Technical Comments

Comment on "Assessment of the Explosive Hazards of Large Solid Rocket Motors"

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THE Note by Zimmer, McDevitt, and Dale[1] is a welcome and commendably frank discussion of a long-standing, difficult problem. I was not surprised to see yet again, the objection that "the conventional sensitivity tests for the hazard classification of propellants are generally arbitrary in nature and based on previous experience." The Note covers shortcomings of the critical model diameter and card gap techniques, but regrettably, offers no concrete alternatives. Without a specific improvement in a related quantitative test technique the "hazard tree" black box approach appears to be wishful thinking as far as advancing the state-of-the-art is concerned. To be more convincing, the boxes might have included some typical data for an illustrative case.

The environmental and motor parameters, of course, are the inputs to any analysis of the over-all hazard problem. In using these for the prediction of TNT equivalence, some updating of the definition of "common practice" is in order. Only the crudest ceiling estimate would still equate the TNT equivalent of the blast potential as "that amount of TNT having the same total energy of explosion." The missing key work here is "yield." For example, in 1964, the low $8\frac{1}{2}\%$ explosive yield[2] of the 120-in. grain motor sled test at China Lake, which I was privileged to observe, successfully demonstrated that detonation and 100% yield did not, and probably could not, occur with the encased rubbery propellant. "Burial and confinement" are not automatically to be taken as one independent factor. True, there was no earth burial of the motor, but there certainly was considerable local grain confinement due to the inertial conditions of rupture.

Most of the propellant in this test was thrown out in a variety of small fragments to large chunks. The smaller pieces strewn over the surrounding area were unburned. The larger pieces must have been burning on their surfaces only, as evidenced by the beautiful star-shell appearance of the explosion in bright sunlight and by the large patches of grey residue left on the sand. Now, there is nothing wrong in the data-reporting logic—after the event—in stating that the resulting damage and blast pressures could have been induced by a particular weight of TNT; and that this is the equivalence fraction of the total propellant weight for the particular conditions of the test.

What is missing and required is a plausible combined theoretical and empirical basis for extrapolating the fractional TNT-equivalent from test conditions to any other set of rationally scaled-up input conditions. In this connection, the rate of energy imparted to the elastic propellant is indeed a prime and nonconventional factor. The concept of just such a basic initiating parameter was presented in a paper at the 1959 Cryogenics Engineering Conference.[3] The pertinence of this paper seems to have missed the attention of the authors of the Note. While the immediate problem then solved was to provide a theoretical basis for standardizing the drop-weight impact test used to qualify materials for use in a liquid oxygen environment, the conceptual relationship for assessing TNT-equivalence is identical. Figure 1 shows how the maximum energy transfer rate parameter was successful in assembling scattered total impact energy test data along a smooth exponential curve depending on the material elasticity.

For recording test model and accident values of TNT-equivalence, and for subsequent prediction of desired scale-up values, the ordinate scale would represent the explosion yield ratio of zero to one, or zero to 100%. The abscissa scale function evaluation would be modified to best suit the detailed impact or other type of energy-rate input conditions. This initiating parameter has the correct dimensions for universal application, whether the maximum energy rate per unit area is generated by an intentional primer or other type donor, by thermal or electrical heating, by intense light or invisible radiation, or by gross physical impact.

Very fast reactions such as detonations and high-order explosions are essentially adiabatic, permitting use of the theoretical input energy rate as the plotting parameter, while neglecting the heat losses, except for the special case of very thin films. However, even with appreciable heat losses in medium- and low-order explosions, the empirical test correlation curve would simply move over to the right, requiring a higher input rate for the various equivalent TNT fractions. Studies and experimental work along these lines are recommended to the authors and to all concerned with this classic problem.

References

[1] Zimmer, M. F., McDevitt, J. A., and Dale, C. B., "Assessment of the Explosive Hazards of Large Solid Rocket Motors," *Journal of Spacecraft and Rockets*, Vol. 7, No. 5, May 1970, pp. 636–638.

[2] McMunn, J. C., Collins, J. D., and Brown, B., "A Hazards Model for Exploding Solid-Propellant Rockets," *Journal of Spacecraft and Rockets*, Vol. 6, No. 12, Dec. 1969, p. 1425.

[3] Africano, A., "Maximum Rate Theory of Impact Sensitivity," *Proceedings of the 1959 Cryogenic Engineering Conference*, University of California, Berkeley; also *Advances in Cryogenic Engineering*, Vol. 5, edited by K. D. Timmerhaus, Plenum Press, New York, 1960, pp. 533–544.

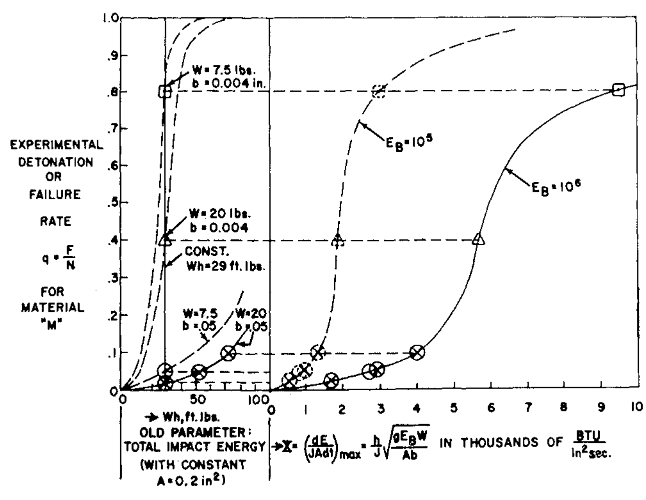

Fig. 1 Comparison of experimental data plotted vs old total impact energy parameter and vs maximum energy transfer rate parameter.

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