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TECHNICAL REPORT ARBRL-TR-02567

HANGFIRES, CAUSES, HAZARDS, AND REMEDIES (CASE STUDY OF XM242 25-MM CHAIN GUN INCIDENT)

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US ARMY ARMAMENT RESEARCH AND DEVELOPMENT CENTER
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This report discusses the causes of a hangfire, the hazards created by hangfires, and the design considerations in externally powered weapons for minimizing the occurrence of hangfires and eliminating their hazardous effects. An actual case study is used as an example to illustrate these discussions; namely, the hangfire incident involving the XM242 Hughes 25-mm Chain Gun which has since been type classified as the M242.

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I. INTRODUCTION

With the advent of externally powered automatic gun systems such as the M242 Hughes 25-mm Chain Gun, hangfires have become a serious matter. Where, in manually and internally powered gun systems, hangfires are disconcerting inconveniences which often forecast misfires, in externally powered gun systems they are a potential hazard to both the gun system and gunner.

A hangfire is defined as an undesirable time delay between the initiation of a gun propelling charge and the application of the initiating energy such as the strike of a firing pin or the impetus from an electrical firing pulse.

This report discusses the causes of a hangfire, the hazards created by hangfires, and the design considerations in externally powered weapons for minimizing the occurrence of hangfires and eliminating their hazardous effects. An actual case study is used as an example to illustrate these discussions; namely, the hangfire incident involving the XM242 Hughes 25 mm Chain Gun which has since been type classified as the M242 weapon. It should be pointed out that this incident is being used as an example of a successful solution to the hangfire problem and that this report does not intend to question or in any way denigrate current safety certification or acceptance of the M242 25-mm Gun. This case is used because it represents a sound engineering approach to a specific hangfire problem.

II. BASIC DEFINITIONS

Before continuing any discussion of hangfires and their hazards, several basic definitions are in order. Hangfire has already been defined and will not be repeated here.

1. Internally Controlled Automatic Gun. An automatic gun whose operating cycle is powered by energy emanating from the combustion gases or recoil forces. If the cartridge does not function, then the weapon stays in the closed bolt locked position as in the M14 and M16 rifles.

2. Externally Powered Automatic Gun. An automatic gun whose operating cycle is powered by energy emanating from a source external to the weapon. Unless special steps are taken to provide an automatic interruption of the gun cycle, the weapon will cycle without regard to the functioning of the cartridge.

3. Operating Cycle. The operating cycle is the sequence of events that is repeated for each shot; namely, load, lock, fire, unlock, extract and eject.

- Load. The cartridge is inserted and seated in the weapon chamber.
- Lock. The bolt or breech block is closed and positioned to accept firing pressures.
- Fire. The ammunition is actuated either by strike of the firing pin or by impetus of the firing voltage.

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- Unlock. The bolt or breech block is positioned for opening or extraction phase of the cycle. In this position the bolt or breech block cannot effectively resist the firing forces.

- Extract. The cartridge case is removed from the chamber.

- Eject. The cartridge case is ejected from the weapon.

4. Cycle Time. The time required to complete one operating cycle.

5. Repetition or Firing Rate. The inverse of cycle time, generally given in rounds per minute.

The general concept of an automatic weapon is that when the trigger device is actuated, the weapon will continue to fire at its repetition rate until the trigger is released or the ammunition supply is exhausted.

For internally powered weapons a hangfire will increase the time duration between the locking and unlocking phases of the cycle in which the hangfire occurs, lengthening that particular cycle time.

For externally powered automatic weapons that have no means of interrupting the operating cycle, the time duration between the lock and unlock phases is constant and does not change due to time delays in the functioning of the ammunition. This means that, under such conditions, a hangfire may cause the ammunition to function during the extraction phase of the operating cycle. This situation creates a potential hazard to both the weapon and the operator.

III. CAUSES OF HANGFIRES

A hangfire is caused by a light strike of a firing pin or low impetus from an electrical firing pulse.

A. Light Strike of Firing Pin

It should be pointed out that "light strike" is a relative condition which is highly specific to a particular combination of weapon and ammunition. This defect is a mismatch between the striking energy of the firing pin and the sensitivity of the percussion primer and may exist in either the weapon, the ammunition or both. Also, the cause may be general to all occurrences of the specific combination or be restricted to certain combination of lots or production runs within the total population of a specific combination.

1. Weapon related faults causing light strikes are as follows:

   a) dirt or debris in the firing mechanism due to inadequate cleaning and maintenance,

   b) broken or damaged firing pin,

   c) inadequate firing-pin spring strength due to aging and wear,

d) broken or damaged firing-pin spring, or

e) inadequate firing-pin energy due to basic design of the weapon.

2. Ammunition faults causing apparent light strikes are as follows:

a) desensitized primers due to aging,

b) errors in ignition train assembly such as missing or misaligned components,

c) damaged ammunition due to mishandling,

d) desensitized primers due to design changes in ammunition, or

e) ammunition not designed for the specific weapon system.

B. Insufficient Impetus of Electrical Firing Pulse.

Again, as in the "light strike" condition, insufficient impetus is a relative condition between specific combinations of weapon and ammunition.

1. Weapon faults causing insufficient impetus are as follows:

a) dirty or corroded electrical contacts and terminals due to inadequate cleaning and maintenance,

b) improper power supply voltage,

c) broken or shorted wiring or electrodes,

d) cracked or wet insulator, or

e) insufficient impetus due to basic design characteristics of the system.

2. Ammunition faults causing the effect of low impetus are as follows:

a) dirty or corroded electrical primers and cartridge cases,

b) desensitized primers due to aging,

c) desensitized primers due to design changes in ammunition,

d) errors in ignition train assembly such as omitted or misaligned parts, or

e) damaged ammunition due to mishandling.

In most field occurrences the basic causes of hangfires are inadequate cleanliness, maintenance, and handling procedures.

IV. HAZARDS FROM HANGFIRES

The source of the hazards from a hangfire is the potential condition of igniting the propelling charge of the ammunition during the extraction phase of the operating cycle. As the cartridge is removed from the chamber, it loses its constraining support from the chamber walls. The ability of the cartridge case to sustain the propellant pressure is now dependent on the burst strength of the unsupported cartridge case wall. Figure 1 illustrates the condition of ignition during extraction. Figure 2 shows the calculated burst pressure versus extraction distance for the 25-mm TP-T projectile.

In the semiextracted condition, a cartridge case ruptures at pressures corresponding to the distance the cartridge has been extracted prior to ignition. This situation creates three separate conditions.

A. Acceleration of Gun Parts

The bolt assembly is accelerated in the receiver housing of the weapon. The severity of the acceleration depends on the maximum pressures achieved in the cartridge case and the resistance offered by the bolt assembly. Depending on the burst pressure, this event can cause damage to the weapon and injury to the gunner ranging from insignificant to catastrophic.

B. Blast Effects

The blast effects associated with the rupturing cartridge case present a hazard to both gun and gunner. Figure 3 shows the overpressure measured at the gunner position during a series of failure replication tests performed by Hughes Helicopter Inc.[1]

These overpressures are dependent on the amount of free volume around the weapon, the available energy in the propellant, and the burst pressure. In this case, damage to adjacent gun components due to blast ranged from insignificant at low pressures to catastrophic at higher pressures. The higher pressures were on the threshold of eardrum rupture based on the data reported by I.G. Bowen, E.R. Fletcher and D.R. Richmond.[2] Although incapacitation of the gunner appears to be minimal in this case, one can expect more severe effects from larger caliber weapons because of the increases in available energy.

C. Fragmentation Effects

Also associated with cartridge case rupture are flying fragments and debris. Depending on the size, mass, and velocity of the fragments, physical damage can occur to adjacent parts of the gun assembly, the gunner and other equipment and personnel in close proximity to the gun. The extent of such damage is dependent on the gun system and caliber.

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1 *Hughes Helicopter Inc. Project Report, HH 78-180, Page 1-84, January 1981.*

2 *I.G. Bowen, E.R. Fletcher, D.R. Richmond, "Estimates of Man's Tolerance to the Direct Effects of Air Blast," Defense Atomic Support Agency Report No. DASA-2113, October 1968.*

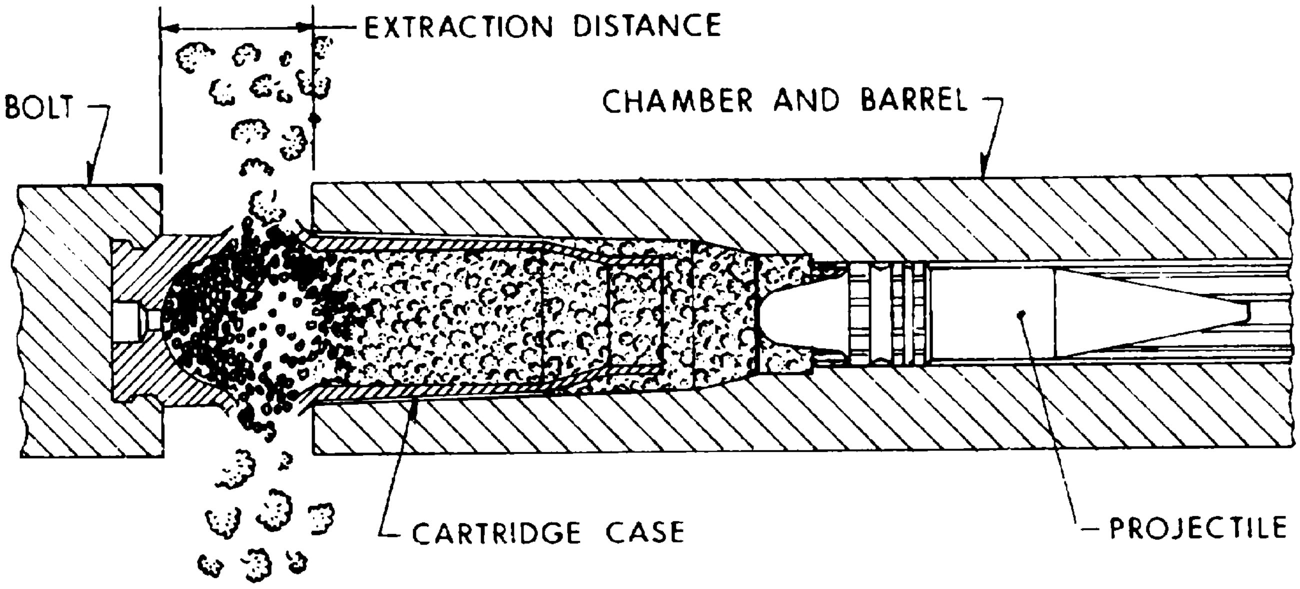

Figure 1. Cartridge Case Rupture During Extraction

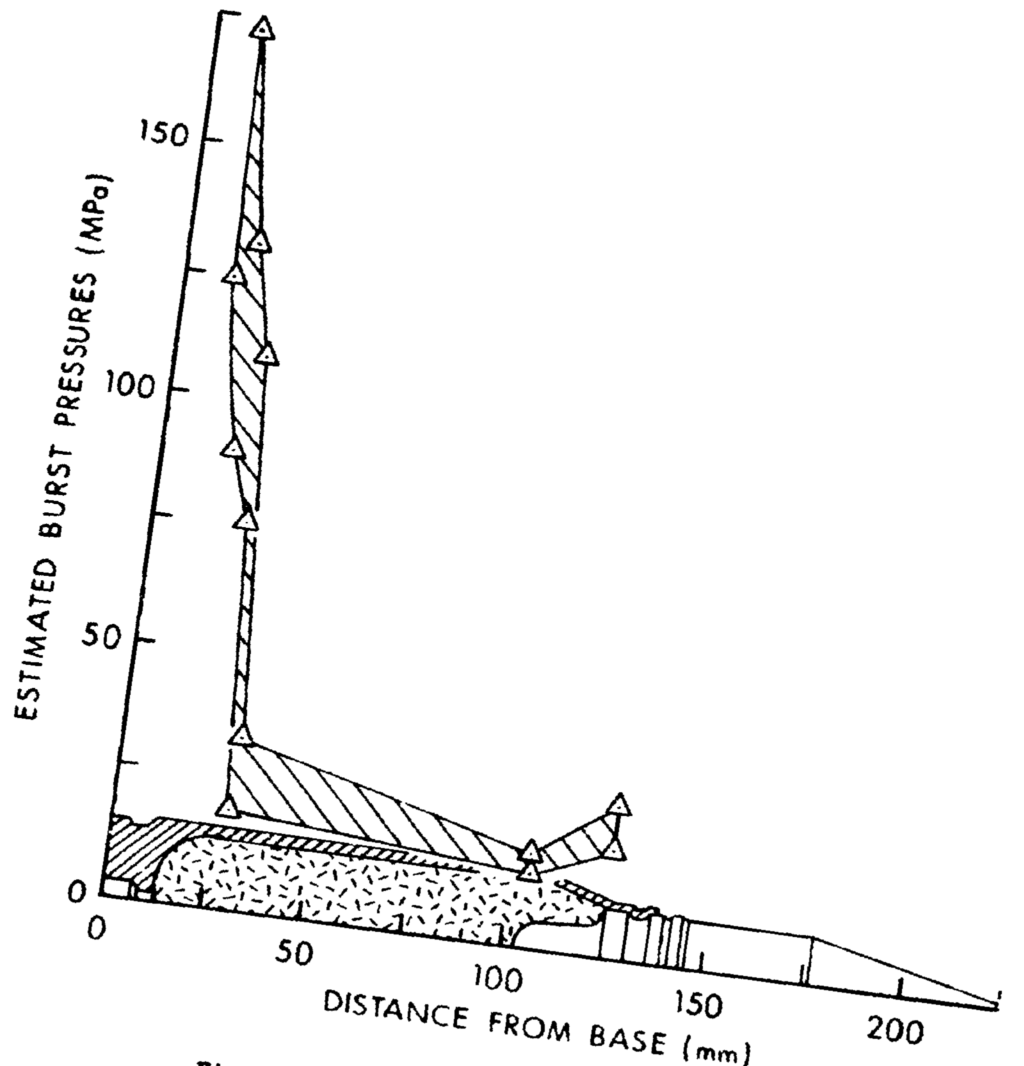

Figure 2. Cartridge Case Burst Pressure

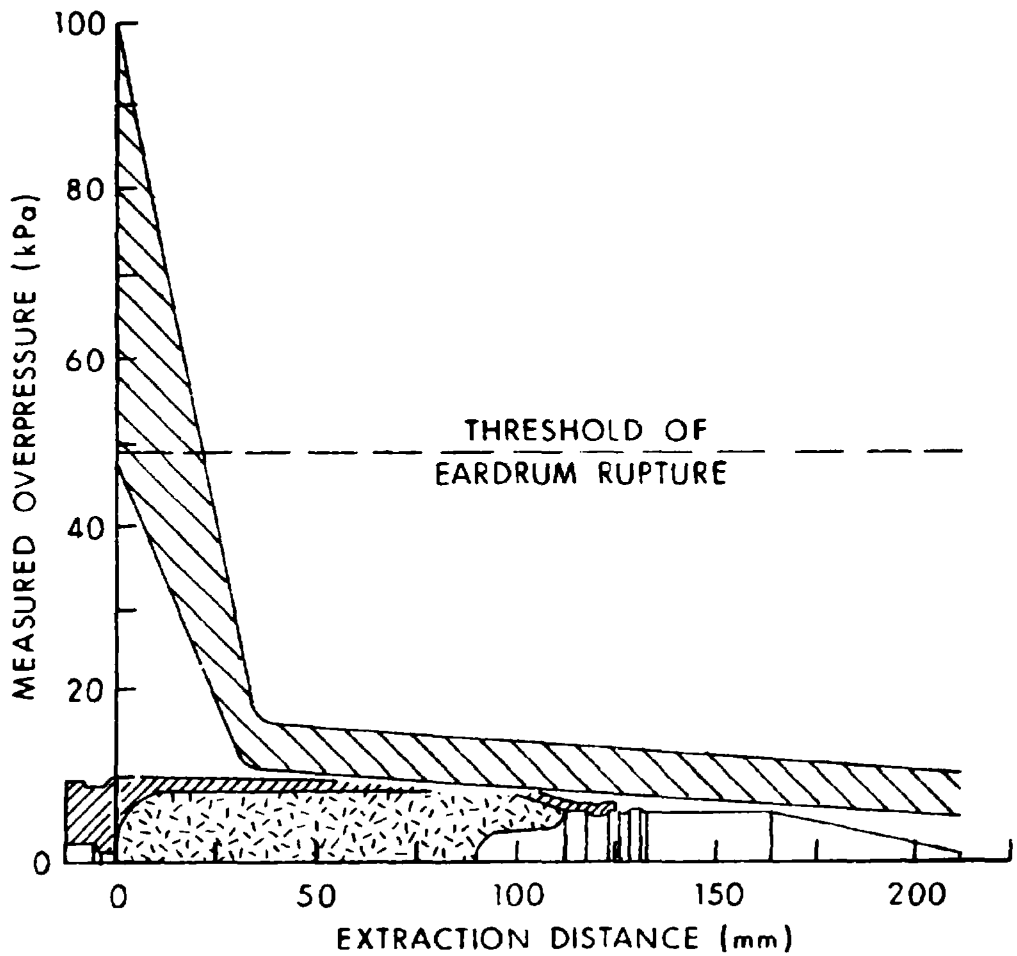

Figure 3. Blast Overpressure at Gunner's Position

V. A CASE HISTORY OF A HANGFIRE

The following is a case history of a hangfire incident involving the 25-mm XM242 (now type classified as the M242) Hughes Chain Gun. This case history is used to illustrate the causes, hazards, and remedies of a hangfire problem.

A. Hangfire Incident

The incident occurred on the 23rd of June 1978 during the DT II Barrel Performance Test of the XM242 Hughes 25-mm Chain Gun at the Materiel Test Directorate of TECOM, APG, MD.

B. Investigation Results

Investigation of the damaged weapon showed that the 25-mm TP-T projectile was initiated during the extraction phase of the operating cycle and that the cartridge case burst when the round had been extracted approximately 19 mm. Calculated estimates of cartridge case burst pressure (shown in Figure 2) indicated that the burst pressure was between 87 and 132 MPa. The damage sustained by the weapon consisted of the bolt carriage assembly being driven into the rear bulkhead of the receiver; the receiver being cracked at the juncture of the rear and bottom walls; and the feed mechanism, feed cover and ejection chute being damaged by the blast and fragments. A pin from the bolt carrier assembly was found loose in the bottom of the receiver and was considered to be a possible cause of the hangfire. The gun was rendered unserviceable.

Based on burst pressure calculations for the cartridge (shown in Figure 2) a worst case condition could possibly cause the rear bulkhead of the receiver to be blown completely free of the weapon.

A series of tests was performed to replicate the incident and establish the hazards generated. The results were that the weapon structure confined all of the fragmentation and potential flying parts; the blast pressure at the gunner's station was as shown in Figure 3. In the worst case the peak blast pressures were on the threshold of eardrum rupture conditions.

Examination of the weapon performance characteristics revealed the following situation. The original M115 igniter specifications that were in force during the design of the XM242 Chain Gun specified 12 inch-pounds of striking energy for the firing pin. The XM242 system was designed to deliver 24 inch-pounds of energy giving a margin of 12 inch-pounds to allow for degradation of performance due to fair wear and tear, and inadequate cleanliness, and for 600 rounds/min firing rate. The updated specifications for the primer specified 19 inch-pounds for firing-pin striking energy, thus reducing the margin for degradation of performance by 58%. This margin was considered by Hughes to be unsatisfactory.

Hangfire data for the ammunition showed that the delay times for the ammunition hangfire reached a maximum of 150 milliseconds. For nominally acceptable ammunition with sufficient firing-pin energy, the probability of a hangfire is 1×10^{-5}.

Examination of the operating cycle for the gun, which is shown in Figure 4, showed that a 17 millisecond window was available for the ammunition to function. All rounds functioning outside this window represented a potential repeat of the experienced incident. Experimental data from Lake City Army Ammunition Plant showed that one out of ten hangfires would function outside the allowable window.* For a nominally functioning weapon/ammunition system the overall probability of a reoccurrence of the incident is 1×10^{-6}. Data from experiments that examined the effect of flawed ammunition showed that the maximum delay was less than 300 milliseconds and that delays beyond that time were misfires. Figure 5 shows the relationship of hangfire delays with respect to the normal 600 rounds/min and 200 rounds/min firing window.

C. Solutions to the Problem

Two approaches were used in the design of modifications to the weapon system. The first approach was to minimize the occurrence of hangfires. The second approach was to eliminate the hazard potential of hangfires.

1. Minimizing the Occurrence of Hangfires. In order to minimize the occurrence of hangfires, the bolt/carriage assembly was modified to provide 1) a higher firing-pin striking energy of 42 inch-pounds, and 2) the bolt retaining pin was redesigned to prevent the possibility of it becoming lodged in the mechanism and restricting firing pin motion. These design changes effectively reduce the probability of occurrence of a hazardous hangfire to that of the ammunition, namely, 1×10^{-6}.

2. Minimizing the Potential Hazard of a Hangfire. The design approach here was to provide a means of neutralizing the hazard potential of a hangfire. Essentially, if the weapon remains locked throughout the time duration of a hangfire, no hazard is created. To accomplish this an auxiliary operating cycle was devised. Basically, a sensor is used to determine the event of weapon recoil as a condition for operating cycle continuation. If the sensor senses recoil during a preset time after the firing pin is actuated, then the cycle continues normally. However, if a hangfire or misfire occurs and no recoil is sensed, the system is caused to dwell in the locked position for 0.5 seconds before continuation of the cycle. A hangfire is then allowed to function with the weapon in the locked condition, thus eliminating any potential hazards. Figure 6 shows the effect of the auxiliary cycle window. Should the round be a misfire, the round will be ejected from the system after the normal operation cycle resumes. The sensing and system logic is designed such that should sensing fail then the system operates on the auxiliary cycle, which is approximately 90 to 100 rounds/min instead of the 600 and 200 rounds/min cycles normally used in the system. This fail safe feature offers a recognizable signature to indicate system failure without denying use of the weapon.

* *Note: The ammunition data in this report was provided by the Lake City Army Ammunition Plant to Hughes Helicopter Inc. and is reported in their Project Report, HH 78-180. See Reference 1.*

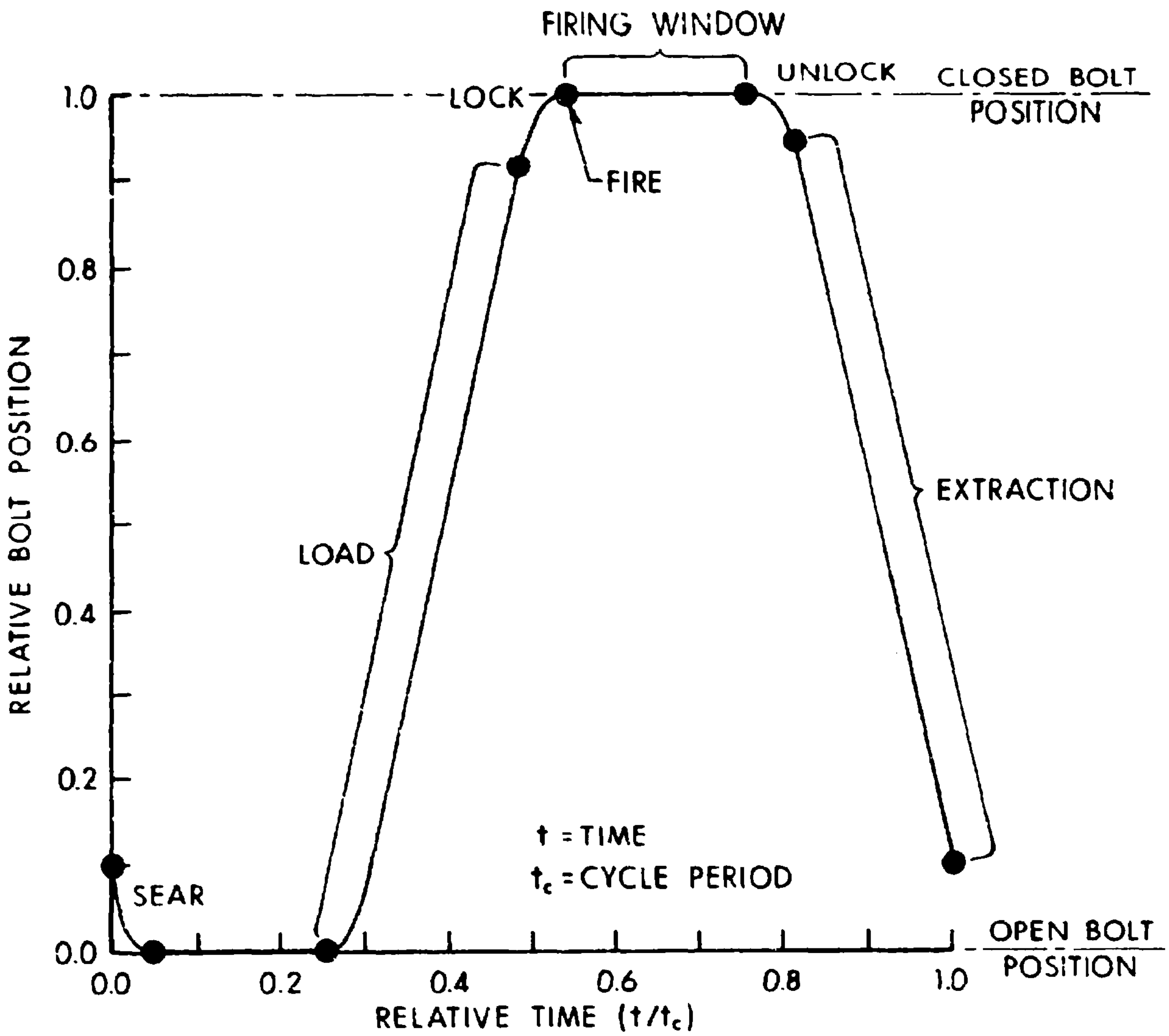

Figure 4. Operating Cycle of XM242

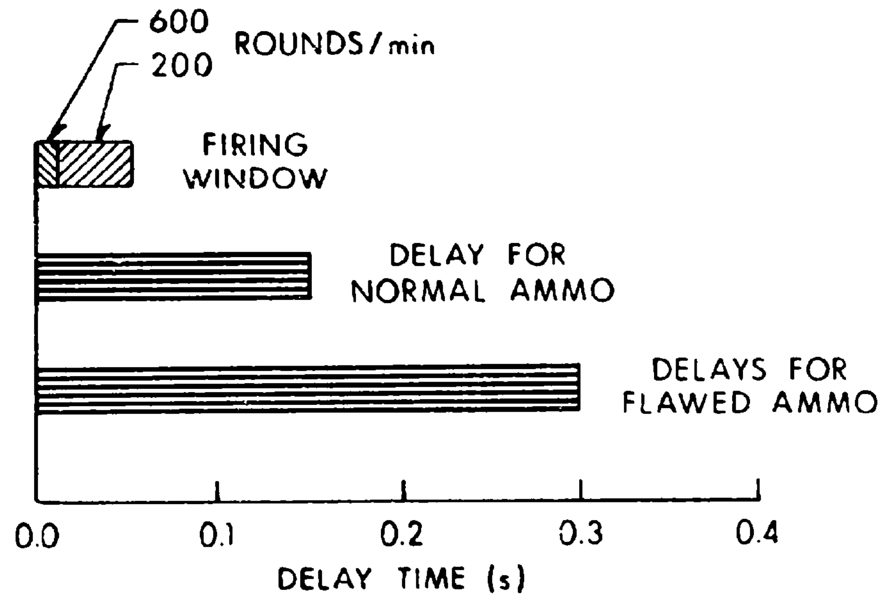

Figure 5. Comparison of Firing Window with Hangfire Delays

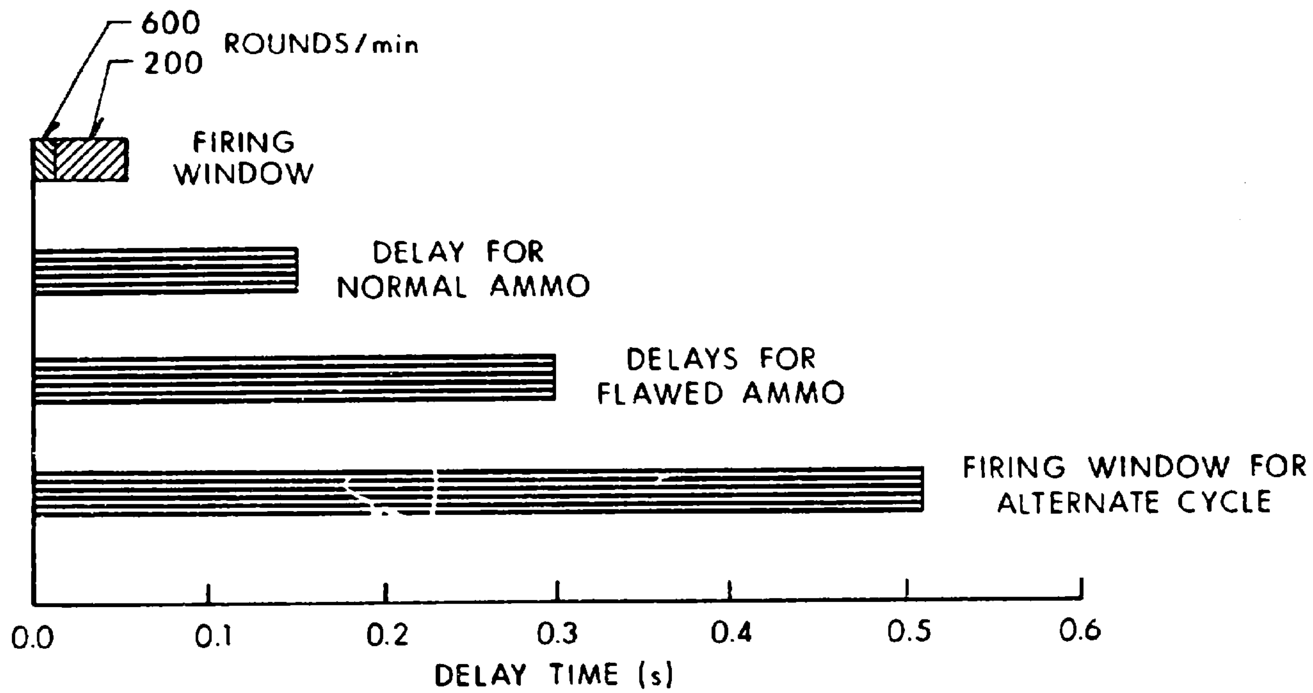

Figure 6. Comparison of Auxiliary Firing Window with Hangfire Delays

VI. SUMMARY OF DISCUSSION

- Hangfires in externally controlled automatic weapons represent a potential severe hazard to both the weapon and the gunner.

- Causes of hangfires can be attributed to the ammunition or the weapon system or both. In determining cause, the following must be considered for both the weapon and the ammunition:

  1. maintenance and cleanliness,
  2. mishandling,
  3. misassembly,
  4. mismatch of weapon and ammunition, and
  5. basic design inadequacies.

- Severity of potential hazards will increase with caliber. The 25-mm system represents a threshold case; larger calibers will be more severe.

- Solutions to the hangfire problem are found in two basic approaches. The first approach is to reduce the occurrence of hangfire to an acceptable level. The second approach is to neutralize the effects of a hangfire. These approaches can incorporate changes in:

  1. weapon system design,
  2. ammunition design,
  3. maintenance doctrine,
  4. use doctrine,
  5. logistics and handling doctrine, and
  6. quality assurance procedures.

- The armament community needs to consider the establishment of test and evaluation criteria determining hangfire frequency and hazard on externally powered weapon systems.

VII. ACKNOWLEDGMENTS

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