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AFATL-TR-73-28

**ADVANCED GUN PROPELLANT CONCEPTS**

**GUN RANGE OPERATIONS BRANCH  
GUNS AND ROCKETS DIVISION**

**TECHNICAL REPORT AFATL-TR-73-28**

**FEBRUARY 1973**

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**EGLIN AIR FORCE BASE, FLORIDA**

# **Advanced Gun Propellant Concepts**

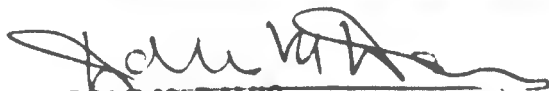
**Otto Heiney**

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## FOREWORD

This technical report is based on work performed at the Air Force Armament Laboratory between January 1972 and January 1973 in support of Project 2560.

This technical report has been reviewed and is approved.



DALE M. DAVIS  
Chief, Guns and Rockets Division

## ABSTRACT

A new series of cool burning, high impetus, low molecular weight gun propellants has been identified. These propellants contain either cyclic or linear nitramines as crystalline oxidizers in the propellant matrix. Current development efforts are concentrating on lowering the inherently high pressure exponent of the linear burning rate associated with these high energy systems. When these advanced formulations become operational, thermal barrel erosion will be virtually eliminated hypervelocity projectile firing from operational guns will become possible, and the potentiality for catastrophic failure resulting from the use of aluminum cartridges will be removed. To realize these benefits, the nitramine combustion anomaly must be obviated.

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## SECTION I

### INTRODUCTION

A principal goal in developing new aircraft cannon ammunition has been cool burning gun propellants. The flame temperatures of available propellants are such that it is not possible to significantly increase the muzzle velocity of advanced weapons while retaining acceptable gun barrel life. A new series of cool burning, high impetus, low molecular weight gun propellant families, largely based on rocket propellant technology has been identified during an exploratory development effort conducted at the Air Force Armament Laboratory (AFATL). These propellant families contain either cyclic or linear nitramines as crystalline oxidizers in the propellant matrix. The generic formulations have consistently demonstrated such promising thermodynamic properties that they constitute a major increase in the state of the art. Advanced development efforts are now underway to tailor the combustion characteristics of these improved systems, and engineering development for gun system application within 3 to 4 years is anticipated.

The low molecular weight linear nitramines used as oxidizers in these systems were developed under AFATL contracts with Hercules Allegany Ballistic Laboratories and with the Rocketdyne Division of North American Rockwell. Current efforts are concentrating on lowering the inherently high pressure exponent of the linear burning rate associated with these high energy systems. When these advanced formulations become operational, a significant increase in both propellant and ammunition technology will occur, and thermal barrel erosion will be virtually eliminated. Hypervelocity projectile firing from operational guns will become possible, and the potentiality for catastrophic failure resulting from the use of aluminum cartridge cases will be removed because the propellant flame temperature will be below the ignition point of aluminum.

This report discusses some rudimentary propellant thermochemistry to demonstrate the importance of generating low molecular weight combustion products, and it also covers the general propellant formulations currently being investigated. The burning rate slope problem that is currently inhibiting the operational employment of nitramine propellants is also covered.

## SECTION II

### PROPELLANT THERMODYNAMICS

The impetus,  $F_p$ , of gun propellants is the basic parameter indicating performance, and it is, in effect, a value of specific performance potential. The value of  $F_p$  in ft-lb/lb is obtained from the following equation:

$$F_p = \frac{T_f}{M} R \quad (1)$$

This equation states that the thermochemical potential of a gun propellant is directly proportional to the combustion flame temperature,  $T_f$ , divided by the mean molecular weight,  $M$ , of the propellant combustion products. The universal gas constant,  $R$ , in engineering units, has a value of 2780 ft-lb/mole  $^{\circ}\text{K}$ .

Gun propellant impetus is similar to the more familiar specific impulse,  $I_{sp}$ , value used for rocket propellants. A rough correlation is that

$$I_{sp} \approx 2.3 \sqrt{F_p/g} \quad (2)$$

Where the premultiplication factor is a lumped term containing a typical flow factor and thrust coefficient and  $g$  is gravity.

An examination of Equation (1) indicates that if the propellant impetus is to be raised and the flame temperature lowered, the only recourse is to drastically decrease the mean molecular weight of the propellant combustion products. Table I illustrates the implication of this equation. The current USAF goal is to formulate propellants which have performance data in the shaded area in the lower portion of the table. When contrasted with the currently operational gun propellant data contained in the shaded upper portion of the table, the proposed improvement is seen to be of a revolutionary rather than evolutionary nature. There is, in general, a virtual 1000 $^{\circ}\text{K}$  temperature differential between propellants having 25 and 17 mean molecular weights. When considering these isochoric flame temperatures, two discrete temperature values are especially significant. The first is 1700 $^{\circ}\text{K}$ , the temperature at which gun barrel steel will melt, and the second is 2300 $^{\circ}\text{K}$ , the ignition point for the aluminum cartridge case material. Quoted values for propellant flame temperatures are at isochoric, or constant volume,  $T_{cv}$ , conditions, while the gun system has an environment closer to isobaric or constant pressure,  $T_{cp}$ , conditions. A simple equation from thermodynamics gives

$$T_{cv} = \gamma T_{cp} \quad (3)$$

Where  $\gamma$  is the mean specific heat ratio of the combustion gases and has a value on the order of 1.22. Thus, it is possible for a propellant formulation to have a theoretical isochoric flame temperature in the area of 2200 $^{\circ}\text{K}$  and still not expose the gun barrel to temperatures above its melting point.

TABLE I. IMPETUS FLAME TEMPERATURE MOLECULAR WEIGHT RELATIONSHIPS				
COMBUSTION PRODUCT, Mean Molecular Weight	PROPELLANT FLAME TEMPERATURES, °K			
	Impetus Level, Ft-Lb/Lb			
	325,000	350,000	375,000	400,000
25	2980	3150	3380	3500
22	2670	2770	2970	3170
20	2350	2620	2700	2880
19	2220	2390	2570	2740
18	2110	2270	2430	2590
17	1990	2140	2290	2450

Figures 1 and 2 illustrate this flame temperature problem. Figure 1 shows a 7.62 minigun after a duty firing cycle of 2000 rounds. The barrels are red hot and ready to fail after an approximately 20-second burst of fire. Figure 2 is a sectioned view of thermally eroded barrels showing the destruction of the rifling in the first several calibers of projectile travel, the area of maximum convective heat transfer.

The sensible flame temperature of the propellant also becomes crucial when considering the interaction with aluminum cartridge case material. Due to cost, weight and the increasing scarcity of copper, new aircraft cannon systems will be designed to use either aluminum or plastic cartridge case materials. Figure 3 provides data on the ignition temperature of aluminum as a function of the ambient stoichiometry. These data (extracted from Reference 1) were obtained only to a -10% oxygen level. From that point, a conservative extrapolation indicates that the majority of high energy advanced propellants will be below the ignition threshold of aluminum. In actuality, the cartridge case ignition points will be even higher than indicated because the data were generated for micron size particles suspended in a flame, and effectively, the cartridge case may well react more like an extended slab. Thus, even a worst case analysis shows that these advanced propellants will preclude the catastrophic case failures previously experienced in aluminum cartridge case development.

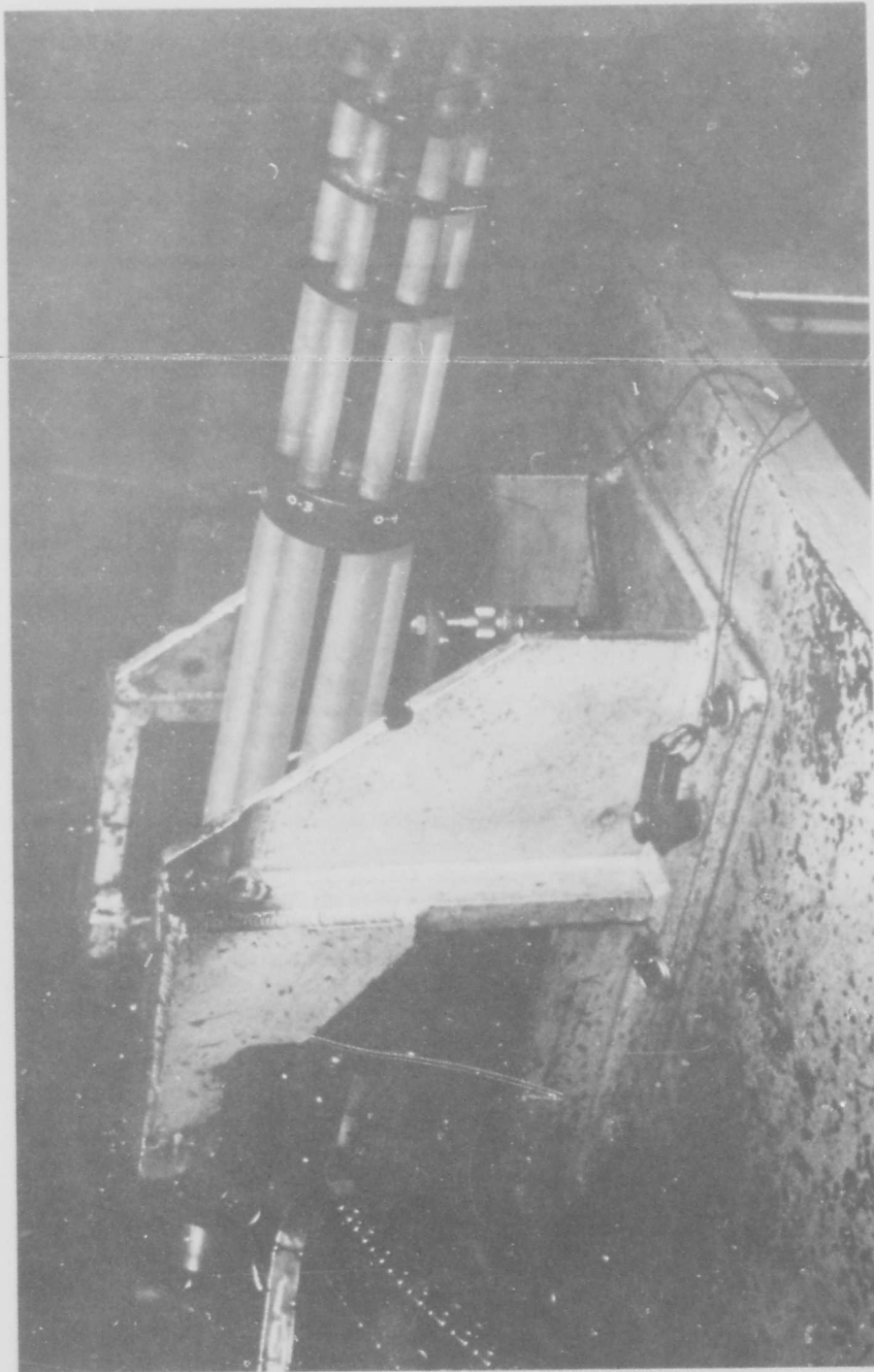


Figure 1. 7.62 Minigun

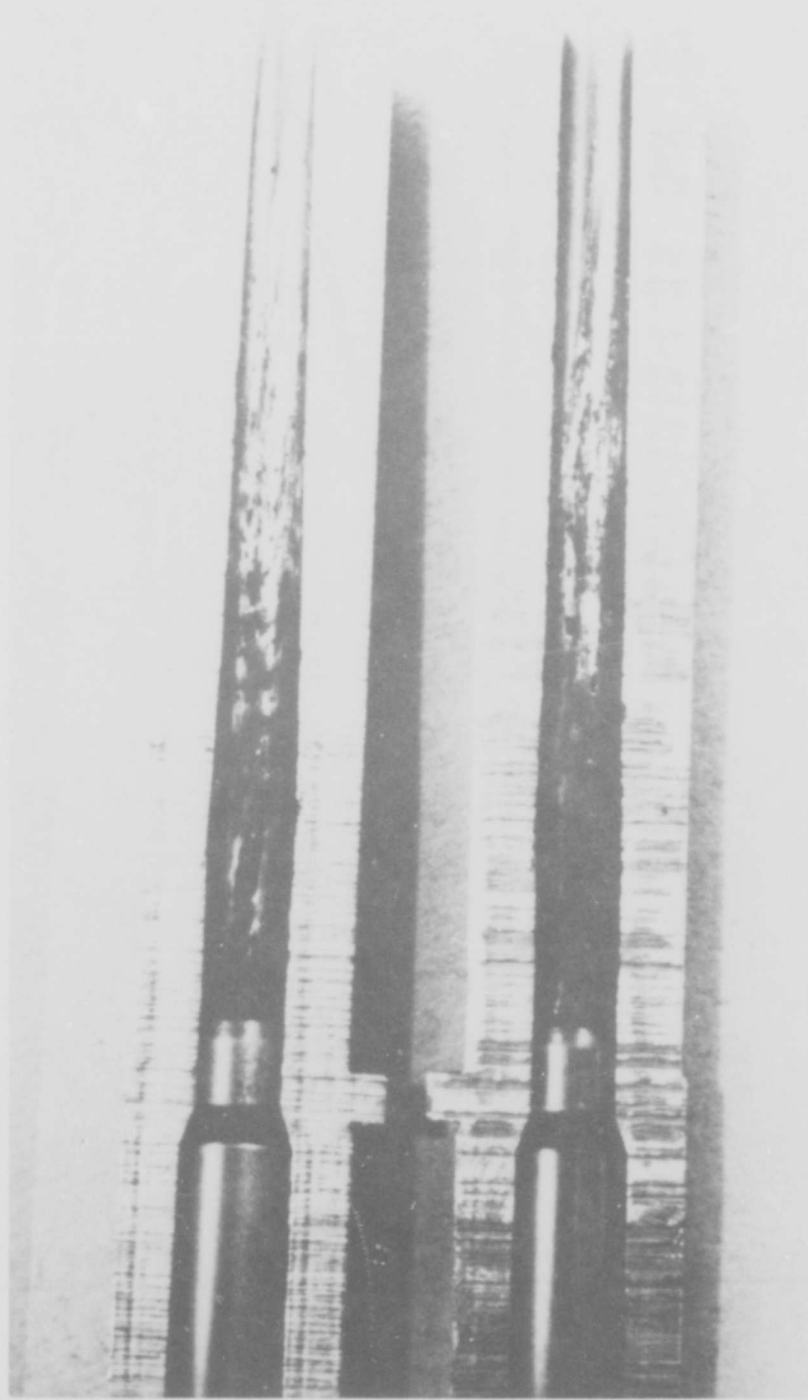


Figure 2. Thermally Eroded Gun Barrels

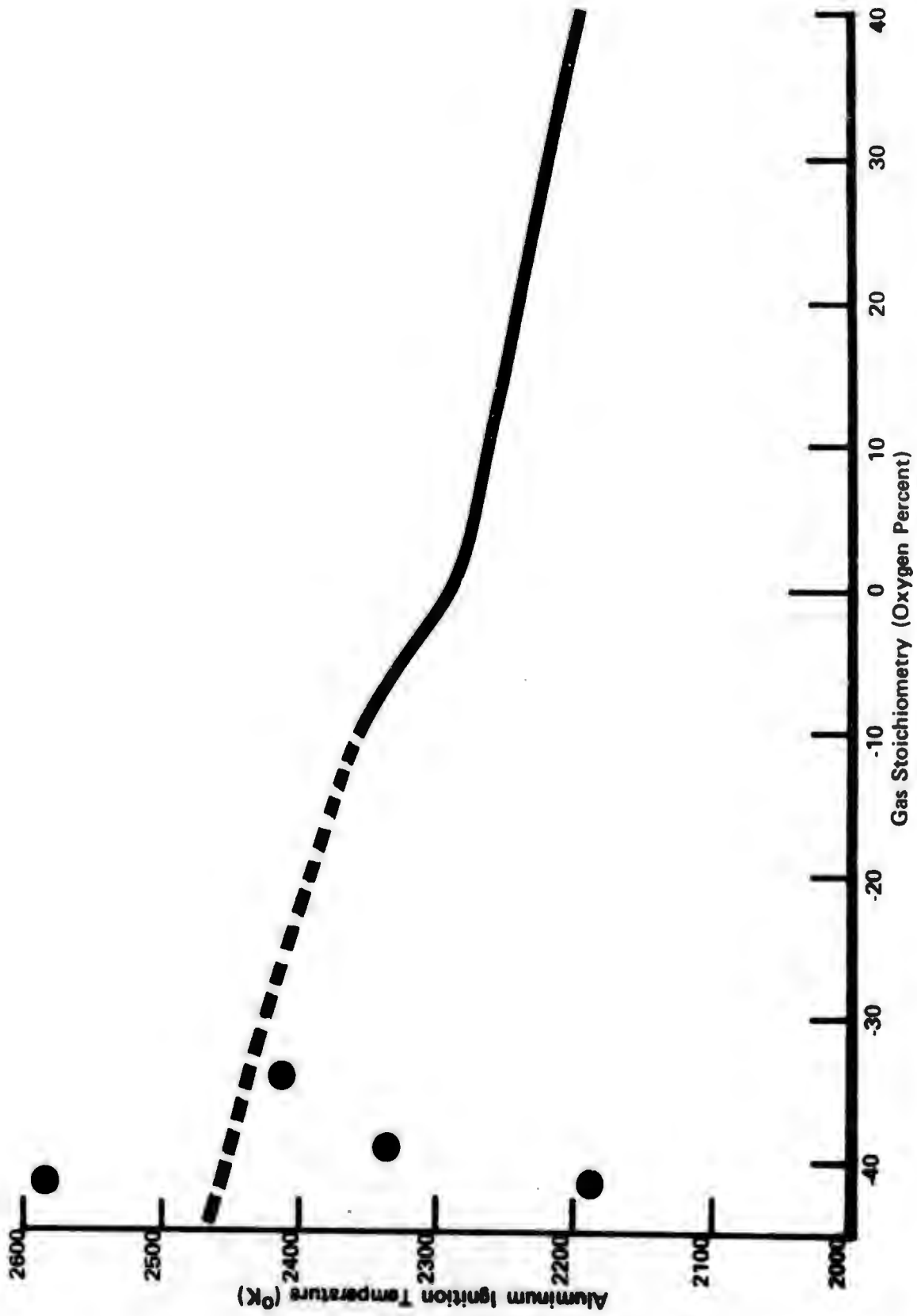


Figure 3. Aluminum Ignition Temperature vs Gas Stoichiometry

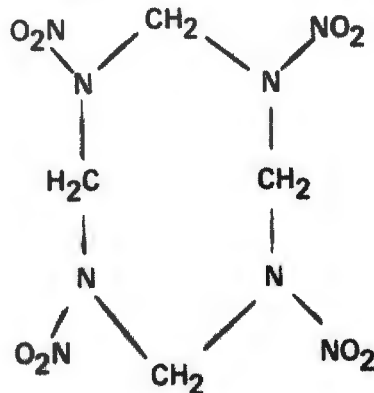
### SECTION III

#### PROPELLANT FORMULATIONS

The preceding sections of this report establish the thermodynamic requirement for low mean molecular weight combustion gas products if propellants are to provide high performance at low flame temperature. This section considers how to generate these low molecular weight gases. It is immediately apparent that all formulations must be of high hydrogen content and of extremely fuel rich stoichiometry. The standard gun combustion products of  $H_2O$  and  $CO_2$  must be replaced by  $H_2$  and  $CO$  and must not form any free carbon in the gun chamber. Free carbon results in very poor combustion efficiency and causes excessive smoke and residue to be generated. Determining the formulations of interest to pursue requires the use of propellant thermochemistry calculations. Computer programs, as discussed in Reference 2, accept the heat of formation of the propellant constitutive ingredients and compute the combustion parameters of the system as it burns at any specified pressure. The results include the flame temperature, mean gas molecular weight, impetus, specific heat ratio, and mole fraction of all the combustion products. These theoretical data are prerequisites for determining which compounds to experimentally pursue with formulation studies. The advanced propellants now being evaluated for combustion characteristics are the results of many free energy calculations.

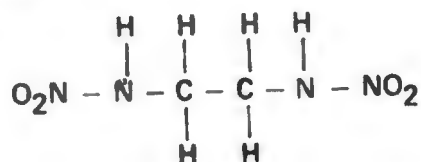
In selecting the binders and oxidizers to experimentally formulate, ingredients of both gun and rocket propellants were considered. The limitations which permit no solid products in the exhaust gas due to gun fouling effects and no halogens due to their corrosivity, have precluded C H O N type ingredients. As a low gas molecular weight is necessary, the stoichiometry of the propellant system must be grossly oxygen starved, thus, the compounds used must contain both high energy and high hydrogen content. These limitations present a seemingly irreconcilable thermodynamic situation because virtually all oxidizing compounds that will satisfy the requirements are, in themselves, explosives. However, if a suitable binder matrix is used, these explosive oxidizers will burn as required rather than detonate. At high pressure, these oxidizers will display a drastic change in the pressure dependence of their decomposition.

The oxidizing compounds which demonstrate the high hydrogen content and requisite thermochemical properties are the cyclic nitramines, the linear nitramines, and triaminoguanidine nitrate. The cyclic nitramine most investigated is HMX with a structure as follows:



This compound has a positive heat of formation,  $\Delta H_F = + 18$  kcal/mole, that is, the decomposition of the material is exothermic. As an oxidizer, HMX is very stable both in a thermal and chemical sense, but while referred to here as an oxidizer, it is really more a monopropellant in the accepted sense. A similar material, RDX, demonstrates many of the same properties and potentially is a less expensive material for formulating propellants. HMX has been selected for the initial USAF nitramine propellant work due to the extant broader base of knowledge with regard to its combustion properties. After a successful propellant formulation using HMX, the next step would be to attempt an RDX substitution to attain the inherent 3 to 1 cost advantage.

The starting material for most of the linear nitramine work is ethylene-dinitramine (EDNA), which was extensively investigated in the 1950's. The structure of EDNA has two active hydrogen sites which will allow the formation of many salts with quite promising thermodynamic properties.



$$\Delta H_F = -23.7 \text{ kcal/mole}$$

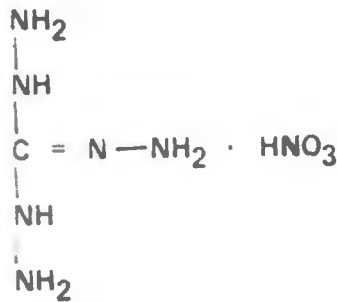
These salts were investigated by Hercules Allegany Ballistic Laboratories under USAF sponsorship and are discussed in References 3 and 4.

To date, the most thoroughly studied of the linear nitramine compounds are as follows:

ABBREVIATION	NAME	FORMULA	$\Delta H_F$ (kcal/mole)
TAGED	Triamino Guanidinium Ethylene Dinitramine	$\text{C}_4\text{H}_{22}\text{O}_4\text{N}_{16}$	+ 60
DMED	Dimethylethylene Dinitramine	$\text{C}_4\text{H}_{10}\text{O}_4\text{N}_4$	- 35.8
DMDTH	Dimethoxy Dinitrazahexane	$\text{C}_6\text{H}_{14}\text{O}_6\text{N}_4$	- 94
DHED	Dihydrazinium Ethylene Dinitramine	$\text{C}_2\text{H}_{14}\text{O}_4\text{N}_8$	- 40

Work on the latter two of these systems has been terminated because DMDTH had a low melting point and DHED had binder interaction chemical stability problems.

Another thermodynamically promising crystalline oxidizing compound being investigated by the Naval Ordnance Station, Indian Head, Maryland, and by Rocketdyne Division of North American Rockwell under USAF sponsorship is triaminoguanidine nitrate



$$\Delta H_f = -11.5 \text{ kcal/mole}$$

This oxidizer provides very high propellant system burning rates, and, in adequate percentage concentrations, appears to partially mask the nitramine combustion slope problem.

Figure 4 illustrates the type of performance which may be attained from these discussed propellant formulations. The circles on the figure correspond to current issue generic gun propellant types. From the lower left to the upper right on the figure, these circles represent cooled nitrocellulose; triple base, straight nitrocellulose; and at very high flame temperatures, nitroglycerine loaded propellants. These operational propellants show a relationship between flame temperature and impetus which has led to the misconception that all possible propellants that can be formulated must fall in this performance band.

The formulations denoted by triangles on Figure 4 illustrate the USAF developed propellant systems discussed in this report, and their performance demonstrates a major breakthrough from previous technology performance limitations. These systems run from cool linear nitramines in a nitrocellulose binder through cyclic nitramines in rubber binders to high energy cyclic and linear nitramines in a nitrocellulose binder. Detailed processing and formulation data on these systems are provided in References 5 and 6.

It is to be emphasized that these systems are not only the result of theoretical thermodynamical computations but have been successfully manufactured. They are thermally and chemically stable and burn with excellent combustion efficiency when fired in a closed impetus bomb. The reason these greatly improved propellant systems are not yet ready for operational gun application is subtle and requires a short discussion of gun interior ballistics.

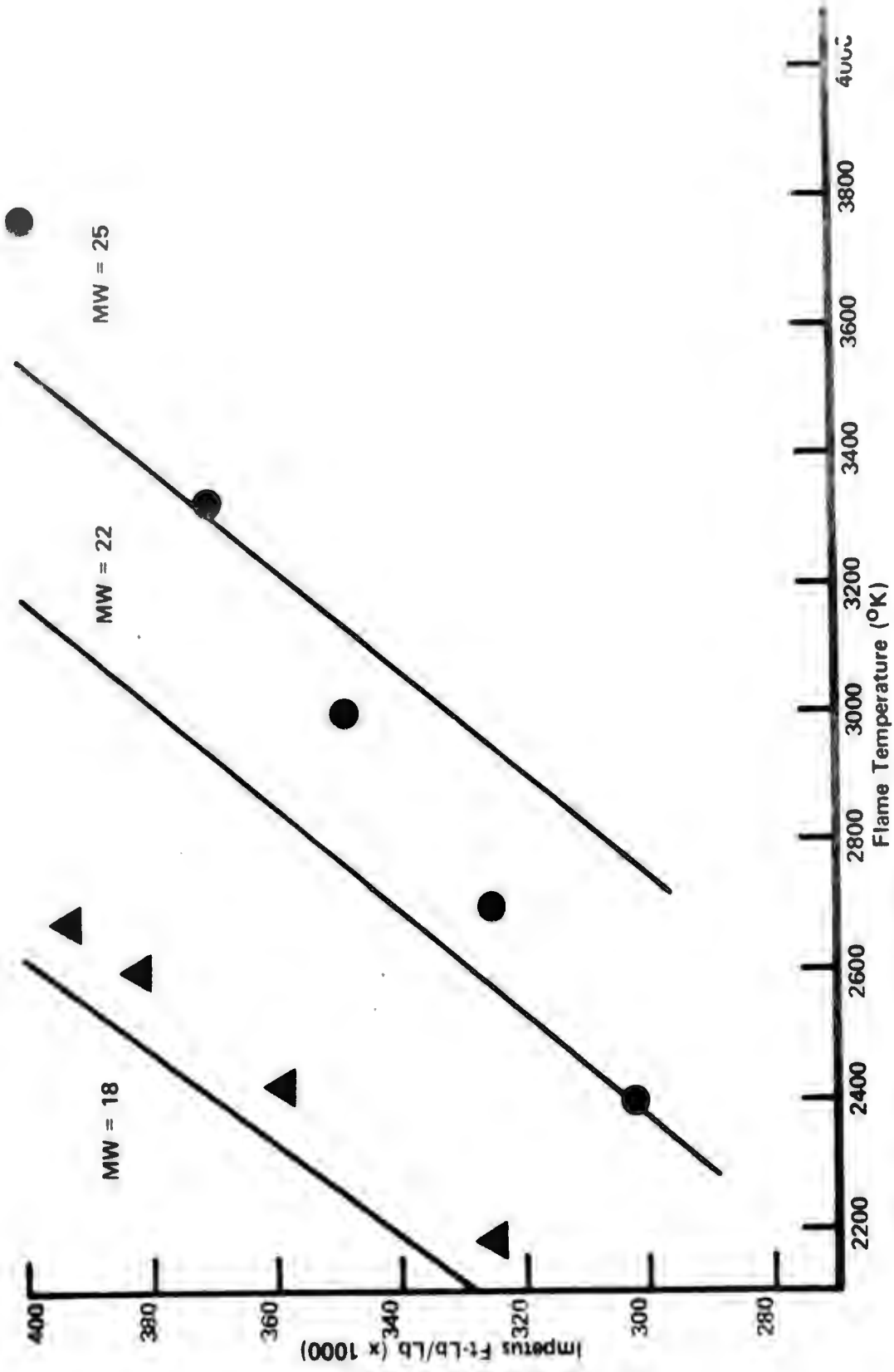


Figure 4. Gun Propellant Performance

## SECTION IV

### INTERIOR BALLISTICS AND BURNING RATE EXPONENTS

Figure 5 compares typical plots for burning rate vs. pressure for conventional and nitramine propellants. An empirical formula used to describe the burning rate of a propellant is

$$r = aP^n \quad (4)$$

Equation (4) states that the regression rate,  $r$ , of a solid propellant will be a function of the chamber pressure  $P$  raised to some exponent  $n$  and multiplied by a constant,  $a$ . This equation arose from early gun closed-bomb combustion studies conducted with nitrocellulose propellants, which are homogeneous solids that burn with a reasonably constant value of  $n \approx 0.9$  across the complete spectrum of gun pressures. Figure 5 illustrates this behavior with a burning rate plot for M-10 propellant, which is composed of 98% nitrocellulose. Composite propellants do not have a homogeneous matrix but rather a dispersion of various sized oxidizer particles wetted by either an inert hydrocarbon or energetic nitrocellulose matrix. Also illustrated on Figure 5 is a plot for a propellant (HES 8301 consisting of 87% HMX and 13% hydrocarbon binder) that exhibits the classical nitramine combustion anomaly. A single  $n$  value can no longer be defined over the entire pressure range. As is seen, a low value exists to approximately 4,000 psi, followed by a slope break and very high  $n$  values, in this case 1.57. In some cyclic nitramine formulations with large oxidizer particles, this second  $n$  term has taken values above 3. Also, typically a second break occurs between 10,000 and 20,000 psi, resulting in an  $n$  value slightly higher than 1.

All advanced nitramine gun propellant formulations test fired by the USAF to date have displayed this combustion anomaly. Whether inert or energetic binder, cyclic or linear nitramine, metallized or non-metallized, the slope break phenomenon is invariably exhibited. This nitramine characteristic was initially encountered during experiments (Reference 7) in the early 1960's. The burning rate slope break onset was found to be a strong function of the crystalline nitramine particle size.

The abrupt change in the mechanism of decomposition was deduced to be related to the depth of the melt layer on the surface of the deflagrating propellant. Recent NASA-sponsored analytic propellant combustion studies at the California Institute of Technology (Reference 8) provide theoretical substantiation to this experimentally generated postulation. The results from these studies anticipate a discrete slope break in the composite propellant combustion rate as surface reactions attain regression rate dominance from a subsurface melt rate control mechanism. The nitramines have the potential for gross  $n$  value changes as they transition from an endothermic melt to an extremely exothermic gaseous decomposition due to their positive heat of formation and highly energetic monopropellant nature.

Experimental and analytic results conclusively indicate that the nitramine propellant regression rate slope discontinuity will be less pronounced as oxidizer particle size is decreased. Current USAF efforts in developing gun propellant formulations are being channeled into oxidizer particle sizes in the micron and submicron range.

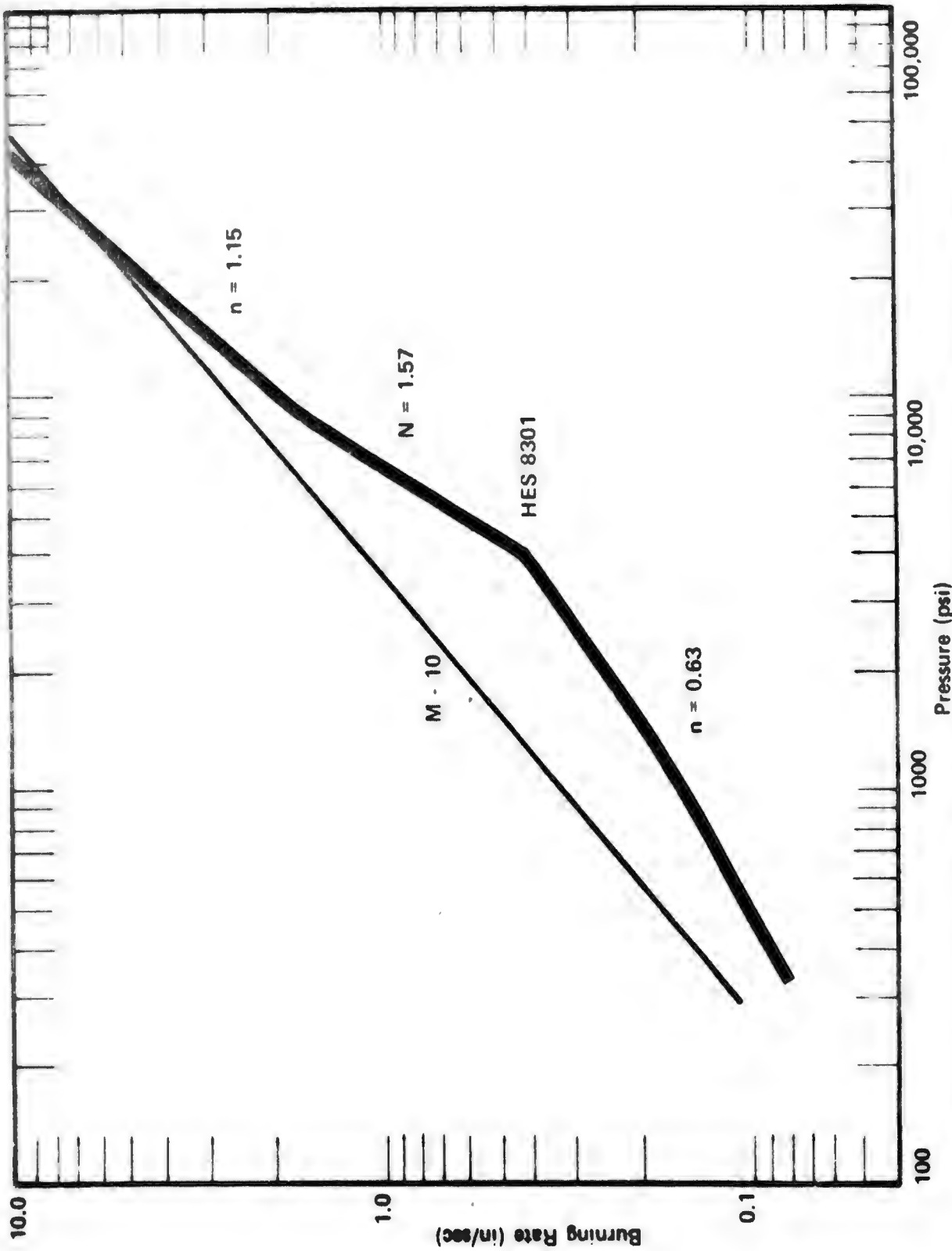


Figure 5. Typical Burning Rate vs. Pressure Plots for Conventional and Nitramine Propellants

Without considering the physics of gun interior ballistics, it might be assumed that these high  $n$  values could be obviated by proper propellant web selection and burning rate progressivity. The fallacy of this assumption is apparent after considering the two types of gun efficiency which the ammunition designer strives to maximize. The first type is ballistic efficiency. In effect, it is the ratio of total thermochemical energy contained in the propellant which, after firing, has been delivered as useful directed kinetic energy to the projectile (ballistic efficiency is equal to projectile kinetic energy/total energy). The total energy available from a given propellant is the impetus divided by a function of the gas specific heat ratio [total energy =  $F_p/(\gamma - 1)$ ].

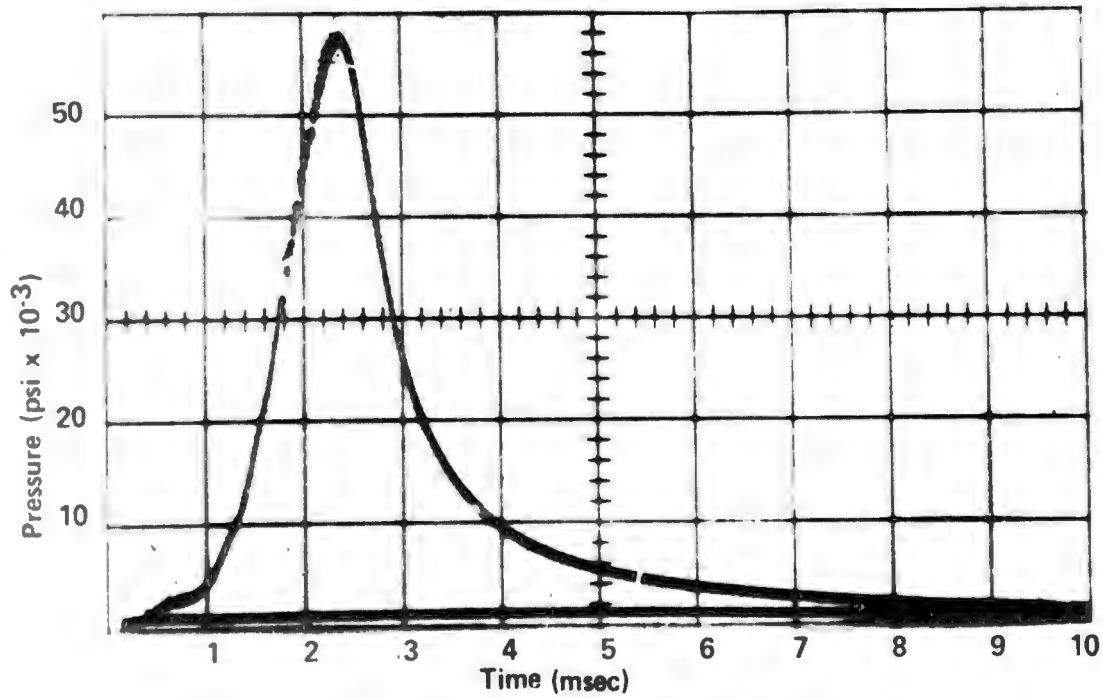
With  $\gamma$  having a value of 1.22 and  $F_p$  typically 352,000 ft-lb/lb, then 1 pound of gun propellant has the potential of 1,600,000 ft-lb of work. A gun propellant is then an amazingly energetic material, and a well designed gun is an efficient thermodynamic engine. Typical gun ballistic efficiencies are in the area of 35%, while most comparable rocket efficiencies are well below 10%.

The next term to be considered is piezometric efficiency. In effect, this is the ratio of the average pressure working on the projectile during the gun firing to the peak chamber pressure attained during the gun firing.

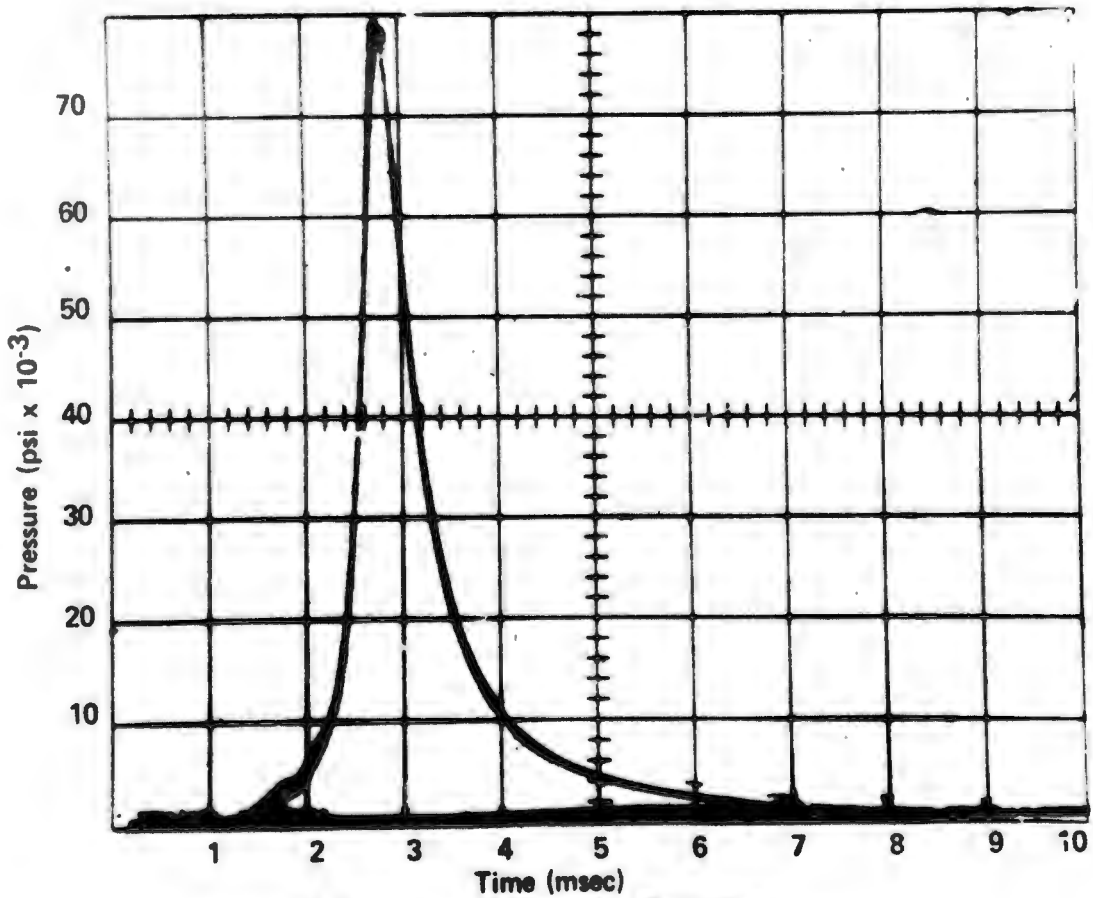
For adequate aircraft cannon ammunition design, a piezometric efficiency of 35% is typical, and some gun designs have even somewhat higher values. In normal gun design, a tradeoff must take place between ballistic and piezometric efficiencies. The design changes which increase one efficiency will invariably decrease the other at any reasonable ammunition configuration.

With the current advanced propellants which have  $n$  values above 1, however, the analytic and experimental interior ballistics data show that as the  $n$  value goes higher, both ballistic efficiency and piezometric efficiency get worse together.

This effect is demonstrated in Figure 6 which illustrates interior ballistic firings in an experimental high performance 20mm aircraft cannon. Figure 6(a) depicts the pressure-time trace of a conventional operational single base gun propellant and demonstrates standard performance with both ballistic and piezometric efficiency about 35%. Figure 6(b) depicts an experimental nitramine gun propellant with combustion slope  $n = 1.4$  and has a higher peak pressure in conjunction with a 500 ft/sec lower muzzle velocity for a gross decrease in both types of efficiency. An examination of these two pressure time plots shows that the high  $n$  value leads to a high spike pressure with a narrow base. As the work done on the projectile is defined as the area under the curve, a high thin curve is non-optimized from all aspects of the physical system. The web of both the conventional and the experimental propellants was optimum as selected by analytic interior ballistic computations. In short, reasonable interior ballistic design is a fundamental thermodynamic impossibility with propellant  $n$  values above 1.



(a) Conventional Single Base Propellant



(b) Experimental Nitramine Propellant

Figure 6. Interior Ballistic Firings with 20mm Aircraft Cannon

## SECTION V

### CONCLUSIONS

The state of the art for aircraft cannon ammunition propellant is on the verge of a major performance breakthrough. When the high energy, low flame temperature formulations become operational, thermal barrel erosion can be eliminated, aluminum cartridge cases can be employed with no possibility of catastrophic failure, and the era of the hypervelocity aircraft cannon will be at hand. To realize these benefits, the current nitramine combustion anomaly must be obviated. The AFATL development effort, in conjunction with industry and other DOD laboratories, is aggressively pursuing the solution to this final factor inhibiting operational test and evaluation.

## REFERENCES

1. Friedman, R.; and A. Macek: "Ignition and Combustion of Aluminum Particles in Hot Ambient Gasses", Combustion and Flame, Vol. 6 (1962), 9-19.
2. Heiney, O. K.: Theoretical Gun Propellant Thermochemical Evaluation, AFATL-TR-71-11, Air Force Armament Laboratory, Eglin Air Force Base, Florida, January 1971 (Unclassified).
3. Simmons, et al: Exploratory Development of New Gun Propellants, AFATL-TR-68-81, Air Force Armament Laboratory, Eglin Air Force Base, Florida, July 1968 (Confidential).
4. Shulman, F. C.: New Gun Propellants, AFATL-TR-70-45, Air Force Armament Laboratory, Eglin Air Force Base, Florida, May 1970 (Confidential).
5. Lancaster, G. B.; and E. H. Zeigler: Development of a New Gun Propellant Containing Titanium, AFATL-TR-71-126, Air Force Armament Laboratory, Eglin Air Force Base, Florida, October 1971 (Confidential).
6. Flanagan, J. E.: High Energy Gun Propellants, AFATL-TR-72-89, Air Force Armament Laboratory, Eglin Air Force Base, Florida, May 1972 (Confidential).
7. Taylor, J. W.: "The Burning of Secondary Explosive Powders by a Convective Mechanism", Transactions of Faraday Society, Vol. 58, 1962.
8. Kumar, R. N.: Some Considerations in the Combustion of AP/Composite Propellants, California Institute of Technology, Daniel & Florence Guggenheim Jet Propulsion Center Report, August 1972.
9. Heiney, O. K. : Analytic and Experimental Interior Ballistics of Closed Breech Guns, AFATL-TR-69-42, Air Force Armament Laboratory, Eglin Air Force Base, Florida, May 1969 (Unclassified).

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	Crystalline Oxidizer						
	Cyclic Nitramines						
	Linear Nitramines						
	High Impetus						
	Low Molecular Weight						
	Advanced Formulation						