Reply by Authors to A. Africano

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WE have read Africano's comments with great interest and appreciate his remarks. We have the following comments to make.

An illustrative example of the hazard tree analysis could not be included because of the limited space requirements of a technical note. The reference, IHTR 274 (Ref. 19 in paper), presents a detailed report of the potential hazards analysis of large solid motors by the hazard tree approach for the operations, handling, transportation, storage, component assembly and checkout, and launch preparation and flight. This systems approach by its representation of the present state-of-the-art and predictions based on past incident data for solid motors is a valuable tool for providing a qualitative estimate of the damage potential and degree of safety of large solid motors. The initial development of the hazard tree further provided a basis for recommending research in the areas of propellant fracturing and nondetonative reactions which are needed to establish the motor parameters for a quantitative assessment.

With respect to TNT equivalence, the point we were making is that for propellant explosions—unless the propellant is consumed at high velocity detonation rates—the description by specification of TNT equivalent is invalid in principle. The introduction of the word "yield" appears to be rhetorical since it in no way solves the problem, but merely asks for a new definition. What is yield referred to? Information on how much of the total energy in a propellant is released during an accident is not sufficient to characterize the resulting blast wave. Of equal importance is the time scale during which said energy is released. As Brinkley[1] pointed out, the concept of TNT equivalent is valid only if 1) the energy propagated by the blast wave is the energy released by the reaction prior to the formation of the suction phase; i.e., any energy released after that time t_s (formation of suction phase) cannot be transmitted to the shock wave and modify it; and 2) the initial pressure values p for both explosives (TNT and material to be evaluated) are the same.

In the highly nonideal explosion we are most likely to encounter in an accidental propellant explosion, the pressure parameter may differ by one or more orders of magnitude from that of TNT. In this case, one cannot employ TNT equivalency to describe an explosion.

From our studies, we conclude that a new model for the explosion process (from incidents involving solid rocket motors) should be developed, rather than describing the explosion in terms of TNT equivalency. The model would describe the parameters of the shock wave as: a) the initial shock wave pressure, and b) the energy release as a function of time, allowing an estimate of the energy released to the time the suction phase occurs.

It seems evident that ground confinement after impact and burial may add an order of magnitude to the inertial confinement of the propellant grain referred to by the commentator.

With respect to Africano's work at Space Technology Laboratories, we think it is a good piece of work; however, it is not clear as to how the detonation probabilities—and if applied to propellants, the explosion probabilities—are related to the energy output, since the energy output (deflagration, explosion, detonation) of a propellant system depends not only on the stimulus but also on many other intrinsic and environmental parameters of the rocket motor.

Received November 9, 1970.

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Reference

[1] Brinkley, S. R., Jr., private communication, May 1967, Combustion and Explosives Research, Inc., Pittsburgh, Pa., private communication, May 1967.