NASA TECHNICAL MEMORANDUM

Report No. 53846

AN INSTRUMENT FOR THE DETERMINATION OF IMPACT SENSITIVITY OF MATERIALS IN CONTACT WITH GASEOUS OXYGEN AT PRESSURES UP TO 50 PSIA

(NASA-TM-X-53846) AN INSTRUMENT FOR THE DETERMINATION OF IMPACT SENSITIVITY OF MATERIALS IN CONTACT WITH GASEOUS OXYGEN AT PRESSURES UP TO 50 PSIA (NASA) 16 p
N74-76468
Unclas
00/99 48486
AND CONTRACTORS ONLY

May 21, 1969

NASA

George C. Marshall Space Flight Center

Marshall Space Flight Center, Alabama

MSFC - Form 3190 (September 1968)

14

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. NASA TM X-53846	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle An Instrument for the Determination of Impact Sensitivity of Materials in Contact with Gaseous Oxygen at Pressures up to 50 PSIA		5. Report Date May 21, 1969
		6. Performing Organization Code
7. Author(s) C. F. Key		8. Performing Organization Report No.
9. Performing Organization Name and Address George C. Marshall Space Flight Center Marshall Space Flight Center, Alabama 35812		10. Work Unit No.
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address		13. Type of Report and Period Covered NASA Technical Memorandum
		14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

An apparatus developed by Marshall Space Flight Center for use in determining the compatibility of materials in gaseous oxygen pressurization systems is described. The MSFC impact tester provides flexibility of testing conditions and reproducible results. Test results illustrating variables which must be controlled in gaseous oxygen impact testing are also presented.

17. Key Words	18. Distribution Statement CSTAR, Requests must be approved by the author

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
U	U	13	

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AN INSTRUMENT FOR THE DETERMINATION OF IMPACT SENSITIVITY OF MATERIALS IN CONTACT WITH GASEOUS OXYGEN AT PRESSURES UP TO 50 PSIA

SUMMARY

An apparatus developed by Marshall Space Flight Center for use in determining the compatibility of materials in gaseous oxygen pressurization systems is described. The MSFC impact tester provides flexibility of testing conditions and reproducible results. Test results illustrating variables which must be controlled in gaseous oxygen impact testing are also presented.

INTRODUCTION

Liquid and gaseous oxygen are the most important oxidizers in the space program. Pure liquid or gaseous oxygen is stable and not subject to detonation by mechanical shock, but mixtures with most organic materials and certain inorganic materials will ignite or explode under conditions of impact and other stimuli. There have been many reported incidents involving gaseous oxygen (GOX) systems.

Marshall Space Flight Center has used the requirements of MSFC-SPEC-106B in all LOX and GOX systems during the past 14 years. While impact or mechanical energy is the basis for these test methods, other forms of energy are capable of triggering these mixtures. These forms of energy can arise from unforeseen, unpredictable, and sometimes unknown sources. The mere fact that an unsatisfactory component or material in a liquid or gaseous oxygen system is not expected to encounter impact energy at the location where it is to function cannot justify its use. The device for transmitting impact energy was favored for this test program because it is basically the simplest method of transmitting a measurable amount of energy to a test fixture. However, questions always arise about the severity of testing in LOX for materials used only in GOX pressurization and supply systems. This program was initiated to study the impact sensitivity of materials in GOX and to compare the relative rating of these materials with results obtained in LOX.

THEORETICAL

It is generally accepted that the high temperatures resulting from nearly adiabatic compression are the cause of ignition in an impact tester. These conditions can also be obtained from the rapid pressurization of a line. The theoretical temperature obtained by adiabatic compression can be calculated by using the following equation:

$$\frac{T_f}{T_i} = \left(\frac{P_f}{P_i}\right)^{\left(\frac{n-1}{n}\right)}$$

where:

P_i = initial pressure

T_i = initial temperature

P_f = final pressure

T_f = final temperature

n = C_p/C_v (specific heat ratio) (1.4 for oxygen)

$$\frac{T_f}{T_i} = \left(\frac{P_f}{P_i}\right)^{\frac{1.4-1}{1.4}} = \left(\frac{P_f}{P_i}\right)^{0.286}$$

Assume an initial pressure of 14.7 psia and an initial temperature of 20°C (293°K)

$$T_f = 293\left(\frac{P_f}{14.7}\right)^{0.286}$$

therefore, the relationship of final pressure to final temperature is shown below.

P_f (psia)	Temperature	
	T_f, °K	T_f, °C
100	506	233
400	761	488
800	922	649
1200	1036	763
2000	1199	926
4000	1455	1182

It is obvious from the above that rapid pressurization of lines with GOX may generate high temperatures. These temperatures are sufficient to ignite a large number of materials.

This report describes in some detail the design and operation of the GOX tester. Comparison of test results with those obtained with the ABMA LOX tester are also presented.

DESCRIPTION OF TESTER

The GOX tester consists of the basic ABMA LOX tester assembly with a pressurized sample holder. The tester is designed to allow a 20-pound plummet to fall through a distance of 43.3 inches. The maximum deviation from free fall allowed is 3 percent. The plummet lands upon the striker pin, protruding from the sample holder. Figure 1 shows details and orientation of striker pin and sample. The basic instrument as shown in Figures 1 and 2 consists of a plummet guided in its vertical fall by two sets of bearings, one set at each end of the plummet. The bearings arranged at the vertices of equilateral triangles roll freely in tracks milled in steel bars. These tracks are bolted rigidly to steel tubing supports and are accurately aligned with shims so that even contact with the ball bearings is maintained at all points along the length of the track. The supports are securely anchored to the top and base plate. The 1-inch thick base plate is anchored in a 1-foot cube of concrete.

PROCEDURE FOR TEST EVALUATIONS

The nature of the sample determines the manner in which it is prepared for testing. Solids and sheet materials are cut into 3/4-inch squares. Oils, greases, and other semi-solids are tested as smears in the bottom of the sample holder.

It is imperative that the sample holder be clean. After each test, the sample holder is dismantled and cleaned with a pure chlorinated hydrocarbon solvent. A clean striker pin is used for each test. The face of the striker pin must be free of pits and scratches. The pin is cleaned by vapor degreasing and alkaline cleaner soak, followed by rinsing in water. A precleaned sample is placed in the test chamber. The cap is placed on the test chamber and bolted. The striker pin is positioned in place, 1/4-inch from the horizontal surface of the sample. The system is purged for 10 minutes, after which the chamber is pressurized to 50 psia. The operator releases the plummet and observes any evidence of reaction.

RESULTS

The results, tabulated in Table I, indicate a good general correlation with liquid oxygen impact sensitivity data [1,2,3,4]; however, the reaction frequency is less on most compounds evaluated. This phenomenon can be readily explained since the GOX tests are conducted at room temperature, the cushioning effect would be greater than at LOX temperature. Another interesting departure from most liquid oxygen impact test data is that the frequency of reaction varied directly with thickness with the four compounds evaluated. This most likely is a direct result of the heat generated by impacting a thin sample being dissipated to surrounding metal and the melting of the sample before it can reach the autoignition temperature.

CONCLUSIONS

The Marshall Space Flight Center and others have used materials, found LOX compatible per MSFC-SPEC-106B, for 14 years in low and high pressure oxygen systems. Based on this experience with no known incident and the results of this study, MSFC will continue to use the LOX impact results to recommend materials for low and high pressure oxygen systems. However, MSFC will continue to study the reactivity of materials in contact with low and high pressure oxygen. Currently under checkout is a new pressure chamber with the capability of obtaining pressures up to 1500 psia. The results of this study will be reported upon completion of the program.

TABLE I. IMPACT SENSITIVITY OF MATERIALS IN GASEOUS OXYGEN

Material	Manufacturer or Source	Thickness, (Inch)	Potential Energy kg-m	No. Reactions/ No. Tests	Comments
Aluminum Grease Cups		0.035	10	0/20	
Andox C Grease		0.003	10	16/20	6 SBs*
Cycolac LT-1000	Marbon Chemical Corporation	0.080	10	16/20	6 SBs
Cycolac LT-1000	Marbon Chemical Corporation	0.060	10	18/20	7 SBs
Cycolac LT-1000	Marbon Chemical Corporation	0.050	10	20/20	12 SBs
Cycolac LT-1000	Marbon Chemical Corporation	0.040	10	19/20	14 SBs
Cycolac LT-1000	Marbon Chemical Corporation	0.030	10	17/20	11 SBs
Cycolac LT-1000	Marbon Chemical Corporation	0.020	10	4/20	4 SBs
Cycolac LT-1000	Marbon Chemical Corporation	0.010	10	2/20	3 SBs
CPR-385-2	Upjohn Company	0.250	10	0/20	
DC-33 Grease, Lot M356	Dow Corning Corporation	0.050	10	2/20	
Ethylene Propylene Rubber		0.070	10	2/20	
FS-1265 Fluid, 300 cs	Dow Corning Corporation	0.025	10	1/20	Flash
FS-1281	Dow Corning Corporation	0.050	10	0/20	
Fluorel Sponge 1062	Mosite Rubber Company	0.200	10	0/20	
Grex Polyolefin	Grace Chemical Company	0.080	10	40/40	10 SBs
Grex Polyolefin	Grace Chemical Company	0.060	10	16/20	7 SBs
Grex Polyolefin	Grace Chemical Company	0.050	10	12/20	9 SBs
Grex Polyolefin	Grace Chemical Company	0.040	10	9/20	7 SBs
Grex Polyolefin	Grace Chemical Company	0.030	10	7/20	4 SBs
Grex Polyolefin	Grace Chemical Company	0.020	10	4/20	3 SBs
Grex Polyolefin	Grace Chemical Company	0.010	10	4/20	3 SBs

* SB - Sustained Burning

TABLE I. IMPACT SENSITIVITY OF MATERIALS IN GASEOUS OXYGEN (Continued)

Material	Manufacturer or Source	Thickness, (Inch)	Potential Energy kg-m	No. Reactions/ No. Tests	Comments
H-4001		0.080	10	8/20	Flashes
H-4001		0.060	10	10/20	6 SBs
H-4001		0.050	10	11/20	6 SBs
H-4001		0.040	10	11/20	8 SBs
H-4001		0.030	10	8/20	6 SBs
H-4001		0.020	10	5/20	3 SBs
H-4001		0.010	10	6/20	5 SBs
Houghton Safe 1120		0.003	10	8/20	4 SBs
LS-53 Fluorosilicone	Dow Corning Corporation	0.062	10	4/25	
L-3251 Fluorel	Raybestos-Manhattan, Incorporated	0.080	10	0/20	
Mylar Tape 49133	Minnesota Mining & Manufacturing Company	0.003	10	2/20	1 SB
Mystic Tape		0.003	10	4/20	4 SBs
Narmco 7343		0.050	10	20/20	1 SB
Neoprene		0.040	10	4/20	1 SB
Neoprene Coated Nylon	Manned Spacecraft Center	0.010	10	2/20	1 SB
Neoprene Gasket		0.100	10	2/10	2 SBs
Plexiglass		0.063	10	0/20	
Reschal Net		0.035	10	2/3	16.7 psia
Silicone Fabric 10470	Manned Spacecraft Center	0.110	10	1/20	
Silicone Hose (Wire)	Manned Spacecraft Center	0.110	10	0/20	

TABLE I. IMPACT SENSITIVITY OF MATERIALS IN GASEOUS OXYGEN (Concluded)

Material	Manufacturer or Source	Thickness, (Inch)	Potential Energy kg-m	No. Reactions/ No. Tests	Comments
Silicone S1-503, White	Manned Spacecraft Center	0.110	10	1/20	1 SB
Silicone Rubber RTV-60	Manned Spacecraft Center	0.075	10	0/20	
Solder, 60% Tin-40% Lead		0.025	10	0/20	
Stainless Steel 347		0.063	10	0/20	
Tape #65	Minnesota Mining & Manufacturing Company	0.003	10	0/20	Burnt Odors
Teflon	Cadillac Plastic Company	0.010	10	0/20	
Teflon Sheet	E. I. du Pont de Nemours & Company	0.010	10	1/21	
T-Film Thread Compound		0.002	10	2/20	
Thermal Barrier, SRGA-0213		0.010	10	7/20	
Tenite II		0.080	10	18/20	2 SBs
Tenite II		0.060	10	14/20	5 SBs
Tenite II		0.050	10	18/20	17 SBs
Tenite II		0.040	10	20/20	20 SBs
Tenite II		0.030	10	20/20	20 SBs
Tenite II		0.020	10	5/20	3 SBs
Tenite II		0.010	10	0/20	
Tenite II		0.005	10	0/20	
Velcro Nylon Pile and Hook on Aluminum Disc		0.200	10	1/4	1 SB, 16.7 psia
Vespel Discs, Batch SRB-184	E. I. du Pont de Nemours & Company	0.050	10	0/20	
Viton A		0.070	10	1/20	1 SB
Zirconium		0.063	10	15/20	12 SBs

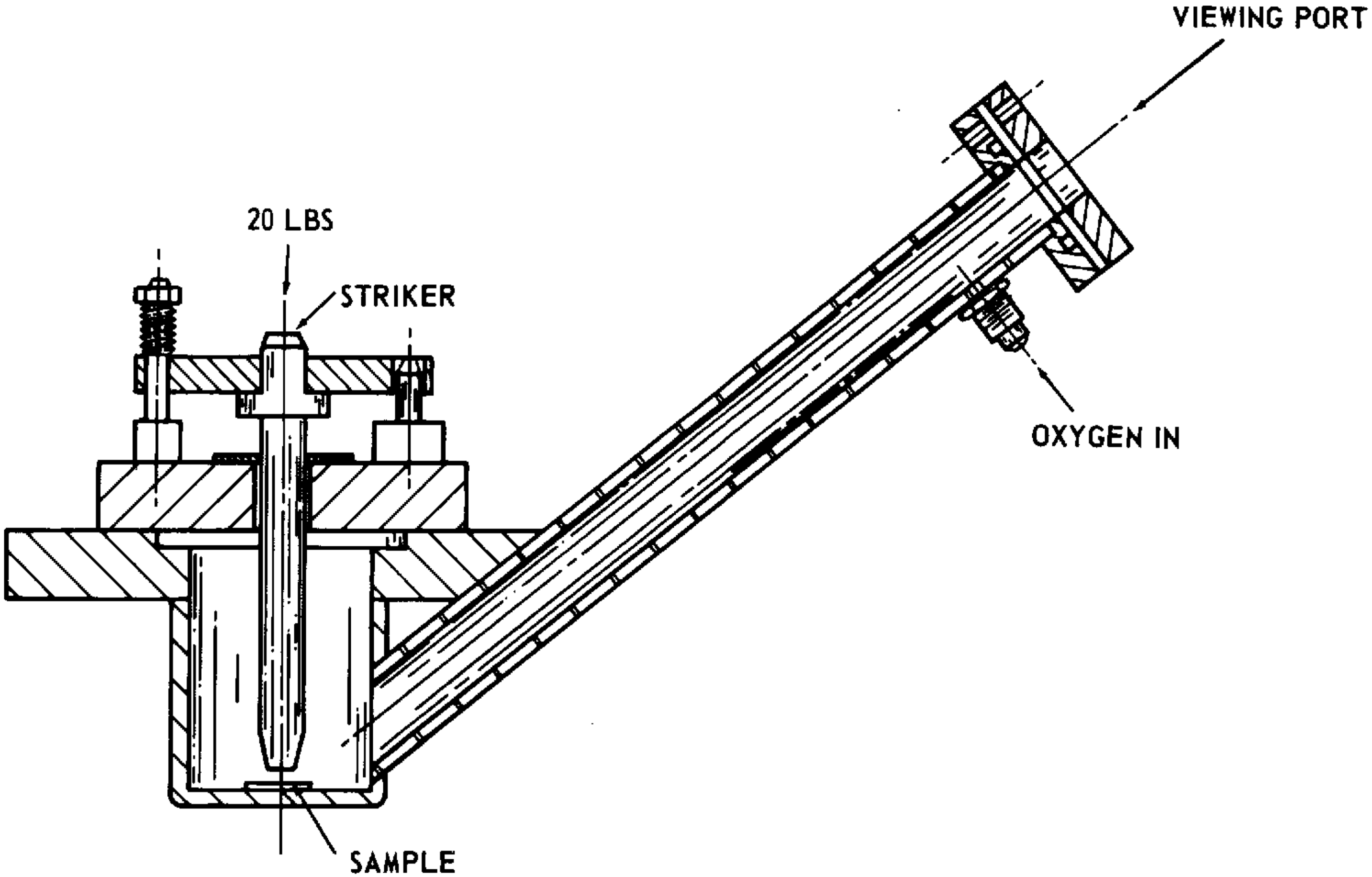

FIGURE 1. GOX IMPACT TESTER,SIDE VIEW

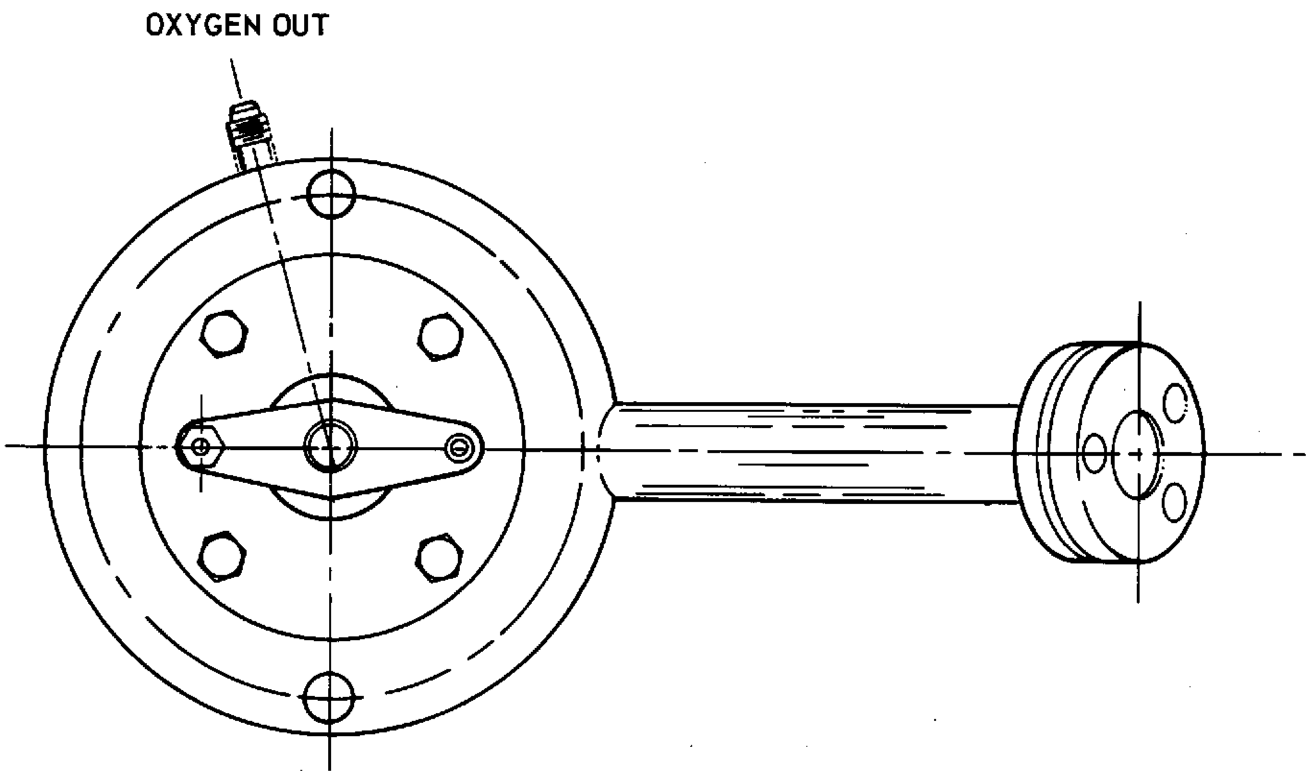

FIGURE 2. GOX IMPACT TESTER, TOP VIEW

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May 21, 1969 NASA TM X-53846

APPROVAL

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By

C. F. Key

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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