93/
2-28-77

A. 746

LA-6676-MS

Informal Report

UC-45

Issued: February 1977

Sensitivity of TATB Explosives

by

W. C. Davis

los alamos
scientific laboratory
of the University of California
LOS ALAMOS, NEW MEXICO 87545

UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
CONTRACT W-7405-ENG. 36

SENSITIVITY OF TATB EXPLOSIVES

by

W. C. Davis

ABSTRACT

Explosives formulated from TATB, only recently used in quantity, are at least 100 times safer than common explosives; that is, they are 100 times less likely to yield energy violently when subjected to the environment of accidental stimuli. The quantitative expression of the safety of an explosive is some measure of its *sensitivity,* which is sometimes divided into its *sensitiveness,* the ease of initiating some sort of reaction, and its *explosiveness,* the ease of transition to violent explosion. All of these measures are useful when they serve to describe an explosive in relation to familiar ones, but the TATB explosives are far from the common ones, and the comparison is not an interpolation but an extreme extrapolation. The meaning of the tests is discussed, and the results are compared on an energy basis. The safety of the TATB explosives is apparent in all the tests.

The sensitivity of an explosive is not a well-defined concept. When one asks about sensitivity, what he really requires is a comparison with his past experience. If he knows, for example, that he has used explosive A for a long time and that now he intends to use explosive B in about the same way, subjected to the same accidental stimuli as was explosive A, what he wants to know is how does the probability of accidental explosive energy release change when he changes from A to B. He also wants to know, if there is any energy released, how violent will the probable explosion be for one explosive compared with the other. Because the small-probability tails of the curves are the parts of special interest, it is very difficult to devise experiments to measure the probabilities accurately, even if the vague concept of "accidental stimulus" could be defined. What is done in practice is to compare the new explosive with familiar old explosives in as wide a variety of tests as possible, so that the individual peculiarities of the new explosive (if there are any) are not overlooked.

These ideas have been well expressed in an excellent review paper by Popolato[1], where he says in his introduction, "To attempt to assess the relative sensitivity of an explosive on the basis of the results obtained from a single test is impossible, and could lead to disaster. This unfortunate situation stems from the fact that the problems of measuring sensitivity are extremely complex. The results obtained depend not only on the type of sensitivity test used, but also on a variety of the physical and mechanical details of the sample used in the test. It is not uncommon, for example, to see reversals in relative sensitivity as minor changes are made in a single test, or when given explosives are subjected to two or more tests. This complex behavior pattern also makes it very difficult to express the relative sensitivity in terms of any single scale or index, even after the explosive has been subjected to a variety of tests."

In his summary he concludes, "The method which we most often use to assess the relative sensitivity of a new explosive is to compare the results obtained in a variety of tests with the results obtained for an explosive for which we have had a long history of factory experience. If, for example, the behavior pattern of the new explosive, as determined in at least six or seven tests, is very nearly the same as that of an explosive which has been in production for many years, we feel fairly confident about the handling and processing techniques we can use. If the material appears to be more sensitive in even a single test, we feel that some degree of caution should be exercised. Because of these considerations, the relative sensitivity of a new explosive is usually expressed in terms of a comparison with a well-established explosive or explosives.

"The fact that sensitivity is a property which depends upon a variety of the physical and mechanical details of the sample being tested, and upon the test being used, was partially demonstrated with the results presented. This is indeed an unfortunate situation. It does, however, serve to emphasize the very important fact that sensitivity comparisons of solid explosives should be based upon many tests in which the explosive sample varies from a few grams to many kilograms and in which wide variations in density and types of stimulus have been considered."

Comparison of the new TATB formulation X-0290 with the old formulations PBX-9404 and Composition B-3 in a variety of tests probably provides the best currently available answer to the question about relative sensitivity. Where possible, the energy yield of the explosive sample in the test is plotted against the energy in the stimulus. The reasoning behind this unconventional plot is that if the stimulus required is about the same as the explosive yield, then the accident without explosive would cause damage only a little less than the same accident with explosive energy released.

An important safety property of explosives is their thermal stability; the question to be answered is, how hot do they have to get before reaction begins. The differential thermal analysis (DTA) curve shows how much heat they evolve as a function of temperature, and the pyrolysis curve shows how much gas they evolve as a function of temperature. Curves for the three explosives are shown in Fig. 1, which is taken from Dobratz[2]. Reaction begins in PBX-9404 and Composition B at about 150°C, while TATB shows no reaction until the temperature reaches about 350°C. This difference provides a large safety factor, because almost all accidental initiations begin with thermal ignition of some kind; the exception is direct shock initiation.

The drop weight impact test consists of a small metal cylinder driven into a pinch of explosive by a weight which falls on the cylinder. It measures the relative ease of ignition of explosives. The results are given in Table I. The value for TATB formulations is obtained from an extrapolation of measurements made on mixtures of TATB and HMX, because the testing machine, which is adequate for almost all other explosives, does not extend high enough to get a value for pure TATB. This fact in itself indicates

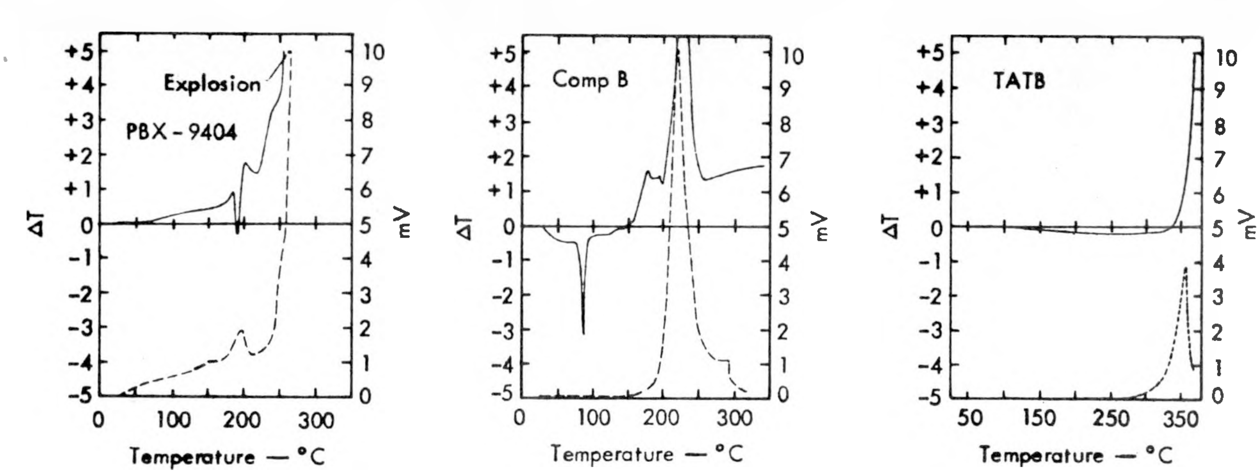

Fig. 1.
DTA (———) and pyrolysis (- - -) curves.

TABLE I

DROP WEIGHT IMPACT SENSITIVITY

Material	50% Point (cm)	Weight Energy (J)
PBX-9404	42.0	10.3
Comp B-3	59.1	14.5
TATB	≃800	≃200

the large safety factor. The pinch of explosive is about 40 mg, and about half of it reacts, so the explosive energy release is about 100 J, appreciable, relative to weight energy for the two comparison explosives, and small, relative to weight energy for TATB.

The large-scale gap test consists of a cylinder of donor explosive (41.3-cm diam x 10.2-cm long), a dural cylinder of the same diameter whose length is changed in the series of shots, and a cylinder of test explosive of the same diameter and length as the donor. These three pieces are carefully assembled and placed with the test explosive end on a steel plate. The resulting dent or absence of dent when the assembly is fired indicates whether or not detonation occurred in the test piece. The length of the dural cylinder is adjusted until the detonation occurs 50% of the time. This test measures the ease of detonation of the explosive. The result for PBX-9404 is 57.66 mm of dural, for Composition B-3 50.29 mm, and for X-0219 14.73 mm; the result for X-0290 is not available, but another gap test shows X-0219 and X-0290 are about the same. Again the test shows a large safety factor for the TATB material.

The results of the drop weight impact test and the results of the large-scale gap test have been used by L. C. Smith (see Ref. 1) to get a safety index for explosives. The idea behind this index is that the impact test combines a measure of the sensitivity to heat and the ability to produce heat by friction in an impact, while the large-scale gap test measures the likelihood that a small amount of heat, produced in this case by shock heating rather than by friction, will develop into a violent detonation. Figure 2 shows a nomograph with the logarithm of the drop height plotted on the left, and the gap thickness plotted on the right increasing downward. It is easy to see that X-0290 is much less sensitive than either of the other explosives.

The Susan test uses a projectile fired from a gun. The test explosive, a cylinder 5.1-cm diam by 10.1-cm long, is contained in a steel projectile with a dural cap, and impacts on a steel plate. Some results[3] are shown in Fig. 3. The experiments with X-0219 have been carried out at velocities of above 0.9 km/s without showing any explosive energy release, while PBX-9404 shows appreciable release at about 0.1% of that impact energy, and Composition B at about 5% of the energy. This result is

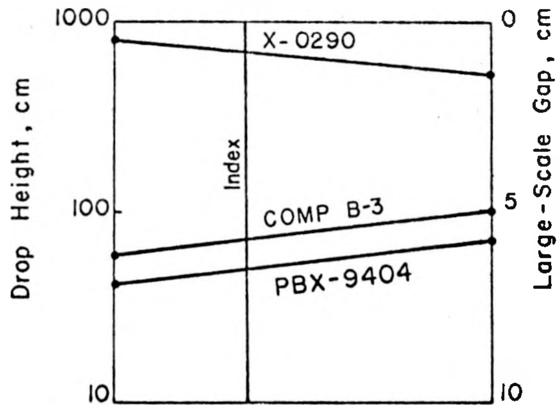

Fig. 2.
Safety Index Plot.

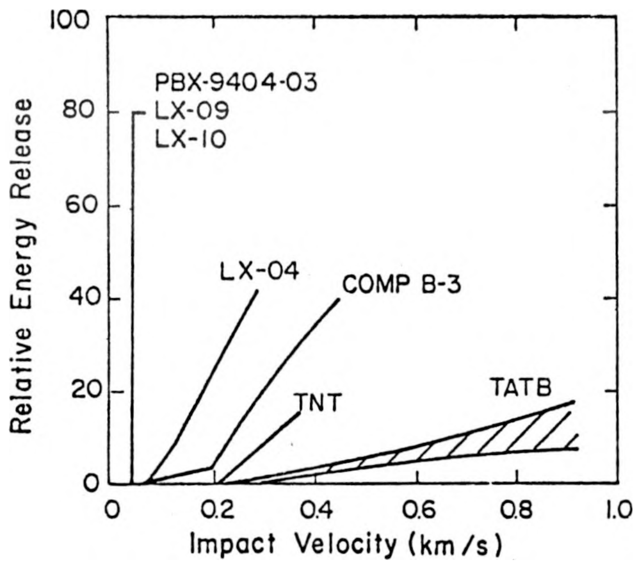

Fig. 3.
Susan Test results.

probably the best test of what might happen when an assembly falls from an airplane or is in an airplane crash; 0.9 km/s is over 2000 mph.

The skid test uses a hemisphere of explosive about 25-cm diam, uncased, which is dropped onto a steel plate coated with sand. The plate is at 45° to the vertical drop direction. The drop height for PBX-9404 is 1.1 m, and it gives a large explosion. For Composition B-3 the height is not known because one test gave a small partial at 3.1 m and all other tests suggest a larger value. (TATB mixtures with HMX give no yield at 19.5m even when the explosive contains 50% HMX/40% TATB/10% Kel F.) The skid test is designed to simulate possible accidents during assembly of explosive into cases.

There are many shock initiation tests which have been performed for all the explosives. They correlate well with the large-scale gap test, but give more easily interpreted data for use in other calculations. A plot of input shock pressure vs the distance to the point where the shock becomes a detonation is shown in Fig. 4. A simpler way to express these results and also many others is to define a critical energy for initiation for an explosive. The values often used[2] are 630 kj/m^2 for PBX-9404, 1500 kj/m^2 for Composition B and 9500 kj/m^2 for the TATB formulations. Rifle bullet tests correlate well with all the shock initiation tests and the large-scale gap test.

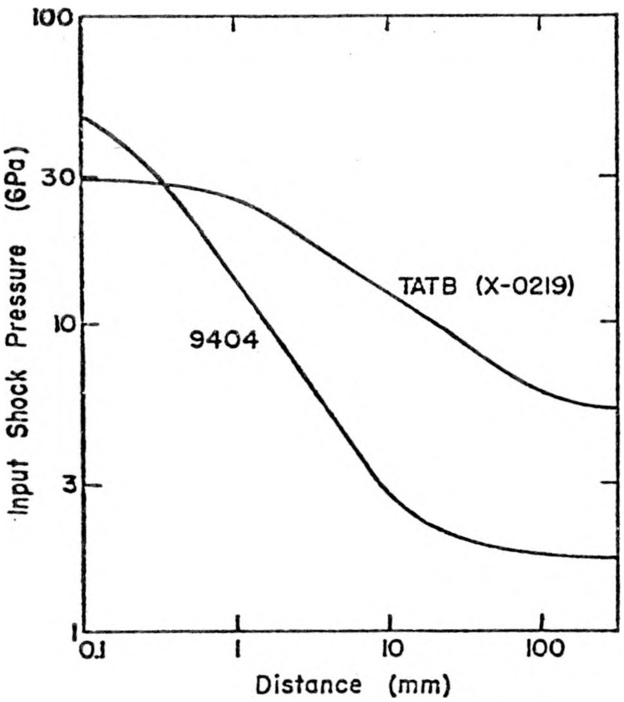

Fig. 4.
Shock initiation comparison of PBX-9404 and X-0219.

Taken as a whole, the tests of the TATB formulations show a consistent picture of an explosive which is much safer to use than any of the past formulations. The behavior of the material seems to be like that of familiar explosives, except that the time, space, and pressure scales are much larger, so we expect no surprises such as finding a new class of stimuli which cause it to react. Both its sensitiveness, its ease of initiating some kind of reaction, and its explosiveness, its ease of transition to violent explosion, are at least one order of magnitude less than those of PBX-9404 and Composition B. Safety is approximately the reciprocal of the product of these two, and is therefore at least two orders of magnitude greater.

REFERENCES

1. A. Popolato, "Experimental Techniques Used at LASL to Evaluate Sensitivity of High Explosives," Proc. Intern. Conf. Sensitivity and Hazards of Explosives, London, October 1-3, 1963, Explosives Research and Development Establishment, Ministry of Aviation, Waltham Abbey, Essex.

2. Brigitta M. Dobratz, "Properties of Chemical Explosives and Explosive Simulants," Lawrence Livermore Laboratory report UCRL-51319 (1972), Rev. 1974.

3. R. K. Jackson, L. G. Green. R. H. Barlett, W. W. Hofer, P. E. Kramer, R. S. Lee, E. J. Nidkick, Jr., L. L. Shaw, and R. C. Weingart, "Initiation and Detonation Characteristics of TATB", 6th Symp. (Intern.) on Detonation, Preprint UCRL-77611, 1976.