

AD 718700

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Material Test Procedure 4-2-701*
Aberdeen Proving Ground

U. S. ARMY TEST AND EVALUATION COMMAND
COMMON ENGINEERING TEST PROCEDURE

IGNITION SYSTEMS FOR ARTILLERY AMMUNITION

1. OBJECTIVE

The objective of this procedure is to instruct personnel in the technique of conducting and evaluating tests on ignition systems for fixed and separate loading ammunition for guns, howitzers, recoilless rifles and mortars.

2. BACKGROUND

To meet current requirements, a satisfactory ignition system must ignite the propellant at all usable temperatures without hangfires or misfires and achieve optimum utilization of the propellant; i.e., it ideally has the maximum area under the time-pressure curve within the maximum pressure limit and thereby attains the highest velocity for a given charge. It must ignite the propellant in such a manner that:

a. The burning propellant meets all interior ballistic requirements such as peak pressures, muzzle velocities, and ejection times of the projectile and cartridge case.

b. A pressure-time record of combustion in the cartridge case or chamber will not show any irregularities or sporadic high pressures.

c. Round-to-round velocity dispersion is kept to a minimum.

Appendix A gives a detailed description on the history, problems, design factors, including loading and temperature factors, and functioning and storage requirements.

3. REQUIRED EQUIPMENT

- a. Stargage
- b. Chronograph
- c. Pressure Gage (Copper Crusher)
- d. Tourmaline Gage or Strain Patches and associated electronic equipment for obtaining pressure-time histories.
- e. Constant Temperature Magazines (-15°F, 70°F, 145°F, 155°F)
- f. Thermocouples and temperature indicating equipment
- g. As required in the following:

- 1) MTP 3-2-815
- 2) MTP 4-2-802
- 3) MTP 4-2-805

- h. Applicable Standard Ignition Systems
- i. Applicable Projectiles

* Supersedes Ordnance Proof Manual 10-60

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j. Applicable Propellant Material

4. REFERENCES

- A. AR 705-15, with Change 1, Research and Development of Materiel: Operation of Materiel Under Extreme Conditions of Environment
- B. Ballistic Research Laboratories Reports, Ballistic Research Laboratories, Aberdeen Proving Ground, Md.:
 - 1) Memorandum Report No. 640, Some Characteristics of the Practical Ignition of Propellants, December 1952
 - 2) Memorandum Report No. 650 (C), Some Problems in a Practical Ignition Study(U), March 1953
 - 3) No. 852(C), On the Performance of Primers for Artillery Weapons (U), March 1953
 - 4) Technical Note No. 799(C), A Method for Reducing the Erosion in Vents and Guns(U), June 1953
- C. Chemical Engineering Progress, Friction and Transfer Coefficients for Single Particles and Packed Beds, May 1952
- D. Bulletin of the Eighth Meeting of the Joint Army-Navy-Air Force Solid Propellant Group(C), 4-6 June 1952, Steady Flow in a Primer Tube(U)
- E. Bulletin of the Eleventh Meeting of the Joint Army-Navy-Air Force Solid Propellant Group(C), 8-20 May 1955, The Present Status of Ignition as a Science(U)
- F. Safety Regulations, Aberdeen Proving Ground, Md.
- G. Frankford Arsenal Report R-1543A, Levine, A., A New Method for Ignition Developed for the Davy Crockett XM28 and XM29 Weapon Systems, January 1961
- H. Firing Records Nos. P66304 and P60113, Aberdeen Proving Ground, Md.
- I. Francis, D., Final Report of Research Study of Ammunition Temperature-Conditioning Time Requirements, Aberdeen Proving Ground, Report DPS-1665, May 1965
- J. MTP 3-2-801, Measurement of Internal Diameters of Cannon
- K. MTP 3-2-810, Weapon Pressure Measurement
- L. MTP 3-2-815, Recoil Motion Measurement
- M. MTP 4-2-606, Standardization Firings of Artillery, Tank, Mortar, and Recoilless Rifle Propellants
- N. MTP 4-2-802, Measurement of Projectile Seating
- O. MTP 4-2-805, Projectile Velocity, Time of Flight, and Ballistic Coefficient

5. SCOPE

5.1 SUMMARY

This MTP describes the necessary techniques and methods to be followed prior to, during, and after test firing test ignition systems and comparable standard ignition systems for artillery ammunition. As discussed

in this MTP, artillery ammunition includes tank, field artillery, recoilless rifle, and mortar ammunition.

5.2 LIMITATIONS

None

6. PROCEDURES

6.1 PREPARATION FOR TEST

6.1.1 General

The project engineer shall be responsible for assuring that all safety measures have been initiated.

6.1.2 Weapon Preparation

a. Check the report of the last firing for the recorded value of the tube land diameter. If the recorded land diameter is greater than the maximum allowed in the weapon specification, the tube shall be considered unserviceable. If no report is available, the tube shall be stargaged as described in MTP 3-2-801.

b. The tube round number shall be verified to ensure that additional rounds have not been fired since the last gage report. If the round number is not in agreement with the last gage report, the discrepancy shall be resolved before firing.

c. Record calibers, models, and serial numbers of recoil mechanism, gun, tube, and carriage.

6.1.3 Ammunition

Preparation of ammunition and ammunition components shall be as follows:

a. All ammunition components, including pressure gage coppers, shall be taken from the same lots.

b. The ammunition supply shall be checked immediately so that needed components can be ordered and the necessary preparation made well in advance of the test date.

c. Check the propellant loading scales for zero reading with the correct counter-balance.

d. Specify lot number, web size, manufacturer, and year manufactured, for the propellant used.

e. Assemble pressure gages with the proper copper lot.

f. Record projectile model and lot number.

g. Weigh all projectiles and record all weights.

h. Number each projectile for future correlation with the round number in the firing record.

i. Record charge weight.

j. If bag type charge is to be used, record composition and grade.

k. Record the following for the standard ignition system(s):

- 1) Prime-model, number of grains, and lot number
- 2) Ignition type, grade and weight

- l. Record fuze model and lot number when used.
- m. Record cartridge case model and lot number.

6.1.4 Final Inspection

The following final inspections shall be made during the last stage of preparation for assembly:

- a. Check propellant container for proper sealing. All containers that do not conform with existing regulations shall be rejected.
- b. When firing fixed ammunition check crimping machine pressure for obtaining the required bullet pull.
- c. Check rounds visually for any defects, such as dents or other abnormalities that would prevent satisfactory functioning.

6.2 TEST CONDUCT

6.2.1 Pre-Firing

The following shall be accomplished on the day of firing:

- a. Measure and record chronograph coil distances (muzzle to first coil, first coil to second coil) as described in MTP 4-2-805.
- b. Measure and record recoil mechanism pressure (MTP 3-2-815).
- c. Ensure that the chronograph operator is given all measured coil distances, the weapon caliber and type, the weight and model of projectile and expected muzzle velocities.
- d. Check the constant temperature magazine to ensure that the rounds have been conditioned as required ($70^{\circ}\text{F} \pm 2^{\circ}\text{F}$; $145^{\circ}\text{F} \pm 2^{\circ}\text{F}$; and $-65^{\circ}\text{F} \pm 2^{\circ}\text{F}$).

6.2.2 Firing

Record the test weapon elevation, gun position and the azimuth of the weapon's line of sight.

6.2.2.1 Conditioning Rounds

Fire two conditioning rounds stabilized at 70°F and record the tube round number and projectile muzzle velocity.

NOTE: Conditioning round projectile velocities shall be used to provide a check on the chronograph prior to the firing of test rounds.

6.2.2.2 Test Rounds

Fire rounds as indicated under the appropriate heading of Table I, alternating the test item and the applicable standard ignition system rounds, stabilized at 70°F, each being fired for the number listed in Table I.

Obtain the following data for all rounds fired:

- a. Weapon tube and gun round number
- b. Test round number
- c. Charge weight
- d. Projectile weight
- e. Projectile seating measurement, as describe in MTP 4-2-802, for separate loading rounds
- f. Travel time from constant temperature magazine to weapon
- g. Time round remains in weapon before firing
- h. Time of firing
- i. Muzzle velocity as described in MTP 4-2-805 and corrected for projectile weight and presence of gages
- j. Chamber pressure, as described in MTP 3-2-810 and corrected for projectile weight and presence of gages

NOTE: If the recorded velocity and chamber pressures of the test and standard rounds differ by more than 2 percent, cease firing and determine the cause.

- k. Estimated amount and color of smoke generated
- l. Estimated amount and color of muzzle flash generated
- m. Residue, if any, in cartridge, case, chamber, or bore
- n. Malfunction of weapon, recoil mechanism, or component parts
- o. Visible evidence of breakdown of tube, breech, recoil mechanism, carriage, etc.

6.2.2.3 High Temperature Tests

Repeat paragraphs 6.2.2.1 and 6.2.2.2 with ammunition that has been subject to conditioning at 145°F as described in paragraph 6.2.1.d.

6.2.2.4 Low Temperature Tests

Repeat paragraphs 6.2.2.1 and 6.2.2.2 with ammunition that has been subject to conditioning at -65°F as described in paragraph 6.2.1.d.

6.2.3 Post-Firing

Upon completion of paragraph 6.2.2.2 through 6.2.2.4, perform the following:

- a. Stargage the weapon as described in MTP 3-2-801.
- b. Remeasure the distance between the gun muzzle and the first chronograph coil and the first and second chronograph coils.

6.3 TEST DATA

TABLE 1

NUMBER OF ROUNDS TO BE FIRED IN UNIFORMITY SERIES

Granulation Type	For Zoned Weapons							
	<u>Zone 1</u>	<u>Zone 2</u>	<u>Zone 3</u>	<u>Zone 4</u>	<u>Zone 5</u>	<u>Zone 6</u>	<u>Zone 7</u>	<u>Zone 8</u>
<u>Single</u>								
*1 Velocity Level	-	-	-	-	-	-	-	-
2 Velocity Levels	7	7	-	-	-	-	-	-
3 Velocity Levels	7	4	7	-	-	-	-	-
4 Velocity Levels	7	4	4	7	-	-	-	-
5 Velocity Levels	7	4	4	4	7	-	-	-
6 Velocity Levels	7	4	4	4	4	7	-	-
7 Velocity Levels	7	4	4	4	4	4	7	-
8 Velocity Levels	7	4	4	4	4	4	4	7
<u>Dual</u>								
3 Velocity Levels								
1 Zone Fast Prop.	7	7	7	-	-	-	-	-
2 Zones Slow Prop.								
4 Velocity Levels								
1 Zone Fast Prop.	7	7	4	7	-	-	-	-
3 Zones Slow Prop.								
2 Zones Fast Prop.	7	7	7	7	-	-	-	-
2 Zones Slow Prop.								
5 Velocity Levels								
1 Zone Fast Prop.	7	7	4	4	7	-	-	-
4 Zones Slow Prop.								
2 Zones Fast Prop.	7	7	7	4	7	-	-	-
3 Zones Slow Prop.								
6 Velocity Levels								
1 Zone Fast Prop.	7	7	4	4	4	7	-	-
5 Zones Slow Prop.								
2 Zones Fast Prop.	7	7	7	4	4	7	-	-
4 Zones Slow Prop.								
3 Zones Fast Prop.	7	4	7	7	4	7	-	-
3 Zones Slow Prop.								
7 Velocity Levels								
1 Zone Fast Prop.	7	7	4	4	4	4	7	-
6 Zones Slow Prop.								
2 Zones Fast Prop.	7	7	7	4	4	4	7	-
5 Zones Slow Prop.								
3 Zones Fast Prop.	7	4	7	7	4	4	7	-
4 Zones Slow Prop.								
8 Velocity Levels								
1 Zone Fast Prop.	7	7	4	4	4	4	4	7
7 Zones Slow Prop.								
2 Zones Fast Prop.	7	7	4	4	4	4	4	7
6 Zones Slow Prop.								
3 Zones Fast Prop.	7	4	7	7	4	4	4	7
5 Zones Slow Prop.								

* For Single Velocity or Fixed Type Round - 10 Rounds

6.3.1 Preparation for Test

6.3.1.1 Weapon

Record the following:

- a. Tube land diameter in inches
- b. Tube round number
- c. Gun caliber, model, and serial number
- d. Tube caliber, model and serial number
- e. Carriage caliber, model and serial number
- f. Recoil mechanism caliber, model and serial number

6.3.1.2 Ammunition

Record the following:

- a. Lot number, web size, manufacturer and year manufactured for the propellant
- b. Projectile model and lot number
- c. Individual projectile weights and numbers
- d. Charge weight
- e. Bag type charge composition and grade
- f. Standard primer model, number of grains, and lot number
- g. Standard igniter type, grade and weight (in ounces)
- h. Fuze model and lot number
- i. Cartridge case model and lot number

6.3.1.3 Final Inspection

Record the following:

- a. Crimp machine pressure (force in inch-pounds for use with fixed ammunition only)
- b. Noticeable round defects
- c. Proper propellant container sealing

6.3.2 Test Conduct

6.3.2.1 Pre-Firing

Record the following:

- a. Chronograph Coil distances, in inches:
 - 1) Muzzle to first coil
 - 2) First coil to second coil
- b. Recoil mechanism pressure, in psi

6.3.2.2 Firing

- a. Record the weapon elevation, in degrees.
- b. Record the azimuth of the weapon line of sight.
- c. Record the weapon position.

6.3.2.3 Conditioning Rounds

Record the following:

- a. Tube round number
- b. Muzzle velocity, in fps
- c. Round temperature, in °F

6.3.2.4 Test Rounds

Record the following for each round fired:

- a. Type igniter system (test, standard)
- b. Round temperature, in °F
- c. Weapon tube round number
- d. Test round number
- e. Charge weight
- f. Projectile weight
- g. Projectile seating measurement, as described in MTP 4-2-802,
for separate loading rounds
- h. Travel time from constant-temperature magazine to weapon, in
minutes.
- i. Time round remains in weapon before firing, in minutes
- j. Time of firing (day, hour, minute)
- k. Muzzle velocity, in fps:
 - 1) Measured
 - 2) Corrected
- l. Pressure values, in psi:
 - 1) Measured
 - 2) Corrected
- m. Amount and color of smoke generated
- n. Amount and color of muzzle flash generated
- o. Residue, if any, in cartridge, case, chamber, or bore
- p. Malfunction of weapon
- q. Visible evidence of breakdown

6.3.3 Post-Firing

Record the following after each temperature test:

- a. Round temperature in °F
- b. Stargage data as recorded and collected in MTP 3-2-801
- c. Chronograph coil distances, in inches:

- 1) Muzzle to first coil
- 2) First coil to second coil

6.4 DATA REDUCTION AND PRESENTATION

Using corrected values, muzzle velocity and chamber pressure means and standard deviations shall be calculated for all 7- or 10-round groups. Maximum dispersion shall be substituted for standard deviation in the case of 4-round groups.

APPENDIX A

IGNITION SYSTEMS FOR ARTILLERY AMMUNITION

1. GENERAL

The development of a satisfactory ignition system requires a thorough knowledge of the elements and functioning of an ideal ignition system and the practical problems that make ideal ignition difficult. The project engineer engaged in testing artillery ammunition should also be aware of these fundamentals. The testing is an integral part of the development process, which ultimately becomes a "cut-and-try" procedure.

2. HISTORY OF IGNITION DEVELOPMENT

a. Before World War II, ignition problems were relatively simple and little attention was given to primer design. Almost any ignition system would operate satisfactorily with the rounds and under the conditions employed at that time. Ignition was initiated at the base of the propelling charge and a few short primers sufficed for all needs. Short primers and base ignition proved inadequate, however, for the higher velocities and correspondingly higher pressures required by World War II weapons. To meet these requirements, long, forward-venting primers were developed.

b. During the Korean conflict, it was discovered that the forward-venting primer did not solve all ignition problems. Experiments showed that this type primer was only an intermediate step between a short primer and one that would provide simultaneous ignition along the axis of the charge. Axial ignition, on the other hand, is not only difficult to achieve but is not always necessary. (Because of the difficulty in achieving axial ignition in a practical ammunition design, its application should be limited to situations where extreme requirements exist or to borderline cases where enough uniformity may be gained to make it desirable, even though acceptable results may be obtained without its use).

c. Although the problems involving recoilless rifle ammunition and separate-loading rounds for low-velocity guns, howitzers, and mortars are fewer than those of fixed rounds for relatively high velocity guns, they are basically similar. Experimental data for these weapons show that effective ignition is necessary for satisfactory performance under extreme conditions.

3. PROBLEMS OF INDIVIDUAL AMMUNITION IGNITION SYSTEMS

3.1 FIXED ROUNDS IN RELATIVELY HIGH VELOCITY GUNS

More problems of a serious nature exist with high-velocity guns than with howitzers, recoilless weapons, and mortars, since the former operate at higher loading densities and muzzle energies. During World War II, requirements were met by the development of a long primer that reached almost to the mouth of the cartridge case and was vented a little more than half the length of the primer, measuring from the front end. (See Figure A-1). Use of the long primer avoided the erratic pressures experienced at low temperatures and significantly reduced the tendency to flash. This long forward-venting

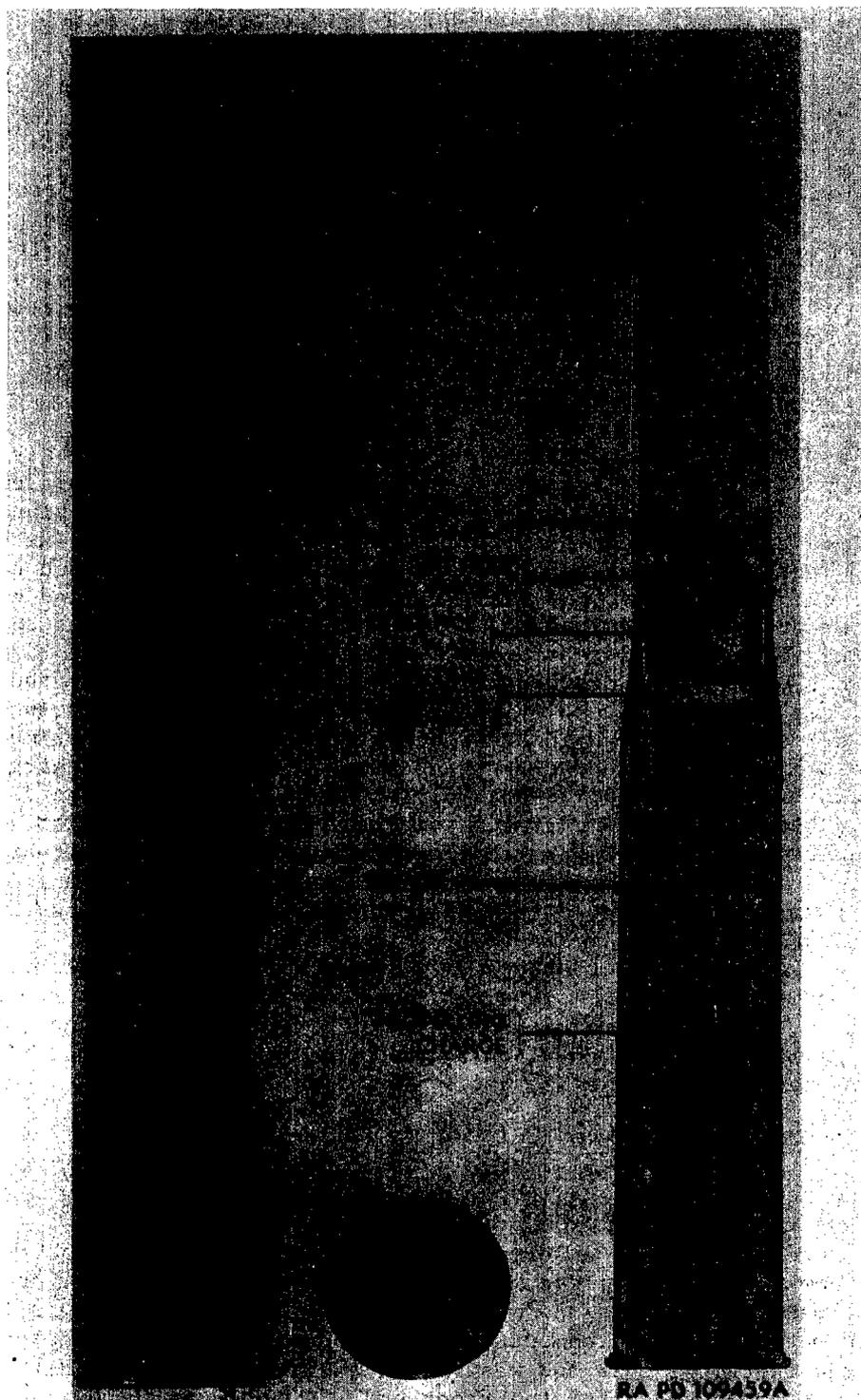


FIGURE A-1. Fixed Round with Long Forward-Venting Primer

primer was a major advance in primer design and was generally adopted as the solution for the more difficult ignition problems. By combining the long primer with nitro-guanidine propellant, control of flash and smoke was achieved to a degree that was impossible a few years earlier. Today, requirements for higher velocities and performance at extreme temperatures are even greater.

3.2 FIXED AMMUNITION FOR RECOILLESS WEAPONS

a. In the design of fixed ammunition for recoilless weapons, the approach to ignition problems is somewhat different from the approach with high-velocity weapons. Projectiles may have pre-engraved rotating bands or obturators which offer little resistance to motion. This results in some differences from other ammunition in propelling charge burning rates since the projectile can move very early in the burning cycle due to its relatively lesser energy requirement from the propellant gases. Also perforated cartridge cases (with plastic liner inserts to cover the perforations) permit the propellant gases to expand into the chamber and finally through a venturi orifice in the breech of the rifle. This condition obviously makes ignition problems different from those of other weapons since some of the propellant moves rearward and out of the rifle before burning is complete. The low operating pressures are not conducive to efficient burning. Another unique and important condition with the perforated cartridge case is that it is supported at its base and mouth only. As the gases from the propellant are vented into the chamber of the rifle, pressure differentials from inside to outside of the case must not be great enough to cause bulging of the case.

b. Proper ignition, therefore, is considered to be a condition affecting proper case functioning. Of considerable importance is the effect of ignition on the rate of evolution of gases and the consequent effect on recoil unbalance. The projectile mass-velocity reaction must be balanced by the mass velocity reaction rate of the rear-vented gases. Minor changes in the ignition system can markedly affect this rate of gas evolution.

3.3 SEPARATE-LOADING AMMUNITION FOR GUNS AND HOWITZERS UTILIZING BAG CHARGES

a. Difficulties such as are associated with fixed rounds can be expected with separate-loading ammunition for guns and howitzers when relatively high densities of loading are employed. (See Figure A-2). Under this condition, base igniters alone are not adequate. These difficulties may result indirectly from insufficient free annular volume around the charge, inhibiting travel of the flash from the base igniter to the forward portion of the chamber. The diameter of the charge must be closely controlled, since looseness or tightness of the propellant in the bag has a direct bearing on the burning rate. Short, stubby charges fired at full chamber pressures, or greater, with very little air space between the charge and the chamber wall, may burn erratically as a result of "choking off" of the chamber and the "shotgun" effect of the propellant and gases as they strike the base of the projectile. In general, if the air space around the charge is sufficient, few abnormalities will arise with base igniters. Further, weapons of this class are usually designed with a comparatively small ratio of chamber length to diameter. Also, the chambers have relatively fewer contour irregularities

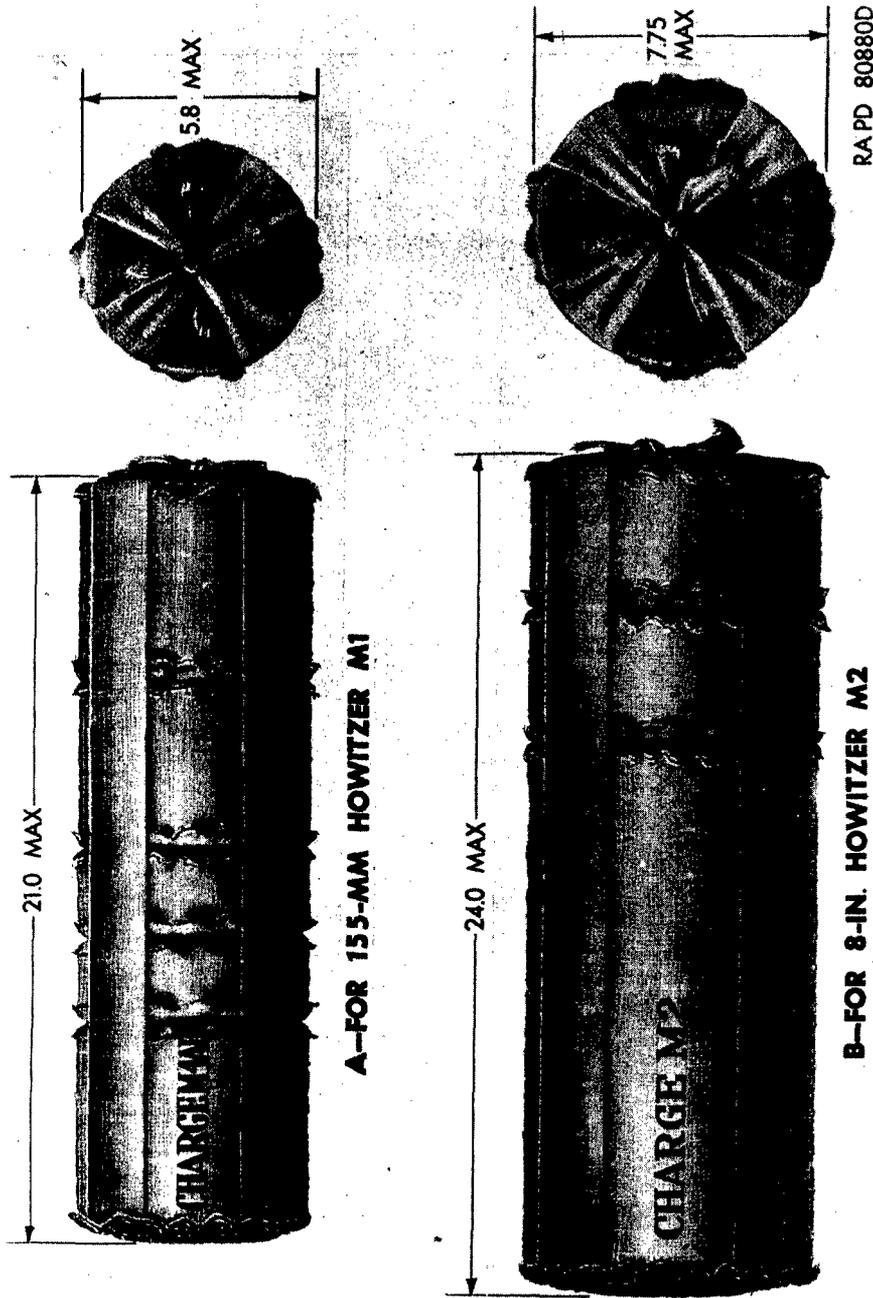


FIGURE A-2. Separate-Loading Bag Charge with Base Ignition

compared with those using hypervelocity fixed ammunition.

b. Ignition difficulties arising from high loading densities can be solved with central axial ignition. This type of ignition is comparable to that described for fixed rounds. Instead of igniting the dumped bag charge at the rear with a black-powder base igniter, a central tube ignition system is substituted. (See Figure A-3). The flash from a 30-grain primer in the mushroom head of the gun is directed into a consumable tube extending the full length of the charge. The propelling charge is approximately the same diameter as the gun chamber with the free volume relocated in the center of the charge. This system gives good axial ignition and eliminates erratic burning where it is impossible to fire the weapon at full charge with the base igniter. The ignition tube must be kept symmetrical, however, any bending or crushing may cause high pressures.

3.4 MORTAR AMMUNITION

a. Mortar ignition problems differ from those of guns and howitzers. The chamber volume and projectile travel are not as great, and large volumes of gases escape past the bourrelet of unobturated projectiles during their short travel in the tube. Because of this, high flame temperature propellants are used so that they can both ignite and burn more rapidly to yield maximum energy at minimum gas loss in the short projectile time-travel period.

b. Double base propellants (high nitroglycerin content) in sheet and flake form are utilized rather than single or multiperforated propellant of single base composition. An ignition cartridge is employed in conjunction with the primer as a booster for igniting the main propelling charge. (See Figure A-4).

c. Temperatures well in excess of +70°F may cause the propellant sheets to stick together, impeding ignition. Low temperatures tend to cause the propellant to become brittle and shatter when hot gases from the ignition cartridge strike directly against the sheets. This condition is minimized when flake propellants of high nitroglycerin content are used.

4. IGNITION SYSTEM DESIGN FACTORS

4.1 GENERAL

Before attempting to optimize the design of any ignition system, consideration should be given to some of the desirable characteristics.

a. In the case of artillery systems, for instance, the primer should initiate the combustion of all particles of the propellant. This characteristic implies that a primer should discharge igniter gases to all regions of the propellant as nearly simultaneously as possible. Simultaneous ignition of the entire propellant bed depends largely on the structure of the bed, but the exchange of energy from the primer to the propellant region should be as uniform as possible with respect to various regions in the bed. In most cases, it is impossible to obtain simultaneous discharge of primer gases to all portions of the propellant; it is necessary to accept, instead, symmetry of discharge with respect to the midpoint of the propellant region.

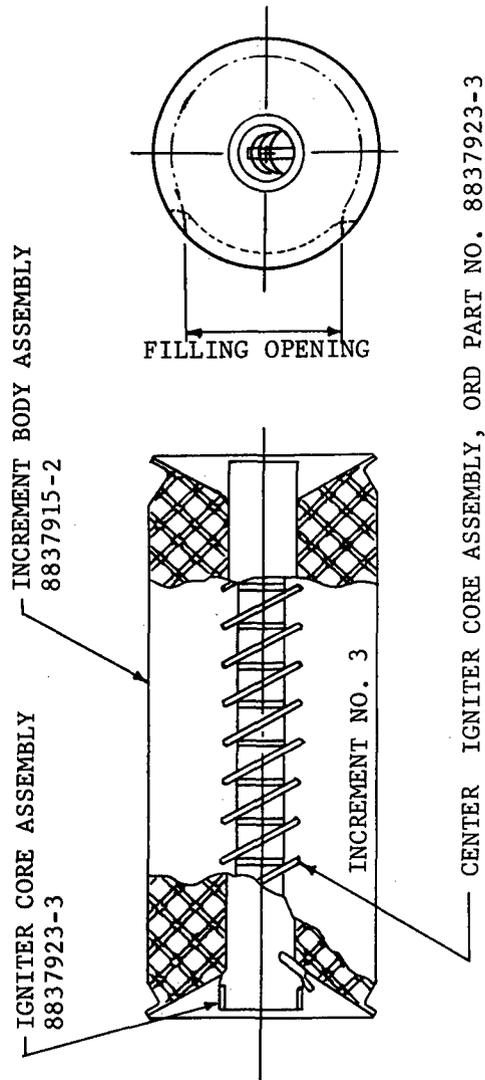
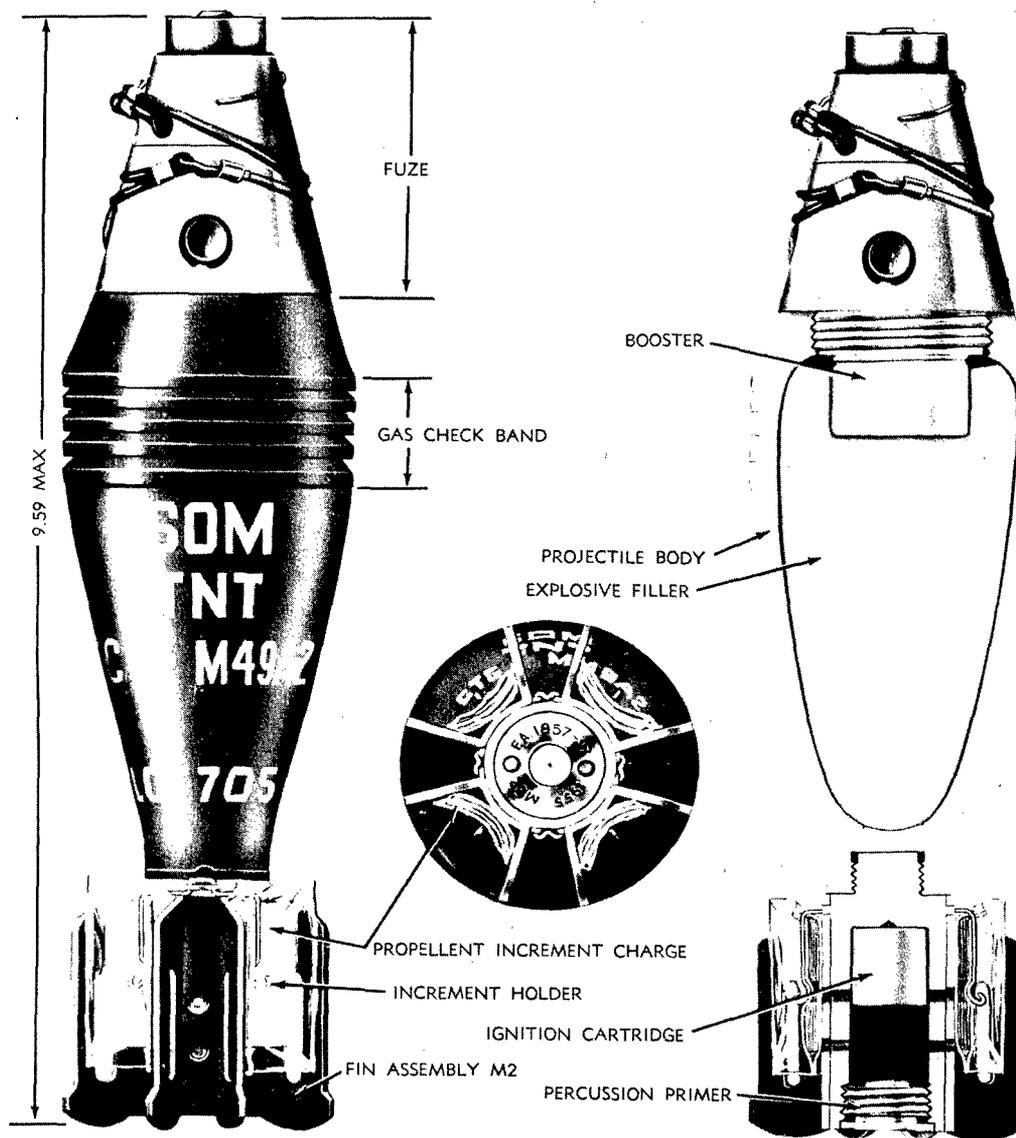


FIGURE A-3. Sample Diagram of Separate-Loading Bag Charge With Central Tube Ignition



RA PD 80729C

FIGURE A-4. Mortar Round Showing Propellant Ignition System

b. Weapon firing data show that by merely changing the position of the igniter charge in the bed of the cartridge case or chamber, the burning such as one that would localize the ignition in a small volume of the case or chamber, ignition in the center of the case or chamber produces the more regular pressure-time curves; for another, there may be a different optimum ignition position. The beneficial effect that the position of the ignition may have is to provide conditions under which shock waves originating at definite positions will be reflected out of phase as they cross each other in the chamber.

c. A good analysis of what occurs when a propelling charge is fired is contained in reference 4B(1). This analysis considers the dimensions of the chamber and of the propellant grains, the before-firing volumes of the igniter and the propellant, the gas velocity, each number and pressure of the igniter gases, and the specific ignitibility of the propellant. From these quantities and from the principles of flow and ignition, it is possible to estimate the time intervals required for various phenomena to take place in the chamber. It is postulated that the relative size of these time intervals determines the regularity of the ignition process and the extent to which it is accomplished by violent gas oscillations. An important point is that, other things being equal, if ignition is to be regular and reproducible, the time required by the primer gases to ignite a particular increment of propellant surface should be long in relation to the time required for the primer gases to distribute themselves uniformly throughout the charge. In other words, as nearly as possible, every grain of the propellant should be ignited by the primer, not by the flame from other grains.

d. In one respect, however, the principle seems at first not to agree with experience. Since it is reasonable to assume that the ignition time for a propellant that ignites with difficulty will be longer than for one which is easily ignited, it would appear that, other things being equal, the former would give the more reproducible results. It does not. The primer gases, in flowing through the propellant, are cooled by expansion and by contact with the first portions of the propellant over which they pass, so that they effectively ignite only these first portions. This principle is in complete agreement with such well-established facts as the following: (1) long chambers and base ignition tend to produce poor uniformity and large pressure waves (with the usual type of granular propellant), (2) simultaneous axial ignition gives good results in difficult situations, and (3) propellant in the form of long sticks, strips, or tubes behaves very well with almost any kind of ignition, especially when the charge is ignited at the base.

e. Anything that prevents the igniter gases from affecting all portions of the propellant uniformly is inimical to regular and reproducible ignition. Viewed in this manner, the larger the distance from the igniter to the most remote part of the propellant, and the more compact and random the arrangement of the grains, the poorer the reproducibility, low specific ignitibility would simply aggravate the resulting difficulties. Thus, the reason for the effectiveness of simultaneous axial ignition (or symmetrical ignition) becomes apparent - it greatly reduces the distance from the igniter to the most remote part of the propelling charge.

f. The most important consideration in the ignition of propellants is the energy provided by the primer. This includes total energy, rate of energy delivery, and efficiency of heat transfer. The total energy is important from the standpoint of hangfires, misfires, or length ejection time. Sufficient energy must be provided for the pressure to rise in the combustion chamber within the number of milliseconds specified by the internal ballistic requirements. The strength of the igniter should not be much greater than is required to avoid hangfires under the most adverse conditions, and powerful blasts from primers should be avoided when possible. Supporting this view, and as an example of some of the phenomena which occur in igniting propellants, is the fact that the tubes of long, forward-venting primers are sometimes flattened for a length of only an inch or two at the first venthole from which flame has a chance to emerge. This type of primer is known to buildup a pressure of 10,000 to 12,000 psi in the nonvented length of the tube. When the first hole burns through, a powerful jet of flame bursts out. The primer tube evidently flattens because this jet "overignites" the propellant in the immediate vicinity and builds up a very high local pressure. The appearance of fired primers indicates that the zone of this abnormal pressure is not more than 2 inches in diameter from around the venthole. Cartridge cases from recoilless weapons are sometimes bulged or ruptured by milder "overignition" or localized burning of a similar nature. Experiments conducted by the Navy have shown that as the strength of ignition is progressively increased above that required to avoid hangfires, a point is reached at which irregularities appear in the pressure-time curve; these grow larger as the ignition is further strengthened.

g. Once sufficient energy is supplied to prevent hangfires or misfires, the important consideration is the rate at which energy is delivered to the surface of the propellant. This is controlled by the rate at which the primer is delivering energy from the burning igniter composition and the efficiency of heat transfer of the combustion product.

An effective primer must release energy rapidly, but not so rapidly that sufficient heating of the solid propellant cannot take place before the initial solid-phase exothermic reactions take place in the propellant. For example, one would not consider a high explosive an effective ignition material. There is reason to believe that the heat transfer mechanism is also important. It appears desirable to employ igniters that carry in their gaseous products hot solid particles which, on striking the propellant grain, are able to heat localized areas to high temperatures very quickly. A comparison of the relative effectiveness of hot gases and hot particles individually must be concerned with the propagation of burning along the surface of the propellant, which is a complicated process in itself.

h. In many weapons, the problems of mass and heat flow from the igniter region to the propellant region are apparently not critical. This is particularly true for low-velocity weapons that employ coarsely granulated propellants with appreciable free-chamber volume. Other weapons, particularly high-velocity guns, offer a challenge to the ingenuity of the designer. Consideration of the design of a number of new types of weapons points out dramatically the necessity for considering the igniter as a part of the complete weapon system. This means, essentially, that many primers appear to be unsatisfactory because of controlling idiosyncrasies of other parts of the system, such as low projectile mass, low resistance to initial motion of the projectile,

improper distribution of the charge with respect to the primer, and other factors. Caution should be exercised to correct design details for the entire weapon system rather than to ascribe all malperformances to the ignition system. Finally, the principal interest is in reliability of operation of a weapon and for this reason one must consider another desirable characteristic of primers, namely, reproducibility of performance from round to round.

i. The design of an "optimum" primer involves a compromise between flame flow rate along the length of a primer (a measure of simultaneity of discharge) and rate of gas generation (a measure of intensity). Since the two factors are not compatible, it may become necessary to deviate from simply packed beds of igniter material to obtain the optimum performance of an igniter.

4.2 FIXED ROUNDS

In designing fixed rounds, the length, diameter, and volume of the primer (usually made of steel or brass seamless tubing) that can be fitted satisfactorily into the cartridge case should be determined. Consideration should be given to whether the case will be filled to maximum capacity or whether a reduced charge will be used. This will dictate the length of the primer. In addition, consider whether or not the system will require distance wadding or increment holders to maintain bagged or loosely loaded propellant in place. The main idea is to design the primer the same length as the charge and attempt to ignite this charge from top to bottom simultaneously.

4.3 SEPARATE LOADING CHARGES

a. Primary ignition for bagged charges is relatively simple since the system ordinarily utilizes a very short primer in the mushroom head of the gun. This primer, which usually holds 15 to 30 grains of black powder, flashes into a main ignition system composed of an igniter pad sewn to the base of the propelling charge. The main consideration is the igniter pad. Usually, the amount of igniter charge is in direct relationship with the volume of the propelling charge. The ideal charge would be the smallest amount that would prevent hangfires while igniting the propelling charge satisfactorily at temperatures from +145° to -65°F. Base igniters are not entirely satisfactory when using a "dumped" granular form of propellant. In special cases, it may be necessary to develop an ignition system similar to that of a fixed round to permit flash to travel instantly through the center of the charge or to use a stick propellant that permits the flash to travel forward without the baffling of gases associated with "dumped" charges in higher velocity weapons of unusual chamber geometry.

b. For the Davy Crockett recoilless guns, simultaneity of initiation along the length of the igniter is achieved by using a core of high explosive surrounded by black powder. The propellant is ignited by the black powder, not by the high explosive directly. In this application, the black powder is contained in a cylinder of fly-screen wire along the length of the charge. This has been called a soft ignition system in that the igniter tube bursts and disintegrates without overigniting the propellant (Ref. 4G). Figure A-5 illustrates the propellant container assembly for the Davy Crockett recoilless gun.

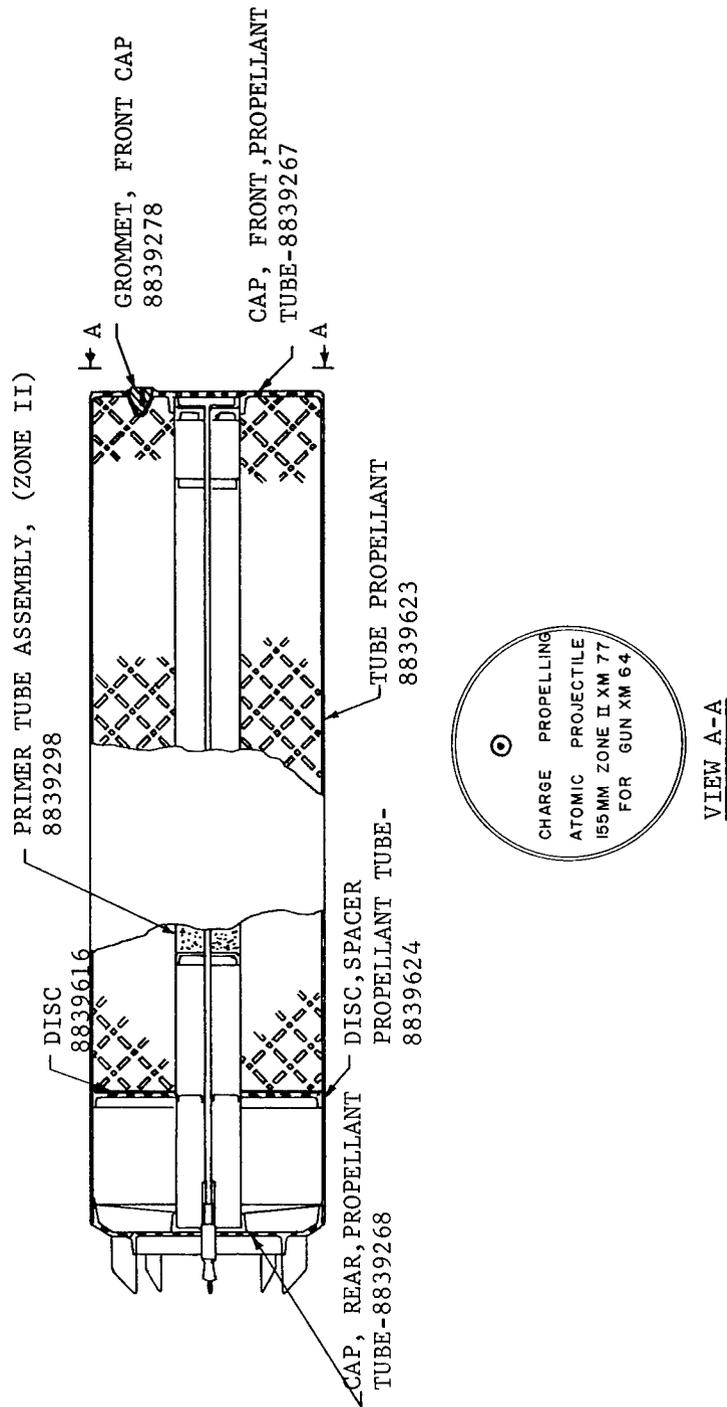


FIGURE A-5. Sample Diagram of Separate-Loading Charge for Davy Crockett Recoilless Gun

4.4 MORTAR AMMUNITION

a. Mortar ammunition employs two types of propelling charges. This makes the approach to optimizing ignition slightly different in each case. Older, standard mortar propelling charges are designed with sheet propellant sewed together in the form of booklets and contained in water-proof wrappings. Propellant arrangements of this type are susceptible to ignition troubles at low temperatures, especially in the range from +40° to -65°F. The blast from the ignition cartridge tends to shatter the sheets if they are located directly over the flash holes opposite the ignition cartridge. Care must be taken on some items to arrange the charge properly to prevent occurrences of excessive pressures and bulging of the mortar. When firing the propellant at elevated temperatures, the sheets may tend to stick together and result in a loss of velocity and pressure. This condition is not serious from a safety standpoint, and in no case has excessive pressure occurred when firing at elevated temperatures.

b. Some mortar items utilize a flake propellant contained in water repellant bags and attached to the fin assembly by means of increment holders. This design is not usually as much affected by extreme temperatures as is sheet propellant; excessive pressure might be obtained, however, if the propelling charge is "overignited" at any temperature.

c. In the design or development of an optimum ignition system for any type of mortar, consider the following:

(1) The volume of the fin assembly in which an ignition cartridge can be placed. This does not mean that the entire volume will be required; it does govern, however, the maximum amount or weight of ignition powder that can be loaded into an ignition cartridge and placed in the igniter housing.

(2) The strength of the fin housing that holds the ignition cartridge. The maximum internal pressure that the ignition housing will withstand determines the amount of powder that can be fired satisfactorily.

(3) The number and size of flash holes in the fin assembly that will vent the flash and hot particles from the igniter to the propellant. The primer and ignition cartridge should be located as closely together as possible. There should be only the minimum number of flash holes to vent the igniter symmetrically and uniformly and to enable it to ignite the propelling charge satisfactorily at subzero temperatures as well as ambient. The increment charges should be placed opposite the flash vents as uniformly as possible to give symmetrical axial ignition. After the igniter charge has been determined, it should be checked in conjunction with the standard propellant at temperatures from -65° to +145°F. If the optimum igniter functions satisfactorily at the lowest temperature required, it probably will operate satisfactorily at any temperature above that point.

5. LOADING FACTORS

The following factors should be considered in loading the charge:

a. Position of propellant in cartridge cases or chamber.

Provision to keep the propellant from moving in the cartridge case can improve velocity uniformity by ensuring uniform ignition. For recoilless rifle

ammunition, shifting of the propellant to leave a void in the rear of the cartridge case has been the cause of the case rupturing. It is common to use distance wadding in cartridge cases to accomplish the positioning. This may consist of a cardboard tube butting against the base of the projectile at one end and against a cardboard disc over the propellant at the other end. (See Figure A-5). The wadding should be rigid enough to maintain its shape, yet of minimum volume and consumable by the burning propellant. For bag charges, short stubby shapes should be avoided, as discussed in paragraph 3.3 of Appendix A. For mortar rounds, increment holders (Figure A-4), to keep the propellant close to the igniter, can have a marked effect in increasing velocity and improving velocity uniformity.

b. Propellant loading density. The influence of loading density is shown by a comparison of the HVAP, M331 and AP, M339 rounds for the 76-mm tank gun M32 (reference 4H). Both rounds, as originally developed, used a propellant of M17 composition, the M58 primer (a long, forward-venting type), and the same cartridge case. There was a slight difference in the web size of the propellant used in the two rounds, 0.056 inch for the M339 projectile and 0.050 inch for the M331 projectile. It seems improbable that this small difference of granulation alone could have been very significant. The weight of charge for the M331 round was approximately 93 ounces, which nearly filled the cartridge case. The weight of charge in the M339 round was approximately 86 ounces, 5.4 percent less than that in the M331 round. The difference in charge weight and loading density seemed to be the only significant differences between the two propelling charges; yet the M331 round, having the lighter projectile, burst the gun while the M339 round behaved normally. A different primer proved necessary for the M331 round. From this comparison and other experiences, it appears that high loading density, particularly with regard to the last few ounces of propellant that can be packed into a case or chamber, has a powerful adverse influence on ignition. Also, it appears that serious ignition trouble is not likely to occur unless at least two of three undesirable factors are present at the same time (i.e., high loading density, high ratio of length of propelling charge to diameter, and low specific ignitibility of the propellant).

6. LOW TEMPERATURE FACTORS

a. A most serious result of low temperature ignition is the appearance of abnormal pressures during propellant burning. A cold-embrittlement theory to account for these abnormal pressures has been suggested. In this case the abnormal pressures are a result of the interrupted burning of the propellant due to broken grains and sheets of propellant which result from cold embrittlement. The breakup of propellant from cold embrittlement alone, however, is not considered great enough to account for abnormal pressures. For this reason, the embrittlement theory applied to granular forms of propellant has been generally rejected. It does apply to sheet propellant used in mortars, as indicated in paragraph 4.4 of Appendix A.

b. More recent evidence indicates that when a propellant is inadequately ignited, particularly at low temperatures, it does not burn normally and does not at once produce the required stable mixture of gases. Instead, it is assumed that the propellant "fizz burns", i.e. it decomposes without flame into an unstable gas mixture consisting of oxides of nitrogen and

combustible gases which react further to produce a virtual detonation. In support of this theory is the fact that under certain conditions a propellant can undoubtedly "fizz burn" to produce an initial gas mixture capable of further reaction or even detonation. There is also the fact that pressure-time curves have been obtained that show an abnormally slow rise in pressure up to a point, and then a nearly vertical rise. (See Figure A-6). This is exactly the sort of curve that would be expected if the propellant should "fizz burn" to form an explosive mixture of gases and that mixture should then detonate. Whether or not a propellant "fizz burns", however, is believed to depend principally on the composition and initial temperature of the propellant, the manner in which it is ignited, and the pressure. In general, it requires a rather special technique to cause a propellant to "fizz burn" if burning of this type is desired. Furthermore, high pressure is not generally believed to be favorable to "fizz burning" although low temperature is. It is therefore doubtful that a large mass of propellant would "fizz burn" to the extent of being almost completely transformed into a high compressed gas mixture and only then detonate. A more difficult question for the "fizz burning" theory to explain is why a propellant of the same composition and almost the same granulation, ignited with the same primer, under the same conditions, should burst the gun in the M331 round but not in the T128 round (paragraph 5.b of Appendix A).

7. FUNCTIONING AND STORAGE TEMPERATURE REQUIREMENTS

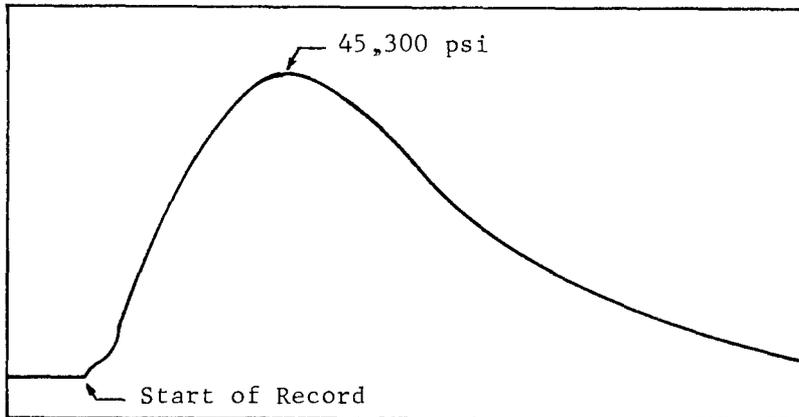
7.1 FUNCTIONING

a. The ultimate objective established for Army material is that it must be capable of satisfactory performance at any air temperature from +145°F to -65°F. There are exceptions to this requirement, but this objective applies to all artillery ammunition. These extreme limits are not intended for use as a starting point on new and untested designs. Due consideration shall be given to safety and protection of materiel.

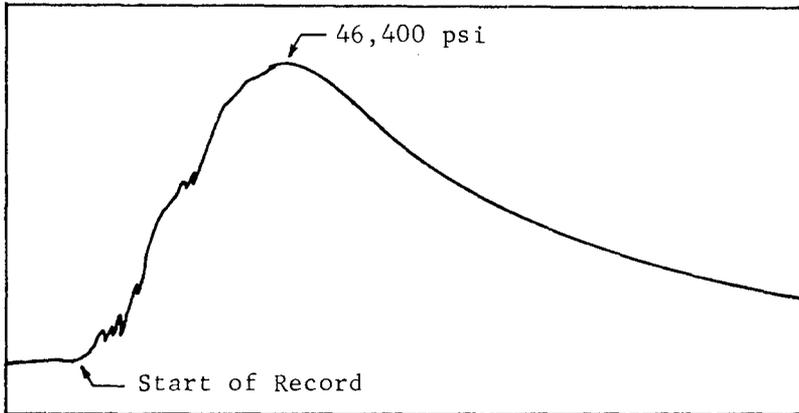
b. Extreme temperature testing of propellants requires specified temperature gradients at which firings are to be conducted. These are: 70°, 100°, 130°, 155°, 30°, 0°, -40°, and -65° Fahrenheit, in that order. Although it is not necessary to cover all of these points for all ammunition components, all intermediate test temperature levels should be selected from the above list in the interest of uniform proving ground hot or cold room requirements, combination of tests, and such. As it is sometimes necessary to test at a temperature between 0° and -40°F, this intermediate point should be established as -25°F.

c. The period of time for which ammunition is conditioned at a given temperature before test may vary with the size and type of materiel in the component being tested. In general, the period for conditioning complete rounds or propelling charges should be no more than 24 hours. Reference 41 gives specific suggested times for various calibers and packaging.

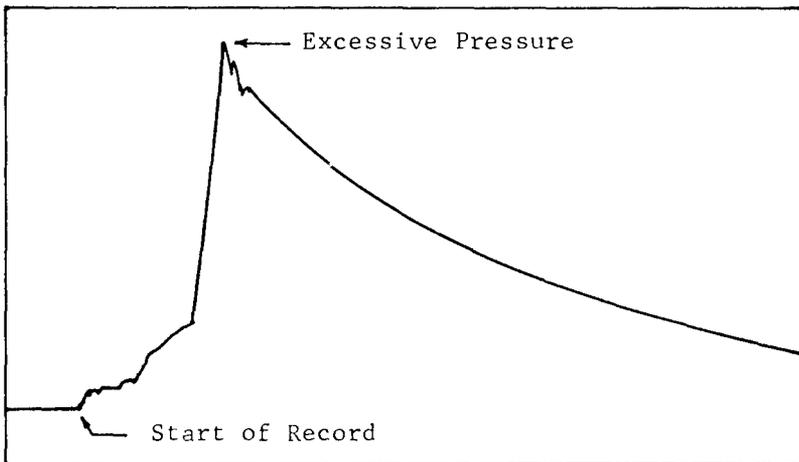
d. Ignition studies are usually concluded when the time-pressure curves show smooth build-up and fall-off (Figure A-6) and when the round-to-round dispersion of velocities and pressures at extreme temperatures is comparable to that obtained at + 70°F.



Typical Smooth Time-Pressure Curve Indicating Satisfactory Ignition



Typical Erratic Time-Pressure Curve Indicating Unsatisfactory Ignition



Typical Detonation Time-Pressure Curve Indicating Unsatisfactory Ignition

FIGURE A-6. Time-Pressure Curves Indicating Satisfactory and Unsatisfactory Ignition

7.2 STORAGE

a. All storable military materiel must be capable of safe storage and transportation without permanent impairment of its capabilities because of temperature effects. The specified temperatures for storage purposes are: lower limit, -65°F for periods of at least 7 days; and upper limit, $+155^{\circ}\text{F}$ for periods as long as 4 hours per day. (Temperatures of this order are encountered within unventilated containers, enclosures, shelters, freight cars, closed vehicles, and such, when the structures themselves are exposed to an air temperature of about $+105^{\circ}\text{F}$ plus full impact of solar radiation, $360 \text{ Btu/ft}^2/\text{hr}$, for periods of approximately 4 hours daily).

b. For materiel whose physical and chemical properties preclude such storage, special means and techniques must be developed and provided to meet this requirement.