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DOE HAZARD CLASSIFICATION FOR INSENSITIVE HIGH EXPLOSIVES (IHE)*

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It seems to me that the only valid rationale behind any system of hazard evaluation and classification is to assure that any operation is performed with the least possible risk to personnel. In other words, we seek to maximize the margin of safety for performing any operation. We recognize, however, that absolute safety is only obtained by not doing the experiment or operation. This is not, generally, an acceptable option. Thus any safety program, while conservative, must be positive, i.e., it must provide a means for operation with maximum safety rather than denying operation.

We must also keep firmly in mind that most, if not all, accidents occur because of the coincidence of two or more improbable conditions. I have heard it said that explosives accidents are statistical. That is, that one can perform an operation on the same material without incident for 1000 times, whereas on operation 1001 a tragic explosion my occur. This fatalistic idea is absolutely invalid. Any accident can be avoided by knowledgeable care.

Let me emphasize the words knowledgeable care. By knowledgeable, I mean intimate familiarity with the details of the operation so that the conditions providing the stimulus and confinement that could lead to a hazardous situation can be defined, and an understanding of the response of the material to these conditions. By care, I mean concern to detail in establishing operating procedures, care in monitoring the application of those procedures and care in continuously educating those involved in operations involving energetic materials.

Thus the human element is all important both in interpreting the results of evaluation tests and in applying that understanding to maximizing that margin of safety mentioned above. (Actually, if the understanding were complete the margin of safety could be absolute.) To thoughtlessly perform a checklist of evaluation tests and then to just as thoughtlessly follow a table of prescribed procedures is tantamount to accepting the statistical nature of accidents.

It is widely recognized that all energetic materials do not react the same to a given stimulus condition. The community generally speaks of primary and secondary explosives. (Some have also used the term "tertiary" explosives.) Primary explosives, of course, are those that

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respond violently to relatively low levels of stimulus; i.e., they are "sensitive." Secondary explosives are those that require a higher stimulus before they react violently; i.e., they are "less sensitive"?

Recognizing this difference in "sensitivity", different constraints are placed on the handling, storage, transportation, etc., of these materials. This is not to say that secondary explosives can be handled less safely but that primary explosives must be handled with greater restraint to obtain the same level of safety as the secondaries. Extending this approach, we now consider an additional class of energetic materials which we call "Insensitive High Explosives". These would require extremely high stimulus levels before reacting violently and consequently less constraint on handling to achieve the same level of safety as work with secondary explosives.

To date, we can only recognize one material, symmetrical triamino-trinitrobenzene or TATB as meeting this definition. Extensive experimentation has been performed on TATB; so much so that I feel comfortable in claiming that we understand the initiation and safety characteristics of TATB better than we do for HMX. TATB is truly insensitive to impact, friction, spark or thermal stimulus under any reasonable confinement condition. Only high amplitude shocks induce detonation and we have not found sustained lower level reactions.

In view of the existence of at least one material that can legitimately be called insensitive we accept the following definitions, similar to those accepted by the DDESB.

INSENSITIVE HIGH EXPLOSIVE (IHE): Explosive substances which, although mass detonating, are so insensitive that there is a negligible probability of accidental initiation or transition from burning to detonation. Those materials passing the DOE qualification tests are classified as IHE.

IHE SUBASSEMBLIES: IHE hemispheres or spheres with booster charges, with or without detonators, which pass the DOE qualification tests.

I must note at this point that we are speaking about materials that are by definition mass detonable explosives. They will detonate if the proper high amplitude shock pulse is provided. Therefore, if they are stored, handled, or transported in conjunction with more sensitive materials that could supply that pulse, they must be counted as hazard class 1.1 in any Q-D considerations. It is only when they are stored alone or with other IHE's that they can be considered as insensitive.

This approach must be viewed as a departure from traditional safety philosophy. It has previously been assumed that an initiating event had a reasonable probability of occurence and that the consequences of that event were predictable. Procedures and Q-D requirements were then imposed so as to mitigate those consequences. We are now proposing that there is no reasonable probability of the accidental delivery of sufficient energy to cause initiation. How does one go about establishing such a claim?

It is obviously not possible to simulate every hazard situation. Fortunately, however, the stimuli a material will experience as a result of an accident can be treated in five categories:

- Thermal
- Electrostatic
- Impact (including crushing impact).
- Shock
- Fragment impact.

Tests for each of these stimuli can be designed so as to be modelable both as to the level of stimulus and the nature of the response. This is not to say that we fully understand each of these initiation mechanisms. Far from it! However, we understand a lot more than we did just a very short time ago. We can use that understanding to better design our hazard tests and to better interpret the results of those tests.

The following are the tests selected by the DOE as a matrix for qualification of IHE and IHE subassemblies. You will recognize many of them as being rather standard in classification schemes; some you may be unfamiliar with. I will discuss those tests marked with an asterisk in somewhat more detail.

<u>Thermal</u>

Small Scale Burn Test	Same as TB-700-2. No explosions allowed.
One Dimensional Time to Explosion.*	No reaction greater than pressure rupture of container.
Bonfire	Similar to TB-700-2, no violent reaction. Test for subassemblies.
Slow Cook-off	No violent reaction. Test for subassemblies.

<u>Electrostatic</u>

Spark	No reaction at 0.25 joules.

Impact

Drop Hammer	Less sensitive than Explosive D.
Friction	No reaction at 5000 pounds normal force.
Spigot	No reaction, 120 ft. drop. For pressed billets and subassemblies.
Skid*	No reaction at 14° impact angle from a height up to 20 ft. or just below the height at which the sample fails. For pressed billets and subassemblies.
Susan*	Less than or equal to 10% of TNT output at specified condition.

Shock

Cap	Similar to TB 700-2 #8 blasting cap.
Gap*	No reaction at 1.5 GPa impact.

Fragment Impact

Bullet Impact	No violent reaction with 5.56 mm and 0.50 cal. under specified conditions. Both materials and subassemblies.

NOTE: In subassembly testing, the booster/detonator must experience the hazard under realistic confinement.

The One Dimensional Time to Explosion or ODTX test is a fully contained, heavily confined thermal test with a one dimensional, isothermal boundary. It has been extensively characterized.

The idea behind a good thermal hazard test is to provoke the explosive to the highest level of reaction possible. This is accomplished as follows:

Confinement - moderately heavy, i.e., a few thousand psi. Light confinement will rupture before reactions can build. Much heavier confinement is unrealistic.

Containment - full containment, i.e., no free volume and no leak path. This condition prevents escaping gases carrying away latent heat and maintains any gas phase exothermic chemistry in contact with the decomposing explosive.

Thermal - the thermal boundary condition is chosen such that the Boundary entire explosive charge has reached the test temperature and such that a hot spot (self heating) is generated in the interior of the explosive charge. If the temperature is too low the slowly evolved gases will rupture the confining medium prior to self neating. If the temperature is too high, a thermal explosion will occur at the charge-boundary interface, rupture the container and quench. In neither of these instances will the maximum reaction be obtained.

Skid Test - In this test, a large, hemispherical billet of the explosive (> than 24 pounds) is dropped from a height and impacts a hard gritty surface at an angle of 14^{o}. This is an impact test with a very large frictional component. The fracture of the billet on impact relieves the conf·nement required for reactions to build and is thus deemed no test: thus, the requirement to test below that height.

Susan Test - In this test, an aluminum projectile, loaded with the test material is fired from a 4" smooth bore gun and impacted against an armor plate target. The results are expressed as resultant energy as a function of impact velocity. (The standard is the full detonation of 280 grams of TNT.) I would like to make four points about the Susan test.

1. The test doesn't mock any reasonable hazard in the normal handling of an explosive.

2. This may or may not be a shock initiation test, depending on the impact velocity.

3. There is data scatter because of variation in projectile impact angle and gage sensitivity.

4. At higher velocities there is significant energy sensed simply from the kinetic energy of the projectile.

Gap Test - It is difficult if not impossible to suggest a scenario that would provide a shock impulse even approaching 0.1 GPa resulting from an accident. Unless, of course, there is a detonation in a neighboring material. Thus the gap test as it is generally employed is not an accident sensitivity test but a propagation test. (We accept that IHE's will propagate a detonation.) We have proposed a 1.5 GPa input as a significant overtest. The test must be designed to be both above the critical diameter and as nearly one dimensional as possible. Thus the booster must be sized correctly with respect to the acceptor.

Assuming that a material can qualify as an IHE according to the above criteria; how do we propose to handle such material?

1. Store as a Hazard Class 1.3 material - let me illustrate saving in real estate as follows.:

Weight of Material		Distance to	
Class 1.1	1500 lbs.	1500 lb. magazine	210 ft.
Class 1.3	100,000 lbs.	1500 lb. magazine	200 ft.
Class 1.1	1500 lbs.	Public highway	275 ft.
Class 1.3	70,000 lbs.	Public highway	270 ft.
Class 1.1	1500 lbs.	Inhabited Bldg.	460 ft.
Class 1.3	300,000 lbs.	Inhabited Bldg.	450 ft.

2. May be stored with mock HE without regard to quantity of mock.

3. Siting and design of storage and/or operating facilities based on hazard class 1.3 distances.

4. Concurrent machining (operator attended) operations if only IHE.

5. Operator attended hole drilling down to 5 mm.

6. Operator attended, dry machining under certain conditions.

7. Uncased HE-Pu activities in cased HE-Pu bays.

8. Storage and transportation of weapons based on Pu concerns.

In summary, the DOE has adopted a hazard classification of IHE and IHE Subassembly based on the premise of no probability of initiation and proposed a test protocol for that classification based on an in depth understanding of the hazards involved and the response of the energetic material to relevant stimuli.