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Deflagration	Fragments	Low-order functioning
Detonation	High explosive	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This background document provides information for determining the order of functioning of explosive charges and types of functioning (detonation or deflagration). Detonation is high-order functioning, and deflagration is low-order functioning. It also provides analysis on explosive functioning in the air, on land, after penetrating armor plate and within weapon tubes.

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US ARMY TEST AND EVALUATION COMMAND
BACKGROUND DOCUMENT

DRSTE-RP-702-103
*Test Operations Procedure (TOP) 4-1-003 — 18 May 1984
AD No.

ORDER OF FUNCTIONING

1. INTRODUCTION.

a. A major consideration in tests of explosive-loaded projectiles is the determination of the order of functioning of the explosive charge. Such investigations have as their objective the classification of the explosive substance in terms of reaction violence. This involves determining the manner of propagation of the explosive reaction from one part of the explosive substance to another.

b. There are two types of explosions: detonations and deflagrations. Functioning of an explosive charge is classified as complete detonation, partial detonation (in which detonation occurs, but part of the explosive either deflagrates or remains intact), deflagration (burning), or failure (dud). Complete detonation of an explosive charge is a high-order functioning; any other action is low-order functioning (e.g., incomplete detonation of the explosive charge and/or deflagration (rapid burning)).

c. Explosives consist of one or more gaseous, liquid, or solid substances which, upon the application of heat, pressure, or shock to a small portion of their mass, may be converted in a short space of time into more stable substances, usually gases with occasional solids. All explosives are capable of being either burned or detonated; some are more readily burned than detonated. Readily detonated substances are termed high explosives; those which ignite easily but are difficult to detonate are considered low explosives. Low explosives undergo a relatively slow chemical transformation thereby producing a deflagration or an explosion, the effect ranging from rapid combustion to low-order detonation. Low explosives are suitable for use in igniter trains and certain types of propellants. Since all explosives may, to some degree, be caused either to burn or to detonate, and since this document is primarily concerned with the nature of the explosions of munitions, no further distinction will be made between high and low explosives.

*Supersedes MTP 4-1-003 dated 23 February 1966.

d. The following paragraphs consider, in general, the nature of explosives and furnish certain criteria for evaluating the order of functioning for a particular charge. Appropriate terms, which are mandatory for reporting such tests, are defined as they occur in the text. The use of these terms in reporting functioning tests ensures uniformity of reports and their interpretation, and allows for correct classification of the data.

e. Reports on projectile functioning should contain an accurate description of the observations, particularly in the case of low-order functioning. When the term "low order" is employed in reports, it must be amplified with "partial detonation," "deflagration," or other acceptable terms. This is especially true when functioning occurs to the rear of plate targets and for land impacts where maximum data are obtainable. Such observations are particularly valuable in development tests of new explosives and components.

2. TYPES OF FUNCTIONING.

2.1 Detonation.

a. A detonation wave is a reaction-supported shock wave. The propagation rate is at the speed of sound relative to the unreacted material. The detonation of an explosive charge, confined or unconfined, generally (but not always) consumes all the explosive. The fragments generated by breakup of the casing of a confined charge are always small with respect to the fragments generated from other levels of reaction violence, and fragment velocities are highest from detonations. The near-field blast wave (at least to distances of 10 charge diameters) is highest for detonations.

b. In detonating nitroglycerin, the rate of propagation by wave action is sometimes as great as 8 km (5 mi) per second. Because a detonation converts the explosive into gas at a much higher rate than does deflagration, the effects on nearby personnel and structures are much greater than those caused by deflagration. A propellent charge of 13.6 kg (30 lb) burning in a 155-mm gun will impart a velocity of 853 m/s (2800 fps) to the 43-kg (95-lb) projectile while leaving the gun unharmed. The same weight of explosive detonated in the same weapon would demolish both gun and projectile.

c. As defined above, detonations can be of only one type or aspect. The so-called low-order detonation is actually a deflagration or burning; it is a low-order functioning, but not a detonation. Explosives either do or do not detonate; detonation may be complete or partial, but it is obvious that the difference is merely one of degree, not of kind.

2.2 Deflagration.

a. If the propagation velocity (i.e., the rate at which the reaction front progresses into the unreacted material) is subsonic, the process is called a deflagration. The violence with which a munition functions when its explosive deflagrates can range from close to that of a detonation, with many small high-velocity fragments and high-pressure blast output, through explosions of varying degrees of violence, to a mild burn which merely pops the casing open.

b. The rate of propagation of such burning or deflagration is relatively slow. Even at the high pressure of 689 MPa (100,000 psi), the rate of burning is approximately 0.6 m/s (2 fps).

3. ANALYZING THE TYPES OF FUNCTIONING.

3.1 General.

a. To correctly classify the type of functioning obtained with an explosive charge, the project engineer must be able to recognize the characteristic evidence from complete and partial detonations and deflagrations.

b. Consideration must also be given to the fact that in certain types of firing the visible evidence, even of a complete detonation, may be meager or nonexistent; in this case, it will be necessary to arrange for recovery of the round before reporting it as a "dud" or failure.

c. It is also possible for the metal container to break into fragments which are characteristic of low-order functioning while, at the same time, having sufficient reaction of the charge to emit black smoke alone.

d. The following paragraphs describe the characteristic evidence of the various types of functioning under two general conditions, functioning in air and functioning on ground impact.

3.2 Functioning in Air. The only manifestations of the order of an explosive charge in the air are the burst (smoke and flame) and the sound. Where a burst occurs close enough to the ground to leave tangible evidence of the action, it may be treated as a ground impact, as described in paragraph 3.3. Where the burst takes place at an altitude that precludes leaving evidence on the ground below, the following considerations apply.

a. For some explosives, particularity TNT and Composition B, the color and amount of smoke produced by the detonation are distinctly different from the color and amount of smoke produced by a deflagration. Since most high explosives contain insufficient oxygen for their complete combustion, large amounts of free and uncombined carbon are released upon detonation, thus creating a black smoke. One exception, the amatol-loaded projectile, produces a small amount of light smoke. It can be stated, generally, that a large amount of black smoke indicates a high-order functioning, although this, in itself, should not be the sole criterion.

b. Consideration must be given to variations in the nature of the explosive, whether or not the natural light is providing a transmitted or reflected illumination, and to the effect of the background upon the apparent color of the burst. Even a moist condition of the atmosphere can affect the appearance of the functioning. A partial detonation of TNT or Composition B will produce yellow smoke; deflagration produces white smoke.

c. A detonation (high-order functioning) has a very distinct cracking, ripping, or crunching sound; the sound of a deflagration (low-order functioning) has a deeper pitch and more nearly approaches a rumble. It is impractical to attempt to identify a partial detonation in air by means of the sound produced. When the explosion is to be identified by means of the sound alone, the functioning should be identified as detonation (high-order functioning), deflagration (low-order functioning), or failure (dud). In addition, when using sound as the basis for determining the order of functioning, the observer should employ geophonic sensing equipment, when practical.

3.3 Functioning on Land. The order of functioning of explosives on land may be determined by the application of one or more of the following classes of criteria.

3.3.1 Evidence During Functioning. The evidence for determining the order of functioning during the actual explosion is identical to that described for functioning in air (para 3.2). The occurrence of the functioning at the earth's surface, however, introduces several complications.

a. Bursts which occur in or near a pool of water may produce a spray or steam which will obscure or discolor the cloud of smoke or explosive dust. A similar effect may result from a burst on dry soil which permits a dust cloud to be raised.

b. If a burst occurs well under the surface of the earth, in a previously formed crater, or some distance from the observers, the sound may be muffled, thus giving the impression of a low-order functioning. In these cases, the after-functioning evidence should be given especially careful attention.

3.3.2 Evidence After Functioning.

a. Fragments of explosive casing - Fragments of projectiles or bomb casings after functioning provide conclusive evidence of the order of functioning. It is important to remember, however, that a single charge may both detonate and deflagrate, producing fragments characteristic of both actions.

b. Fragment size - In general, low-order functioning produces larger fragments than are caused by detonation. For example, a complete detonation normally results in hundreds of small fragments, while a low-order functioning may cause the casing to break into only a few large fragments.

c. Types of casing separations - A detonation results in jagged tearing of the casing and produces edges of razor-like sharpness. The normal fragment is narrow and has its longest dimension parallel to the longitudinal axis of the casing. The surfaces of the separation are usually about 45° to the normal of the wall of the casing. On the other hand, fragments resulting from deflagration have smooth edges with a surface of separation normal to the walls. Deflagration fragments have no characteristic shape except that, in general, their longer dimension is also parallel to the longitudinal axis of the case. The normal fracture surfaces of deflagration fragments will usually reveal a "herringbone" or "chevron" pattern. The direction of the apex of this pattern is opposite to the direction of the crack propagation which opened the surface. This information is of use in determining the source of malfunction.

d. Discoloration of site of functioning - The discoloration of the area of the burst will be the same color as the color characteristic of smoke emitted from the type of burst, the color of the unconsumed explosive, or a combination of both of these features. A black discoloration in the vicinity of the functioning of a TNT or Composition B charge would indicate detonation of the charge. The presence of small pieces of unconsumed explosive is, of course, evidence that a partial functioning took place.

e. Ground effects of instantaneous fuze action - When a fuze functions at the instant of impact, the detonation produces a relatively small crater since all the earth removed is blasted out from above. For any given missile, the size of the crater will depend upon the angle of impact as well as the resistance of the earth. Detonation of artillery projectiles, especially those that have a low angle of impact, tends to produce "hatchet marks" on the ground, emanating from the crater at approximately right angles to the line of fire. These hatchet marks are made by fragments from the side of the casing striking the ground at high velocities.

f. Ground effects of delay fuze action:

(1) In the case of delay fuze actic , the projectile or bomb penetrates the earth to a certain depth before functioning. The detonation then results in a crater of considerable size, unless the charge has penetrated to such a depth that the pressure from the ground above it prevents the formation of a crater.

(2) Two types of craterless detonations are recognized: the "globe of compression" (fig. 1) and the "camouflet" (fig. 2).

(a) A globe of compression is caused by the bomb or projectile penetrating to a comparatively great depth. The explosive action is sufficient only to raise the soil slightly but insufficient to expel the earth and form a crater. The ground above the globe of compression may be greatly disturbed and have the appearance of a mound of earth with a number of cracks in the surface.

(b) In a camouflet, the missile penetrates so deeply that the detonation leaves no visible evidence of functioning on the surface. A camouflet is easily confused with a failure and should be investigated carefully before a final report is made. Whenever possible suitably calibrated geophonic instrumentation should be used. The instrumentation and examination of the crater should be the basis for making the determination.

NOTE: Caution should be used regarding camouflets as they may be filled with carbon monoxide (CO) which is a toxic gas.

(3) Double craters are sometimes formed by very large missiles having delay action fuzes. Usually one crater is much larger than the other. This condition is caused by the shell exploding beneath the surface of the ground at a point well beyond the point of entrance. While forming a crater at the point of detonation, a portion of the blast effect travels back to the point of entrance and creates a second crater.

(4) In craters caused by artillery projectiles, the maximum size is obtained when the projectiles have penetrated to a depth and distance of at least six to eight calibers.

3.4 Functioning After Passing Through Armor Plate. With the exceptions described below, functioning of explosives after striking or penetrating armor plate may be evaluated in the same manner as that for functioning on land (para 3.3).

a. As a result of its impact on the plate, a projectile may break up and scatter its explosive without having detonated.

b. Explosive dust is also scattered when the fuze is stripped from the projectile body and blown from the projectile in such a way as to cause a part of the charge to be issued from the recess. When this condition is suspected, inert projectiles with similar fuzes may be fired against the plate. If the fuze body and the projectile, or its fragments, fall on opposite sides of the plate, it is clear evidence that the fuze threads are being stripped.

c. It is difficult, if not impossible, to determine functioning of a fuze or a fuze and booster assembly by the sound emitted when firing against the plate. The ringing sound of the impact will last longer than the delay time of the base-detonating fuzes used for armor-piercing attack.

d. When firing projectiles, it is expedient to photograph the burst with a high-speed motion picture camera since the action is so fast that it is hard to spot the burst and to observe the necessary details with the unaided eye. A high initial rate of increase in brightness is an indicator of detonation.

e. High order detonation of explosive projectiles on the surface of armor plate will produce fragments having sufficient velocity to gouge the surface of the plate. Deflagrations will not produce damage to the plate away from the point of impact.

3.5 Functioning Within Weapon Tubes (in-bore prematures). See Appendix A of TOP 3-2-806 for information on determining the exact location of detonation in a weapon tube and whether the projectile detonated low or high order.

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APPENDIX A

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