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STATUS REPORT
BSD-TDR-62-223

STORABLE PROPELLANT DATA FOR THE TITAN II PROGRAM

Prepared by

BELL AEROSYSTEMS COMPANY
Division of Bell Aerospace Corporation
Buffalo 5, New York

Ralph R. Liberto
Project Engineer

Third Progress Report
Contract Number AF04(694)-72
2 April through 20 July 1962

Bell Report No. 8182-933006
September 1962

Prepared for

AIR FORCE BALLISTIC SYSTEMS DIVISION
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FOREWORD

Presented in this report is the progress accomplished by the Bell Aerosystems Company during the period 2 April through 20 July 1962 for the Ballistic Systems Division of the Air Force Systems Command. The report includes results of the investigation conducted as a supplemental effort under Contract AF04(694)-72. This effort will continue through 31 December 1962.

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

Harold W. Stafford
Technical Editor

ABSTRACT

Material compatibility tests were conducted with metals and nonmetals and the Titan II propellants, N_2O_4 as the oxidizer and a 50/50 blend of UDMH and N_2H_4 as the fuel.

Tests were conducted with butyl and ethylene-propylene rubbers to determine seal capabilities with 50/50 fuel blend under pressures to 500 psig.

Fire hazards of various materials were determined during separate drip tests with N_2O_4 and 50/50 fuel blend.

Permeability data is presented from tests with various Teflons exposed to N_2O_4.

Also presented is information regarding the compatibility of lubricants with the Titan II propellants, obtained from contractors principally using this propellant combination.

SUMMARY

Samples of tungsten carbide and copper-aluminum (2014-T6) couple showed no significant visual effects after partial immersion in the Titan II propellants for 45 days. The propellant temperatures were 160°F for the fuel blend and 65°F for N_2O_4.

Six nonmetallic materials were found to be incompatible with N_2O_4 during 30-day tests at 65°F. Amerplate, a polyvinyl chloride, hardened during the 30-day exposure in N_2O_4; the other materials dissolved or fell apart.

Three elastomers (Parco 805-70, Parker B496-7, and Resistazine 74) were effective dynamic seals in 50/50 fuel blend at pressures to 500 psig.

Three materials were exposed to Titan II propellant drip tests at room temperature to determine if a fire hazard exists. None of the materials exhibited signs of ignition.

Permeability tests indicated that Teflon 30 is more permeable to N_2O_4 than Teflon TFE-7 and Teflon FEP under identical conditions.

A list of lubricants known to exhibit no visible sign of reaction with the Titan II propellants was compiled from information obtained at The Martin Company and Aerojet-General Corporation.

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SYMBOLS/ABBREVIATIONS

AFBMD	Air Force Ballistic Missile Division
AFBSD	Air Force Ballistic Systems Division
AFFTC	Air Force Flight Test Center
ASD	Aeronautical Systems Division
RMD	Reaction Motors Division of Thiokol Chemical Corporation
FUEL BLEND	Nominal 50/50 Blend by Weight of UDMH and N_2H_4 MIL-P-27402 (USAF)
50/50 FUEL BLEND	Nominal 50/50 Blend by Weight of UDMH and N_2H_4 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
UDMH	Unsymmetrical Dimethlhydrazine, Specification Grade MIL-D-25604B (ASG)
EPR	Ethylene-Propylene Rubber
LOX	Liquid Oxygen
cc	Cubic Centimeter(s)
MPY	Mils Per Year

SECTION I
INTRODUCTION

This program concerns the compilation of propellant data in support of the Titan II ballistic missile which utilizes nitrogen tetroxide (N_2O_4) as the oxidizer and a nominal 50/50 blend by weight of unsymmetrical dimethylhydrazine (UDMH) and hydrazine (N_2H_4) as the fuel.

The principal objective of this supplemental contract is to up-date the Titan II Storable Propellant Handbook published in March 1962 by the Bell Aerosystems Company for the Ballistic Systems Division (Report AFBSD-TR-62-2). As new information becomes available, it will be added to the handbook by means of supplemental pages.

This report contains information obtained from laboratory tests conducted at Bell Aerosystems during the period 2 April through 20 July 1962. Also included is a summary of the lubricants that are compatible with the Titan II propellants. This data was gathered during discussions with The Martin Company and with Aerojet-General Corporation.

SECTION II
MATERIALS COMPATIBILITY

Material compatibility tests with various metals and nonmetals are continuing during this supplemental effort. These tests are being conducted in a similar manner to those performed when this program was started in May 1961 (Reference 1). Information from the tests was used to rate the materials as to their compatibility with the Titan II propellants. An explanation of these ratings is presented in the Appendix of this report.

A. EFFECTS OF 50/50 FUEL BLEND ON METALS

Specimens of tungsten carbide (obtained from Union Carbide Metals Co., Niagara Falls, N.Y.), copper-aluminum (2014-T6) couple, and mercury-aluminum (2014-T6) couple were partly immersed in fuel blend at 160°F for a 90-day test. These samples have been in test for 46 days with no significant visual changes noted.

B. EFFECTS OF 50/50 FUEL BLEND ON NONMETALS

1. Plastics

Samples of DuPont's H-Film (proprietary) dissolved immediately on contact with the fuel blend. Samples of Amerplate (polyvinyl chloride obtained from Amercoat Corporation, Southgate, California) dissolved overnight in the fuel blend.

2. Dynamic Seal Tests

An existing dynamic seal test apparatus (Reference 2) was modified for testing butyl rubber seals in fuel blend at pressures of 100 psig and 500 psig at room temperature. This apparatus consists of a cylinder approximately 2 x 2 inches with a piston located in the center of a shaft. The piston shaft, which extends out of the ends of the cylinder, is sealed at either end with O-rings to be tested. The piston contained one O-ring seal. The three O-rings were lubricated with high-vacuum Dow Corning silicone grease. The linkage between the apparatus and the motor was fitted with a calibrated load cell to permit a recording of the force required to move the piston, feeding a signal to a pen recorder. Figure 1 is a photograph of the assembled unit prior to dynamic testing.

The assembled unit was pressurized with nitrogen gas to 100 psig and then to 500 psig to detect any gas leakage under static and dynamic conditions. The pressure was released and

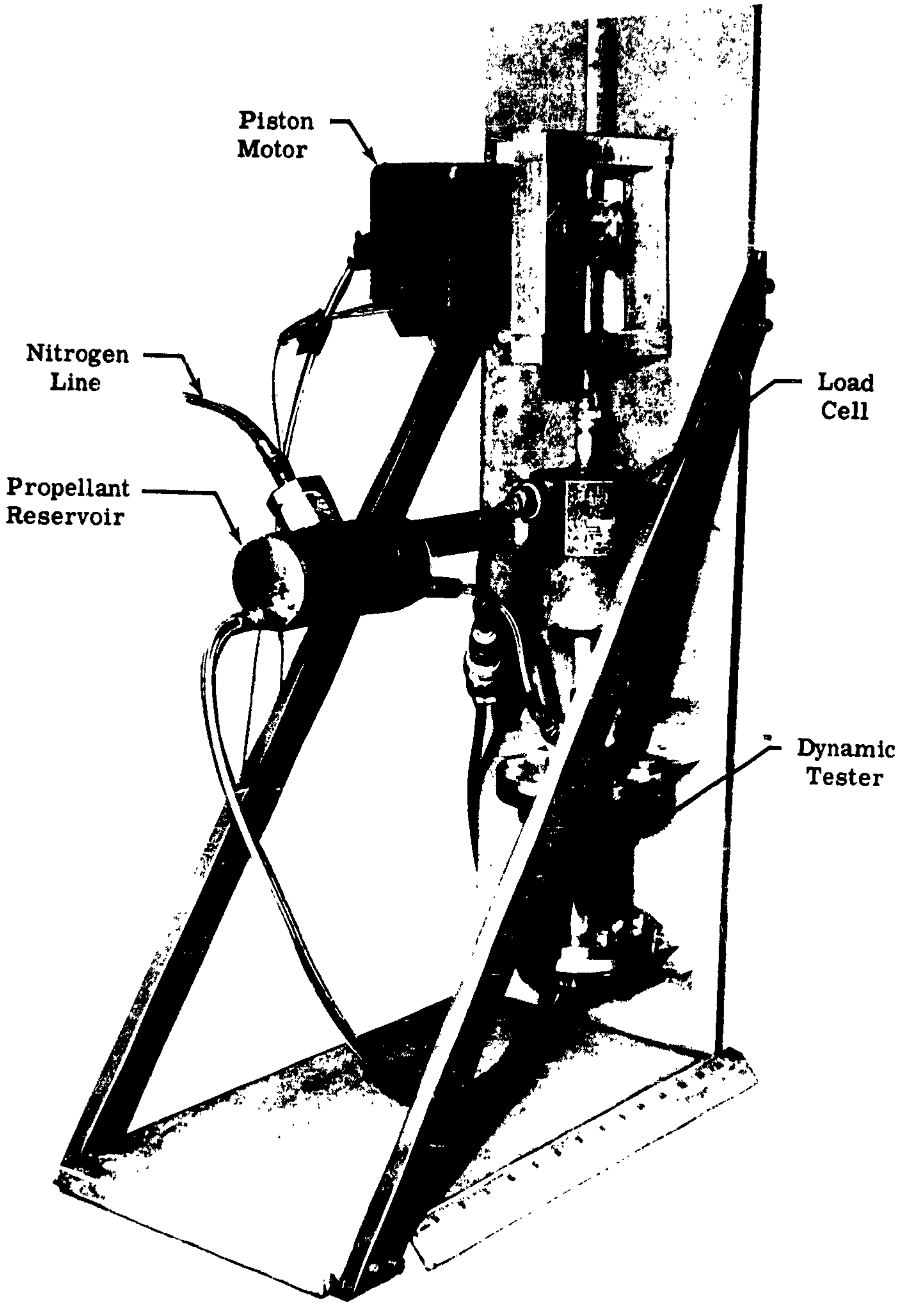

Figure 1. Dynamic Seal Test Unit

the reservoir was filled with fuel blend. The fuel blend was pressurized first to 500 psig and the unit was operated dynamically. The first 15 minutes of operation were utilized for adjusting to the final desired pressure. Load readings were recorded for 1 minute every 8 minutes. Each test was run for approximately 1000 cycles (approximately 5 hours). The interpretation of the data acquired was based upon the change in force required to move the piston during the test, the force required to move the piston after having set idle for several hours (overnight) at elevated pressures (break away force), and the condition of the shaft and O-ring seals after the test.

Dynamic tests were conducted on O-rings made from Parco 805-70 (butyl rubber from Plastics and Rubber Products Co., Los Angeles, California), Parker B496-7 (butyl rubber from Parker Seal Co., Cleveland, Ohio), and RMD Resistazine 74 (an ethylene-propylene rubber supplied by ASD). These tests were run in 50/50 fuel blend pressurized to 500 psig and 100 psig with nitrogen. The results are shown in Figure 2 as plots of force and pressure versus cycles. No abnormal changes occurred during the push and pull strokes of all the tests. The only significant force change (51 lb) occurred during the break away test at 500 psig with Parco 805-70; however, during the succeeding two cycles, the force required for the push and pull strokes returned to normal. Changes in pressure after standing overnight might be attributable to temperature changes.

No visible liquid leakage was detected during all the tests and no significant physical damage was noted in any of the O-rings after test. The Parco 805-70 O-rings increased 1.5%.

It is concluded that any of the elastomers tested may be used as dynamic seals with 50/50 fuel blend pressurized to at least 500 psig.

C. FIRE HAZARDS OF MATERIALS EXPOSED TO 50/50 FUEL BLEND

Tests were conducted at room temperature and one atmosphere to determine if MIL-L-7808D hydraulic oil, Brayco 718 oil (Bray Oil Co., Los Angeles, California), and black, vinyl electrical tape would constitute a fire hazard in the event of contact with the fuel blend.

The procedure used for testing these materials with the fuel blend is as follows. A 400-cc beaker was used to hold the test material and approximately 2 to 3 cc of the fuel blend were dripped on the test sample by means of a syringe. Observations were then made and any significant changes were noted for a minimum period of 1 hour. No ignition constituted the absence of a fire hazard under the test conditions.

The results of these tests are shown in Table 1. None of the materials tested exhibited signs of ignition.

Code	Description		Break Away	
			Force, lb	Pressure, psig
1	Parco 805-70	100 psig	22.5	100
2	Parco 805-70	500 psig	51	435
3	Parker B496-7	100 psig	27	160
4	Parker B496-7	500 psig	27	510
5	Resistazine 74	100 psig	15.8	108
6	Resistazine 74	500 psig	19.2	440

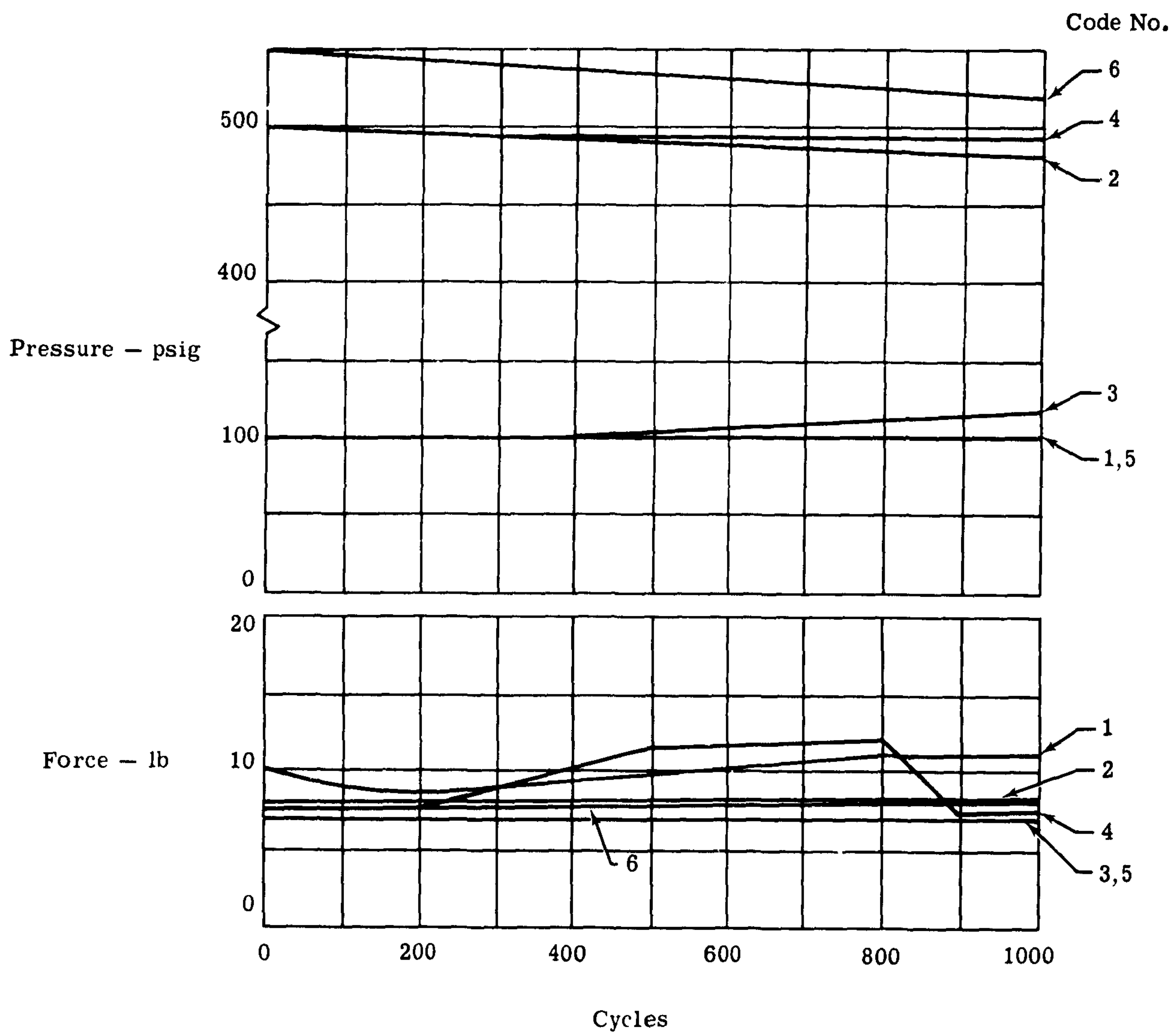

Figure 2. Dynamic Seal Test Results with 50/50 Fuel Blend

TABLE 1

FIRE HAZARD TESTS OF VARIOUS MATERIALS EXPOSED TO 50/50 FUEL BLEND AT ROOM TEMPERATURE

	Material	Observations
Liquids		
	7808D Oil	No ignition
	Brayco 718 Oil	No ignition
Solids		
	Black, vinyl electrical tape	No ignition

D. EFFECTS OF N_2O_4 ON METALS

Samples of tungsten carbide, copper-aluminum (2014-T6) couple, and mercury-aluminum (2014-T6) couple were partly immersed in N_2O_4 at 65°F for a 90-day test. Within 24 hours, the mercury-aluminum couple amalgamated and the test was discontinued. The other samples have been in test for 45 days with no significant visual changes noted.

E. EFFECTS OF N_2O_4 ON NONMETALS

1. Plastics

Samples of Amerplate were completely immersed in N_2O_4 at 65°F for 30 days. The material hardened and was given a "D" rating. The results are shown in Table 2.

2. Elastomers

Four ethylene-propylene rubber (EPR) specimens were completely immersed in N_2O_4 at 65°F. Industrial Electronic Rubber Company of Solon, Ohio, supplied samples of XE 105 (Montecatini EPR), E-612-2 (DuPont EPR), and E-622-2 (DuPont EPR). The Resistazine 74 (EPR) was supplied by ASD. The XE 105 and E-612-2 dissolved and became gummy in 4 days; the E-622-2 became gummy in 7 days and the Resistazine 74 crumbled in 17 days.

A butyl rubber, L823-1 (supplied by Industrial Electronic Rubber Company), became soft and gummy after 7 days immersion in N_2O_4 at 65°F.

The results of these tests are shown in Table 2.

3. Dynamic Seal Tests

An existing dynamic seal test apparatus (similar to that used for the fuel dynamic seal tests) was used for testing Omniseals (Teflon-covered seals with stainless steel spring inserts

TABLE 2

COMPATIBILITY OF NONMETALS WITH N_2O_4 AT 65°F

Propellant Quantity:	One fluid ounce per test tube.
Specimens:	ASTM D1457-56T die tensile bars or rectangular bars.
Number of Specimens:	Three per material in individual test tubes.
Condition:	Full immersion - static.
Apparatus:	Pressure-tight, screw-top, aluminum-foil-gasketed, culture test tubes.
Data:	Average of three specimens.

Material	Time In Days	Shore Hardness Control	Tensile Ksi Control	% Elong. Control	Before Outgassing % Wt Change	Before Outgassing % Vol Change	After Outgassing Shore Hardness	After Outgassing Tensile Ksi	After Outgassing % Elong.	After Outgassing % Wt Change	After Outgassing % Vol Change	Rating (a)	Remarks
PLASTIC													
Amerplate	30	50-60 D	2.42	242	+11.87	-1.15	76D	3.86	52	-16.48	-7.08	D	-
ETHYLENE-PROPYLENE RUBBERS													
XE 105	4	-	-	-	-	-	-	-	-	-	-	D	Soft & Gummy
E-612-2	4	-	-	-	-	-	-	-	-	-	-	D	Dissolved
E-622-1	7	-	-	-	-	-	-	-	-	-	-	D	Soft & Gummy
Resistazine 74	17	-	-	-	-	-	-	-	-	-	-	D	Crumbled
BUTYL RUBBER													
L 823-1	7	-	-	-	-	-	-	-	-	-	-	D	Soft & Gummy

(a) - Definitions of ratings are given in the Appendix of this report.

obtained from Reid Enterprises Inc., Long Beach, California). This tester is illustrated in Figure 3 and is described in Reference 3.

These seals were previously tested at 100 psig (Reference 3). As part of this program, the seals were to be tested at 500 psig and repeated at 100 psig. After the seals were mounted and the N_2O_4 was loaded, the pressure was gradually increased in 10-pound increments. At approximately 50 psig, the piston seals leaked and subsequent examination of these seals revealed no damage. The unit was again assembled and the test was repeated with the same results.

Upon contacting the seal vendor, it was learned that the seals did not contain the double-spiralled stainless steel spring inserts specified for use at elevated pressures. New samples will be sent to Bell and the tests will be repeated.

4. Permeability Tests

Permeability tests were performed with Teflon 30 (an aqueous dispersion of Teflon TFE made by Minnesota Mining and Manufacturing Co.) to compare the results with the transmission rates of Teflon FEP and Teflon TFE-7 in N_2O_4. These tests were conducted at room temperature and later corrected to 32°F.

The test procedure used was based upon an ASTM procedure (D1434-58). The test apparatus shown in Figure 4 was modified to fill the requirements of the propellant with respect to compatible materials. A description of the apparatus appears in Reference 3.

The transmission rates were obtained for air at one atmosphere differential pressure and for N_2O_4 at 16 to 17 psia differential pressure. Permeability data for Teflon FEP and Teflon TFE-7 is repeated in Table 3 for comparison with the data obtained with Teflon 30. The results indicate that Teflon 30 is the most permeable to both air and N_2O_4.

TABLE 3

PERMEABILITY DATA FOR VARIOUS TEFLONS

Teflon Specimen	Thickness (Mils)	Density at 82°F (gm/cc)	Transmission Rate (cc/100 in.^{2}/24 hr) Air	N_2O_4
TFE-7	10.0	2.186	20.0	275.9
FEP	10.6	2.138	30.0	81.8
30	10.0	2.168 (av)	88.3	592.6

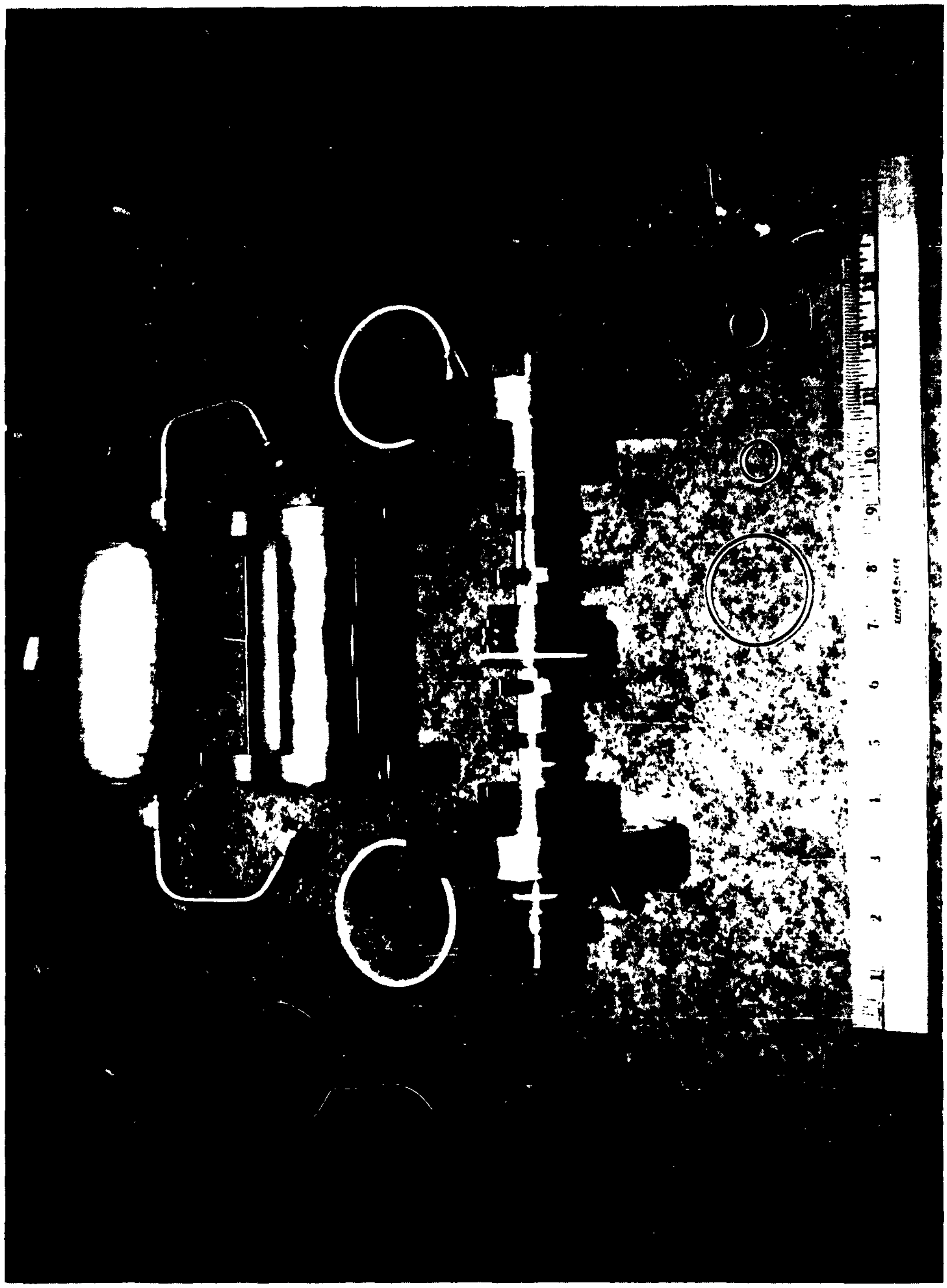

Figure 3. Disassembled Dynamic Seal Tester

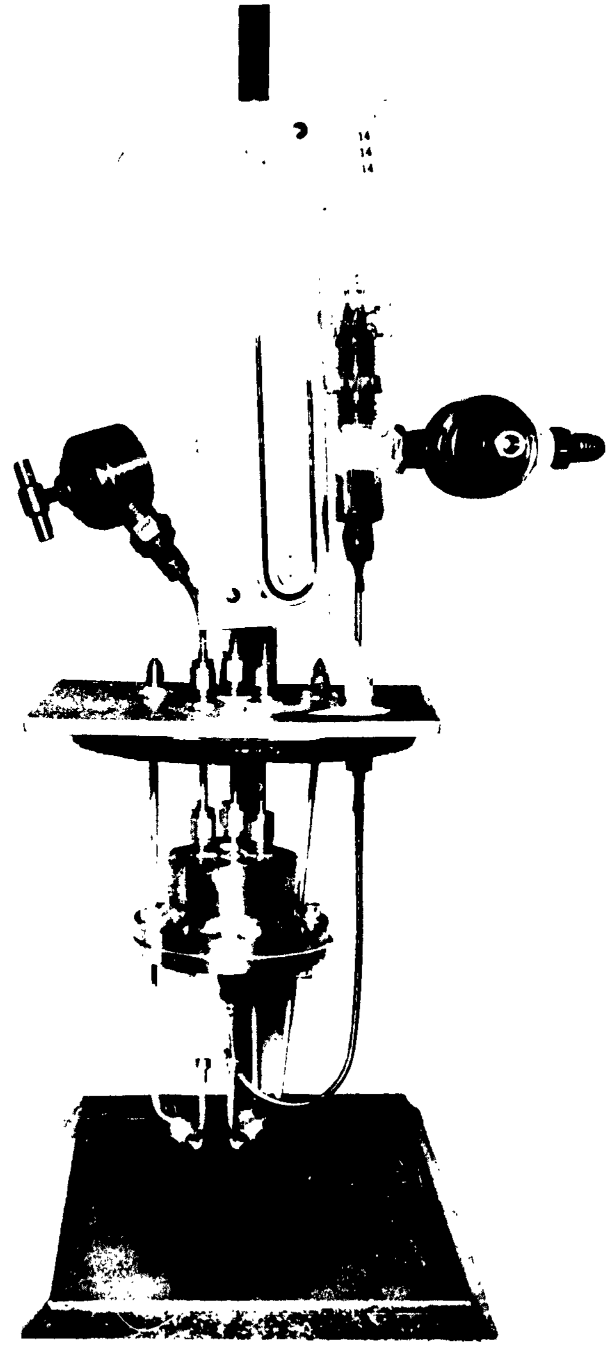

Figure 4. Apparatus for Measuring Permeability Rates of N_2O_4 Through Teflon

F. FIRE HAZARDS OF MATERIALS EXPOSED TO N_2O_4

1. Liquids

Fire hazard tests were conducted at room temperature and at one atmosphere with MIL-L-7808D hydraulic oil and Brayco 718 oil exposed to drops of N_2O_4. The test procedure is outlined in Reference 3.

Briefly, the procedure consists of dripping 2 to 3 cc of N_2O_4 on the liquids in a 3-inch diameter watchglass. Liquids which showed any indication of reaction were tested further. The first test consisted of dripping N_2O_4 on the surface of the liquid sample contained in a small cylindrical glass container 2.5 inches long and 1 inch in diameter. A second test consisted of introducing the N_2O_4 beneath the surface of the liquid. Temperature increases were measured with a mercury thermometer.

The results of these tests are shown in Table 4. None of the liquids gave indications of ignition.

2. Solids

Fire hazard tests were conducted at room temperature and at one atmosphere with black, vinyl electrical tape exposed to drops of N_2O_4 and soaks in N_2O_4.

Briefly, the procedure consists of dripping N_2O_4 on the sample and observing the results for a minimum of 1 hour. Also, the specimen was soaked in N_2O_4 for 20 seconds and then allowed to gas off for a minimum of 1 hour on a 3-inch diameter watchglass.

The vinyl tape did not ignite during these tests (see Table 4).

TABLE 4

FIRE HAZARD TESTS OF MATERIALS EXPOSED TO N_2O_4 AT ROOM TEMPERATURE

Material	Observations	
Liquids		
7808D oil	No ignition, turned cloudy, opaque liquid, no significant temperature rise	
Brayco 718 oil	No ignition, no temperature rise, changed from green to brown, remained fairly transparent	
Solids	Soak Test	Drip Test
Black, vinyl electrical tape	No ignition	No ignition

G. EFFECTS OF PROPELLANTS ON LUBRICANTS

A visit was made to The Martin Company of Denver, Colorado, and to Aerojet-General Corporation of Sacramento, California, to gather information on the compatibility of lubricants with the Titan II propellants.

The selection of a group of lubricants that is compatible with the Titan II propellants poses a problem owing to the lack of a generally accepted definition of "compatible." Different criteria have been established by the two contractors most intimately associated with the Titan II propellants, Martin and Aerojet-General. Their criteria, however, while different from the standpoint of exposure time, accomplish the same end, in that they are short-term screening tests with rejection or approval based upon visual examination. Therefore, the material listed in Table 5 can only be considered as having no visible reaction with the propellants for test periods of from 1 to 24 hours; in no way does the table indicate the acceptability of these materials in terms of lubricating characteristics either before or after propellant exposure.

The following criteria were used in the screening of lubricants.

1. Fuel Blend
   a. Martin
      (1) Immerse in fuel blend for 1 hour.
      (2) Observe for an indication of a reaction between the sample and the fuel blend. Note any changes in either sample or fuel blend.
   b. Aerojet-General
      (1) Immerse in fuel blend for 24 hours.
      (2) Observe for an indication of a reaction between the sample and the fuel blend. Note any changes in either sample or fuel blend.
2. N_2O_4
   a. Martin
      (1) Immerse in a 70% nitric acid solution for 1 hour.
      (2) Observe the effect of the acid on the lubricant.
      (3) Expose the sample coated with the lubricant to a high concentration of N_2O_4 fumes and moisture for 1 hour.
      (4) Observe the effect of the N_2O_4 on the lubricant.

b. Aerojet-General

(1) Immerse in N_2O_4 for 24 hours.

(2) Observe for an indication of a reaction between the sample and the N_2O_4. Note any changes in either sample or the N_2O_4.

Even with the difference in screening tests used by Martin and Aerojet, the results agreed with few exceptions. Martin pointed out that, when selecting a lubricant, consideration should also be given to the lubricant's LOX impact sensitivity. This is often required if a component utilizing the lubricant must be assembled in a clean room, also used for cleaning and assembling components for liquid oxygen service.

Because hydraulic oils are not really considered as lubricants, no data was collected on these fluids. However, lubricating oils were examined, inasmuch as there is a requirement for their use in the engine gearbox. The criteria associated with the compatibility of the lubricating oil are somewhat different than those utilized in selecting the list of lubricants in Table 5. These criteria were established by Aerojet-General:

(1) The oil must be compatible with MIL-L-7808D.

(2) When mixed with equal parts of either fuel blend or N_2O_4, there must be no temperature rise and no evidence of precipitation over a period of 24 hours.

A naphthene-base oil which meets these requirements is designated Aerospace Gear Oil 61R-717. This oil is available from California Research Corporation.

TABLE 5

LUBRICANTS COMPATIBLE WITH TITAN II PROPELLANTS[a]

Material	Vendor	Compatible With Fuel Blend	Compatible With N_2O_4	Remarks
Greases				
Braycote 660 AMS	Bray Oil Co. Los Angeles, California	See Remarks	Yes	Suitable for fuel blend splash and fume exposure. However, not recommended for extended fuel exposure, particularly in a confined area, due to slow catalytic decomposition of the fuel.
Royco 60 AMS	Royal Lubricants Hanover, New Jersey	See Remarks	Yes	Suitable for fuel blend splash and fume exposure. However, not recommended for extended fuel exposure, particularly for a confined area, due to slow catalytic decomposition of the fuel.
Apiezon L[b]	Shell Chemical Co. San Francisco, California	Yes	Yes	
DC 11[b]	Dow Corning Corp. Midland, Michigan	Yes	Yes	Deteriorated in N_2O_4 after 7 to 10 days.
DC 55[b]	Dow Corning Corp. Midland, Michigan	Yes	Yes	Deteriorated and washed out in N_2O_4 within 7 to 10 days.
XC 150[b]	Dow Corning Corp. Midland, Michigan	Yes	Yes	
DC High Vacuum[b]	Dow Corning Corp. Midland, Michigan	Yes	Yes	Some washout.

(a) Since compatibility is the only criterion considered, this list should in no way be construed as an endorsement of these materials in terms of lubricating characteristics. Compatibility is based upon visual examination after exposure ranging from 1 to 24 hours.

(b) May be LOX impact sensitive.

TABLE 5 (CONT)

LUBRICANTS COMPATIBLE WITH TITAN II PROPELLANTS

Material	Vendor	Compatible With Fuel Blend	Compatible With N_2O_4	Remarks
Greases (cont)				
Valve Seal A(b)	Dow Corning Corp. Midland, Michigan	Yes	Yes	Some washout.
Kel F 90	Minnesota Mining & Mfg. Co. St. Paul, Minnesota	No	Yes	
Fluorolube MG 600	Hooker Electrochemical Co. Niagara Falls, New York	No	Yes	
Fluorothene G	Hooker Electrochemical Co. Niagara Falls, New York	No	Yes	
Halocarbon Grease	Halocarbon Products Corp. Hackensack, New Jersey	No	Yes	
Dry Lubricants				
Flake Graphite	J. Dixon Crucible Co. Jersey City, New Jersey	Yes	Yes	Easily washed out.
Drilube 7, Type A(b)	Drilube Corporation Glendale, California	See Remarks	Yes	Suitable for fuel blend splash and fume exposure. However, not recommended for extended fuel exposure, particularly in a confined area, due to slow catalytic decomposition of the fuel.
Drilube 1, Type B	Drilube Corporation Glendale, California	See Remarks	Yes	Suitable for fuel blend splash and fume exposure. However, not recommended for extended fuel exposure, particularly in a confined area, due to slow catalytic decomposition of the fuel.

(b) May be LOX impact sensitive.

TABLE 5 (CONT)

LUBRICANTS COMPATIBLE WITH TITAN II PROPELLANTS

Material	Vendor	Compatible With Fuel Blend	Compatible With N_2O_4	Remarks
Dry Lubricants (cont)				
M8800, Type A[b]	Alpha-Molykote Corporation Stanford, Connecticut	See Remarks	Yes	Suitable for fuel blend splash and fume exposure. However, not recommended for extended fuel exposure, particularly in a confined area, due to slow catalytic decomposition of the fuel.
X106, Type B	Alpha-Molykote Corporation Stanford, Connecticut	Yes	Yes	
X15, Type C	Alpha-Molykote Corporation Stanford, Connecticut	Yes	Yes	Soluble in warm alkaline water.
Molykote Z	Alpha-Molykote Corporation Stanford, Connecticut	See Remarks	Yes	Suitable for fuel blend splash and fume exposure. However, not recommended for extended fuel exposure, particularly in a confined area, due to slow catalytic decomposition of the fuel.
Microseal 100-1[b]	Microseal Products Sales Torrance, California	Yes	Yes	
Thread Lubricants and Sealants				
LOX Safe[b]	Redel Corporation Anaheim, California	See Remarks	Yes	Suitable for fuel blend splash and fume exposure. However, not recommended for extended fuel exposure, particularly in a confined area, due to slow catalytic decomposition of the fuel.

(b) May be LOX impact sensitive.

TABLE 5 (CONT)

LUBRICANTS COMPATIBLE WITH TITAN II PROPELLANTS

Material	Vendor	Compatible With Fuel Blend	Compatible With N_2O_4	Remarks
Thread Lubricants and Sealants (cont)				
Reddy Lube 100[b]	Redel Corporation Anaheim, California	Yes	Yes	
Reddy Lube 200[b]	Redel Corporation Anaheim, California	Yes	Yes	
Teflon Tape (unsintered)	Permacel, Le Page's Inc. New Brunswick, New Jersey	Yes	Yes	Preferred over all others.
Drilube 822	Drilube Corporation Glendale, California	Yes	Yes	Deteriorated slightly in N_2O_4 and discolored the fuel in 7 to 10 days.
Drilube 842	Drilube Corporation Glendale, California	Yes	Yes	Discolored in contact with N_2O_4. Discolored the fuel blend and experienced some washout within 7 to 10 days.
Oxylube Sealant[b]	Drilube Corporation Glendale, California	No	Yes	

(b) May be LOX impact sensitive.

SECTION III

REFERENCES

1. AFBMD, "Storable Propellant Data for the Titan II Program," Bell Aerosystems Company, Progress Report, AFBMD TR-61-55, July 1961.

2. AFFTC, Edwards Air Force Base, "Research and Development of the Basic Design of Storable High-Energy Propellant Systems and Components," Bell Aerosystems Company, Final Report, AFFTC TR-60-61, May 1961

3. AFBSD, "Storable Propellant Data for the Titan II Program," Bell Aerosystems Company, Second Progress Report, AFBSD TDR-62-6, March 1962.

APPENDIX

DEFINITION OF RATINGS GIVEN TO MATERIALS FOR USE WITH PROPELLANTS

METALS

A: These metals are suitable for unrestricted use with propellants. The corrosion rates are less than 1 MPY. Typical uses are storage containers and valves where the propellant is in constant contact.

B: These metals are for restricted use such as transient or limited contact. The corrosion rates are a maximum of 5 MPY. Typical uses are for valves and lines on aerospace ground equipment, for hardware which contacts the propellant intermittently in the liquid and vapor phases, and for pumps and feed lines in which the residence time is limited to loading and unloading.

C: These metals have limited resistance, and corrosion rates are between 5 and 50 MPY. Typical use is where the metals are exposed to spillage and momentary contact, such as test stand hardware and aerospace ground equipment. Also, these metals have application where corrosion can be tolerated to the extent that it will not affect functional operations.

D: These metals are not recommended for use because their corrosion rates exceed 50 MPY and/or they cause propellant decomposition.

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 reviewed specifications, the following ratings were derived for the nonmetals.

(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

Ratings	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.