NASA TECHNICAL MEMORANDUM

NASA TM X-53194

JANUARY 22, 1965

NASA TM X-53194

NONMONOTONICITY IN SENSITIVITY TEST DATA

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ABSTRACT

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In general, the frequency of reactions for sensitivity test data of the "go-no-go" type increases monotonically with increasing levels of stimulus. However, occasional instances of nonmonotonic behavior have been noted.

One such instance has been investigated by carrying out a sufficient number of replicate tests to permit a statistical analysis of the data. The results indicated that over a considerable range of stimulus levels the frequency of response decreased significantly with increasing stimulus levels. The significance of this finding to sensitivity testing in general is discussed.

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ACKNOWLEDGMENT

The assistance of Mr. C. F. Key, who conducted the experimental portion of this work, is gratefully acknowledged.

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SUMMARY

In general, the frequency of reactions for sensitivity test data of the "go-no-go" type increases monotonically with increasing levels of stimulus. However, occasional instances of nonmonotonic behavior have been noted.

One such instance has been investigated by carrying out a sufficient number of replicate tests to permit a statistical analysis of the data. The results indicated that over a considerable range of stimulus levels the frequency of response decreased significantly with increasing stimulus levels. The significance of this finding to sensitivity testing in general is discussed.

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INTRODUCTION

For sensitivity data of the "go-no-go" type, the frequency of reactions is expected to increase monotonically with increasing level of stimulus. Conversely, the frequency of reactions is never expected to increase with decreasing level of stimulus. Failure of any given set of data to conform to expected behavior usually is attributed to experimental error.

During a recent investigation of factors which influence the reliability of sensitivity test data (Ref. 1), several instances of apparent nonmonotonicity were noted for impact test results. Although the statistical significance of these results was not established, it was pointed out that the mechanism of initiation is complex and that the nature of the test method does not rigorously preclude the occurrence of nonmonotonicity as is frequently assumed.

DISCUSSION

To obtain additional information on this problem, a detailed survey of the results of more than 20,000 LOX impact tests was made. While many sets of data gave evidence of departing from expected behavior, in no instance was the departure sufficiently marked to be statistically significant at an acceptable confidence level. Moreover, the combined evidence from numerous incidents was difficult to treat mathematically because any given stimulus/response pattern logically should be characteristic of the particular material tested and, therefore, can neither confirm nor refute the pattern for any other material.

As a direct approach to the problem, routine LOX impact test results were screened until a marked instance of apparent nonmonotonicity was noted. Tests on this material were repeated until a statistically significant result was obtained.

The material selected for testing was a composite insulation consisting of a Mylar-aluminum-Mylar laminate (2 mils thick) that was adhesively bonded to a polyester foam. Figure 1 shows the details of the test specimens. The test apparatus and experimental procedure have been described previously (Ref. 2). Briefly, a test consisted of dropping a plummet of known weight (9.04 Kg) from heights up to 1.1 meters onto a plunger resting on the test specimen in the bottom of an aluminum cup. The remainder of the sample cup was filled with liquid oxygen. Occurrence of a flash or audible report on impact was taken as an indication of a reaction. The data are presented graphically in FIG 2, with each point representing results for 100 individual drops.

Attempts to analyze sets of data exhibiting apparent nonmonotonicity previously had been fraught with difficulties in deciding what type of statistical test to use and over what range of stimulus levels it should be applied. For this particular set of data, these difficulties were not encountered; any of several statistical tests applied over any reasonable portion of the data indicated departure from expected behavior at an extremely high level of confidence. Therefore, it was concluded that the departure was real rather than apparent and that it must be attributed to some complex physical or chemical phenomena associated with the initiation process. Additional tests on individual constituents of the insulation indicated that the nonmonotonic behavior was associated with the polyester foam. Tests on several lots and thicknesses of this foam gave similar results. Because it appears that the cellular nature of this material may be partly responsible for the observed behavior, studies on other foams and also studies in which the impact tester is provided with an accelerometer and other instrumentation to obtain information on the nature of the initiation process are planned.

Most sensitivity tests are complex which allows the possibility of multistimuli and changing mechanisms. The LOX impact test is particularly complex due to the presence of three phases, i.e., a solid specimen, liquid oxygen, and bubbles of gaseous oxygen which may undergo adiabatic compression and, thereby, contribute to the initiation process. For this reason, it is difficult to postulate an acceptable mechanism to account for the data given in FIG 2 without additional information. This lack of an acceptable mechanism has been largely responsible for the reluctance of previous investigators to attribute departures from expected behavior to any cause other than normal experimental variations. However, once the existence of nonmonotonic stimulus/response patterns is accepted, it is a simple matter to devise simulation schemes involving dual stimuli and/or changing mechanisms which will simulate nonmonotonic behavior.

Numerous such schemes involving a variety of chemical and physical processes could be devised. However, it may be of interest to cite an actual case of nonmonotonicity in sensitivity test data for which an acceptable mechanism is available. Specifically, the frequency of penetration of targets of any given thickness as a function of projectile velocity would be expected to approximate closely the pattern shown in FIG 2. The accepted mechanism for this process stipulates that for low velocities the projectile remains more or less intact and simply punches a hole in the target. At higher velocities, the projectile tends to fragment on impact and, therefore, is less effective in penetrating the target. At still higher velocities, the projectile is completely consumed, by the energy released on impact, with simultaneous formation of a crater considerably larger than the projectile itself. Thus, at low velocities, the projectile per se is responsible for target penetration; whereas, at very high velocities, the explosive energy released at impact is responsible, and the projectile does not actually traverse the thickness of the target.

CONCLUSIONS

The nonmonotonic behavior of hypervelocity impact data for which a widely accepted mechanism is available and the ease with which simulation processes can be devised to give any desired stimulus/response pattern constitute compelling arguments that similar patterns cannot be precluded for other types of sensitivity test data, even when no acceptable mechanism is evident. This is particularly the case for the more complex test methods. Conversely, the sparsity of previous reports on nonmonotonic behavior and the failure to note other statistically significant sets of data in our survey of test results for several hundred materials suggest that such occurrences are extremely rare.

These findings in no way constitute an indictment of sensitivity data in general but instead reemphasize the need for caution in interpretation of results of empirical tests, particularly when the process is obviously complex. Also, it should be pointed out that many tests which were developed to provide rough indications of the relative characteristics of similar materials have been used for applications for which they were never intended, with sometimes disappointing results. This in no way detracts from their usefulness for their intended applications.

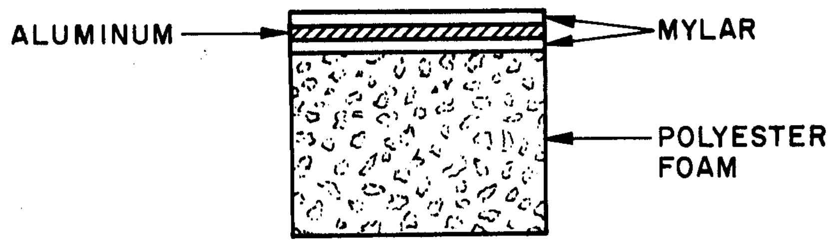

FIGURE I. DETAILS OF TEST SPECIMENS

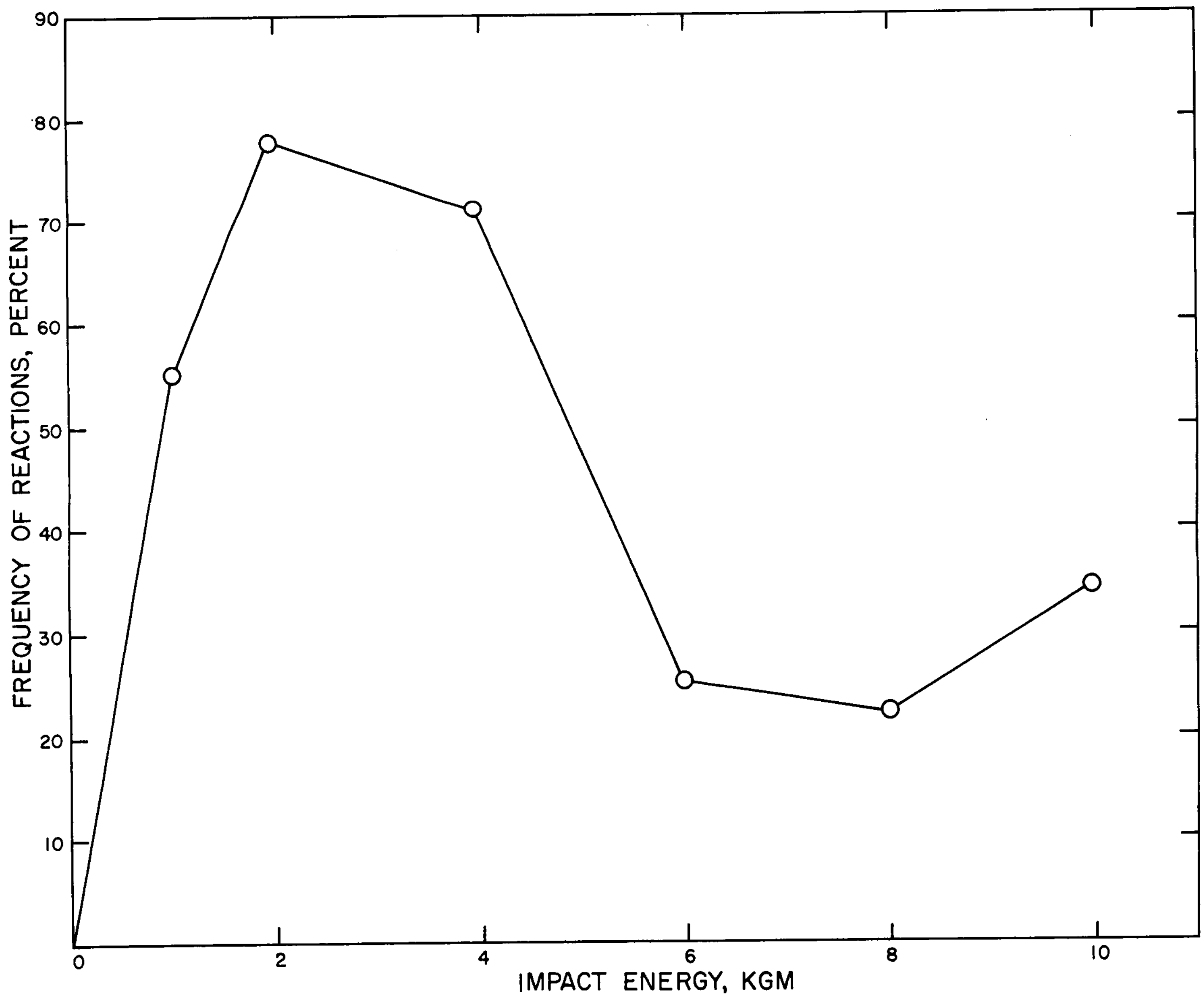

FIGURE 2. RESULTS OF IMPACT TESTS

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2. "An Instrument for Determination of Impact Sensitivity of Materials in Contact with Liquid Oxygen," by William R. Lucas and Wilbur A. Riehl, ASTM Bulletin, February 1960, No. 244, pp. 29-34.

January 22, 1965 APPROVAL TM X-53194

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

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