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A SURVEY OF SOME OF THE RECENT APPLICATIONS OF PYROTECHNICS TO SMALL ARMS AMMUNITION AND MILD DETONATING FUSE SYSTEMS

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UNITED STATES ARMY
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FOREWORD

The author wishes to express his appreciation to the colleagues, mentioned in Figure 1, who contributed to the items presented in this survey. The unclassified literature sources are listed in the References. Additional information was obtained from unclassified unpublished technical data.

ABSTRACT

Mild detonating fuse (MDF) applications to aircraft escape systems are presented. The explosive components for MDF systems are discussed. Explosives and pyrotechnics with high stability temperatures are needed to increase the ability of the explosive components to withstand temperatures encountered on aerodynamic heating or in highly ionized media. Desired properties of explosives are listed. The mechanical and thermochemical approaches in designing reliable non-fragmenting MDF systems, utilizing pyrotechnic delays, are discussed. Other MDF topics discussed include transition from detonation to deflagration, delays, and ignition through metal webs (or through bulkhead ignition) from one hermetically sealed MDF system to another hermetically sealed MDF system which requires the use of pyrotechnic delay mixtures. Terminal boosters and their components are discussed.

A new method for the laboratory simulation of gun barrel tracer functioning is presented. This is an increased severity test, based on the impact sensitivity of the igniter portion of tracer ammunition. This test has been developed to determine the quality, on a lot basis, of tracer ammunition. Several methods of delivering an impact have been investigated. A ball falling on a firing pin having a 0.015 inch diameter flat surface on the apex of a thirty degree cone, has been found to be optimum in effecting ignition. Statistical analysis similar to that used for evaluating impact sensitivity of percussion primers has been applied to evaluate sensitivity results. Preliminary correlation has been established between gun firing data and impact sensitivity.

A tracer mixture with high visibility and a new method of tracer projectile charging are presented. The method of charging uses extruded metal tubes with very thin walls that contain the tracer composition and that can be readily inserted in place into the tracer cavity.

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INTRODUCTION

This presentation is a survey of some of the recent unclassified applications at Frankford Arsenal of pyrotechnics to small arms ammunition and mild detonating fuse systems. Each of these applications has been the subject of one or more unclassified presentations at Frankford Arsenal. They are being presented together in this survey paper in the hope that exposure to a larger audience will lead to wider acceptance.

1. Mild Detonating Fuse (MDF) Engineering Studies

a. Types of Explosive Components. The adaptability of mild detonating fuse (MDF), a low-energy detonating cord, to aircraft escape systems has been demonstrated, and simple prototype escape systems having MDF as the energy transfer medium have been tested. Explosive components for these systems include (1) detonators (primary and secondary high explosives), (2) boosters (secondary high explosives), and (3) delays (pyrotechnic mixtures).

(1) Until recently, these components were limited to operational temperatures fixed by the stable temperature range of the common high explosives - RDX, PETN, Lead Styphnate, etc. The recent synthesis of several explosives having higher stability temperatures may increase the ability of explosive components to withstand temperatures encountered on aerodynamic heating or in highly ionized media. Properties of particular interest in explosive and pyrotechnic components proposed for applications in mild detonating fuse systems are (1) explosion or ignition temperature, (2) sensitivity to sympathetic detonation, (3) energy output, and (4) impact sensitivity.

b. Problem Areas and Approaches. The general problem areas encountered with each component are those of (1) establishing a highly reliable explosive train in a non-fragmenting system, and (2) using explosives capable of withstanding temperatures approaching those encountered during aerodynamic heating or in highly ionized media. The aforementioned problem areas have led to two approaches toward the overall objective of a highly reliable, non-fragmenting system having high-temperature capability. The approaches are (1) mechanical and (2) thermochemical in nature.

(1) Mechanical Approach. The first approach is mechanical in nature, and involves explosive train design, fabrication, and testing of individual components, in an effort to determine practical design limits. Prototype components that have been developed include PETN-loaded, terminal transfer boosters, two to five second pyrotechnic delays for in-line use with MDF, through-barrier transfer boosters, and through-barrier MDF delays.

(2) Thermochemical Approach. The second approach is thermochemical in nature, and involves comparative testing of new explosives, with the object of replacing standard explosives, such as lead styphnate, PETN and RDX with explosives having high-temperature capability.

c. Transition from Detonation to Deflagration by Use of Pyrotechnics. The relative ease of the transition from a detonating explosive to a deflagrating pyrotechnic delay mixture - a transition required in powder-train delays for detonating cord systems - depends heavily upon the composition of the detonating explosive.[1]* This transition has generally been accomplished in delay blasting devices by the series arrangement, as indicated by solid arrows in Figure 2. A similar transition back to detonation generally occurs in the reverse direction, as indicated by the dashed arrows.

(1) The sequence 1 → 8 is the basis for the design of many two-way delays (i.e., initiated from either end) for use in detonating fuse lines. In such delays, the secondary high explosive is ordinarily PETN, TNT or RDX, while either lead azide or mercury fulminate have been found to be suitable primary explosives.

(2) In some cases, the deflagrating composition may be omitted, although the extent of baffling between steps two and four must be adequate to prevent "blow through". Where a deflagrating composition is employed, black powder, a mixture of smokeless powder/potassium chlorate/lead sulfocyanate, or mixtures such as magnesium, barium peroxide/selenium, and bismuth/selenium/potassium chlorate, are common.

d. Delays. A device for introducing delay times of several seconds between two segments of mild detonating fuse has been developed. This device is hermetically sealed from the ambient environments and from the two MDF segments. Furthermore, it is made readily adaptable with these segments by its plug-in type receptacles.

(1) In Figure 3, a schematic of this device is shown as it would be used with MDF. This is a partial longitudinal section view. The delay unit itself consists of two metal cylinders, 1 and 2, which thread into each other and together comprise the delay housing.

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*See References

(2) Primary explosive charges are contained in the four axial cavities, numbers 3, 4, 5 and 6. These cavities, in addition to the primary explosive charges, also contain adjacent terminal booster (secondary explosive) charges.

(3) The primary charges on each end of the delay housing are separated by a definite web thickness of metal such that on initiation of either charge, the charge on the opposite side of the metal web will be initiated by sympathetic detonation. Cock[2] shows that detonation can be propagated through metal and glass plates if the plate thickness is less than a certain critical value, Sc.

(4) Upon initiation of the MDF cord, either number 7 or 8, detonation proceeds to the primary explosive charge (usually lead azide) in the terminal booster cup, number 3 or 6, depending upon which MDF starts the initiation.

(5) Initiation of either terminal booster cup primary charge causes the detonation to propagate through the sub-critical metal web thickness and initiate the internal primary explosive charge, number 4 or 5, by sympathetic detonation. The brisance of this initiation is attenuated by the adjacent containers of relatively gasless igniter material (such as boron/potassium nitrate). Ignition of the gasless igniter material, in turn, ignites the delay column, which proceeds at a reproducible rate. The explosive train starting from the gasless delay mixture to the MDF is in the reverse sequence as described above. Itemization of the large number of gasless delay mixtures that may be used is beyond the scope of this presentation.

(6) Because there has been little or no demand in the past for delays of several seconds in low energy detonating cord systems, few developmental efforts on such devices have been reported. However, detonating fuse delay devices with delay times in the range of 20 to 300 milliseconds have been developed for use in the blasting industry. Such devices, with appropriate modifications, hold promise for use as low energy detonating cord delays with delay times of several seconds.

(7) Scaling up the delay time from milliseconds to seconds involves modifications in the basic design. This involves not only establishing a proper delay column length, but also maintaining effective and reliable detonation to deflagration transition. Determining such factors as baffle size, shape and delay composition is largely empirical, but design technology in this area is highly developed.

f. Terminal Boosters. Terminal boosters are explosive charges situated at the detonating cord ends. These boosters were designed and fabricated for use with 1 grain-per-foot low energy detonating cord. This design has been found to be highly reliable from the standpoints of initiation sensitivity and continuity of detonation. Three consecutive sections can be described by their functional use and relationship to adjacent sections:

(1) Terminal Charge Section. The terminating explosive charge must be sufficient to provide adequate output power to initiate and also to be sensitive enough to initiate from the output of other boosters. These two functions have been determined to be related to loading pressure.

(2) Intermediate Section. Energy from the terminal charge must be directed to the lead sheathed explosive core(and energy from the core conducted to the terminal charge) in a most efficient and reliable fashion. A high-density frustrum-shaped section has been found to reliably accomplish this energy transfer. The smaller diameter approaches the diameter of the lead sheath.

(3) Confining Section. In order to insure minimum loss of energy in the MDF adjacent to the intermediate section, and thereby insure successful initiation to high-order detonation, the lead sheathed explosive must be confined for several centimeters by a steel cylinder. Inadequate confinement has been found to result in a significant loss in initiation reliability.

This work is being continued in an effort to obtain a measure of reliability for cross-initiation of these boosters.

2. Laboratory Simulation of Gun Barrel Tracer Functioning

a. Types of Tracer Functioning Tests. "Laboratory Simulation of Tracer Functioning" is the subject of Frankford Arsenal Report No. R-1704.[8] This report describes an increased severity test, based on the impact sensitivity of the igniter portion of tracer ammunition, that has been developed to determine the quality, on a lot basis, of tracer ammunition.

(1) Production line testing of tracer ammunition requires a random sampling of the projectiles during the production run. Before the lot can be completed, this sample is gun-fired in a "go-no go" test for acceptance. Failures include not only non-functioning tracer bullets (called blinds), but early and late ignition and short traces. Gun firings of tracer ammunition can show large variances in any two acceptance tests of the same lot.

Contributing factors would include loading variables, such as consolidation pressures, punches, intermixing, basing and also the condition of the gun barrel.

(2) Gun firing of tracers will not show trends of performance as will an increased severity test. With an increased severity test, the difference in impact sensitivity of the igniters of lots of tracers during manufacture and loss of sensitivity during storage could be detected and evaluated. Sampling during manufacture of a lot of tracer ammunition may detect poor or marginal conditions that may be corrected before an entire lot of inferior quality is completed. By using an increased severity test, quality control charts may be kept so that trends may be detected and corrections effected without interruption of production. Any knowledge gained concerning the factors influencing tracer sensitivity and stability would aid in developing improved tracers with increased storage stability.

(3) In developing an increased severity test of tracers, a knowledge of the sequence of events in a gun chamber during firing is required. More specifically, the mechanism of tracer initiation should be understood so that a test can be designed.

(4) The relative effects of flame, time, and impact of expanding gases have been discussed by Stevenson.[3,4] Experiments involving shortened gun barrels indicate that only at zero barrel length were blinds encountered. From a pressure time-bullet travel curve it is seen that peak pressure is reached after the bullet has traveled about one inch. Thus, the full impact of the propellant explosion strikes the igniter surface before the bullet moves appreciably. By decreasing the impact sensitivity by the incremental addition of zinc stearate, the incidence of blinds increased as the percent stearate was increased. The effect of high temperature cannot be completely ignored, as some ignition was obtained with as high as six percent zinc stearate in the igniter mixture.

(5) The type of test desired is one that gives reproducible results when performed by any trained operator who may or may not have a technical background. In addition, this test must reliably indicate the quality of tracer ignition.

b. Methods of Delivering Impact Energy. Three methods of delivering impact energy were investigated, namely, (1) primer energy output, (2) air-driven lightweight firing pin, and (3) the falling ball-firing pin drop test machine. The primer energy output and air-driven lightweight firing pin methods were abandoned because of experimental difficulties in obtaining uniform changes in initiation energy and reproducible data.

(1) The falling ball-firing pin drop test machine, which is the standard method used to ascertain the sensitivity of percussion primers[5] was adopted and modified for this investigation. The utilization of the standard primer drop test machine required the development of a firing pin of critical geometry. The pin, at the point of contact, would not be so small as to fail to compress the igniter mixture, nor so large as to dissipate the energy over too large a surface and not effect ignition.

(2) The configuration adapted was one with a 0.015 inch diameter flat surface at the apex of a 30° taper on a 0.120 inch diameter steel pin. This configuration allowed the point to impact on the igniter in the center of the tracer cavity, where it follows the contour of the consolidating punch. These pins are replaceable in a firing pin holder. A U. S. Army M1903 Springfield rifle bolt action was modified to act as a retracting mechanism to remove the firing pin and holder after impact. This was necessary to remove the firing pin from the zone of the burning tracer. By this technique, it is possible to re-use the firing pin repeatedly until the point configuration is changed.

(3) A standard U. S. Army drop test machine (Dwg 24-49-1) was modified to take the firing pin retracting arrangement and the tracer projectile support. An enclosure of transite was used to duct smoke and fumes from the burning tracer away from the working area. The procedure for conducting a sensitivity test, and obtaining statistical data is the same as for percussion primers.[5] Briefly, the method consists of increasing, by equal increments, the height of the drop of the falling ball onto the firing pin. These heights are varied from a nonfunctioning height to an all-functioning height. The resulting data are analyzed statistically for a 50 percent fire height ($\bar{H}$) and a standard deviation (σ).

c. Impact Ignition by Falling Ball.

(1) Two sizes of tracer projectile were tested: 7.62mm M62 tracers and caliber .50 M1 tracers. These were obtained from ammunition storage and from local production. There were tested as removed from the cartridge case, and if present, the base seal was left intact. Figure 4 presents the 50 percent fire ($\bar{H}$) and the standard deviation (σ) as calculated from the rundown data for the M62 tracer lots.

(2) The sensitivity data in Figure 4 were calculated from a complete rundown from all fire to no fire, testing ten at each height. Skewness, although calculated, is not significant as there is no test for normality for small sample sizes. The confidence in normality in such cases must come from past experience.[6]

(3) Figure 5 presents drop test data from caliber .50 M1 tracer projectiles, which were labelled "Deteriorated Tracer Element", as received from storage depot. Only one lot, TW-18036, produced a 50 percent fire height and a meaningful standard deviation. These had a base seal of gilding metal, which protected the igniter mixture. The other lots had no protection for the igniter.

(4) While it is probable that the use of heavier balls at greater heights would produce a greater percent of fire, this would be undesirable. The ignition phenomena that is of interest concerns itself, to a greater extent with the igniter mixture rather than the tracer mixture. As the igniter mixture becomes less sensitive, a greater blow is needed to cause ignition. As the energy becomes greater, the depth of penetration of the firing pin also becomes greater. In current production testing, this effect will be negligible as the sensitivity appears to be satisfactory. In surveillance testing, however, as the surface of the igniter becomes less sensitive, the sensitive part of the mixture lies deeper under the surface of the igniter, and the firing pin must penetrate more deeply to effect the ignition. However, the igniter is only a finite thickness, and the firing pin may go through it and compress the tracer mixture. The sensitivity of the tracer mixture is much less than that of the igniter mixture, but at the conditions of high impact it may be possible to initiate the tracer mixture. Thus, the tracer projectile would appear to be more sensitive than it would be when fired in a gun.

d. Gun Firing Results

(1) The lots of tracer rounds that were subjected to drop tests were also gun-fired. The 7.62mm M62 rounds were fired in accordance with the Spec MIL-C-45281A (ORD) -4.4.6. With the caliber .50 tracers, only the number of blinds were recorded. Figure 6 presents the results of 7.62mm lots when fired for lot acceptance. Minimum acceptance is the 85 percent level.

(2) Lot FA-4674 shown in Figure 4, having failed the first test, was retested and passed. The defects were early ignition of trace, late ignition of trace, and blinds. The only blind encountered was with the lot that failed the first test.

(3) The occurrence of blinds is not emphasized more than late or early trace. While in conventional tracer rounds blinds are not critical due to a high rate of fire, with spotter-tracer rounds the trace must function with a much higher degree of reliability.

(4) Figure 7 presents the gun firing data for caliber .50 M1 tracer projectiles with "deteriorated tracer element".

(5) Lot TW-18036, shown in Figure 7, was the only lot to have a base seal protecting the igniter; consequently, it functioned after 20 years of storage at ambient conditions, whereas the other lots failed.

(6) Figure 8 presents the original acceptance tests performed at the time of manufacture. At least 100 rounds were fired in each test.

e. Correlation of Gun Tests and Drop Tests

(1) Figure 9 presents the 50 percent fire ($\bar{H}$) and the percent satisfactory results of the 7.62 mm M62 tracer projectiles.

(2) The results of these two tests (i.e., the sensitivity drop tests and the gun firing tests) were examined to determine whether a statistical correlation existed. This calculation[7] shows that a significant correlation of the 95 percent confidence level exists, which supports the validity of the drop test.

(3) When comparing the gun-firing results and the sensitivity data of the caliber .50 M1 tracer projectiles, the effect of blinds is vividly demonstrated. As pointed out previously, the one lot with the gilding metal base seal was the only lot that was 98 percent satisfactory in gun firing and that gave sensitivity data. The lots that did not yield sensitivity data were no more than 15 percent satisfactory in gun firing.

f. Conclusions. The falling ball test is the most promising approach to a quality control procedure for evaluating the functioning reliability of the igniter portion of a tracer projectile. The correlation to gun functioning appears high enough to warrant continued investigation.

3. Tracer Mixtures with Increased Visibility and A New Method of Charging Tracer Projectiles.

a. Visibility. There has been a trend in recent years in the development of small arms weapons toward the consideration of smaller diameter projectile systems (i.e., smaller than 0.30 inch diameter) traveling at higher velocities (i.e., faster than 2200 feet per second). Since it is highly desirable that each system contain a tracer cartridge, experimental efforts have been initiated in each caliber to attain them. In one miniature projectile having a tracer cavity of 0.060 inch diameter, standard compositions were found to perform unsatisfactorily. Nonstandard compositions, however, were formulated that were visible when fired at night, but in the daytime their performances were considered marginal. Consequently, research effort was applied toward the development of pyrotechnic compositions having increased visibility to be used in these newer small tracer cavities.

(1) Because of the unusual interior and exterior ballistic characteristics under consideration, it was expected that the conventional approaches and/or modifications to standard techniques would not provide an immediate and simple solution. In a survey,[9,10] it was learned that a computer study had been completed in which the flame temperature of metals (including magnesium, aluminum, lithium, calcium, nickel, titanium, bismuth, boron, vanadium, molybdenum, chromium, manganese, zirconium and hafnium) reacting with gaseous oxygen were programmed. Subsequently, an experimental effort revealed that brightness of a reaction in addition to being a function of high flame temperature (in excess of 5500°K being sought) was dependent upon the boiling point of the oxide and the solubility of the metal in its oxide. These studies revealed that the brightness flashes under atmospheric conditions were obtained with hafnium and zirconium, and reaction times when oxidized by potassium perchlorate were in the 50 microsecond range.

(2) The experimental effort of this project was divided into three phases; the first, to evaluate the known standard and nonstandard pyrotechnic compositions to get a base-line upon which to improve; the second, to formulate and evaluate pyrotechnic compositions to obtain brighter displays; and thirdly, to submit the most promising compositions for a weapon system evaluation to coordinate the research and developmental effort.

(3) In order to initiate the first phase, an inexpensive test vehicle had to be established. The first considered was a solid caliber .30 brass projectile with holes of 0.060 inch diameter drilled to simulate tracer cavities. Heat transfer problems were experienced as evidenced by the fact that burning could not be sustained with some compositions, so standard 7.62 mm tracer bullets were used and each combination was loaded at 80,000 psi.

(4) The following data in Figure 10 were obtained in static burning tests using the apparatus described in FA Report R-1287.[11] From these data it is indicated that, under these test conditions, experimental compositions producing values in excess of 1000 foot candles (measured from 3 feet) and having burning rates of less than, but close to, one inch per second are being sought. Selected standard and non-standard tracer formulas are shown in Figure 11, for study of variations in formulations.

(5) Zirconium was selected as a fuel in this study since it was known to produce a very high flame temperature when oxidized and was also most efficient in converting chemical energy to radiant energy. Both potassium chlorate and potassium perchlorate were considered for oxidizers; the former was selected because it was considered to be more sensitive tribochemically, and the latter because of its increased oxygen content. It was recognized that both oxidizers would react very rapidly with zirconium, so diluents had to be found to slow the reaction. VAAR (vinyl alcohol acetate resin) recommended by the technical personnel of Picatinny Arsenal was the first diluent considered. It also served as a binder.

(6) Several series of tests were conducted with experimental mixtures, each lot then being dual-charged with R 328 composition, i.e., each projectile contained a based charge of 4 grains R 328 mixture upon which the experimental composition was loaded. It was found that by using this technique, in addition to establishing the performance characteristics of the experimental mixes as tracers, supplemental ignition characteristics could be studied. Specifically, it was noted that slower burning and brighter appearing experimental mixes were better igniters for the R 328 as evidenced by its variation in performance. It was noticed, further, that the performance of the experimental mixtures was also dependent upon its igniter efficiency, so the data in Figure 12 are somewhat empirical. These data indicate that compositions having approximately 70 to 30 ratios of fuel to oxidizer with approximately 5 per cent VAAR should compare favorably, performance-wise, with R 340 for miniature projectile tracer mixtures.

(7) Since all of the above experimental compositions were white in color, a limited effort was initiated to obtain a red tracer. The brightest red tracer evaluated in our laboratory to date was the R 328 composition, and it was reasoned that if the burning rate could be increased, the brightness would be also. Both PETN, an explosive, and zirconium, a fast burning fuel, were added and the results obtained are in Figure 13. The addition of PETN to R 328 composition loaded into 7.62 mm tracer projectiles at 80,000 psi did not increase the intensity of the red tracer output, but the addition of fine zirconium did make it brighter with a tendency to be whiter.

(8) A method was developed to pelletize the VAAR compositions, and several of the lots listed in Figure 13 were loaded into miniature projectiles of 0.060 inch diameter for engineering tests. In a limited number of tests, none of the red colored tracers were visible at high velocities, but the VAAR-Zr/$KClO_3$ and VAAR-$KClO_4$ compositions were visible both day and night.

b. Method of Charging Tracer Projectiles. The second problem presented by a small diameter tracer cavity is related to loading and charging techniques that are adaptable to production methods. This problem has been solved by using extruded metal tubes with very thin walls that contain the tracer composition and that can be readily inserted in place. This eliminates the difficulties involved in loose powder and pellet loading procedures. In addition, it is proposed to hydraulically apply conventional loading pressures (100,000 psi) to the extruded tubes containing the tracer mixtures.

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LIST OF ACKNOWLEDGMENTS

Survey Item	Contributor
Mild Detonating Fuse (MDF) Engineering Studies	J. F. Kowalick
Laboratory Simulation of Gun Barrel Tracer Functioning	T. A. Doris W. W. Cavell
Tracer Mixtures with Increased Visibility and Method of Charging	J. J. Caven W. E. Perkins W. W. Cavell

Figure 1

Series Arrangement in Blasting Caps

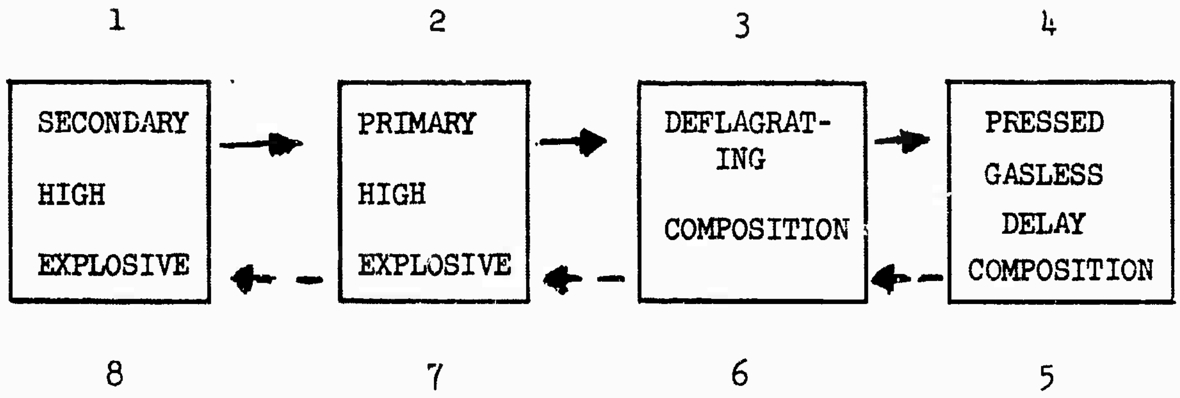

Figure 2

MILD DETONATING FUSE (MDF) THROUGH-BULKHEAD DELAY

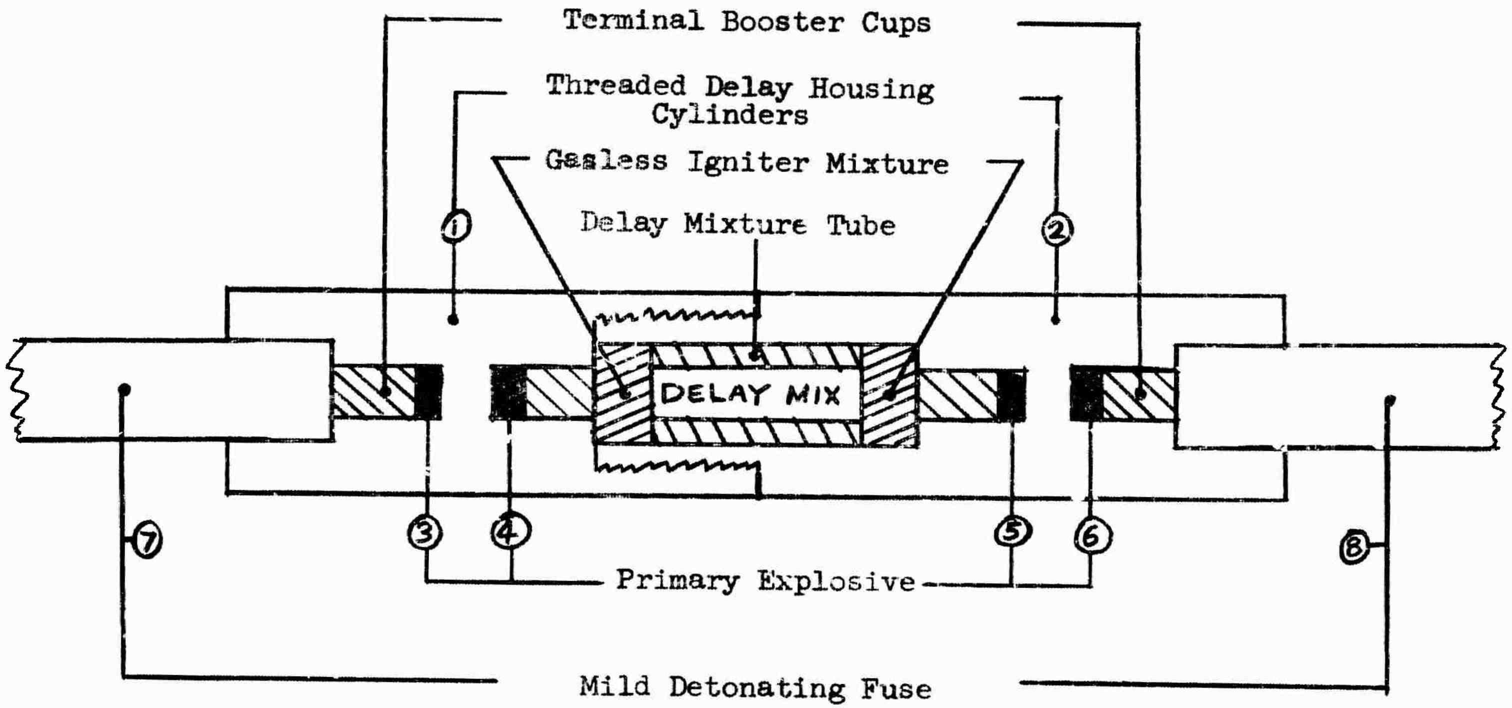

Figure 3

Drop Test Data, 7.62 mm M62 Tracer Bullets
Using 14-oz Ball

Ammunition Lot No.	$\bar{H}$ (in.)	σ
RA-5052	5.6	2.0
FA 4	6.6	2.3
WC-86011	7.8	2.4
FA-4674	13.[illegible]	3.7
FA-4675	12.4	5.8

Figure 4

Drop Test Data for Caliber .50 M1
Tracer Bullets

Ammunition Lot No.*	Drop Test Data	Impact-Energy (in.-oz)
SL-8591	33% function	550
TW-18047	0% function	550
U-16327	50% function	504
DM-20345	6% function	550
TW-18225	0% function	550
TW-18036**	$\bar{H} = 6.8$ in.; $\sigma = 2.4$ (14 oz. ball)	

*SL - St. Louis Ordnance Depot
TW - Twin Cities Ordnance Depot
U - Utah Ordnance Depot

** Base Seal

Figure 5

Acceptance Test Results, 7.62 mm
M62 Tracer Bullets

Ammunition Lot No.	No. Fired	No. of Defects	% Satisfactory
RA-5052	100	2	98
FA-4	100	1	99
WC-86011	100	4	96
FA-4675	50	6	88
FA-4674	50	10	80 (failed)
FA-4674 (retest)	100	14	86 (passed)

Figure 6

Test for Blinds, Caliber .50
M1 Tracer Bullets

Ammunition Lot No.	No. Fired	No. of Defects	% Satisfactory
SL-8591	55	47	15
TW-18074	48	48	0
U-16327	57	54	5
DM-20345	57	57	0
TW-18225	48	43	9
TW-18036	50	1	98

Figure 7

Original Performance Data, Source, and Date
of Manufacture of M1 Tracers

Lot No.	Source (Ordnance Depot)	Date of Manufacture	% Acceptable Trace
SL-8591	St. Louis	Jan 1944	93
TW-18047	Twin Cities	Jul 1942	92.3
U-16327	Utah	Nov 1943	100
DM-20345	Des Moines	May 1943	94
TW-18225	Twin Cities	Nov 1942	98
TW-18036	Twin Cities	Jul 1942	99.3

Figure 8

$\overline{H}$ vs Percent Satisfactory

Results of the 7.62mm M62 Tracer Bullets

Ammunition Lot No.	$\overline{H}$ (in.)	% Satisfactory (Gun Firing)
RA-5052	5.6	98
FA-4	6.6	99
WC-86011	7.8	96
FA-4675	12.4	88
FA-4674	13.8	83 (avg)

Figure 9

Static Burning Tests of Standard and Non-Standard Tracer Mixes

Standard Tracer Mixtures		Burning Rate (Inches/sec)	Peak Intensity (ft-c)	Feet
R 257 NATO	Deep red light	0.10	20	2
R 284 Cal. .30	" " "	0.10	100	2
FA TR-060964-883	Bright red light	0.14	225	2
R 328 FA experimental	" " "	0.14	300	3
Non-Standard Tracer Mixtures				
I 237 Cal. .50 Headlight Tracer	Bright white	1.00	1000	3
R 340 Miniature Projectile Tracer Mixture	" "	0.66	1000	3

Figure 10

Selected Standard and Non-Standard Tracer Formulas

R 257

Magnesium	28.0
Strontium Nitrate	40.0
Strontium Oxalate	8.0
Calcium Resinate	4.0
Potassium Perchlorate	20.0

R 284

Magnesium	28.0
Strontium Nitrate	55.0
Polyvinyl Chloride	17.0

I 237

Magnesium	25.0
Strontium Peroxide	70.0
Zinc Stearate	1.0
Barium Peroxide	4.0

R 334

Magnesium	7.0
Barium Peroxide	39.2
Barium Nitrate	10.0
Zirconium (coarse)	16.2
Zirconium (fine)	3.8
Lead Peroxide	10.0
PETN	10.0
Parlon	2.8
Toluidine	0.5
Zinc Stearate	.5

R 340

Magnesium	25.6
Barium Peroxide	31.16
Barium Nitrate	8.0
Zirconium (coarse)	12.96
Zirconium (fine)	3.04
Lead Peroxide	8.0
Parlon	2.24
Toluidine	0.5
Zinc Stearate	0.5
PETN	8.0

Figure 11

Experimental Compositions

Purpose of Test	Dry Blend Ratio Zr to $KClO_3$		VAAR %	Burning Rate (In/Sec.)	Brightness Ft-c at 3 ft.
Establish fuel to oxidizer ratio with 10% VAAR	25	75	10	0.08	30
	50	50	10	0.20	200
	70	30	10	0.66	700
Establish VAAR ratio	70	30	2.5	4.0	1400+
	70	30	5	1.1	1100
	70	30	7.5	1.0	1000
	70	30	10	.7	700
	70	30	12.5	.5	400
	70	30	15	.2	300
Establish fuel to oxidizer ratio with 5% VAAR	60	40	5	.7	700
	70	30	5	1.1	1100
	75	25	5	1.0	1100
	80	20	5	.7	1450
	90	10	5	.7	1400
Establish VAAR ratio in lower percentages	75	25	2.5	1.0	1500
	75	25	3.5	1.0	1300
	75	25	5	1.0	1100
Changed oxidizer from $KClO_3$ to $KClO_4$	Zr to $KClO_4$				
	60	40	5	.8	1200
	70	30	5	.8	1200
	80	20	5	1.0	1400
	90	10	Ignition not sustained		
Increase VAAR content	70	30	10	.6	350

Figure 12

PETN and Zirconium Additions to R 328 Tracer Mixture

Composition	Burning Rate (In/Sec.)	Peak Intensity Ft-c at 3 ft.
R 328	.13	200
R 328 + 5% PETN	.17	190
R 328 + 10% PETN	.17	180
R 328 + 5% zirconium through 325 mesh	.19	250
R 328 + 10% zirconium through 325 mesh	.20	300
R 328 + 20% zirconium through 325 mesh	.24	450
R 328 + 30% zirconium through 325 mesh	.24	650

Figure 13

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13. ABSTRACT
Mild detonating fuse (MDF) applications to aircraft escape systems are presented. The explosive components for MDF systems are discussed. Explosives and pyrotechnics with high stability temperatures are needed to increase the ability of the explosive components to withstand temperatures encountered on aerodynamic heating or in highly ionized media. Desired properties of explosives are listed. and mechanical and thermochemical approaches in designing reliable nonfragmenting MDF systems, utilizing pyrotechnic delays, are discussed. Other MDF topics discussed include transition from detonation to deflagration, delays, and ignition through metal webs (or through bulkhead ignition) from one hermetically sead MDF system to another hermetically sealed MDF system which requires the use of pyrotechnic delay mixtures. Terminal boosters and their components are discussed.

A new method for the laboratory simulation of gun barrel tracer functioning is presented. Several methods of delivering an impact have been investigated. Statistical analysis similar to that used for evaluating impact sensitivity of percussion primers has been applied to evaluate sensitivity results. Preliminary correlation has been established between gun firing data and impact sensitivity.

A tracer mixture with high visibility and a new method of tracer projectile charging are presented. The method of charging uses extruded metal tubes with very thin walls that contain the tracer composition and that can be readily inserted in place into the tracer cavity.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
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