-80	1	D	80				Surface attack
ETHYLENE-PROPYLENE RUBBER								
Resistazine 74	65	5	C	79				Discolored N_2O_4 and softened
Formula 132	60	3	A	71				
	60	5	B	71				Shore A decrease 8 units
	60	7	D[b]	71				Shore A decrease 16 units
	68-72	1	B	72				Shore A decrease 9 units
	68-72	5	D	72				Degraded
	63-67	30	D	51				Fell apart on handling

a - Definitions of ratings are given on page 4-18.

b - Based upon hardness and/or volume changes, otherwise satisfactory for use.

TABLE 5.2 (CONT)

COMPATIBILITY OF NONMETALS WITH N_2O_4

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	LIQUID RATING[a]	LIQUID REFERENCE	VAPOR TIME IN DAYS	VAPOR RATING[a]	VAPOR REFERENCE	REMARKS
ETHYLENE-PROPYLENE RUBBER (CONT)								
X105	65	4	D	74				Soft and gummy
E-612-2	65	4	D	74				Dissolved
E-622-1	65	7	D	74				Soft and gummy
X-7000-1 thru 7, and 9 thru 11	63-67	18	D	51				Dissolved
BUTYL RUBBERS								
Parco 846-80	65	1	D[b]	79				35% volume swell
Parker B496-7	70-80	-	D	69				Dissolving in 1 hr
Enjay 268	65	1	D	79				Dissolving
Enjay 551	65	1	D[b]	79				40% volume swell
Hycar 2202	65	1	D	79				Dissolving
Parco 805-70	70-80	-	D	80				Blistered in 4 hr
Parker XB-1235-10	70-80	7	D	1,46				63% volume swell, Shore A decrease 50 units
Stillman SR 613-75	65	-	D	79				Sample flowed in 3 hr
11092-3A	70-80	1	D[b]	65				Shore D decrease 14 units
TC-419-19A	70-80	1	D	65				Shore D decrease 28 units
Precision 1330 x 20	70	7	D	79				Became tacky

a - Definitions of ratings are given on page 4-18.
b - Based upon hardness and/or volume changes, otherwise satisfactory for use.

TABLE 5.2 (CONT)

COMPATIBILITY OF NONMETALS WITH N_2O_4

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	RATING[a]	REFERENCE	VAPOR TIME IN DAYS	RATING[a]	REFERENCE	REMARKS
BUTYL RUBBERS (CONT)								
Formula 120 (resin cured)	63-67	-	D	79				55% volume swell in 2 hr
Formula 121 (resin cured)	63-67	-	D	79				64% volume swell in 2 hr
	140				-	D	79	90% volume swell in 6 hr
FLUORO RUBBERS								
Parker								
XV-1235-2	70-80	7	D	1				500% volume swell, Shore A decrease 60 units
XV-1235-5	70-80	7	D	1				43% volume swell, Shore A decrease 60 units
TFNM-TFE (Trifluoro-nitroso-methane tetrafluoro-ethylene)	70-80	7	D	20				174% volume swell, poor elastomeric properties, different oven cures reduce swell to 48% but re-tain poor elastomeric properties
Viton A	55-60	30	D	46				Fell apart
	70-80	-	D	69				200% volume swell
Viton B	55-60	30	D	46				Extremely swollen
	70-80	-	D	69				100% volume swell in 1 hr, shrinkage in 24 hr
Stillman Ex 774M-1	63-67	30	D	4				181% volume swell

a - Definitions of ratings are given on page 4-18.

TABLE 5.2 (CONT)

COMPATIBILITY OF NONMETALS WITH N2O4

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	LIQUID RATING[a]	LIQUID REFERENCE	VAPOR TIME IN DAYS	VAPOR RATING[a]	VAPOR REFERENCE	REMARKS
Omni X-FBF-4	70	-	D	79				300% volume swell in 3 hr
FLUORO RUBBERS (CONT)								
Parker V494-7	63-67	-	D	79				234% volume swell in 2 hours
(Viton B) EX 821-A70	55-60	30	D	46				170% volume swell, very soft
	70-80	1	D	69				Blistered
Formulas 75-79, 84, 85, and 94-99	70-80	7	D	20,24				Fluoro rubbers with added fillers did not reduce volume swell below 199%, poor to good strength retention
Kel-F								
3700	55-65	-	D	15,19				> 300% volume swell in 45 min
5500	55-60	14	D	66				900% volume swell
	70-80	-	D	69				Dissolved in 2 hr
Stillman TH 1057	55-65	31	D	19				205% volume swell
	70-80	-	D[b]	69				50% volume swell in 1 hr, shrinkage in 24 hr
Fluorel	55-60	30	D	46				> 300% volume swell, fell apart
	70-80	-	D	69				100% volume swell in 4 hr
Parker 77-545 (Viton A)	60	-	D	79				90% volume swell in 0.5 hr

a - Definitions of ratings are given on page 4-18.
b - Based upon hardness and/or volume changes, otherwise satisfactory for use.

TABLE 5.2 (CONT)

COMPATIBILITY OF NONMETALS WITH N_2O_4

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	LIQUID RATING[a]	LIQUID REFERENCE	VAPOR TIME IN DAYS	VAPOR RATING[a]	VAPOR REFERENCE	REMARKS
FLUORO SILICONE RUBBERS								
LS 53	55-60	5	D	66				>500% volume swell
	70-80	-	D[b]	69				50% volume swell in 1 hr shrinkage in 24 hr
LS 63	70-80	1	D	69				Crumbled
Hadbar Series 58789-23	70-80	7	D	1				>185% volume swell
58789-23GT	63-67	1	D	4,79				Swollen and blistered
MISCEL-LANEOUS RUBBERS								
Buna N	55-60	-	D	46				Dissolved
Neoprene	70-80	-	D	48				Decomposed in 4 hr
B 318-7	70-80	-	D	69				Blistered in 1 hr
Cohrlastic 500 (Sili-cone)	55-60	30	D	46				Dissolved
Garlock 900	65	1	D	79				Sample delaminated and swollen
Garlock 22	65	1	D	79				Blistered badly
Natural	70-80	-	D	69				Broke up in 30 sec

a - Definitions of ratings are given on page 4-18.

TABLE 5.2 (CONT)

COMPATIBILITY OF NONMETALS WITH N_2O_4

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	LIQUID RATING[a]	LIQUID REFERENCE	VAPOR TIME IN DAYS	VAPOR RATING[a]	VAPOR REFERENCE	REMARKS
LUBRICANTS								
DC 11	63-67	14	B	4	14	B	4	Washed off in liquid, partly in vapor
DC55	70-80	7	B	75				Washed out
DC Hi VAC	63-67	14	B	4	14	B	4	Washed off in liquid, partly in vapor
	70-80	1	B	65				Washed out
XC150	70-80	1	A	65				
Rayco -30 Grease	55-60	30	D	11				Decomposed
Kel-F 90	55-60	30	B	11				Washed out
	70-80	1	A	75				Very slightly soluble
Polygylcol Oils	63-67	14	D	4				Reaction
FX45	63-67	14	B	4				2-Phase layer washed off
Molykote Z	55-60	30	A	46				
Drilube 703	55-60	30	C	46				Hard and brittle
	55-60	7	A	66				
Electrofilm 66-C	55-60	30	C	46				Softened, could be rubbed off
Rayco -32 Grease	55-60	30	D	11				Decomposed
	55-60	7	D	66				Flaky
Halocarbon Grease	63-67	14	B	4	14	B	4	Washed off in liquid, partly in vapor
Nordcoseal 147S and 421	70-80	-	B	4,19				Partly washed off
Microseal 100-1	63-67	100	A	4				
PD 788	63-67	1	D	51				Washed off and left powdered residue
Lox Safe	70-80	1	A	65				
Flake Graphite	70-80	1	A	65				

a - Definitions of ratings are given on page 4-18.

TABLE 5.2 (CONT)

COMPATIBILITY OF NONMETALS WITH N_2O_4

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID			STATIC EXPOSURE VAPOR			REMARKS
		TIME IN DAYS	RATING[a]	REFERENCE	TIME IN DAYS	RATING[a]	REFERENCE	
Valve Seal A	70-80	1	B	65				Some washed off
Apiezon L	70-80	1	C	75				Material hardened and discolored
Fluorolube MG600	70-80	1	A	75				
Fluorothene G	70-80	1	A	75				
<u>THREAD SEALANTS</u>								
Reddy Lube 100	63-67	14	A	4	14	A	4	
	160	30	A	65				
Reddy Lube 200	63-67	14	A	4	14	A	4	
	160	30	A	65				
Waterglass Graphite	63-67	14	A	4	14	A	4	
Vydax A	63-67	14	C	4	14	C	4	Partly washed off
Oxylube Sealant	70-80	1	A	65				
Teflon Tape (Unsintered)	70-80	1	A	75				
<u>ADHESIVES</u>								
Armstrong A-6	55-60	-	D	46				Reaction
EC 847	55-60	-	D	46				Reaction
HT 424	55-60	-	D	46				Reaction
3M-AF-10	55-60	-	D	46				Reaction
4-3	70-80	1	A	67				
Epon 422	70-80	1	D	67				Lost adhesion
<u>CERAMICS</u>								
Temporell 1500	55-60	30	B	11				Slight precipitate
Sauereisen P-1	55-60	30	A	11				

a - Definitions of ratings are given on page 4-18.

TABLE 5.2 (CONT)

COMPATIBILITY OF NONMETALS WITH N_2O_4

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	LIQUID RATING[a]	LIQUID REFERENCE	VAPOR TIME IN DAYS	VAPOR RATING[a]	VAPOR REFERENCE	REMARKS
CERAMICS (CONT)								
Sauereisen 31	55-60	30	B	11				Slight precipitate
Sauereisen 47	75	-	D	4				Dissolved within 10 min
COATINGS								
Rockflux	75	-	C	4				N_2O_4 was absorbed, slight lifting from concrete
Rezklad 1, 2, and 3	55-60	1	D	51				Concrete coating, binder dissolved
Aluminous	70-80	-	D	51				Blistered badly
Epoxy No. 1	55-60	-	D	66				Stripped immediately
Modified Epoxy No. 5	55-60	-	D	66				Stripped immediately
Epoxy No. 7	55-60	-	D	66				Stripped immediately
Epoxy No. 9	55-60	-	D	66				Stripped immediately
Epoxy 6809	55-60	-	D	66				Stripped immediately
Alkyd No. 4	55-60	-	D	66				Stripped immediately
Polyurethane	55-60	-	D	66				Stripped immediately
Catalac								
Primer and Finished on Mild Steel	63-67	-	D	4				Paint lifted within minutes

a - Definitions of ratings are given on page 4-18.

TABLE 5.2 (CONT)

COMPATIBILITY OF NONMETALS WITH N_2O_4

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	LIQUID RATING[a]	LIQUID REFERENCE	VAPOR TIME IN DAYS	VAPOR RATING[a]	VAPOR REFERENCE	REMARKS
COATINGS (CONT)								
Catalac Improved	63-67		D	4				Paint lifted, and blistered within 2 min
Acrylic Nitro-Cellulose	55-60	-	D	66				Stripped immediately
Vinyl	55-60	-	D	66				Blistered immediately
Primer MIL-P-6889	55-60	-	D	66				Stripped in minutes
Tygon K	75	-	D	4				Blistered within 20 min
Co-Polymer P-200G	75	-	D	4				Dissolved in 2 min
CA 9747 Primer	75	-	D	4				Reacted and dissolved within 2 min
Corrosite Clear 581	75	-	D	4				Blistered within 20 min
Proseal 333	55-60	35	A	51				
Markal DA8, DA9, DA9 (grey)	70-80	-	D	51				Blistered badly
POTTING COMPOUNDS								
PR 1422	55-60	-	D	66				Dissolved immediately
RTV 20	55-60	14	D	66				Dissolved
	70-80	1	D	69				Dissolved
Epon 828	55-60	14	D	11				Dissolved
	70-80	-	D	69				Decomposed in 1 hr

a - Definitions of ratings are given on page 4-18.

TABLE 5.2 (CONT)

COMPATIBILITY OF NONMETALS WITH N_2O_4

MATERIAL	TEMPERATURE DEGREES FAHRENHEIT	STATIC EXPOSURE LIQUID TIME IN DAYS	LIQUID RATING[a]	LIQUID REFERENCE	VAPOR TIME IN DAYS	VAPOR RATING[a]	VAPOR REFERENCE	REMARKS
POTTING COMPOUNDS (CONT)								
Paraplex P-43	55-60	14	D	66				Dissolved
Proseal 793	55-60	14	D	66				Dissolved
Fairprene 5159	55-60	14	D	66				400% volume swell
Crystal M&CF	55-60	90	D	46				Fell apart
	55-60	30	A	46				
GRAPHITES								
Johns Manville No. 60	55-65	7	D	19				Salts formed
Graphitar 2, 14, 39, 50, and 86	55-67	30	A	19,51				
CCP-72	63-67	30	A	51				
Purebon P3N and P5N	63-67	30	B	50				N_2O_4 darkened

a - Definitions of ratings are given on page 4-18.

5.3 EFFECTS OF N_2O_4 ON MATERIALS OF CONSTRUCTION

Table 5.3 lists materials frequently used for construction. Included are the compatibility results of short exposures to N_2O_4 drip tests (References 4 and 51). The resistance of the materials of construction was determined by dripping N_2O_4 at an approximate rate of 1.5 cc/min on the specimens while partly immersed in water. The N_2O_4 was allowed to drip on the portion of the specimen exposed to the atmosphere. Of the organic coatings, only Proseal 333 exhibited sufficient resistance to N_2O_4. Water glass protected concrete from the N_2O_4 and from the nitric acid formed when N_2O_4 and water combined. The binder material in the Rezklad slowly washed away.

5.4 EFFECTS OF CONTAMINANTS ON N_2O_4

Traces of type 347SS, 6061 aluminum alloy, and lint can be found as contaminants in missile systems. To determine the effects of such contaminants on N_2O_4, quantities of lint and shavings of type 347SS and 6061 aluminum alloy were exposed to N_2O_4 at 70°F for 7 days. No severe pressure build-ups were encountered during these tests and the N_2O_4 composition was unchanged (Reference 19). Water is a serious contaminant since it combines with N_2O_4 to form dilute nitric acid which exhibits more-corrosive properties than N_2O_4. Also, the presence of organic compounds, such as alcohols, acetones, and gasoline, are undesirable contaminants because of their reactivity with N_2O_4.

TABLE 5.3

COMPATIBILITY OF CONSTRUCTION MATERIALS WITH N_2O_4

Material	Temperature (°F)	Exposure Time	Remarks
Birch Wood	75	30 min	Surface darkened; attacked at H_2O-N_2O_4 interface
Concrete			
Bare	75	1 hr 42 min	Concrete attacked
Coated with water glass	75	1 hr	No apparent reaction; affords protection
Coated with water glass and floor enamel (Esco Brand 41138)	75	30 min	Reaction at H_2O-N_2O_4 interface after 6 minutes; stripped to water glass
Coated with water glass and Chex-Wear floor enamel	75	3 min	Only paint removed
Coated with Rockflux	75	1 hr 15 min	N_2O_4 absorbed; adhesion weakened; material turned white
Rezklad 1, 2, 3	75	1 hr 30 min	Binder washed away to a maximum depth of 0.05 inch
Mild Steel Coated with			
Tygon K paint	75	20 min	Paint blistered
Catalac, improved	75	10 min	Paint blistered; lifted when totally immersed
Co-Polymer P-200G	75	2 min	Dissolved immediately
Sauereisen 47 (4 coatings)	75	10 min	Dissolved
CA9747 Primer Paint	75	2 min	Reaction and discolored immediately
Corrosite Clear 581	75	30 min	Blistered
Proseal 333	75	2 hr	Unaffected

5.5 SHORT-TERM COMPATIBILITY

As was stated in Section 4.6 of this handbook, many components may be subjected to liquid or gaseous N_2O_4 as a result of leakage or splashing during filling or storage periods. Splash and fume tests were performed similar to the procedures outlined in Reference 47. The splash test consisted of wetting the surface of the material with N_2O_4 and air drying at 80°F for 24 hours at a relative humidity of less than 80%. The fume test consisted of exposing the sample for one hour to N_2O_4 fumes in a chamber at 70°F and a relative humidity of no less than 80%. After the exposure period, the sample was air-dried at 80°F for 24 hours at a relative humidity of less than 80%. Table 5.4 contains compatibility data for various materials exposed to N_2O_4 splash and/or fume tests.

5.5.1 Plastics

Of the plastic materials listed in Table 5.4, only Nylon and Delrin were completely unsatisfactory for use with N_2O_4 under these test conditions.

5.5.2 Elastomers

Neoprene, Hycar 2202, and Buna N rubbers were the only elastomers completely unsatisfactory for use with N_2O_4 under these test conditions.

5.5.3 Potting Compounds

Of the potting compounds listed in Table 5.4, only Paraplex P43 and RTV20 were satisfactory for use with N_2O_4 under these test conditions.

5.5.4 Coatings

Valdura, Swedlow RD101, Dimetcote, and Proseal 333 proved to be satisfactory for use with N_2O_4 under the conditions of the splash test.

5.5.5 Lubricants

All dry film lubricants listed in Table 5.4 are compatible with N_2O_4 under the conditions of the splash test.

5.5.6 Tapes and Markings

All the tapes and marking materials listed in Table 5.4 were resistant to the N_2O_4 splash test; only metallized Mylar tape and PD455 were not resistant to the N_2O_4 fume test.

TABLE 5.4 (CONT)

COMPATIBILITY OF MATERIALS EXPOSED TO N_2O_4 SPLASH AND FUME TESTS

Material	Rating[a]	Test[b]	Reference	Remarks
PLASTICS (CONT)				
Polyamide				
Nylon	D	S	46	Surface dissolving, swell 3.5%, Shore D decrease 16 units
(Zytel 101)	D	F	46	Surface dissolving, swell 9.3%, Shore D decrease 19 units
Polyester				
Mylar	B	S	46	White spots, no volume change, Shore D increase 2 units
	A	F	46	No visible change, no volume change, Shore D hardness unchanged
Laminates-Glass				
Polyester	A	S	46	No visible change
Silicone	A	S	46	No visible change, swell < 1% Very slightly yellow, swell < 1%
Polyvinylidene Chloride				
Saran	A	S	46	No visible change, shrinkage <1%, Shore D decrease 1 unit
	A	F	46	No visible change, swell 2.7%, Shore D increase 2 units
Polyformaldehyde				
Delrin	D	S	46	Reacts vigorously
Polycarbonate				
Lexan	B	S	46	Surface softened, swell 3.1%, Shore D decrease 2 units
	B	F	46	Surface softened, swell < 1%, Shore D decrease 2 units
Polymethyl Methacrylate				
Plexiglas II UVA	C	S	46	Surface frosted, swell < 1%, Shore D hardness unchangedswell < 1%,Shore D
Plexiglas CR-39	C	F	46	Surface frosted, swell < 1%, Shore D decrease 2 units
	A	S	46	No visible change, shrinkage <1%, Shore D hardness unchanged
	B	F	46	Slightly yellow, swell 1.3%, Shore D increase 1 unit

a - Definitions of ratings are given on page 4-18

b - S - Splash Test

F - Fume Test

TABLE 5.4 (CONT)

COMPATIBILITY OF MATERIALS EXPOSED TO N_2O_4 SPLASH AND FUME TESTS

Material	Rating[a]	Test[b]	Reference	Remarks
BUTYL RUBBERS				
Parker B496-7	A	S	46	No visible change, swell < 1%, Shore A hardness unchanged
	A	F	46	No visible change, shrinkage < 1%, Shore A decrease 2 units
Enjay 268	C	S	46	Pitted and sticky, swell 4.8%, Shore A decrease 9 units
Enjay 551	C	S	46	Sticky, swell < 1%, Shore A hardness unchanged
	C	F	46	Sticky, shrinkage < 1%, Shore A increase 1 unit
Hycar 2202	D	S	46	Very sticky, swell < 1%, Shore A decrease 2 units
	B	F	46	Slightly sticky, shrinkage < 1%, Shore A hardness unchanged
FLUORO RUBBERS				
Viton A	A	S	46	No visible change, swell 1.3%, Shore A hardness unchanged
	A	F	46	No visible change, swell < 1%, Shore A decrease 3 units
Viton B	B	S	46	No visible change, swell < 1%, Shore A decrease 4 units
Kel-F 5500	B	S	46	Slightly yellow, shrinkage < 1%, Shore A decrease 4 units
	B	F	46	Light yellow, swell 4.4%, Shore A decrease 8 units
MISCELLANEOUS RUBBERS				
Buna N	D	S	46	Cracked and blistered, swell 36.1%, Shore A decrease 5 units
Cohrlastic 500	B	F	46	No visible change, swell < 1%, Shore A decrease 8 units
Garlock 22	A	S	46	No visible change, swell 1.2%, Shore A increase 1 unit
	C	F	46	White crystals formed, swell 1.4%, Shore A decrease 1 unit

a - Definitions of ratings are given on page 4-18
b - S - Splash Test
F - Fume Test

TABLE 5.4 (CONT)

COMPATIBILITY OF MATERIALS EXPOSED TO N_2O_4 SPLASH AND FUME TESTS

Material	Rating[a]	Test[b]	Reference	Remarks
MISCELLANEOUS RUBBERS (CONT)				
B318-7	C	S	46	Sticky, swell 1.4%, Shore A decrease 3 units
	C	F	46	Sticky, swell $< 1\%$, Shore A decrease 1 unit
Garlock 900	C	S	46	Slightly yellow with crystals, swell 3.1%, Shore D hardness unchanged
	C	F	46	Slightly yellow with crystals, swell 3.7%, Shore D decrease 3 units
Hypalon 20	B	S	46	No visible change, swell $< 1\%$, Shore A increase 4 units
	A	F	46	No visible change, swell $< 1\%$, Shore A increase 2 units
LS-53	A	S	46	No visible change, swell $<1\%$, Shore A hardness unchanged
	A	F	46	No visible change, swell $<1\%$, Shore A hardness unchanged
Natural Rubber	B	S	46	Surface hard, brittle, swell 3.7%, Shore A increase 3 units
	B	F	46	Surface hard, brittle, shrinkage 1.5%, Shore A increase 4 units
Neoprene	D	S	46	Pitted, cracked, brittle, swell 50%, Shore A increase 7 units
	C	F	46	Slightly cracked, no volume change, Shore A hardness unchanged
POTTING COMPOUNDS				
Epon 828	C	S	46	Dark yellow, swell $<1\%$, Shore D hardness unchanged
	D	F	46	Surface dissolving, swell 8.2%, Shore D decrease 9 units
Fairprene 5159	D	S	46	Heavy blistering, swell 32.3%
	C	F	46	Slight blistering, swell 5.1%
PR 1422	D	S	46	Badly deformed due to dissolving
	D	F	46	Badly deformed due to dissolving

a - Definitions of ratings are given on page 4-18

b - S - Splash Test

F - Fume Test

TABLE 5.4 (CONT)

COMPATIBILITY OF MATERIALS EXPOSED TO N_2O_4 SPLASH AND FUME TESTS

Material	Rating[a]	Test[b]	Reference	Remarks
POTTING COMPOUNDS (CONT)				
Proseal 793	D	S	46	Dissolved
	D	F	46	Dissolved
RTV 20	B	S	46	No visible change, shrinkage 1.7%, Shore A hardness unchanged
	A	F	46	No visible change, swell 3.4%, Shore A hardness unchanged
Paraplex P43	A	S	46	No visible change, swell 3.0%, Shore D decrease 1 unit
	B	F	46	No visible change, swell 2.1%, Shore D decrease 7 units
COATINGS				
Proseal 333	A	S	51	Paint unaffected even when immersed in N_2O_4 (5 weeks) and when N_2O_4 dripped on coating partly immersed in water (2 hr)
Aluminous	D	S	51	Blistered badly
Markal				
DA8	D	S	51	Blistered badly
	D	F	59	Blistered badly
DA8-Grey	D	S	51	Blistered badly
Da-8 Improved	D	S	79	Blistered badly
DA9	D	S	51	Blistered badly
	D	F	59	Blistered badly
Magna Polyurethenes NTH	B	S	60	Coating discolored
	D	F	60	Coating destroyed
Chem Seal	D	S	60	Attacked
	D	F	60	Attacked
Hysol 1C	B	S	78	Surface discolored
	B	F	78	
Valdura (Vinyl)	A	S	79	
Swedlow RD101	A	S	79	
Dimetcote 1731/1741	A	S	79	

a - Definitions of ratings are given on page 4-18.

b - S - Splash Test

F - Fume Test

TABLE 5.4 (CONT)

COMPATIBILITY OF MATERIALS EXPOSED TO N_2O_4 SPLASH AND FUME TESTS

Material	Rating[a]	Test[b]	Reference	Remarks
LUBRICANTS				
Braycote 660 AMS (Rayco 60 AMS)	C	S	58	Base oil is soluble, leaves residue harder than virgin grease
	C	F	58	
Drilube 822	B	S	58	Oil component is soluble, washes away
	B	F	58	
Drilube 842	B	S	58	Poor adhesion, washes off easily, good thread lubricant
	B	F	58	
Microseal	A	S	4	
Drilube 7, Type A	A	S	76	
	A	F	76	
M8800, Type A	A	S	76	
	A	F	76	
X106, Type B	A	S	76	
	A	F	76	
Drilube 1, Type B	A	S	76	
	A	F	76	
X15, Type C	A	S	76	
	A	F	76	
TAPES AND MARKINGS				
Mylar				
Matallized tape	A	S	36	
	D	F	36	
Declar 956	A	S	36	
	A	F	36	
Y9040 (Al backed)	A	S	36	
	A	F	36	
SLI-281011				
Al backed	A	S	36	
	A	F	36	
Tedlar backed	A	S	36	
	A	F	36	
Teflon backed	A	S	36	
	A	F	36	

a - Definitions of ratings are given on page 4-18.

b - S - Splash Test F - Fume Test

TABLE 5.4 (CONT)

COMPATIBILITY OF MATERIALS EXPOSED TO N_2O_4 SPLASH AND FUME TESTS

Material	Rating[a]	Test[b]	Reference	Remarks
TAPES AND MARKINGS (CONT)				
Butyl Phenolic Adhesive				
Polyethylene	A	S	36	
	A	F	36	
Fiberglass	A	S	36	
	A	F	36	
Y9050 Tape	A	S	36	
	A	F	36	
Black AX-Aero	A	S	36	
Metal Ink	A	F	36	
PD 455	A	S	36	
(Al backed)	D	F	36	
Polyplate Decal	A	S	36	
	A	F	36	

a - Definitions of ratings are given on page 4-18

b - S - Splash Test

F - Fume Test

5.7 IMPACT TESTS OF VARIOUS NONMETALS IN N_2O_4

The Martin Company (Reference 62) and Aerojet (Reference 48) performed drop-weight tests with a modified Army Ballistic Missile Agency impact tester. The materials were immersed in N_2O_4 and the plummet was dropped. The results of the tests as shown in Table 5.6 indicate that only polydimethylsiloxane and penton 1215 (a chlorinated polyether) detonated on impact. Some of the others exhibited chemical attack.

TABLE 5.6

RESULTS OF IMPACT TESTS IN LIQUID N_2O_4

Material	Energy, ft-lb	Results	Reference
Polychloroprene	70	Passed	62
Polydimethylsiloxane	70	Failed	62
	60	Failed	62
	50	Passed	62
Polyethylene, Branched	70	Passed	62
Polyethylene, Linear	70	Passed	62
Polypropylene	70	Passed	48,62
Polyvinylidene Fluoride	70	Passed	62
Fluorel (Viton A)	70	Passed	48,62
Alathon 34 (Irradiated)	70	Passed	48
Parco 805-70	70	Passed	48
Linear 7806-70	70	Passed	48
Precision 9257	70	Passed	48
Kel-F 300	70	Passed	48
Penton 1215	70	Failed	48
	60	Failed	48
	50	Passed	48
Teflon TFE 1	70	Passed	48
Teflon 100X	70	Passed	48
Resin Cured Butyl (Formula 121)	$400/in.^2$	Passed	71
Ethylene Propylene Rubber (Formula 132)	$400/in.^2$	Passed	71

5.8 PERMEABILITY OF TEFLON TO N_2O_4

Permeability tests performed by Bell Aerosystems (References 51 and 79) showed that the permeability rate for Teflon TFE 7 is three times greater than for Teflon FEP (Table 5.7) and that permeability increases with an increases with an increase in pressure differential across the Teflon FEP (Figure 5.1). The tests were performed at room temperature and gas transmission rates were corrected to 60°F.

Aerojet-General Corporation (Reference 65) performed permeability tests with Teflon 100 (FEP) at various thicknesses and temperatures. Results show that permeability increases with increasing temperature and decreases with increasing thickness.

TABLE 5.7

PERMEABILITY DATA FOR VARIOUS TEFLONS AT ΔP OF 16 PSIA
CORRECTED TO 60°F

Teflon Specimen	Thickness (mils)	Density at 82°F (gm/cc)	Transmission Rate (cc/100 in.^{2}/24 hr) N_2O_4
TFE 7	10.0	2.186	311.9
FEP	10.6	2.138	92.5
30	10.0	2.168	669.9

5.9 EFFECTS OF N_2O_4 VAPORS ON VARIOUS MATERIALS

Compatibility tests were conducted (Reference 79) with various materials exposed to 40 ppm, 1000 ppm, and concentrated N_2O_4 vapors in an atmosphere at a relative humidity of at least 80%. These materials also were exposed to the high-humidity atmosphere alone as controls. The results of the control tests appear in Table 4.8. Table 5.8 summarizes the test results of the materials exposed to these environments for 1 hour to 90 days at temperatures ranging from 70° to 77°F. All the metals exposed to these environments were adversely affected in some manner, resulting in pits and/or salt formations.

Nylon was compatible with 40 ppm N_2O_4 vapors for 90 days, but became tacky after 7 days exposure in 1000 ppm N_2O_4 vapors and after 1 hour exposure to concentrated N_2O_4 vapors.

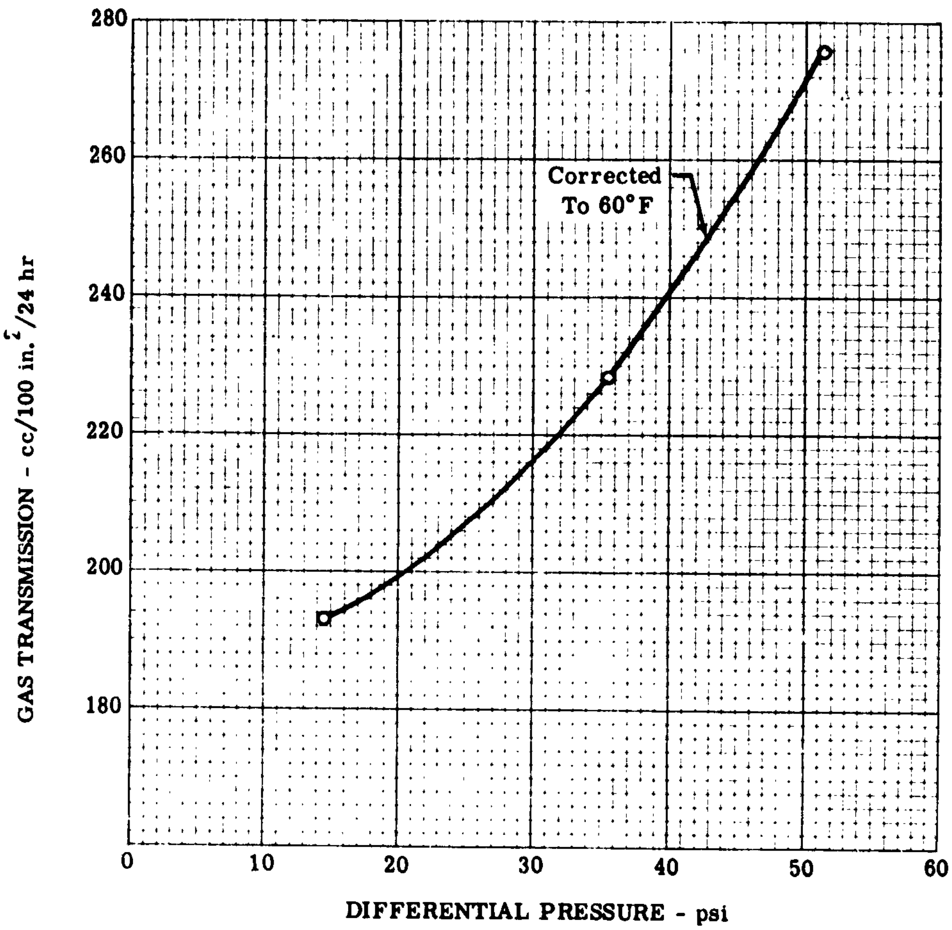

Figure 5.1. Gas Transmission of N_2O_4 Through Teflon FEP (10 mil thick) at Various Differential Pressures

TABLE 5.8

COMPATIBILITY OF MATERIALS WITH N_2O_4 VAPORS IN AIR AT 80% RELATIVE HUMIDITY

Material	Rating	Remarks
		Concentrated N_2O_4 Vapors
2014-T6 Al	C	Visually unaffected after 5 hr, 3 to 12 MPY
Zytel 101 (Nylon)	D	Weight increase of 14.3% and tacky in 1 hr, flowed in 2 hr
7075 Al	C	Visually unaffected after 5 hr, 6 to 25 MPY
1010 Mild Steel	C	Rusted after 5 hr, weight increases
AZ-31A Mg	D	Severly attacked during 5 hr, 230 to 450 MPY
Copper	C	Slight discoloration after 5 hr, 5 to 20 MPY
		1000 ppm N_2O_4 Vapors
2014-T6 Al	C	6 to 10 MPY through 90 days, salt deposits in 7 days
Zytel 101 (Nylon)	D	Weight increase 13.7% and tacky in 21 days, flowed in 60 days
7075 Al	C	8 to 19 MPY through 90 days, salt deposits in 7 days
1010 Mild Steel	D	36 to 53 MPY through 90 days, badly crusted in 7 days
AZ-31A Mg	D	24 to 32 MPY through 90 days, salts and badly pitted in 7 days
Copper	C	0.4 to 4 MPY through 90 days, salts in 4 days
		40 ppm N_2O_4 Vapors
2014-T6 Al	B	$<$ 1 MPY, salts in 17 days
Zytel 101 (Nylon)	A	Max. 4% weight increase, visually unaffected in 90 days
7075 Al	B	$<$ 1 MPY, slight pitting in 17 days
1010 Mild Steel	C	$<$ 5 MPY, heavy scattered rusting in 17 days
AZ-31A Mg	C	$<$ 5 MPY, salts in 17 days
Copper	D	$<$ 1 MPY, salts in 28 days

geneous mixture through diffusion was obtained (Reference 4). This method is not recommended for use because of the time element and the uncertainty of its effectiveness when blending large quantities.

6.2.3 Mixing by Mechanical Stirring

Approximately one quart of fuel blend was mixed in a glass container. Complete mixing was accomplished in a nitrogen atmosphere with a glass stirrer turning at 760 rpm for five minutes; complete mixing also was accomplished by stirring at 1 rpm for 72 hours. The ratio of the area of the stirrer (2.5 sq in.) to the volume of the blend (48.7 cu in.) was 0.005 If this technique is feasible for large-scale mixing, it can be used with success.

6.2.4 Mixing by Gas Bubbling

A nitrogen gas flow rate of 0.025 cu ft/min for two hours was sufficient to mix approximately one quart of fuel blend in a round bottom glass flask of 15 sq in. cross-sectional area. This method is not recommended because UDMH losses are incurred during the operation (Reference 4).

6.2.5 Mixing by Impingement

A mixing chamber similar to that described by W. R. Ruby (Reference 26) was used to mix laboratory quantities of the fuel blend. Photographs of the apparatus and a detailed procedure is presented in Reference 4. Mixing was accomplished when two streams of UDMH impinged with two streams of N_2H_4.

Wyle Laboratories (Reference 37) successfully mixed approximately 41,000 pounds (110 drums) of the fuel blend by recirculating the fuels through a blender (which caused mixing similar to the impingement technique) and into a storage tank. Following the initial transfer of each fuel into the storage tank, two centifugal pumps provided continuous circulation through the blender for approximately two hours before mixing was accomplished.

Aerojet-General Corporation (Reference 1) also has blended thousands of gallons of the fuel blend by pumping the fuel components simultaneously from each tank into a concentric nozzle (containing a swirling mechanism to enhance mixing) and then into the fuel blend storage tank.

6.2.6 Mechanical Mixing Unit

A Mixing unit has been developed under Air Force contract and installed at Rocky Mountain Arsenal, Denver, Colorado. Details of this unit can be obtained from Food Machinery Chemical, Ordnance Division, San Jose, California.

6.3 FREEZE AND THAW OF 50/50 FUEL BLEND

A laboratory test was conducted to determine the effect of alternate freezing and thawing of the fuel blend. The apparatus used, a description of the test procedure, and the detailed test results are presented in Reference 2. Results of these tests indicate that the fuel blend separates when subjected to freezing or thawing. When thawing, the UDMH melts at -71°F, followed by

N_2H_4 which melts at 35°F. During the experiment, solid particles were detected falling to the bottom of the test container. It is suspected that these particles were predominantly N_2H_4 because N_2H_4 is more dense than UDMH. Since analyses indicate that separation of the fuel blend occurs during freezing, fuel blend known to have frozen should be re-mixed prior to use.

6.4 STORAGE

Fuel blend was stored for 15 months at 60° ±5°F in a two-quart 1100 aluminum alloy tank and a one-quart Pyrex glass bottle. No fuel decomposition was detected in either container (Reference 51).

Spectral analyses of the fuel blend in a one-quart Pyrex glass bottle gave no evidence of fuel blend separation after 12 months at 60° ± 5°F (Reference 51).

The fuel blend was stored in sealed Pyrex glass ampules at 200°F for 12 weeks (Reference 50). Using the weight loss technique for measuring fuel decomposition indicated that no significant decomposition occurred.

Low-temperature and high-temperature storage tests were conducted with N_2O_4. Allied Chemical Corporation stored N_2O_4 out-of-doors in a small carbon steel container for nine years at temperatures ranging from 68° to 100°F. Analyses showed no change in propellant composition.

In another test, N_2O_4 was stored in 10-gallon tanks made from PH 15-7 Mo stainless steel and 6061-T6 aluminum alloy for six months at temperatures ranging from 0° to 100°F. Chemical analyses after this test showed no change in propellant composition and a visual examination of the interior of the tanks indicated no metal attack (Reference 19).

For three months, N_2O_4 was stored at 270°F ±10°F in two-quart tanks made from PH 15-7 Mo and 347SS and from 6061-T6 aluminum alloy. The N_2O_4 remained unchanged except for a trace of nitric acid found by spectral means and an indication of the entry of water. Visual examination of the tanks disclosed salt deposits.

In the foregoing high-temperature storage tests, the salt deposits may have resulted from moisture entering the system and reacting with the N_2O_4 to form nitric acid. The acid in turn would have reacted with the stainless steel and aluminum alloy to form nitrates that are insoluable in N_2O_4.

A one-month storage test of N_2O_4 in a titanium tank (C120AV) was conducted at cycling temperatures between 90° and 150°F (Reference 19). No abnormal pressures were detected during the test period; at the conclusion of the test, a 50-pound weight was dropped from a height of two feet onto the tank to determine if shock-sensitive deposits had formed. No reaction to this shock was observed. The chemical composition of the N_2O_4 remained unchanged and examination of the tank interior showed no signs of deposits.

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56. Reaction Motors, Division of Thiokol Chemical Corporation, "Research on Elastomeric and Compliant Materials," Report RMD 2028-P4, 31 July 1961.

57. Reaction Motors, Division of Thiokol Chemical Corporation, "Elastomers and Compliant Materials for Contact with Liquid Rocket Fuels and Oxidizers," Report ASD-TR 61-76, Part 1 May 1961.

58. Communication with McCullough, T. W., The Martin Company, Denver, Colorado, 6 February 1962.

59. The Martin Company, "Evaluation of Marked DA-8 and DA-9 Aluminum Coatings for Titan B Compatibility," Report No. ME-142, 11 October 1961.

60. The Martin Company, "Evaluation of Magna Polyurethane NTH Coating and Chem Seal Fluorinated Polymer Coating for Titan B Propellant Compatibility," Report No. ME-116, 10 August 1961.

61. Aerojet-General Corporation, "Compatibility Studies of Metals," Murchison, M. L., Report No. MM-155-4, 13 March 1961.

62. The Martin Company, "Mechanically Initiated Reactions of Organic Materials in Missile Oxidizers," ASD TR 61-324, October 1961.

63. Rocketdyne Letter 61RC2147 to Space Technology Laboratories, Inc.

64. Reaction Motors Division of Thiokol Chemical Corporation, "Elastomeric and Compliant Materials for Contact with Liquid Rockets Fuels and Oxidizer," Report RMD2028-P5, March 1962.

65. Aerojet-General Corporation, Liquid Rocket Plant, "Storable Liquid Propellants Nitrogen Tetroxide/Aerozine 50," Report LRP198, Second Edition, June 1962.

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67. Aerojet-General Corporation, IDEP-501.01.60.80-A6-01 "Non-Metallic Materials, Adhesive Tapes, Rolled," LRP, 22 March 1962.

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70. Reaction Motors,Division of Thiokol Chemical Corporation, "Elastomeric and Compliant Materials for Contact with Liquid Rocket Fuels and Oxidizer," Report ASD-TR-61-76, Part II, November 1961.

71. Reaction Motors, Division of Thiokol Chemical Corporation, "Elastomeric and Compliant Materials for Contact with Liquid Rocket Fuels and Oxidizers," Report RMD2028-P7, September 1962.

72. Reaction Motors, Division of Thiokol Chemical Corporation, "Elastomeric and Compliant Materials for Contact with Liquid Rocket Fuels and Oxidizers," Report RMD2028-P6, June 1962.

73. Aerojet-General Corporation, "Compatibility Studies of Metals for Titan II Engines," Report No. Rm-7693(M155-5), 10 October 1961.

74. AFBSD, "Storable Propellant Data for the Titan II Program," Bell Aerosystems Company, Third Quarterly Progress Report, BSD-TDR-62-223, September 1962.

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APPENDIX A

VENDOR INDEX FOR NONMETALLIC MATERIALS

MATERIALS	COMPOSITION	SOURCE
CERAMICS		
Sauereisen 47, 31, and P-1	Not Known	Sauereisen Cements Co., Pittsburgh, Pa.
Temporell 1500	Not Known	Not Known
GRAPHITES		
Purebon P3N, P5N	Carbon - graphite	Purebon Carbon Co. Inc., St. Marys, Pa.
Graphitar 2, 14, 39, 50, 86	Carbon - graphite	U.S. Graphite Co., Saginaw, Mich.
CCP-72	Carbon - graphite	National Carbon Co., Pittsburgh, Pa.
Johns Manville No. 60	Carbon - graphite	Johns Manville Co., New York, N. Y.
PLASTICS		
Aclar 191	Fluorohalocarbon	Allied Chemical and Dye Corp., New York, N. Y.
Alathon 34 (Irradiated)	Low Density Polyethylene	Raytherm Corp., Redwood City, Cal.
Amerplate	Polyvinyl Chloride	Amercoat Corp., South Gate, Cal.
Armalon 7700, 7700B	Teflon TFE Fibers	DuPont, Wilmington, Del.
Capran 391	Polyamide	Allied Chemical and Dye Corp., New York, N. Y.
Delrin	Polyformaldehyde	DuPont, Wilmington, Del.
EC 1469	Epoxy	Minnesota Mining and Manufacturing Co., St. Paul, Minn.
Epon V1, 828, 1031 (with PMDA)	Epoxy	Shell Chemical Co., San Francisco, Cal.
Fluorobestos	Asbestos-filled Teflon	Fluorocarbon Co., Fullerton, Cal.
Fluorogreen	Ceramic-filled Teflon	R. S. Hughes, Denver, Colo.
F120 - 55	Asbestos-filled Phenol - Formaldehyde	Reinhold Eng. and Plastics Co., Norwalk, Cal.
Genetron GCX3B	Polychlorotrifluoroethylene	Allied Chemical and Dye Corp., New York, N. Y.
Genetron XE2B	Polychlorotrifluoroethylene	Allied Chemical and Dye Corp., New York, N. Y.
H-Film	Proprietary	DuPont, Wilmington, Delaware

MATERIALS	COMPOSITION	SOURCE
PLASTICS (CONT)		
Hypalon 20	Chlorosulfonated Polyethylene	DuPont, Wilmington, Delaware
Kel-F 300	Polychlorotrifluoroethylene	Minnesota Mining and Manufacturing Co., St. Paul, Minn.
Kel-F (unplasticized)	Polychlorotrifluoroethylene	Minnesota Mining and Manufacturing Co., St. Paul, Minn.
Kodapak II	Cellulose Acetate Butyrate	Eastman Kodak Co., Rochester, N.Y.
Kynar	Vinylidenefluoride	Pennsalt Chemical Corp., Philadelphia, Pa.
Lexan	Polycarbonate	Dow Chemical Co., Midland, Mich.
Marlex 50	High Density Polyethylene	Phillips Chemical Co., Bartlesville, Okla.
Marlex 5003	High Density Polyethylene	Phillips Chemical Co., Bartlesville, Okla.
Mylar	Terephthalate Polyester	DuPont, Wilmington, Del.
Narmco X3168	Not Known	Not Known
Nylon 31, 63, 101	Polyamide	DuPont, Wilmington, Del.
Opalon 1219, 1220, 1444 and 81222	Polyvinylchloride	Monsanto Chemical Co., St. Louis, Mo.
Penton 1215	Chlorinated Polyether	Hercules Powder Co., Wilmington, Del.
Phenolic - Asbestos	Phenolic - asbestos	Reinhold Eng. and Plastics Co., Norwalk, Cal.
Plexiglas	Polymethyl methacrylate	Rohm and Haas Co., Philadelphia, Pa.
Polyethylene HD	High Density Polyethylene	Visking Corp., Chicago, Ill.
Polyethylene (irradiated)	Polyethylene	General Electric, Pittsfield, Mass.
Polypropylene	Polypropylene	Campco Division, Chicago Molded Products, Chicago, Ill. and Hercules Powder Co., Wilmington, Del.
P-4010	Not Known	Dow Chemical Co., Midland, Mich.
Raythene N	Irradiated Polyolefin	Ray Chem Corp., Redwood City, Cal.
Rigid PVC	Polyvinyl Chloride	B. F. Goodrich Chemical Co., Cleveland, Ohio
Saran	Polyvinylidene Chloride	Dow Chemical Co., Midland, Mich.
Silicone R-7001	Silicone	Dow Chemical Co., Midland, Mich.
Teflon Asbestos	Teflon Asbestos	Fluorocarbon Co., Fullerton, Cal.
Teflon FEP (100X)	Tetrafluoroethylene-hexafluoropropylene	DuPont, Wilmington, Del.

MATERIALS	COMPOSITION	SOURCE
PLASTICS (CONT)		
Teflon-Graphite	15% Graphite	Fluorocarbon Co., Fullerton, Cal.
Teflon Molydisulfide	2% Molybdenum Disulfide	Fluorocarbon Co., Fullerton, Cal.
Teflon TFE-1	Tetrafluoroethylene	DuPont, Wilmington, Del.
Teflon TFE Felt 7550	Teflon Felt	DuPont, Wilmington, Del.
Tedlar 30	Polyvinyl Fluoride Resin	DuPont, Wilmington, Del.
Trithene A	Polychlorotrifluoroethylene	Visking Corp., Chicago, Ill.
Ultron	Polyvinyl Chloride	Monsanto Chemical Co., St. Louis, Mo.
30000	Not Known	Dow Chemical Co., Midland, Mich.
BUTYL RUBBERS		
Enjay 268	Butyl	Enjay Co., Inc., New York, N. Y.
Enjay 551	Chlorobutyl	Enjay Co., Inc., New York, N. Y.
Goshen 1357	Butyl	Goshen Rubber Co., Inc. Goshen, Ind.
Hycar 2202	Bromo-butyl	B.F. Goodrich Chemical Co., Cleveland, Ohio
Linear 7806-70	Butyl	Linear, Inc., Philadelphia, Pa.
Parco 805-70	Butyl	Plastics and Rubber Products Co., Los Angeles, Cal.
Parco 823-70	Butyl	Plastics and Rubber Products Co., Los Angeles, Cal.
Parker B496-7	Butyl	Parker Seal Co., Cleveland, Ohio
Parker B480-7	Butyl	Parker Seal Co., Los Angeles, Cal.
Hadbar XB800-71	Butyl	Hadbar, Inc., Temple, Cal.
Parker B318-7	Butyl	Hercules Packing Co., Lancaster, N.Y.
Precision 9257	Butyl	Precision Rubber Products Corp., Dayton, Ohio
Precision 9357	Butyl	Precision Rubber Products Corp., Dayton, Ohio
Precision 1330x20	Butyl	Precision Rubber Products Corp., Dayton, Ohio
Precision 214-907-9	Butyl	Precision Rubber Products Corp., Dayton, Ohio
Precision 940x559	Butyl	Precision Rubber Products Corp., Dayton, Ohio

MATERIALS	COMPOSITION	SOURCE
BUTYL RUBBERS (CONT)		
Stillman SR 613-75	Butyl	Stillman Rubber Co., Culver City, Cal.
Parker XB-1235-10	Butyl-phenolic	Parker Seal Co., Los Angeles, Cal.
Formulas 120, 121	Resin-cured Butyl	Reaction Motors Division, Denville, N. J.
11092-3A	Butyl-phenolic	Minnesota Mining and Manufacturing Co., St. Paul, Minn.
TC-419-19A	Butyl-phenolic	Plastic and Rubber Products Co., Los Angeles, Cal.
EHTYLENE-PROPYLENE RUBBERS		
X-7000-1 thru 7, 9, 10, 11	Ethylene Propylene	Seals, East Orange, New Jersey
Formula 132 Resistazine 74	Ethylene Propylene	Reaction Motors Division, Denville, N. J.
FLUOROSILICONE AND FLUORORUBBERS		
Fluorel	Vinylidene Fluoride-hexafluoropropylene Coplymer	Minnesota Mining and Manufacturing Co., St. Paul, Minn.
Hadbar 58789-23GT	Fluorosilicone	Hadbar Inc., Temple, Cal.
Hadbar 58789-23	Fluorosilicone	Hadbar Inc., Temple, Cal.
Kel-F 3700, 5500	Polymer of Monochlorotrifluoroethylene and Vinylidene Fluoride	Minnesota Mining and Manufacturing Co., St. Paul, Minn.
Omni X-FBF-4	Fluoro	Carlton Controls, East Aurora, N.Y.
Parker XV-1235-2	Fluoro	Parker Seal Co., Los Angeles, Cal.
Parker XV-1235-5	Fluoro	Parker Seal Co., Los Angeles, Cal.
Parker V-494-7 (Viton B)	Fluoro	Parker Seal Co., Cleveland, Ohio
Silastic LS 53	Fluorosilicone	Dow Corning Corp., Midland, Mich.
Silastic LS 63	Fluorosilicone	Dow Corning Corp., Midland, Mich.
Stillman Rubber EX774-M-1 (Viton B)	Fluoro	Balanrol Corp., Niagara Falls, N. Y.
Stillman SR 277-70 (Viton A)	Fluoro	Balanrol Corp., Niagara Falls, N. Y.
Stillman TH 1057	Fluoro	Stillman Rubber Co., Culver City, Cal.
EX821-A70	Fluoro	Stillman Rubber Co., Culver City, Cal.
TFNM-TFE	Trifluoronitrosomethane-Tetrafluoroethylene	U.S. Army Quartermaster Research and Engineering Center, Natick, Mass.

MATERIALS	COMPOSITION	SOURCE
FLUOROSILICONE AND FLUORORUBBERS (CONT)		
18007 and 18057	Fluoro	Precision Rubber Products Corp., Dayton, Ohio
Viton A	Vinylidene Fluoride-hexafluoropropylene	DuPont, Wilmington, Delaware
Viton B	Vinylidene Fluoride-hexafluoropropylene	DuPont, Wilmington, Delaware
POLYBUTADIENE RUBBERS		
Acushnet SWK 849, SWK 850, SWK 851, BWK 422	Polybutadiene	Acushnet Process Co., New Bedford, Mass.
Stillman EX904-90 (Hydropol)	Hydrogenated Polybutadiene	Stillman Rubber Co., Culver City, Cal.
MISCELLANEOUS RUBBERS		
Buna N	Styrene Butadiene	B.F. Goodrich Chemical Co., Cleveland, Ohio
B318-7	Not Known	Plastics and Rubber Products Co., Los Angeles, Cal.
Cohrlastic 500	Silicone	Connecticut Hard Rubber Co., New Haven, Conn.
Garlock 22	Natural	Garlock Packing Co., Culver City, Cal.
Garlock 900	Composite	Garlock Packing Co., Culver City, Cal.
Neoprene	Chloroprene	Delta Products, Houston, Texas
Amber Plus	Not Known	Pretty Products Inc. Coshocton, Ohio
Davol	Natural Rubber	Davol Rubber Co., Providence, R. I.
Ebonettes	Natural Rubber and Neoprene	Pioneer Co., Unknown
Latex, Seamless	Natural Rubber	Not Known
Neosole SA8-8N-3032	Not Known	Charleston Rubber Co., Unknown
National Glove	Not Known	Not Known
Rollproof 32894	Not Known	Braun Co.
PAINTS AND COATINGS		
Alkyd No. 4	Not Known	Not Known
Aluminous	Aluminum	Aluminous Coatings Inc., Hallandale, Fla.

MATERIALS	COMPOSITION	SOURCE
PAINTS AND COATINGS (CONT)		
Catalac	Not Known	Finch Paint and Chemical Co., Torrance, Cal.
Chem Seal	Fluorinated Polymer	Chem Seal Corp., Los Angeles, Cal.
Chex-Wear	Titanium Dioxide	Benjamin Moore and Co., New York, N. Y.
Co-Polymer P-200G	Epoxy	Co-Polymer Chemicals, Inc., Livonia, Mich.
Corrosite Clear 581	Not Known	Corrosite Co., Chrysler Building, New York, N. Y.
Dimetcote 1731/1741	Zinc Silicate	Amercoat Corp., South Gate, Cal.
Epoxy 1, 5, 7, 9, and 6809	Epoxy	Not Known
Floor Enamel 41138	Chlorinated Rubber Base	Schuele and Co., Buffalo, N. Y.
Markal DA8 and DA8 Grey	Aluminum	Markal Co., Chicago, Ill.
DA9	Aluminum-Silicone	Markal Co., Chicago, Ill.
Magna Polyurethane NTH	Polyurethane	Magna Coatings and Chemical Corp., Los Angeles, Cal.
Primer MIL-P-6889	Not Known	Not Known
Primer CA9747	Zinc Chromate	Sherwin Williams Co., Cleveland, Ohio
Proseal 333 (BLACK)	Butyl	Coast Pro-Seal and Mfg. Co., Los Angeles, Cal.
Rezklad 1, 2, 3	Epoxy	Atlas Mineral Products Co., Mertztown, Pa.
Swedlow HD 101	Butyl	Swedlow Inc., Los Angeles, Cal
Tygon K	Polyvinyl Chloride	U.S. Stoneware, Plastics and Synthetic Division, New York, N.Y.
Hysol 1C	Epoxy Resin	Hysol Corp., So. El Monte, Cal.
Valdura	Vinyl	The Martin Company, Denver, Col.
ADHESIVES		
Armstrong A-6	Epoxy	American Cyanamid Co., Oakland, Cal.
EC 847	Rubber base	Minnesota Mining and Manufacturing Co., St. Paul, Minn.
HT 424	Not Known	Hadbar Inc., Rosemead, Cal.
Rockflux	Cave Rock, Quartz, Cement	Flexrock Co., Philadelphia, Pa.
3M-AF-10	Not Known	Not Known

MATERIALS	COMPOSITION	SOURCE
ADHESIVES (CONT)		
Epon 422	Epoxy-Phenolic	Shell Chemical Co., San Francisco, Cal.
4-3	Epoxy-Phenolic-Silicone	Westech Co. Address unknown
LUBRICANTS, GREASES, AND OILS		
Andok C	Petroleum Base	Esso Standard Oil Co., New York, N.Y.
Apiezon L	Proprietary	Shell Chemical Co., San Francisco, Cal.
Braycote 660 AMS	MIL-G-25760 ± Molybdenum Disulfide	Bray Oil Co., Los Angeles, Cal.
DC 11	Silicone Grease	Dow Corning Corp., Midland, Mich.
DC 55	Silicone Grease	Dow Corning Corp., Midland, Mich.
DC High Vacuum Grease	Silicone Grease	Dow Corning Corp., Midland, Mich.
Drilube 1, Type B	Graphite-Molybdenum Disulfide	Drilube Corp., Glendale, Cal.
Drilube 703	Not Known	Drilube Corp., Glendale, Cal.
Drilube 7, Type A	Graphite-Molybdenum Disulfide	Drilube Corp., Glendale, Cal.
Drilube 822	Fluorocarbon Wax and Fluorinated Ester Oil	Drilube Corp., Glendale, Cal.
Drilube 842	Fluorinated Wax in Freon (in Aerosol Can)	Drilube Corp., Glendale, Cal.
Electrofilm 66C	Solid Film	Electrofilm Inc., North Hollywood, Cal.
Flake Graphite	Graphite	J. Dixon Crucible Co., Jersey City, N.J.
Halocarbon Grease	Halocarbon	Halocarbon Products. Corp., Hackensack, N. J.
Kel-F 90	Chlorotrifluoro Grease	Minnesota Mining and Manufacturing Co., St. Paul, Minn.
FX45	Fluorochemical	Minnesota Mining and Manufacturing Co., St. Paul, Minn.
LOX Safe	Halogenated Oil	Redel Corp., Anaheim, Cal.
Microseal 100-1, 100-1 CG	Graphite Coating	Microseal Products Sales, Torrance, Cal.
Molykote Z	Molybdenum Disulfide	Alpha Molykote Corp., Stanford, Conn.
Nordcoseal 147S, 421	Proprietary	Rockwell Manufacturing Co., Pittsburgh, Pa.
Oxylube Sealant	Molybdenum Disulfide	Drilube Corp., Glendale, Cal.
PD788	Fluorocarbon	Frankford Arsenal, Philadelphia, Pa.

MATERIALS	COMPOSITION	SOURCE
LUBRICANTS, GREASES, AND OILS (CONT)		
Polyglycol Oils	Polyglycol	Dow Chemical Co., Midland, Mich.
Rayco 30 and 32	Not Known	Royal Lubricants, Hanover, N. J.
Rayco 60 AMS	MIL-G-25760 + Molybdenum Disulfide	Royal Lubricants, Hanover, N. J.
Rockwell-Nordstrom No. 950	Proprietary	Rockwell Manufacturing Co., Pittsburgh, Pa.
S#58-M Oil	Petroleum Base	New York and New Jersey Lubricating Co., New York, N. Y.
UDMH Lube 50/50 Mixture of UDM Lube and Electro Mechanics No. 20057	Proprietary Silicone	Superlube Inc., Cleveland, Ohio Electro Mechanics, Inc., New Britian, Conn.
Valve Seal A	Silicone	Dow Corning Corp., Midland, Mich.
Vydax A	Tetrafluoroethylene	DuPont, Wilmington, Del.
XC150	Silicone	Dow Chemical Corp., Midland, Mich.
X15, Type C	Graphite	Alpha Molykote Corp., Stanford, Conn.
X106, Type B	Graphite-Molybdenum Disulfide	Alpha Molykote Corp., Stamord, Conn.
M8800	Graphite-Molybdenum Disulfide	Alpha Molykote Corp., Stanford, Conn.
Fluorolube MG600	Fluorinated	Hooker Electrochemical Co., Niagara Falls, N. Y.
Fluorothene G	Fluorinated	Hooker Electrochemical Co., Niagara Falls, N. Y.
THREAD SEALANTS AND POTTING COMPOUNDS		
Crystal M and CF	Not Known	Minnesota Mining and Manufacturing Co., St. Paul, Minn.
Epon 828	Epoxy	Shell Chemical Co., San Francisco, Cal.
Fairprene 5159	Not Known	Not Known
Paraplex P-43	Not Known	Not Known
Proseal 793	Polysulfide Sealant	Coast Pro-Seal and Mfg., Los Angeles, Cal.

MATERIALS	COMPOSITION	SOURCE
THREAD SEALANTS AND POTTING COMPOUNDS (CONT)		
PR 1422	Polysulfide Sealant	Products Research Co., Burbank, Cal.
Reddy Lube 100, 200	Waterglass-graphite	Redel Corp., Anaheim, Cal.
RTV 20	Silicone	General Electric Co., Pittsfield, Mass.
Teflon Tape (Unsintered)	Tetrofluoroethylene	Permacel, LePage's Inc., New Brunswick, N. J.
TAPES AND MARKINGS		
Y9050	Butyl-phenolic	Minnesota Mining and Manufacturing Co., St. Paul, Minn.
Mylar		
Metallized	Terephthalate Polyester	Pee-Cee Tape and Label Co., Los Angeles, Cal.
Declar 956	Terephthalate Polyester	Permacel, LePage's Inc., New Brunswick, N. J.
Y9040	Not Known	Minnesota Mining and Manufacturing Co., St. Paul, Minn.
SL1-281011	Butyl-phenolic	Minnesota Mining and Manufacturing Co., St. Paul, Minn.
Butyl Phenolics	Butyl-phenolic	Minnesota Mining and Manufacturing Co., St. Paul, Minn.
Black AX - Aero	Ink	Speciality Ink Co., Brooklyn, N. Y.
PD455	Not Known	Mystik Adhesive Products, Inc., Chicago, Ill.
Polyplate Decal	Not Known	W. H. Brady Co., Milwaukee, Wis.

Bell Aerosystems Company, Division of Bell Aerospace Corporation, Buffalo 5, New York TITAN II STORABLE PROPELLANT HANDBOOK, Revision B, by R. R. Liberto. March 1963. 188 p. incl. illus. tables (Bell Report No. 8182-933004; AFBSD-TR-62-2) (Contract AF04(694)-72)
Unclassified report

Summarized are the physical properties, materials compatibility, handling techniques, flammability and explosivity hazards, and procedures for storing, cleaning, and flushing of the Titan II propellants, N_2O_4 as the oxidizer and a nominal 50/50 blend of UDMH and N_2O_4 as the fuel. The data presented was **derived both**

(over)

UNCLASSIFIED

1. **Physical Properties of 50/50 fuel** blend and N_2O_4
2. Materials Compatibility, 50/50 fuel blend and N_2O_4
3. Propellant Handling, Safety, and Flammability and explosivity Hazards

I. Liberto, R. R.

UNCLASSIFIED

from a literature survey and from a test program conducted at Bell Aerosystems Company and at the U. S. Bureau of Mines.

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II. Contract AF 04(694)-72

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Bell Aerosystems Company, Division of Bell Aerospace Corporation, Buffalo 5, New York TITAN II STORABLE PROPELLANT HANDBOOK, Revision B, by R. R. Liberto. March 1963. 188 p. incl. illus. tables (Bell Report No. 8182-933004; AFBSD-TR-62-2) (Contract AF04(694)-72)
Unclassified report

Summarized are the physical properties, materials compatibility, handling techniques, flammability and explosivity hazards, and procedures for storing, cleaning, and flushing of the Titan II propellants, N_2O_4 as the oxidizer and a nominal 50/50 blend of UDMH and N_2O_4 as the fuel. The data presented was **derived both**

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1. **Physical Properties of 50/50 fuel blend and N_2O_4**
2. **Materials Compatibility, 50/50 fuel blend and N_2O_4**
3. **Propellant Handling, Safety, and Flammability and Explosivity Hazards**

I. Liberto, R. R.

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from a literature survey and from a test program conducted at Bell Aerosystems Company and at the U. S. Bureau of Mines.

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