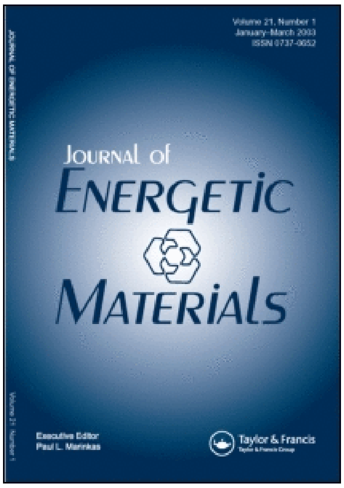

Journal of Energetic Materials

Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713770432

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To cite this Article Chick, M. C.(1985) 'A novel technique for the controlled initiation of explosives', Journal of Energetic Materials, 3: 3, 221 — 238

To link to this Article: DOI: 10.1080/07370658508010626

URL: http://dx.doi.org/10.1080/07370658508010626

A NOVEL TECHNIQUE FOR THE CONTROLLED INITIATION OF EXPLOSIVES

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ABSTRACT

The observation that the jet initiation of covered and bare explosive occurs by quite different mechanisms has been used to devise a novel technique for producing either prompt detonation at a predetermined position within an explosive charge or failure and disruption.

The method consists of firing a jet at an appropriately covered explosive containing a void located where the onset of detonation is required. The void contains a low density medium to dissipate the bow wave shock and may be positioned within the bulk of the explosive or on the surface. When the jet strikes the far side of the void prompt detonation occurs and spreads throughout the explosive. However, when the jet is aimed to miss the void, failure occurs.

The technique is described in detail and illustrated by flash radiographs showing both the detonation and failure modes

Journal of Energetic Materials vol. 3, 221-238 (1985)

Published in 1985 by Dowden, Brodman & Devine, Inc.

for a Composition B charge containing a spherical void located near its center. For Composition B the estimated maximum depth of locating the void, and therefore the point of initiation, is approximately 320 mm from the charge surface.

Potential applications and some limitations of the method are discussed.

The technique is the subject of patent action.

INTRODUCTION

The initiation of bare explosives has been shown to be dependent on the ability of the shock from the jet striking the surface of the explosive supporting detonation for a sufficient time to establish a stable, curved detonation front[1].

Recent reports have shown that the jet initiation of covered and bare explosive occurs by different mechanisms[2,3]. Thus the initiation of covered explosive is controlled by the bow wave shock associated with the jet penetrating the explosive[3]. However, this mechanism does not apply to very thin covers struck by high velocity jets where the decaying impact shock causes detonation[2,4].

One result of these different mechanisms is that explosive in the bare state exhibits greater sensitivity to jet initiation than when it is covered[3]. For example, the critical velocities of the jet generated from a 38 mm diameter shaped charge which are required to initiate steel covered and bare cast Composition B have been measured at 5.2 and 3.2 mm/μs respectively. Similar measurements of the critical velocities for the jet initiation of steel covered and bare pressed TNT gave values of 4.2 and 2.9 mm/μs respectively.

These differences are attributed to the action of the bow wave. Thus, during the jet penetration of covered explosive, the peak pressure of the bow wave can be several orders of magnitude less than that at the jet tip target interface. Further, it has been demonstrated that, when the bow wave fails to cause detonation, the explosive is desensitised to the action of the closely following jet tip[2,3]. Therefore the removal of the desensitising bow wave by the introduction of a void or air gap in the explosive allows the jet to strike unstressed explosive. A potential failure will then be converted into a prompt detonation if the jet velocity is greater than the critical value to initiate the bare explosive.

This paper describes a technique, based on these observations, for producing either the disruption of an explosive charge or its prompt detonation at a predetermined position on the surface or within the bulk of the explosive.

DESCRIPTION OF TECHNIQUE

The technique is described by reference to Fig. 1 which shows a covered charge with a spherical void located towards its center.

The mode of operation is as follows. When the jet strikes the top of the cover a large impact shock is produced that travels ahead of the jet but decays rapidly. As the jet penetrates the cover a bow wave shock is established which is transmitted across the cover/explosive interface into the explosive ahead of the jet. This shock decays and is replaced by the bow wave from the jet penetrating the explosive. The cover thickness is selected so that the shock(s) transmitted into the explosive is too weak to cause detonation but still capable of preconditioning and densensitising the explosive to the following jet. Consequently, when the jet is aimed to miss the void as illustrated in Fig. 1(b), penetration continues through the explosive without detonation. However, the explosive will be shocked causing some disruption.

When the jet is aimed to hit the void the bow wave shock is dissipated by the low density medium and the jet strikes the far surface (Fig. 1(c)) where the bare explosive has not been desensitised by the bow wave shock. Under these conditions detonation occurs providing the jet velocity is greater than the critical velocity for the initiation of the bare explosive.

This mode of initiation is prompt so that, even near the critical initiated threshold, detonation occurs in less than about a microsecond and within a few millimeters[2,3]. Otherwise the small geometry of the initiating system allows rarefactions to quench the reaction quickly. The detonation wave then expands throughout the whole charge including through the explosive penetrated and shocked.

These conditions contrast to conventional shock initiation where the critical time and distance for the establishment of detonation is usually several microseconds and tens of millimetres respectively. Therefore, compared to conventional shock initiation, jet initiation of bare explosive produces less loss in explosive impulse during the build-up to detonation process.

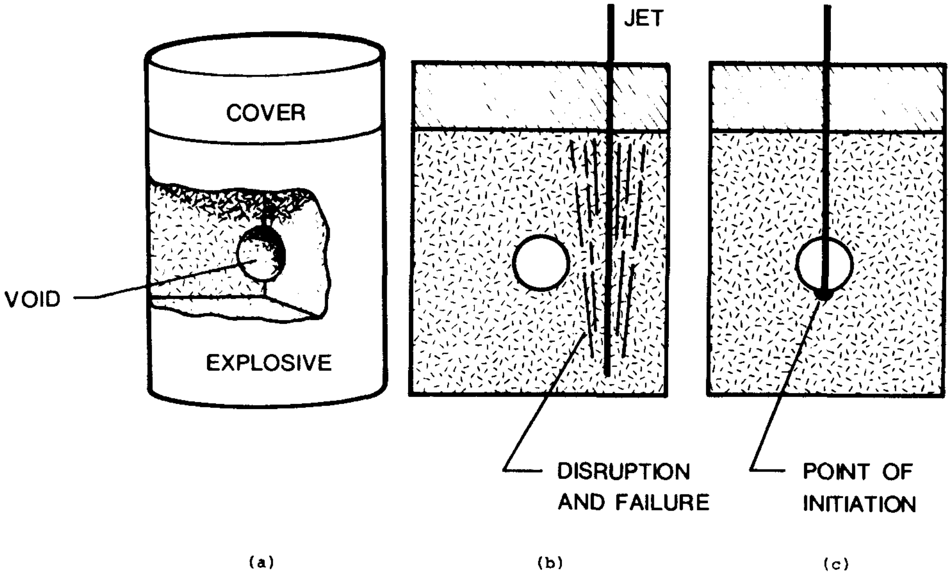


FIGURE 1

Schematic illustration of the technique to produce either controlled detonation or disruption of an explosive charge.

The technique has been developed from an extensive range of experiments. Although most work has been carried out on steel covered Composition B, cover material, explosive type and jet material have been varied.

The method of measuring the critical jet velocities for the initiation/failure threshold for covered and bare explosives has been described in detail[6]. Briefly, the critical cover thickness was determined that produced detonation in 50% of a series of firings. The Bruceton procedure was used to vary the thickness of the cover in a prescribed manner dependent on whether the previous event had been a detonation or failure. There were between 10 and 20 firings per critical cover thickness determination.

Measurements on bare explosive were made by a similar method except that a 15 mm air gap was introduced between the cover and explosive. This standoff cover arrangement was designed to remove any effects of the bow wave shock from the jet penetrating the cover thus enabling the jet to strike unstressed explosive while still allowing the jet characteristics to be altered by varying the cover thickness.

The critical velocities were then determined both by direct measurement in separate experiments using multiple flash radiography and by calculation using the DiPersio/Simon relationship for a stretching jet penetrating the critical cover thickness[7]:

$$V_j = V_{tip} \left(\frac{x_{crit}+S}{S}\right)^{-\gamma} \quad (1)$$

where V_j the critical jet velocity, V_{tip} the initial jet tip velocity, x_{crit} the measured critical cover thickness, S the standoff from the virtual origin position of jet formation to the surface of the cover and γ the square root of the ratio of target density to jet density. Recent data show good correlations between the experimentally determined and calculated values.[4]

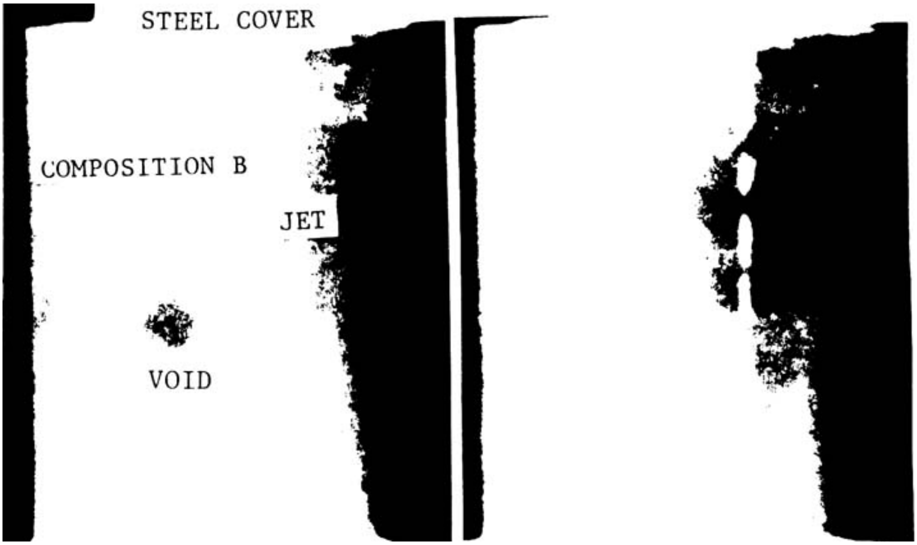
DEMONSTRATION OF TECHNIQUE

The technique has been proved using a steel covered Composition B charge containing a spherical void at a predetermined position as illustrated in Fig. 1(a). Multiple flash radiography was used to record various stages of the functioning of the device in both the detonation and disruption modes.

The jet was generated from a 38 mm diameter shaped charge and had a tip velocity of 7.3 mm/µs. The 76 mm thick steel cover was in intimate contact with the Composition B (RDX/TNT/WAX, 55/45/1) explosive charge of 60 mm square cross section and 102 mm length. A steel witness block was used to support the receptor, detect the result of the firing and record residual penetration. The centre of the 19 mm diameter spherical void was located along the axis of the charge 60 mm from the explosive/steel interface. The spherical void was positioned by sticking together two charges with a 19 mm diameter hemisphere machined in the center of the interface surface of each. The thickness of the steel cover was selected to be between the measured critical thicknesses for the initiation of covered (60 mm) and bare (140 mm) Composition B. As previously discussed these thicknesses are equivalent to critical jet velocities for the initiation of covered and bare Composition B of 5.2 and 3.2 mm/µs respectively.

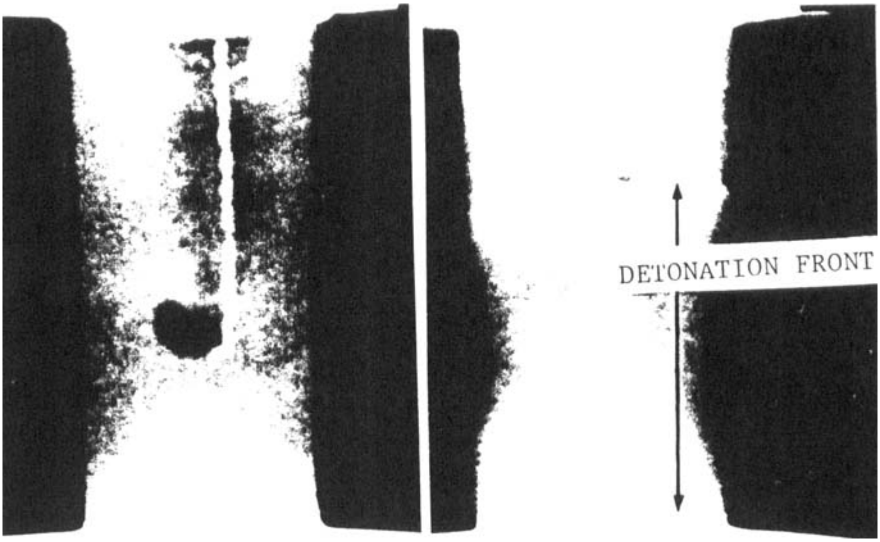
Fig. 2 shows two flash radiographs from a series of 4 firings where the jet was aimed to miss the void. In Fig. 2(a) the jet is observed passing to one side of the void and in Fig. 2(b) the jet has completely penetrated the charge. The later picture shows explosive spall in the void collapsing from the action of the bow wave shock. Flash radiographs showed that in one firing of the series the jet passed within 5 mm of the void. All four firings failed to detonate as indicated from the lack of marks on the witness block and cover plate and the Composition B recovered from the firing cell.

Fig. 3 consists of two flash radiographs from a series of firings where the jet was aimed to hit the void. Fig. 3(a)



(a) FIGURE 2 (b)

Flash radiographs of a jet aimed to miss a spherical void located at a predetermined position within a steel covered Composition B charge. The round failed to detonate.



(a) FIGURE 3 (b)

Flash radiographs as per Figure 2 but showing prompt detonation from the jet aimed to strike the far side of the void.

shows the jet striking the far surface of the void and the penetrated explosive (about 50 mm deep) not detonating. In Fig. 3(b) taken a few microseconds later prompt detonation has occurred and the front has spread in all directions consuming the explosive. The residual penetration of the witness block was significantly less than for the rounds that did not detonate. The three rounds fired in this series all detonated. Thus there were no contradictions from a total of 7 charges fired.

CONTROLLING FACTORS AND DESIGN CONSIDERATIONS

Properties of the jet, cover and explosive as well as characteristics of the void are important in controlling the jet initiation/failure processes.

The explosive may be pressed or cast but the critical diameter to support detonation should be sufficiently small to allow the jet initiation of bare explosive to occur.

The explosive should not be in a granular form nor contain significant voids in the path of the jet other than those deliberately incorporated as part of the technique. Since bow wave initiation is essentially a shock process, sensitivity controlling properties such as density, degree of inhomogeniety, inert content, particle size, etc, would be important in determining the critical jet velocity.

The void may be any size or shape, sufficient to dissipate the bow wave in front of the jet tip. It is assumed the void may be composed of low density material providing the bow wave shock is sufficiently dissipated to allow the jet to initiate the explosive on the far side of the void.

The maximum depth of locating the void in the explosive, T_m, may be calculated from a rearranged form of the DiPersio/Simon relationship (equation 1) where V_{tip} is redefined as, V_c, the velocity of the jet entering the explosive from the cover of thickness, x, and V_j is redefined as, V_b, the velocity of the jet striking the bare explosive in the void;

$$T_m = (S + x)\left[\left(\frac{V_c}{V_b}\right)^{1/\gamma} - 1\right] \qquad (2)$$

where the total standoff distance is now S + x. The application of the equation to a jet penetrating an energetic material such as Composition B is supported by the good agreement found between calculated and measured values.[4]

The largest value for T_m will occur for the critical cover thickness, x_{crit}, and the corresponding critical value for jet initiation, $V_{c\ crit}$. For thinner covers, i.e. $x < x_{crit}$, jet bow wave initiation will occur precluding the use of the technique. As the cover thickness is increased, V_c will decrease and since V_b is constant, V_c/V_b decreases.

Substitution shows that this decrease has a greater effect than the increase of x and therefore T decreases. The limit is reached when x approaches the critical thickness for the standoff cover for the jet initiation threshold of the bare explosive, $V_{b\ crit}$. Thus V_c approaches $V_{b\ crit}$ and T approaches zero, i.e. the maximum depth for the void has moved to the surface of the explosive.

The maximum depth of placing the void in Composition B for the critical cover thickness condition has been estimated using equation 2 to be about 320 mm. The measured $V_{c\ crit}$ and $V_{b\ crit}$ values for the system discussed in the introduction section were used in deriving the estimate. This would allow central initiation of a charge up to about 640 mm diameter. Similarly, using the previously discussed critical jet velocities for initiating pressed TNT with a cover of critical thickness gives a maximum depth for placing the void of about 290 mm.

In practice the selected value of V_c must be less than $V_{c\ crit}$ since a failure is required. If the jet breaks up during penetration then one of the modified forms of equation 1 is used.[7]

The cover performs two important functions. One is to control the jet penetration velocity; this is dependent on the density of the cover and determines its thickness. The other is to produce the precursor shock ahead of the jet (either the decaying impact shock or bow wave shock) that enters and densensitises the explosive to the jet.

Jet density, velocity and diameter are important in controlling the initiation of covered and bare explosive. The threshold for initiating bare explosive may be predicted from the relationship developed by Held[8] and Mader and Pimbley[1];

$$V_b^2 d\rho = k \tag{3}$$

where d the jet diameter, ρ jet density and k a constant for the explosive under test. A similar predictive relationship for covered explosives is under investigation[9] and the importance of jet velocity and diameter have been established[2,3,10]. Jet density would only appear to have an effect in that it controls the rate of penetration.[4]

Thinly covered explosive can be used in the technique by the appropriate choice of shaped charge to produce a jet of the desired parameters (e.g. velocity, diameter, density). Alternatively jet velocity can be adjusted by firing it through standoff cover plates.

SOME POTENTIAL APPLICATIONS

By appropriate choice of explosive geometry and void location the technique could be used to produce particular or directional blast and shock wave patterns for use in explosive research and development. Thus for example, detonation of a spherical charge with a void at its centre could be used to produce a near spherical blast wave to interact with an inclined surface for the study of shock reflections and Mach stem formation.

The technique could be used to produce a detonation or self disruption mechanism for explosive munitions. This may be undertaken by using an arrangement similar to that shown in Fig. 4. When the jet is fired from position A it traverses the air gap and initiates the bare (or thinly covered) explosive thus setting in train the intended function of the device. When the jet is fired from position B the inert cover material characteristics are selected so that the jet disrupts the explosive and the system fails to detonate. Positions A and B could be occupied by the same shaped charge that has the capacity to be turned to face either direction. This type of explosive logic system may be extended to produce directional explosive effects by firing more than one jet to initiate the explosive filling at multiple positions. In Fig. 4 this may be achieved by firing jets from positions A and C.

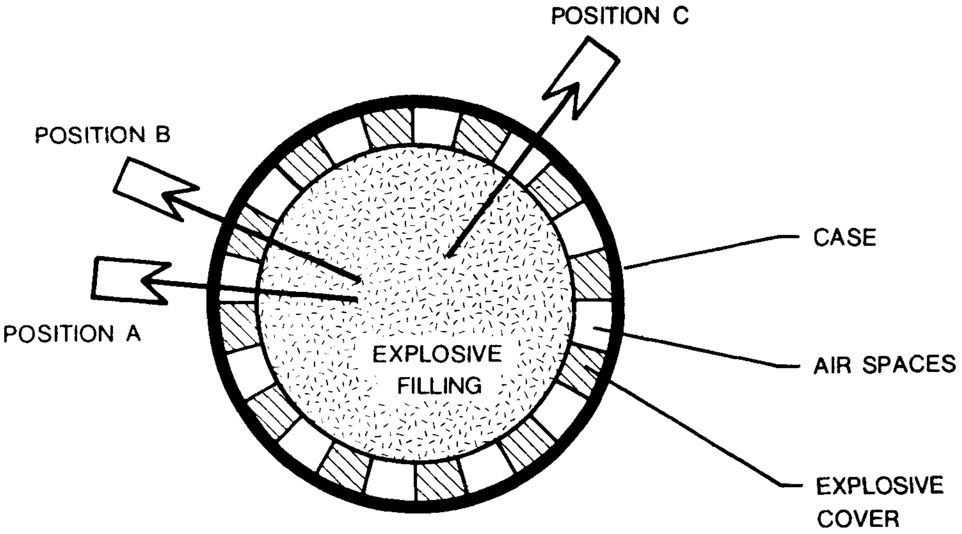


FIGURE 4

An illustration of applying the technique to a charge with the options for single initiation, multiple initiation or a failure.

ADVANTAGES AND LIMITATIONS

The advantages of the technique include the following:

1. The technique can produce detonation or disruption of explosive depending whether the jet is aimed to hit or miss the void.
2. The technique can produce detonation at a position(s) within or on the surface of an explosive charge by the appropriate location of the void(s).
3. By the appropriate choice of explosive shape and void shape and location, detonation wave shaping and directional effects can be produced.

4. Detonation always occurs promptly with a minimal loss of explosive impulse due to the prompt build-up to detonation process in the jet initiation of bare explosive.
5. There are no moving parts, primary explosives or explosive trains in the main charge. The shaped charge is separated from the main charge and can be initiated by a high voltage detonator.

The limitations of the technique include the following:

1. There may be difficulties in locating the void in the desired location, e.g. single pressings.
2. Some explosives may exhibit a small difference between the critical jet velocities for initiating the bare and covered configurations. This will limit the maximum depth of placing the void to small values.
3. Some disruption of the explosive will occur from jet penetration for the detonation mode. Although, in most cases the jet will be promptly overtaken by the detonation, there may be small, unwanted residual penetration side effects.
4. The detonation of the shaped charge may produce unwanted side effects. This can be minimised by baffling and standing the shaped charge away from the main charge.

5. Explosives with large critical diameters with respect to the jet diameter may fail to be initiated in the bare configuration due to early quenching of the detonation[1]. Alternatively this type of explosive/jet combination may produce similar critical jet velocities for the bare and covered configurations due to the bow wave initiation mechanism controlling both cases, e.g. creamed TNT initiated by the jet from a 38 mm diameter shaped charge[4].

CONCLUSIONS

A technique has been described and demonstrated which uses a high velocity metal jet to produce either prompt detonation at a predetermined position within an explosive charge or failure and disruption.

Flash radiographs are presented which illustrate the application of the method to a Composition B charge.

The technique is subject to patent action.

ACKNOWLEDGEMENTS

I should like to thank Mr F.G. May for helpful discussions, Mr L. Learmonth for assistance in all stages of the experiments, members of the Explosives Casting and Machining Section for preparing the charges and Messrs I. Macintyre and T. Bussell for assistance with the flash radiography.

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