produced by both baffle arrangements. Thus, although the response curves calculated from the equivalent mechanical model representation, based on damping values obtained from the measured data, are not in particularly good agreement with the measured force response, the disagreement is probably no more than should be expected from a linearized representation.

Discussion and Conclusions

The results of this study would appear to reveal several important features of sloshing in spherical tanks. For example, although the basic predictions of the Budiansky theory[3] have been confirmed, particularly for liquid natural frequency, the force response is quite dependent on the magnitude of the excitation amplitude. Hence, large amplitude liquid free surface motions are excited more easily and appear to be of more importance in modifying the total force response in spherical tanks than in cylindrical tanks.

Perforated ring baffles oriented horizontally appear to be quite effective in providing force amplitude damping, with significant lowering of the fundamental resonant frequency. No baffling apparently is required for large liquid depths, say $h/d > 0.75$. A linear mechanical model representation for baffled tanks would appear to be satisfactory only for order of magnitude estimates.

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Safety Information from Propellant Sensitivity Studies

Donna Price[1] and Irving Jaffe[2]
U. S. Naval Ordnance Laboratory, White Oak, Silver Spring, Md.

This paper summarizes recent results of propellant sensitivity studies at the Naval Ordnance Laboratory. It emphasizes the use of gap and other small scale test results to help answer practical safety questions. Measured initiating pressures are highest near the critical diameter of the test material and decrease to their lowest value, for a given donor, at an effectively infinite acceptor diameter. The confinement of the standardized gap test increases the effective acceptor by about 2.5 times for Composition B. Gap test results show good correlation with large-scaled field tests and the approximately one-dimensional wedge test results; it is therefore believed that the gap test measures a 50% initiating pressure very close to that for an infinite diameter acceptor. A supplement to the Naval Ordnance Laboratory shock sensitivity test for propellants has been devised whereby the judicious choice of explosive witness systems makes it possible: 1) to assess the strength of reactions of too low impulse to produce a positive result under the conditions of the standardized test, and 2) to measure the sensitivity to shock initiation of substances exhibiting such reactions.

THE objective of the continuing work on propellant sensitivity is to understand the process of initiation (by any external stimulus) and any subsequent self-propagating reaction. With sufficiently detailed information, it should be possible to answer practical questions arising from safety considerations. Some of the important questions are as follows:

1 How easily will ignition and propagation of burning occur?

2 Can detonation occur?

3 If so, what is the probability of transition from burning to detonation?

4 What damage will a runaway reaction cause?

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1 Acting Chief, Physical Chemistry Division.

2 Supervisory Chemist, Physical Chemistry Division.

It has been found (1)[3] that propellants generally exhibit high to very high impact sensitivity. Hence, these substances are easy to ignite and burn, a characteristic to be expected of materials used as propellants. Work is underway at many laboratories to assess the degree of fire hazard, and much still remains to be done in this field, but the present work has been concentrated on reactions more damaging than simple combustion. Any easily combustible material capable of energetic exothermal reaction immediately suggests the possibility of detonation. By use of a standardized gap test (1, 2), it has been possible to obtain much information on whether a propellant is detonable and, if so, how easily. Since the gap or shock sensitivity test measures the minimum initiating pressure required to induce detonation, it also provides some information about the probability of an occur-

3 Numbers in parentheses indicate References at end of paper.

Table 1 Effect of confinement on gap test values

Confinement	Outer diameter, cm: Test charge	Outer diameter, cm: Container	50% point: Gap, no. cards	50% point: Incident pressure, kbars
Cast pentolite 50/50, PETN/TNT				
None	3.81	...	266	5.3
Steel	3.66	4.76	264[a]	5.5
Cast Comp. B, RDX/TNT/wax, 60/40/1				
Lead	3.66	4.76	204	17.1
Steel	3.66	4.76	201	17.7
Aluminum	3.66	4.76	179	21.5
None	4.76	...	159	25.9
Glass	3.66	4.44	158	26.3
Lucite	3.66	4.76	156	26.8
None	3.81	...	143	30.0

[a] Tested at ambient temperature; all other tests at 25°C.

rence of transition from burning to detonation in the propellant; the lower the pressure required for initiating detonation, the more probable it is that such a shock pressure could be built up by confined burning of the propellant (3) and, hence, that a transition could occur.

Variation of Shock Test Values with Test Diameter

The critical diameter of a detonable material has a limiting effect on any test for shock sensitivity. If the test diameter used is less than the critical diameter for propagation of detonation, the result from the standardized gap test at zero gap is a no-go. Even if the effective test diameter is above but near the critical diameter, the intuitive expectation is that a higher pressure would be required for initiating detonation than in the case of a charge of larger diameter. That this is, in fact, the case is shown for cast TNT. The computed detonation pressure just above the critical diameter is about 150 kbar (4); under near-failure conditions, where the possibility of reaction build-up is negligible, this should also be the required initiating pressure. In contrast, the measured *initiating* pressure on the standard gap test is 37.3 kbar.

It was pointed out previously (2) that the pressure transmitted into the test charge, the initiating pressure, is 15 to 30% higher than the pressure incident at the Lucite/acceptor boundary. The standardized gap test measures the incident pressure. To compute the initiating pressure, it is also necessary to know the Hugoniot data of the unreacted propellant. In general, these are not known, but the Hugoniots for nonporous propellants and explosives can be approximated by that for unreacted cast TNT (2). The initiating pressures of this report have been obtained by using this approximation.

Although quantitative work on shock sensitivity is still chiefly confined to measurement and interpretation of peak pressures, there is general agreement that initiation is the result of the entire pressure loading, i.e., of the pressure-time history of the initiating shock. In the region in which the shock attenuation by rarefaction is due only to lateral rarefaction waves, the shock duration should be proportional to the charge diameter. Thus, increased shock duration can explain the decrease in required peak pressure for initiation as charge diameter is increased.

The trend, decreased initiating pressure with increased acceptor diameter, has been found experimentally. For example, Cachia and Whitbread (5) found for a 0.5-in.-square donor and acceptor that the initiating pressure for cast RDX/TNT, 60/40, was 90 kbar, whereas Marlow and Skidmore (6) found for a 2-in.-diam donor and acceptor that the initiating pressure was 20 kbar for the same cyclotol. Although this comparison includes a donor diameter effect, the data of Table 1, for a fixed donor, do not; they also show decreased initiating pressure with increased acceptor diameter. Since the trend is both expected and demonstrated, an estimate of the effective diameter of the standardized test would be desirable. "Effective" diameter is used to designate the diameter of the unconfined charge for which the gap test value is equal to that found under the standardized confinement. Obviously, the closer the effective acceptor diameter is to an infinite diameter, for the standardized loading from the standard donor, the better will be the approximation of considering the measured initiating pressure an intrinsic sensitivity property of the test material.

Effect of Confinement on Test Results in Standardized Gap Test

Six different materials, including the explosive itself, were used as confinement in the standard test geometry (1, 2). The results for two cast explosives, pentolite and Composition B (Comp. B), are given in Table 1. The more shock sensitive material, pentolite, exhibited no confinement effect; for this charge the effective diameter in the standard test is approximately infinite. On the other hand, Comp. B showed a definite confinement effect; these results indicate that the effective diameter in the standard geometry will differ for each charge composition and that the confinement will have increasing effect as the shock sensitivity of the test charge decreases.

In the case of Comp. B, confining materials of shock impedance approximating that of the explosive (glass, Lucite, and Comp. B itself) all have approximately the same effect on the gap test value. The metals (lead, steel, and aluminum) have an appreciably greater effect. If it is assumed that the required incident pressure varies linearly with the reciprocal diameter of the equivalent bare charge, the data for the two unconfined charges (Table 1) give

$$d^{-1} = 0.0127P - 0.119 \quad [1]$$

where d is diameter in centimeters and P is incident pressure in kilobars. The probable validity of Eq. [1] over the range of 3.66 to 4.76 cm in diameter is supported by the result of extrapolating it to a $\frac{1}{2}$ in. diameter, incident pressure of 70 kbar and hence an initiating pressure of 88 kbar, in excellent agreement with the 90 kbar measured by Cachia and Whitbread (5). Extrapolation in the opposite direction to a 2-in. diameter gives an initiating pressure of about 30 kbar, appreciably higher than the 20 kbar measured by Marlow and Skidmore (6). The lower experimental value, which is very close to the 21.2 kbar measured in the standard confinement, is attributed to the length to diameter ratio of 3 for the donor used in the earlier work.

Use of Eq. [1] shows that the standard steel confinement has increased the effective diameter of cast Comp. B by a factor of 2.5.[4] Moreover, if the confining tubes are treated as having a simple inertial effect, i.e., the tube mass is replaced by an equal mass of Comp. B in the cylindrical configuration, all the data of Table 1 can be fairly well approximated by Eq. [1]. The apparent correlation may be a fortuitous result of the selection of confining materials because the shock impedance of the confinement, which was not measured, would be expected to control the confining effect.

Prediction of Large-Scale Field Test Results from Gap Test Values

For propellants, which generally exhibit shock sensitivities less than that of Comp. B, the confinement of the standardized

[4] This is the diameter effect for a given donor; it is not the factor to be expected when both the donor and acceptor are scaled.

gap test should be quite effective, and the initiating pressures so measured should approximate those required under large-scale field test conditions. This has so far seemed to be the case.

Data are now available for large scale (20 lb or more), 40-ft drop tests of three propellants; the sample is dropped onto a flat, 3-in.-thick steel plate backed up by a concrete slab. Drops are also made on plates containing 0.75-in.-diam by 1-in.-high steel lugs. Three propellants have been tested; their gap test values ranged from no-go to 70 cards and impact height values from 9 to 22 cm. Field experience has shown no unsafe incidents from handling nonporous propellants with such characteristics, and the gap test value gives a required initiating pressure of 65 kbar or more to induce detonation in the two materials detonable in the standard configuration. After a 40-ft free drop, the impact velocity is 51 fps or 0.016 mm/μsec; the resulting pressure in the propellant is about 1 kbar. Consequently no detonation would be expected from this height drop, nor was any obtained. In some cases, particularly from drops on lugs, burning did occur.

These results may be compared with those for five cast high explosives. The explosives showed a gap test value range of 138 to 201 cards (minimum initiating pressure of 21.2 kbar) and of 45 to 215 cm in impact height values. Again no detonation would be expected, and none was observed. There was only one case of burning induced by the drop; this shows, as does the impact height test values, that the propellants are easier to ignite and burn than commonly used high explosives.

Steel cases, loaded with about 104 lb of a detonable propellant (propellant A), were placed on rocket sleds that were accelerated to 940 to 970 fps. The sleds were stripped off, and the charge struck the target at a velocity of about 1000 fps (680 mph). The target was either $1\frac{1}{4}$-in. steel plate or 12-in. reinforced concrete walls. In both cases, the charge completely penetrated the target without detonating, although rapid deflagration did occur after penetration in one case.

Propellant A′, a propellant very similar to that used in the field test, was examined in the laboratory. The gap test value was 74 cards; the impact test height was 14 cm. The required initiating pressure is 63.5 kbar, whereas that induced by 1000-fps impact on steel is only 14 kbar. Consequently no detonation would be expected from the 1000-fps impact test. The burning, after impact and penetration, is in accord with the low impact test height.

Both the effect due to the acceptor confinement on the gap test values and the correlation found between the gap test values and the large-scale field tests indicate that the initiating pressures measured in the standardized test are quite close to the infinite diameter values, i.e., are a measure of the intrinsic shock sensitivity of the material tested. Very recent work (10) offers stronger evidence.

The wedge test developed by Majowicz and Jacobs (7) and now in fairly general use (e.g., Refs. 8 and 9) approximates a one-dimensional or infinite diameter experiment. This is so because the initial plane shock is not attenuated by lateral rarefaction as is the case in most experimental geometries. Liddiard and Drimmer (10) in recent shock initiation studies of several explosives with the wedge test showed that "the value of pressure, which will just produce detonation in wedges and cylinders in an indefinitely long run distance (asymptotic value), appears to be approaching that of the 50% card-gap pressure value."

Comparison of Gap and Blunt-Nosed Bullet Tests

Further safety information is available from the blunt-nosed bullet test. Indeed, because of its equivalence to the gap test, the bullet test results assist also in the interpretation of the standardized test results.

Brown and Whitbread (11) first established the equivalence between the gap and the blunt-nosed bullet tests. They measured the velocity required for the 50% probability of detonation of explosives struck by high velocity cylinders and balls; they showed for nine explosives that the 50% brass gap thickness varied linearly with the 50% velocity measured for steel balls. Both the donor and the ball diameter were 0.5 in. Moreover, using 0.5-in.-diam cylinders, effectively infinite in length, of four different materials, Brown and Whitbread were able to determine the required initiating pressure of the test explosive. They did this by using projectile materials for which the Hugoniot data (pressure-particle velocity) were known; the measured 50% velocity value for a given projectile material gave the initial point from which its curve could be drawn in the pressure-particle velocity plane. The curves for the four materials intersect at the pressure required to initiate the test material. By this procedure, the initiating pressure was measured for two explosives: tetrytol 91/9 and RDX/wax 83/17.

An alternative method would be to determine the initiating pressure at the intersection of the Hugoniot of the projectile material with the Hugoniot of the explosive in the pressure-particle velocity plane. This procedure has the advantage of giving a larger-angled intersection of Hugoniots and thus minimizes the error of reading the point of intersection and of small errors in the measured 50% velocities. It shows these advantages even when the Hugoniot of the particular explosive is unknown and must be approximated by the Hugoniot of a similar explosive, such as TNT. This alternative method has therefore been used for derived values presented later.

The acceptor diameter effect on the measured initiating pressure has already been described; there is an analogous donor diameter effect (12). In the projectile test, the diameter of the cylindrical bullet corresponds most closely to the diameter of the explosive donor in the standardized gap test, and, just as there is a donor diameter effect on the initiating pressure measured by the gap test, a projectile diameter effect is also to be expected. (It has, in fact, been observed in Ref. 13.) Thus the initiating pressure measured by a 0.5-in.-diam projectile impacting on a 1.5-in.-diam unconfined acceptor should be appreciably greater than that measured by a 2.0-in.-diam explosive donor on a 1.5-in.-diam confined acceptor. Such is indeed the case, for Brown and Whitbread measured an initiating pressure of 50 kbar for RDX/wax 83/17, whereas Comp. B of nearly the same shock sensitivity (see Table 2) exhibits an initiating pressure of 21.2 kbar in the standardized gap test.

It would be expected that, with identical effective diameters for donor and acceptor, the gap and blunt-nosed bullet tests would measure the same initiating pressures on the same test material. To obtain such agreement, comparable donor length would also be required; in the bullet test (11) the projectiles were effectively infinite in length, whereas in the standardized gap test the donor, with a length to diameter ratio of only 1, is not. Finally, there is a difference in the pressure-time history of the loading in the two cases. Brown and Whitbread believe that a square pressure pulse is formed (on the axis of the acceptor) and report a required duration of 0.6 μsec or more for RDX/wax, 83/17. The shock loading of the standardized gap test produces a peak pressure followed by an exponential pressure decay; it is estimated that the pressure will fall to 50% of its peak value in 2 to 5 μsec (4). This difference in loading curve will probably introduce a small difference in initiating pressures measured in the two ways.

If any difference caused by the different loading curves is ignored, the Hugoniots for iron and TNT can be used to compute, from the initiating pressures measured in the gap test, the corresponding 50% velocities for steel cylinders equivalent to the effective donor diameter and length (2 $\times$ 2 in.) of the standardized gap test. Moreover, from comparison with the Brown and Whitbread data, the change in 50% velocity with bullet diameter and shape and with the removal of confine-

Table 2 Comparison of gap and steel bullet test values at the 50% point[a]

	From gap test		Velocity for 0.5-in.-diam projectiles	
Material	Initiating pressure, kbar	Cylinder velocity, fps	Cylinders, fps	Spheres, fps
Propellant A′	63.5	3592	(>4000)	(>7000)
TNT(c)	37.3	2296	(s.m. 3720)	6924[b]
Tetrytol 91/9(c)	(s.l. 37.3)	(s.l. 2296)	3720[b]	6650[b]
RDX/wax(c) 83/17	(s.m. 21.2)	(s.m. 1411)	2980[b]	5655[b]
Comp. B(c)	21.2	1411	(s.l. 2980)[c]	5471[b,d]

[a] Values in parentheses are estimates: s.l. means slightly less than and s.m. slightly more than.
[b] Brown and Whitbread values (11).
[c] Dewey (13) gives a velocity of 2940 fps for Comp. B.
[d] Value for cyclotol 60/40, Bridgewater RDX.

ment from the acceptor can be seen. Data for these comparisons have been assembled in Table 2.

Propellant A′ has been included in Table 2 as typical of the shock sensitivity of the double-base and older hybrid double-base propellants and also because of the large-scale field test described earlier. The other materials are cast explosives examined by Brown and Whitbread. Where available, initiating pressures and corresponding 50% cylinder velocities from the standardized gap test are given; when such measurements have not been made, semiquantitative estimates (those enclosed in parentheses) have been made with the aid of the 50% velocities for steel balls.

The variation found is that to be expected: an increase in the measured initiating pressure with a decrease in the impacted area from that corresponding to the standardized gap test to that corresponding to the 0.5-in.-diam steel ball. The 50% velocity for propellant A′ is 3.5 times the velocity used in the field test and again explains the failure of this material to detonate after an impact at 1000 fps. It is also interesting to note that the initiation of cast TNT by a steel ball of 1.27 cm is an example of initiating when the impact area is of a diameter much lower than the critical diameter of the material; the critical diameter of cast TNT is about 2.7 cm (14).

Shock sensitivity can be equally well measured by either the blunt-nosed bullet or the gap test. Under comparable geometric conditions, the results should be essentially the same. Neither test, however, can replace a sharp-nosed bullet test. In the latter test, deep penetration of the charge can occur, and the effect of heating large surface areas, confined by the rest of the charge, is superimposed on the effects of shock and compression.

Information about Low Impulse Reactions

The standardized gap test is designed to measure the shock sensitivity of materials reacting to give a high impulse; the minimum impulse for the reactions it tests is that necessary to punch a hole in the cold-rolled steel witness plate (2). All nonporous propellants that have been tested have produced either much more than this minimum impulse or so little that the witness plate was undamaged. However, some porous charges have exhibited no-go at zero gap, i.e., failed to punch the plate, but have also shown a shock initiated reaction of sufficient impulse to bulge and bend the witness plate. Any reaction capable of damaging a $\frac{3}{8}$-in.-thick steel plate is of importance for safety considerations, even if the damage it can cause is less than that of the higher impulse reactions. It is therefore desirable to have a means of assessing such lower impulse reactions.

In principle, it is possible to design separate tests to measure: 1) sensitivity to initiation of any self-propagating reaction, and 2) the strength, i.e., maximum pressure, of the self-propagating reaction initiated by shock. In practice, such an absolute division in testing nonporous propellants seems unnecessary because no sample tested has been in the lower impulse region; the division seems undesirable because of the long time required to develop new, reliable tests. Consequently, the standardized gap test will be used, as in the past, to cover simultaneously parts of 1 and 2, and, if a material is found to damage, but not punch, the witness plate, information will be obtained to supplement the gap test result.

The simplest way to obtain such supplementary information is to use the standardized test geometry with the replacement of the $\frac{3}{8}$-in. witness plate by another sensor capable of responding unambiguously to lower impulse loadings. The first substitute investigated was thinner witness plates. It was found that they gave too small a range in response and were too variable from lot to lot to be satisfactory. The variation does not affect previously reported results for high impulse reactions because the plate loading is so much greater than that required to punch a hole.

The method that was then developed, and which is satisfactory, uses an explosive witness system. Fig. 1 shows the standardized gap test with a steel witness plate. To study lower impulse reactions, i.e., those that result in pressures of about 55 kbar or less in the reacting material, the steel plate adjacent to the test material is replaced by another 5.5-in.-long tube of any detonable material for which the initiating pressure is already known; the modified geometry is shown in Fig. 2. As Fig. 2 shows, the steel plate is still used to witness the high impulse reaction of the explosive witness after the high impulse reaction has been initiated by the low impulse reaction of the test material.

The choice of explosive sensors can be made from materials already studied. A typical selection is shown in Table 3. Intermediate levels can be obtained by combining or diluting these materials. Since all of them are nonporous and have approximately the same impedance as the nonporous propellants, the incident pressure, or pressure generated by the reaction of the test material and the quantity of interest in assessing damage, will be nearly equal to the initiating pressure required by the explosive witness. Porous sensors, e.g., PETN at $\rho_0 = 1$ g/cm^3 with 2.5 kbar initiating pressure (9), should be avoided because the incident pressure from a nonporous test charge must be much higher than the low initiating pressure of a porous sensor to induce its detonation. Similar difficulties with impedance mismatch arise in testing a porous charge with a nonporous explosive witness. The study of low impulse materials by the method indicated in Fig. 2 is best applied only to nonporous charges.

The present method provides not only an estimate to reaction pressure of the test material but also, if the strength of the reaction warrants it, a way of measuring the shock sensitivity of the reaction. This can be done by using the

Table 3

Explosive witness	Initiating pressure, kbar
Propellants	ca. 50
TNT (cast)	37.3
Comp. B (cast)	21.2
DINA (cast)	6.3

Table 4 Study of low impulse reactions

Material	Density, g/cm³	Temperature,[a] °C	Witness system	50% gap, no. cards	Initiating pressure, kbar	Comments
TNT (c)	1.613	6.7 to 10.6	Steel plate	141 ± 1	36.7	
Comp. B(c)	1.697	12.2	Steel plate	195 ± 1	23.2	Same value within difference to be expected for temperature difference
Comp. B(c)	1.697	7.0 to 8.0	Comp. B(c)	$185 < N < 188$	24.5	
AP[b]	ca. 0.85	20.6	Steel plate	$N < 0$	?	Plate deformed by large hump
AP	ca. 0.85	23.9	Comp. B(c)	$212 < N < 225$	ca. 5	See text. Gap value same within difference to be expected for temperature difference
AP	ca. 0.85	13.4 to 14.3	TNT(c)	207	ca. 5	
Gap placed between acceptor and witness system[c]						
AP	ca. 0.85	24 to 25	Comp. B(c)	$100 < N < 150$		Reaction of AP gives impulse more than sufficient to initiate cast TNT, and therefore much more than sufficient to initiate Comp B. Excess of impulse over that to initiate TNT is small
AP	ca. 0.85	12.8 to 14.4	TNT(c)	$18 < N < 25$		

[a] Temperature conditioning facilities were not available at time of this work.
[b] The ammonium perchlorate used was micromilled to an average particle size of 25 μ.
[c] Zero gap between donor and acceptor.

standard gap testing procedure with the appropriate explosive witness system in place of the steel witness plate. Thus a measure of both the ease of initiation and of the strength of a low impulse reaction can be obtained.

Although the method is designed to study nonporous materials, it is necessary to illustrate its application with a porous charge because no nonporous propellant exhibiting the lower impulse behavior is available. Ammonium perchlorate (AP) of average particle size of 25 μ and loading density of 0.85 g/cm³ was chosen; the test results are given in Table 4.

First, the initiating pressures of cast TNT and cast Comp. B, the materials to be used in explosive witness systems, were determined to be about 37 and 23 kbar, respectively. It was shown also that doubling the length of the Comp. B acceptor had no effect on the measured initiating pressure, i.e., that the length/diameter ratio of the standard gap test is sufficient for complete buildup. Earlier results on a porous charge of AP were repeated: a no-go at zero gap in the standardized test but obvious damage to the witness plate. With both of the explosive witness systems a go was obtained, and in both cases the required *incident* pressure was about 15 kbar. To determine the pressure required to initiate the AP, it is necessary to use a Hugoniot for this material. Of the available Hugoniot data, that set which might best approximate a porous charge of AP is the Hugoniot for pressed PETN at $\rho_0 = 1$ g/cm³ (9). Use of this Hugoniot with an incident pressure of 15 kbar at the Lucite/AP boundary gives an initiating pressure of about 5 kbar for the AP. This material is therefore very shock sensitive, and its low impulse reaction easy to initiate.

The maximum pressure generated by the low impulse reaction is harder to estimate since it requires Hugoniot data for the reaction products. Qualitatively, it is more than sufficient to initiate TNT, the less sensitive explosive, but not much more than sufficient since an attenuation of about 0.22 in. of Lucite prevents the initiation. The computed density of the detonation products for AP ($\rho_0 = 0.85$) is about 1.16 g/cm³ (15). Since Lucite has a density of 1.18 g/cm³, it is reasonable to assume a sufficiently good impedance match between the AP products and Lucite to make the pressure transmitted equal to the incident pressure exerted by the detonation products. This pressure is then that in the Lucite at zero gap. Without running a complete calibration curve for the AP ($\rho_0 = 0.85$) loading of Lucite, its maximum pressure can be estimated from the two points[5] on this calibration curve,

[5] These two points were not completely defined (see Table 4). For this estimate, the midrange values of 125 cards (Comp. B) and 21.5 cards (TNT) were used.

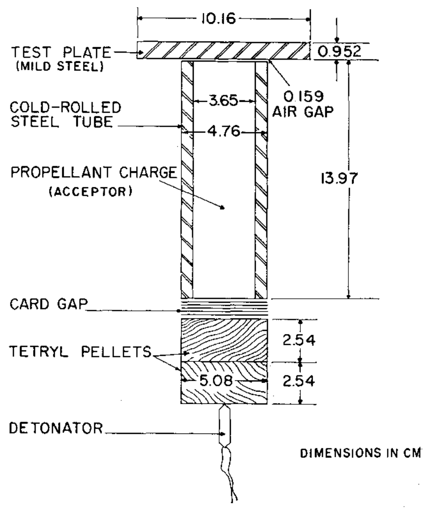

Fig. 1 Charge assembly and dimensions for Naval Ordnance Laboratory standardized gap test

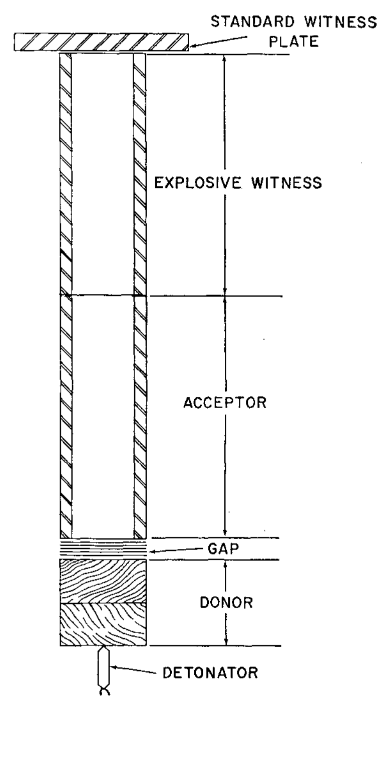

Fig. 2 Test assembly using the explosive witness system

given by Comp. B and TNT used as explosive witnesses. The curve, log (pressure) vs gap thickness, can be expected to be linear, as was that for tetryl (2), and extrapolation of the linear curve to zero gap gives a pressure of 33 kbar. For such an approximate treatment, the value of 33 kbar is in good agreement with the theoretically computed value of 25 kbar (15). Hence a 25-kbar loading of the 0.215-in. gap of Lucite by the AP detonation products is a reasonable one to result in the transmission of about 37 kbar to the TNT witness and thus initiate its detonation.

Finally, the test data in Table 4 for the length of gap between the acceptor and explosive witness, necessary to attenuate the loading from the AP reaction until it is too weak to initiate the explosive witness, serve also to show that the initiation of the explosive witness is by shock and not by a flame front from the decomposing AP. The plastic material of the gap will transmit compression pulses but prevent propagation of any normal burning front.

The explosive witness test has been recommended as best suited for studying nonporous charges; it can, of course, be used with any test material for which Hugoniot data are available. Because such data for the test materials are generally unknown, the test is best used so that the rating obtained from the known incident pressures is the same rating that would be given by the transmitted (initiating) pressures. This condition is satisfied only if all the test materials have approximately the same shock impedance. Thus it is possible to rate a series of nonporous propellants of about the same impedance or a series of low bulk density, granular propellants of about the same impedance. But it is not possible to obtain a quantitative comparison between a nonporous, high bulk-density and a porous, low bulk-density propellant without Hugoniot data for both materials. For example, the incident 50% point pressure for the boundary Lucite/cast TNT is 31.3 kbar, and the transmitted pressure is 37.3 kbar, an *increase* of about 20%. In contrast to this, the incident 50% point pressure for Lucite/AP ($\rho_0 = 0.85$) is 15 kbar, and the transmitted pressure is 5 kbar, a *decrease* of about 67%. The shock sensitivities of cast TNT and pressed AP are determined by the respective initiating pressures of 37.3 and 5 kbar and not by the required incident pressures of 31.3 and 15 kbar. Similar considerations of the impedance matching of the reaction products to the explosive witness must be made when the explosive witness procedure is used to estimate maximum pressure of the reaction products.

Important Results of Study

The more important results of the present study can be briefly summarized as follows:

1 The pressure required to initiate detonation in a given detonable material decreases from its highest value near the material's critical diameter to its lowest value at a charge diameter that is effectively infinite.

2 The confinement used in the standardized gap test varies in effectiveness with the material tested; for cast Comp. B, it increases the effective diameter by about 2.5 times for the standard loading provided by the standard tetryl donor.

3 The initiation pressure measured by the standardized gap test is near that for the infinite diameter charge; this is indicated by the correlations found between 1) large scale field tests and 50% gap values, and 2) the wedge test results and 50% gap values.

4 Either the blunt-nosed bullet or the gap test can be used to measure shock sensitivity. Neither can replace the sharp-nosed bullet test.

5 Shock-initiated reactions of such low impulse that they damage but do not punch the standard witness plate can be studied by use of a high explosive system as a witness.

6 Judicious choices of explosive witnesses permit the measurement not only of the shock sensitivity but also of the maximum pressure generated by the low impulse reaction. The latter quantity gives an estimate of the damage to be expected from the reaction.

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