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REPRODUCIBILITY OF LIQUID OXYGEN IMPACT TEST RESULTS

J. B. Gayle

John F. Kennedy Space Center
Kennedy Space Center, Fla. 32899

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J. B. Gayle

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Results for 12 000 impacts on a wide range of materials were studied to determine the reproducibility of the liquid oxygen impact test method. Standard deviations representing the overall variability of results were in close agreement with the expected values for a binomial process. This indicates that the major source of variability is due to the "go - no go" nature of the test method and that variations due to sampling and testing operations were not significant.

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By J. B. Gayle
John F. Kennedy Space Center

INTRODUCTION

Under suitable conditions, oxygen reacts violently with a wide range of materials. Methods for assessing the hazard of any given oxygen/material combination are therefore essential for the design and operation of equipment and facilities used in the manufacture, storage, transportation, and utilization of oxygen.

Although many testing methods have been developed, probably the most widely accepted is the liquid oxygen (LOX) impact test in which specimens are subjected to mechanical impact while submersed in LOX. The most common version of this test, developed by Lucas and Riehl (ref. 1), was originally known as the Army Ballistic Missile Agency (ABMA) Impact Sensitivity Test. Today, three similar test methods are widely used: (1) NASA MSFC-SPEC-106-B, (2) AF Specification Bulletin 527, and (3) ASTM Test for Compatibility of Materials with Liquid Oxygen, D-2512-70.

As an aid to the reader, where necessary the original units of measure have been converted to the equivalent value in the Système International d'Unités (SI). The SI units are written first, and the original units are written parenthetically thereafter.

DISCUSSION

During the past 16 years, approximately 250 000 individual test drops on more than 2000 different materials have been conducted by NASA in accordance with MSFC-SPEC-106-B. This test procedure consists of imparting a known amount of energy from an essentially free falling plummet to a striker pin that rests directly on a test specimen immersed in LOX. The test is relatively simple, and the impact energy is easily controlled by varying the drop heights of the plummet. In most instances, a 9.09-kilogram plummet (20 pounds) is dropped from a height of 1.1 meters (3.7 feet) onto a striker pin with a 1.27-centimeter diameter (0.5 inch), thereby imparting an impact energy of 7.72×10^5 J/m^2 (10 kilogram-meters) to the test specimen immersed in LOX. The occurrence of a reaction is indicated by (1) an audible report, (2) a visible flash (in a darkened room), or (3) burning or charring of the specimen, or any combination of these three. Because each drop or trial either results in a reaction or does not, impact tests belong to the general category of "all-or-none" or "go - no go" type tests that can result in only one of two possible outcomes. The test is normally repeated several times, and the percent of total trials yielding a particular outcome is reported.

The impact and other "all-or-none" type tests possess the characteristic features of a binomial process. The observed reproducibility of results should therefore reflect the inherent variability of a binomial process and any contributions associated with the sampling and testing operations. This inherent variability may be represented by the standard deviation of a binomial process which depends on the distribution of outcomes and the number of trials as follows:

$$\overline{\sigma}_{\text{binomial}} = \sqrt{\frac{p\,q}{n}} \qquad (1)$$

where

p = percent of one outcome

q = (100-p) = percent of other outcome

n = number of trials

$\overline{\sigma}_{\text{binomial}}$ = expected standard deviation of a binomial process

To obtain direct experimental information on the variability of the test, results were pooled for 121 groups of data, each including five sets of 20 impacts on replicate samples of a single material in LOX. Approximately one-third of these data was supplied by the Director of the Materials and Processes Laboratory at Marshall Space Flight Center. Results were included for a wide range of materials such as titanium alloys, plastics, elastomers, and lubricants. The percent reactions ranged from 0 to 100, but most values were well below 50. Because the amount of data for materials giving more than 50 percent reactions was small, the definitions of success and failure for these few tests were interchanged before pooling. Thus, a set of data giving 60 percent reactions was treated like a set giving 40 percent reactions and was pooled with other sets giving approximately 40 percent reactions.*

The resulting pooled data that corresponds to a binomial type process with up to 50 percent reactions is presented in table I and figure 1.

TABLE I. – COMPARISON OF OBSERVED STANDARD DEVIATIONS FOR LOX IMPACT TEST RESULTS WITH EXPECTED VALUES FOR CORRESPONDING BINOMIAL PROCESS

Number of Sets	Average Pooled Values, Percent	Range of Pooled Values, Percent	Standard Deviation, Percent	
			Pooled Values	Binomial Process
10	1.00	1.00 – 1.00	2.2	2.2
7	2.00	2.00 – 2.00	2.7	3.1
15	3.00	3.00 – 3.00	3.4	3.8
10	4.00	4.00 – 4.00	4.5	4.4
11	5.00	5.00 – 5.00	4.7	4.9
9	6.56	6.00 – 7.00	6.0	5.5
13	9.08	8.00 – 10.00	6.6	6.4
16	15.62	11.00 – 20.00	7.9	8.1
10	25.60	21.00 – 30.00	8.5	9.8
20	40.00	31.00 – 50.00	12.5	11.0

* The basis for this procedure is equation (1), which indicates that interchanging the definitions of success and failure has no effect on the binomial standard deviation.

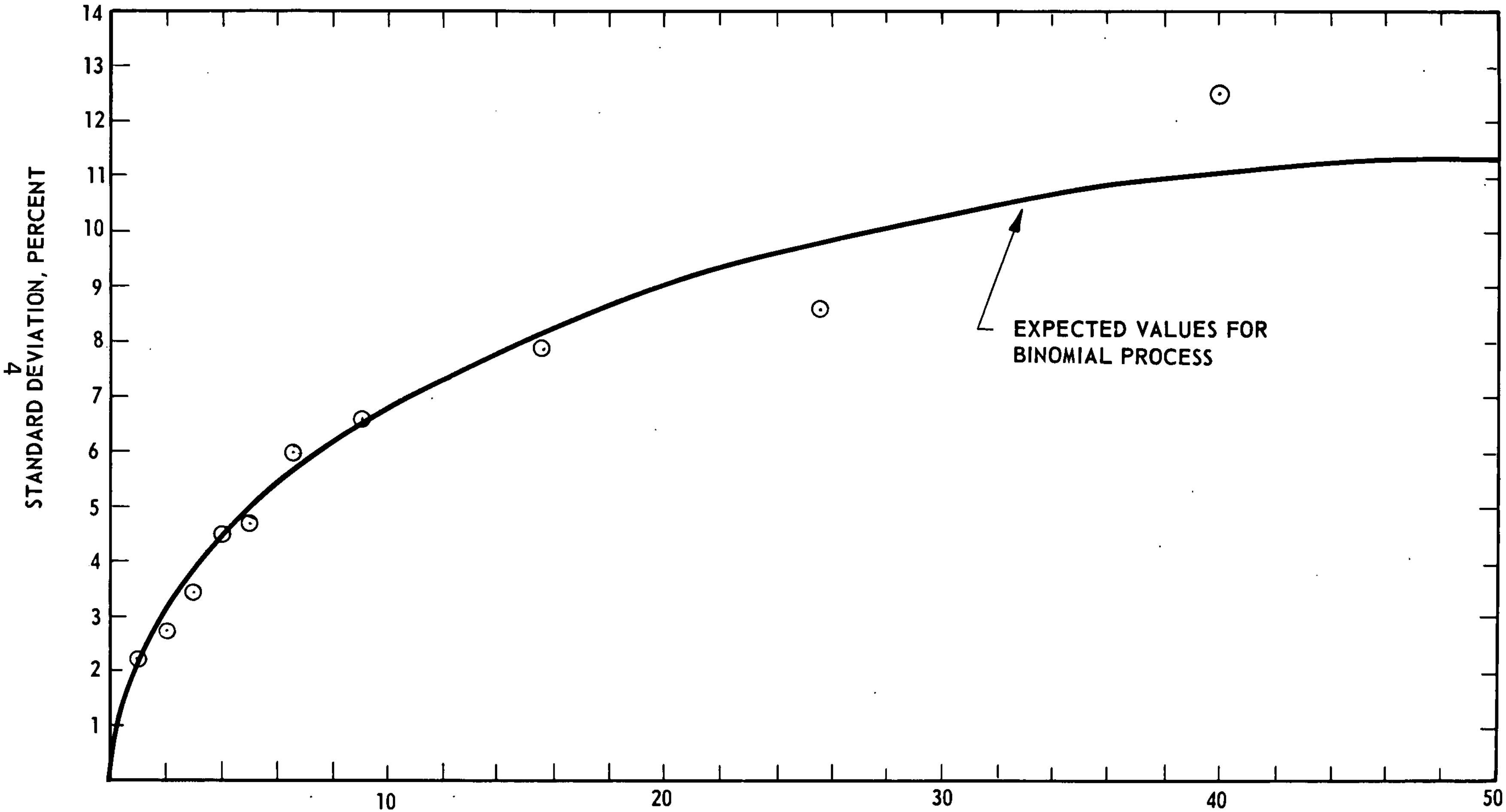

Figure 1. Comparison of Observed Standard Deviations for Lox Impact Test Results With Expected Values for a Binomial Process

Inspection of the data indicates close agreement between the observed standard deviations and the expected values for a binomial process, and F tests on the corresponding variances failed to indicate significant differences.

Any contributions to the variability of test results due to sampling errors or to testing variations would be expected to increase the observed standard deviations in accordance with the following relation:

$$\underset{\text{(observed)}}{\text{std dev}} = \sqrt{\underset{\text{(binomial)}}{\text{std dev}^2} + \underset{\text{(sampling)}}{\text{std dev}^2} + \underset{\text{(testing)}}{\text{std dev}^2}} \qquad (2)$$

where std dev is standard deviation.

CONCLUDING REMARKS

The fact that the observed standard deviations did not significantly exceed the expected values for a binomial process indicates that for these data, sampling and testing errors were not significant. It therefore appears that the binomial model can be used as a close approximation for impact test results for most applications.

John F. Kennedy Space Center
National Aeronautics and Space Administration
Kennedy Space Center, Florida, November 25, 1974

REFERENCE

1. Lucas, W. R.; and Riehl, W. A.: An Instrument for Determination of Impact Sensitivity of Materials in Contact with Liquid Oxygen. ASTM Bulletin, No. 244, Feb., 1960, pp. 29-38.

NASA-Langley, 1975

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