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STANDARDIZATION OF A SAFING AND ARMING DEVICE FOR ARTILLERY AMMUNITION

by

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Manufacturing Technology Directorate

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This report summarizes the work performed under task, Advanced Artillery Fuzing/Artillery Safing and Arming, Project No. 1W66361DE5509 during FY 74. Exploratory efforts initiated January 1973.

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Fuzes	Fluidic Devices
Timing Devices	Gearless Mechanisms
Delay Arming Devices	Turns to Arm

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

This report summarizes the previous efforts performed on the standardization of an S&A device for use on spin stabilized artillery ammunition. The purpose is to replace existing S&A devices with a single S&A, minimize proliferation and gain the economic and logistic benefits derived from standardization. Efforts were coordinated with other government agencies to develop and establish the physical and military requirements. Design studies were initiated on the current S&A devices.

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20. ABSTRACT (Cont)

Two or more with the most potential for use as the all purpose device will be configured, tested and evaluated. Selection will be based on cost effectiveness, compliance with the requirements and predicted or demonstrated reliability.

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INTRODUCTION

Scope

Frankford Arsenal was tasked to develop and standardize a safing and Arming (S&A) device for use on Spin Stabilized Artillery Rounds. The objective is to replace existing S&A's for single or special projectile applications by a single device, minimize proliferation and gain the economic and logistic benefits derived from standardization. The initial effort involves establishing realistic requirements of a universal S&A by conducting literature searches both foreign and domestic and conducting surveys of government agencies coordinating the data and information obtained. This will be followed by the study and evaluation of S&A's in current stages of development or in production. Potential devices will be selected and final selection will be based on trade-offs between cost effectiveness, compiance with requirements and predicted or demonstrated reliability.

A two phase work plan was initiated and goals established over a three year period. However, due to funding and priority constraints, only the first year, FY74 efforts were performed. Contacts were established with concerned Government agencies, the contractors involved and the Field Artillery School to establish the physical and military characteristics for the desired S&A. Data and information were acquired from both domestic and foriegn surveys on S&A devices, fuzes and artillery weapons to assure complete coverage of all current mechanisms and applications.

The need for a coordinated Artillery S&A to achieve maximum commonality was cited at the MUCOM FAB meeting No. 1-73 (U), on 13 January 1973. Frankford was assigned to develop the S&A and coordinate efforts with concerned Government agencies as noted in AMSMO-RE-FS letter dated 9 February 1973. The mission objective, CDOG 412b (19) 438 q was revised to CARDS; OCO 112 para. f.

Background

The current S&A devices used on spin stabilized artillery rounds are each being developed for specific fuze applications. Little or no thought has been given to the development of an S&A capable of multiple fuze applications even though these fuzes are fired in the same weapon systems. Consequently, there now exists a significant number of new S&A for single fuze applications, which fail to take advantage of benefits that could be derived from standardization. Furthermore, in the past, several of the S&A performance characteristics were arbitrarily chosen by the user or by the S&A developer. In the design of any mechanism, a precise definition of S&A requirements for all fuze applications is required prior to development of the end item.

Although the primary functioning modes are similar, design concepts differed. The booster concept is an adapter that contains the delay machanism and is attached to the threads of the fuze; the modular concept is a complete assembly that is inserted into the fuze or booster cavities, and the design concept that is integral to the fuze.

The turns to arm concept* describes the arming cycle in terms of projectile rotational travel and can be used to analyze and determine the optimum escapement design for the desired S&A device.

Description

A safing and arming device is a mechanism whose primary function is to prevent an unintended detonation prior to safe separation and in turn allow the explosive train of the munition to function after the munition has reached the proper point in time or space.

The principal parts of an S&A are: setback and spin detents, the independent safety features that lock and release the rotor assembly, the interrupter, that arms and/or aligns the elements of the explosive train after the safe separation distance is attained and the escapement assembly that is the delay element.

Function of the S&A is independent of the fuze except for the initiation of the explosive train at the predetermined time. Upon launch, linear acceleration forces the setback assembly to depress as angular acceleration and spin, force the spin detents out to release the rotor. Centrifugal force rotates the rotor driving the delay element that aligns the explosive train and completes the arming cycle.

The parameters considered for the design of the S&A involved a modular concept, that is self contained, small and compact and contains the rotor, delay element, spin and setback detents and the explosive train. This module may be supplied in kit form with a removeable setback assembly and an inclosing ring to compensate for size or use as a slider in certain applications. Such a module would conform to the established requirements for the S&A and be adaptable with minimum modifications to various fuzes.

*Frankford Arsenal Report R-2006, May 1971 by L.P. Farace and S.D. Shapiro.

SUMMARY

Program

An advanced development program was initiated to accomplish the two phase task with planned activities for a three year period. Planned activities for FY75 and FY76 have not been performed due to suspension of the program after FY74.

Planned and Initiated Actions for FY74

Literature surveys, both foreign and domestic, were conducted and information obtained on S&A devices, fuzes and artillery weapons. Other Government agencies were contacted and information exchanged on the status, stage of development, and requirements of current S&A programs. A coordinated plan was formulated with these agencies to develop and establish the physical and military characteristics for the universal S&A device.

Lethality studies were initiated with Picatinny Arsenal to provide assistance in running a computer program to compile safety data and resolve the non-arming/arming requirements. Final development of the non-arming/arming requirements will be coordinated with the user agency.

In-house studies were initated for the reliability and safety assessments, setback pin configuration and analytical studies of S&A devices. Other tasks considered were explosive train, producibility and comparison studies of current S&A devices.

Surveys were conducted of the concerned government agencies and their contractor facilities involved in the development, testing and assembly of current S&A devices to determine the capabilities available.

Contact was established with the field artillery school at Fort Sill, Oklahoma in reference to the arming requirements.

Planned Action for FY75

Design studies will continue on the current S&A devices. The design task will be to determine the interface problems associated with each device and the capability for the multi-purpose use. Seven Mechanical S&A's currently in the advanced development stage and/or in production were selected for evaluation.

Hardware of each device, will be acquired, modified as indicated by design studies, and assembled for material and operational testing. The hardware will include the aluminum and brass bodies, modular devices, and test fuzes.

Testing and evaluation of the prototypes will consider the following factors:

1. Conformance to the requirements of MIL-STD 1316A and the appropriate tests selected from MIL-STD 331.

2. The reliability as demonstrated by S&A's with past performance and the predicted reliability of S&A's without previous testing.

3. Adaptability of the designs to interface requirements.

4. The merits of miniaturization and of modular concepts.

Plans are to select two or three of the designs that have shown the potential to meet the formalized requirements based on the results obtained from the operational testing.

Planned Action for FY76

Optimum designs for the setback pin, escapement assemblies, and the proven lubrication will be incorporated in the two or more designs selected for testing and evaluation.

The test program will include sequential and factorial tests of both the MIL-STD 331 tests and ballistic firings. The test plan will assure safety and reliability requirements.

Hardware of current S&A mechanisms are available at the non-government facilities. Cost analysis will determine make-or-buy of hardware/modifications.

Producibility engineering and planning input (PEP) for the S&A will be initiated in FY77 under Field Ammunition Indirect Firing Safing and Arming Program, 1W664602DO28.14.

The test program will include firings in the weapons as listed:

Artillery Weapons	Tank Weapons
105mm How	90mm Gun
4.2 in Mortar	105mm Gun
155mm How	120mm Gun
175mm Gun	152mm Gun
8 in How	

Ammunition will include, HE, smoke, ICM, and illuminating rounds.

Fuzes will include the PD fuzes, M557 and M572E2 and the MT and ET fuzes the M577, M587, M564 and M565.

Technical Approach

Phase I involved establishing the physical and military characteristics for the desired S&A device. The data and information obtained from the surveys and from sources both within and outside the Army, dictated the parameters to be considered as listed below:

1. Dual safety and safety as per MIL-STD-1316A Fuze, Design Safety, Criteria for.

2. Dynamic environment; ruggedness and rough handling as per MIL-STD-331, environmental and performance tests.

3. Climatic conditions as per AR 70-38, Research, Development, Tests and Evaluation of Material for Extreme Climate Conditions.

4. Reliability - establish function reliability at the confidence level comparable to the fuze system.

5. Arming characteristics - establish the non-arm and arming requirements in full accordance with the user and authorized agencies.

6. Interfacing Problems - establish the physics and geometry to suit the various fuze systems.

7. Appropriate field tests - storage, transportability and air delivery as per MIL-STD-331.

8. Other factors - such as electromagnetic radiation, nuclear vulnerability, CBR effects, loading problems.

In addition, the source of these requirements will be established thus providing complete guidance on each S&A under development or in production.

A study was conducted to determine the performance characteristics desired in the S&A. Each performance requirement has to be evaluated based on overall system needs and effectiveness and from the standpoint of defining the method best suited to meet the requirement. Conflicting requirements will be resolved as to the priority assigned to each requirement, to its cost effectiveness, and to the risk involved in eliminating the requirement. An example of such a conflict is the use of inertia self-destruct system, as desired in electronic fuzes, in conjunction with PD fuzes requiring a delay mode of operation. The existence of the self-destruct system will override the delay element in the PD fuze.

In the case of the arming delay, minimum safe distance will be analyzed by use of a math model of the lethal effects of a premature detonation of the round rather than an arbitrary figure assigned by the developer or user. The maximum delay is dictated by tactical considerations. The spread between the two would dictate the method or technology to be applied. If the spread is small, the accuracy requirements will dictate a more precise and hence, more costly approach, however, if the spread is large, a greater number of approaches can be considered and the least costly approach taken.

Finally, a thorough review of the existing Military Standard Tests will be made in order to select those which are applicable to the S&A. After all the performance characteristics have been assessed and resulting conflicts resolved, it is planned to formalize the results of this study in the form of an Operational Capability Objective (OCO) document for the S&A device.

Following formal approval of the OCO and funcing authorization, a development program will be initated. Two or three concepts with the most potential for use in the universal S&A will be pursued in the concept formulation phase.

The proposed requirement for an artillery safing and arming mechanism (S&A), the rationale and the draft proposed Operational Capability Objective (OCO) are outlined in Appendix A.

The Safing and Arming Mechanisms

Seven S&A mechanisms were considered as candidates for the all purpose S&A. The physical and military characteristics are shown in Table 1. The S&A devices as designated are as follows:

1. The M125A1, Figure 1, is modular in concept, contained in the booster and attached to the applicable fuzes. The diameter of 1.575 Max. rates as the largest similar to XM732 S&A but different in contour.

2. The M125A1 Alternate, Figure 2, is machined and components inserted and attached to the applicable fuzes. Functioning and components including the explosive train are similar to the M125A1.

3. The Gearless S&A, Figure 3, is modular in concept, self contained, small and compact. The balanced escapement element replaces the gear train and is considered gearless. The diameter of 1.314 is comparable to the M572E2 and XM587E2 S&A and contained in the M577 SSD.

Table 1. The Safing and Arming Devices

	FA M125A1 ALT	FA M125A1	PA M577 SSD	HDL XM732 S&A	HDL XM587 S&A	PA M572E2 S&A	FA Gearless
Spin RPM Arm	2000	2000	1800	2500	1700	1700	2000
Spin RPM Non-Arm	1000	1000	1000	1000	1100	1100	1000
Setback "g"	30g	30g	250g	Non-Arm 900g *Arm 1200g	Non-Arm 850g *Arm 1200g	20g	30g
Nominal Turns To Arm	41	30	38	Non-Arm 36 Arm 39	Non-Arm 22 Arm 32	24	28
Envelope HT	.455 Max	.486 Max	.426 Max	.506 Max	.560 Max	.53 Max	.532 Max
Envelope DIA	1.614 Max	1.575 Max 1.378 Max	1.485 Max	1.575 Max	1.351 Max	1.31 Max	1.314 Max
Setback Pin Location (Int. or Ext. To Module)	EXT	EXT	EXT	INT	INT	INT	INT

*Non-Returnable Setback Pin

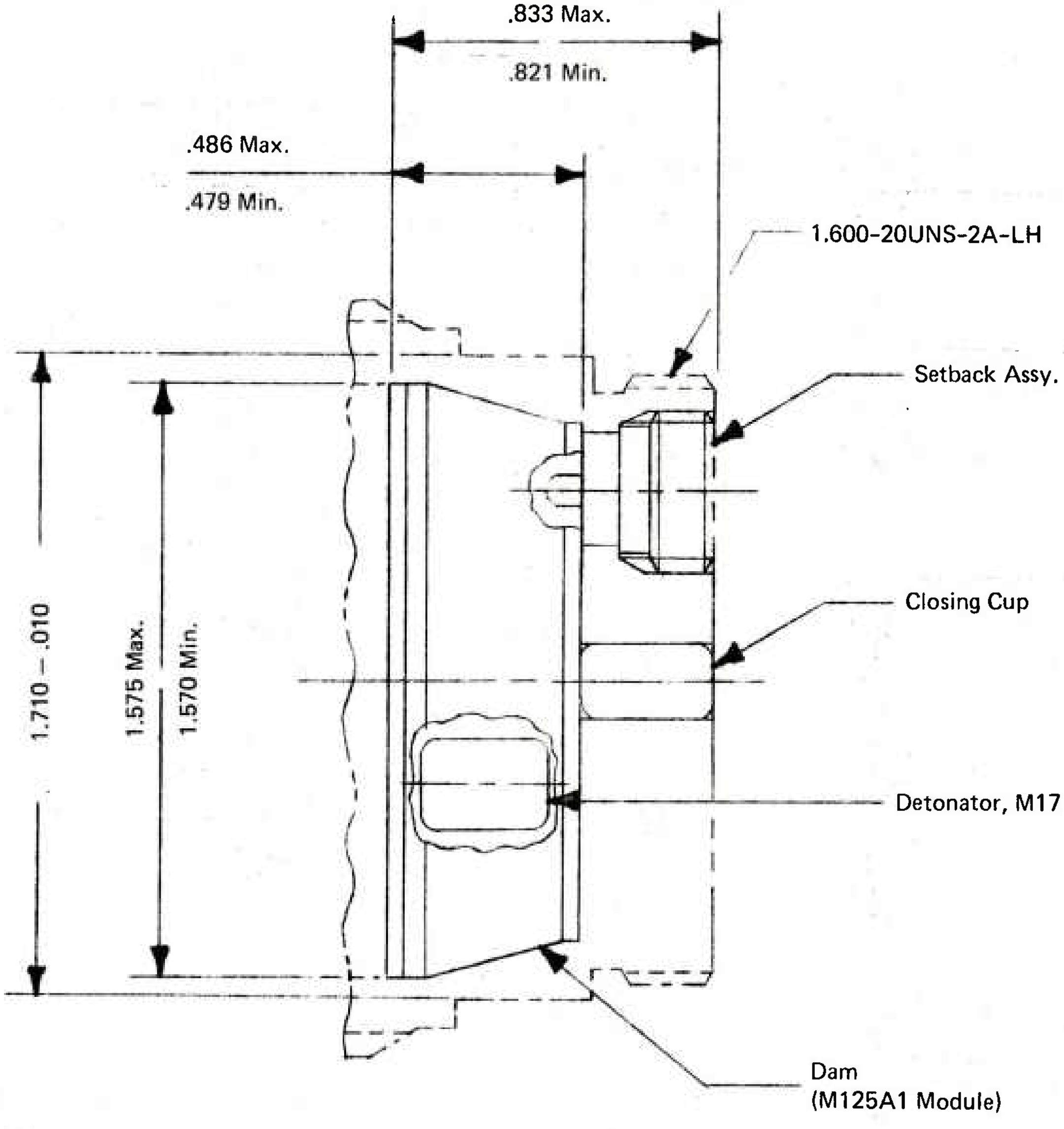

Figure 1. M125A1 (MOD) Booster

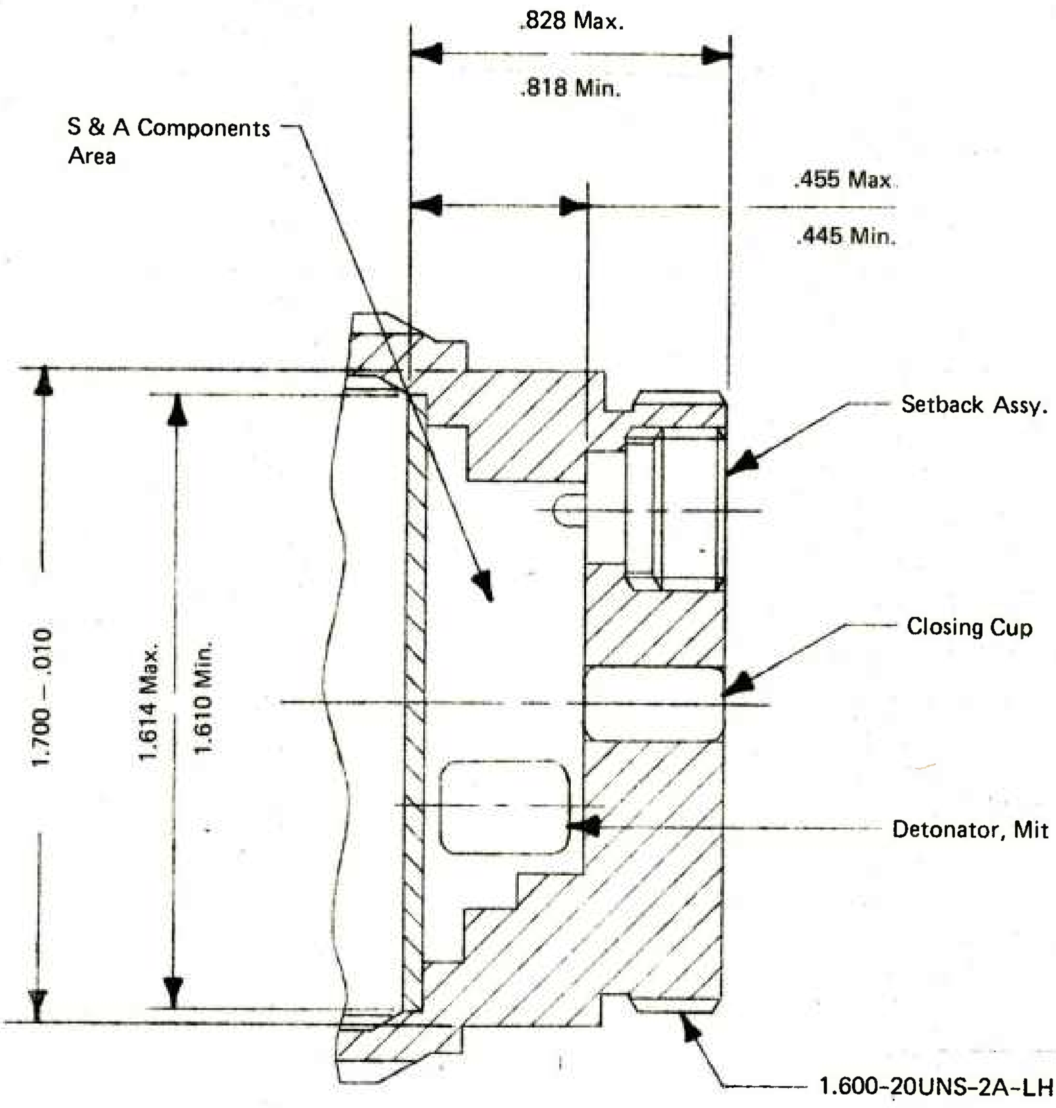

Figure 2. M125A1 (ALT) Booster

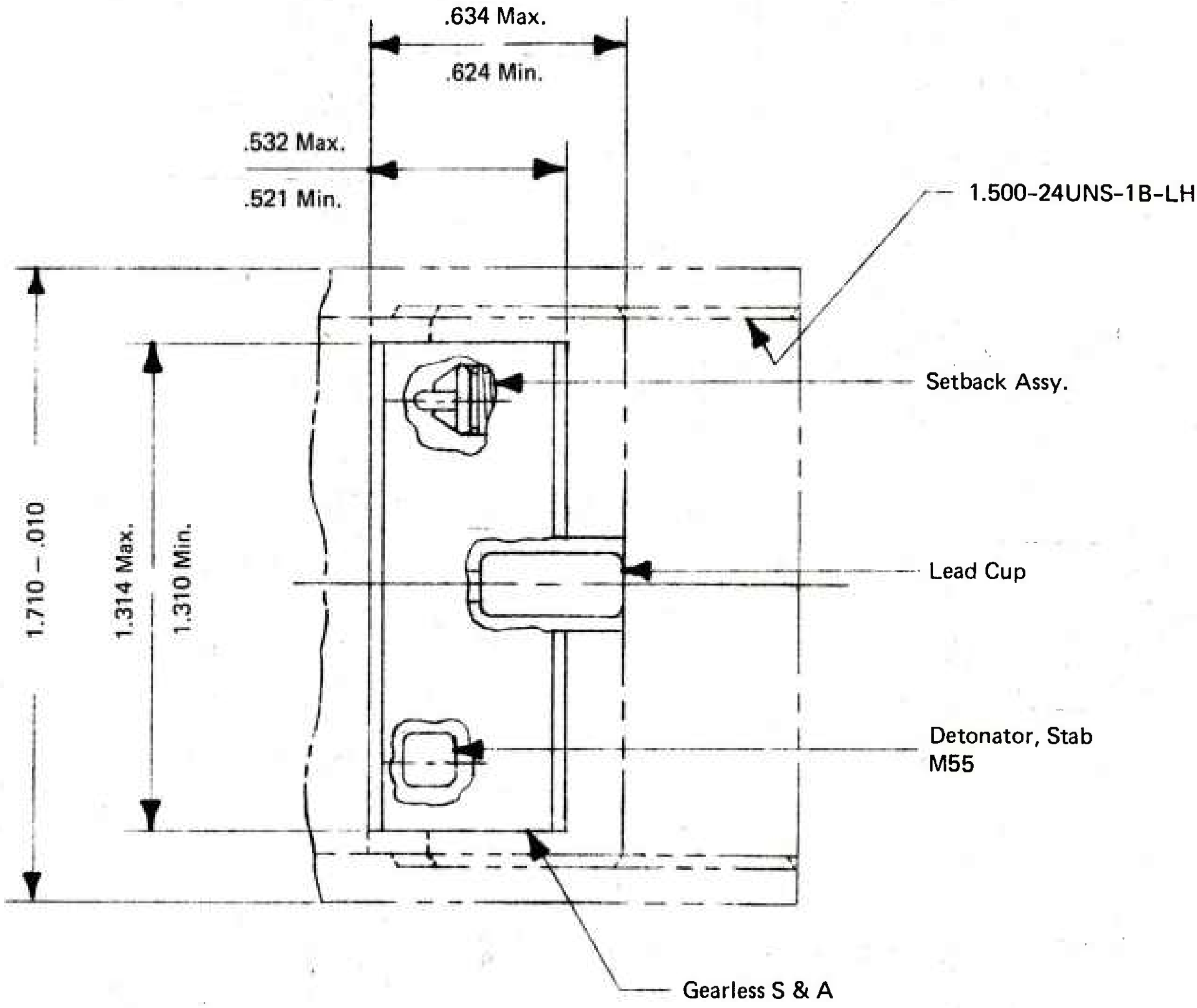

Figure 3. Gearless S&A

4. The M577 SSD, Figure 4, is integral to the mechanical time fuze, initiated by a triggering device and modular in concept.

5. The M572E2 S&A Figure 5, for PD Fuze is modular in concept, self contained, small and compact. The diameter of 1.310 is the smallest, comparable to the gearless.

6. The XM587E2, Figure 6, S&A for the electronic time fuze is modular in concept and similar in size to the XM572E2 and the gearless.

7. The XM732 S&A, Figure 7, for the proximity fuze is modular in concept, similar in size to the XM125A1, contains all elements and is inserted in base of fuze.

A review of the S&A devices show a variation in sizes from the small 1.310 diameter to the Max. of 1.575 diameter. The heights vary from a minimum of .426 to a max. of .560. All dimensions in inches.

The explosive trains show that four devices employ the stab detonator, M55, two have the M17 and one has the M94.

Six of the devices are modular, four contain all elements, two have external setbacks and one initiated by a triggering device.

The setback pin assemblies are of the spring mass type as the low and medium 'g' level returnable and the high 'g' non-returnable. Other concepts considered among developers include the Ball and Helix*, Liquidic BLD** and the Zig-Zag Sensors. Design concepts are shown in Figure 8.

An investigation on setback pin motion to develop or improve current designs was initiated. The outline of the approach is as follows:

The motivation for the present study of setback pin motion was the method utilized in previous studies. In the previous studies, a range of motions were hypothesized, the appropriate force diagrams shown and the Newtonian Equations of motion derived. It was felt that this procedure only succeeded in deriving the motion of the pin as originally hypothesized. Thus, the present study was to determine if the motion could be analyzed without any prior assumptions of motion type.

To this end, it was decided to utilize the Hamiltonian approach in which the forces are not actually considered.

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*HDL-2009-1, Modular Ball and Helix Setback Mechanism, August 1973.

**FA-TR-75057, Development of a Liquidic Two Signature S&A Device for Mortars, Phase 2, August 1975.

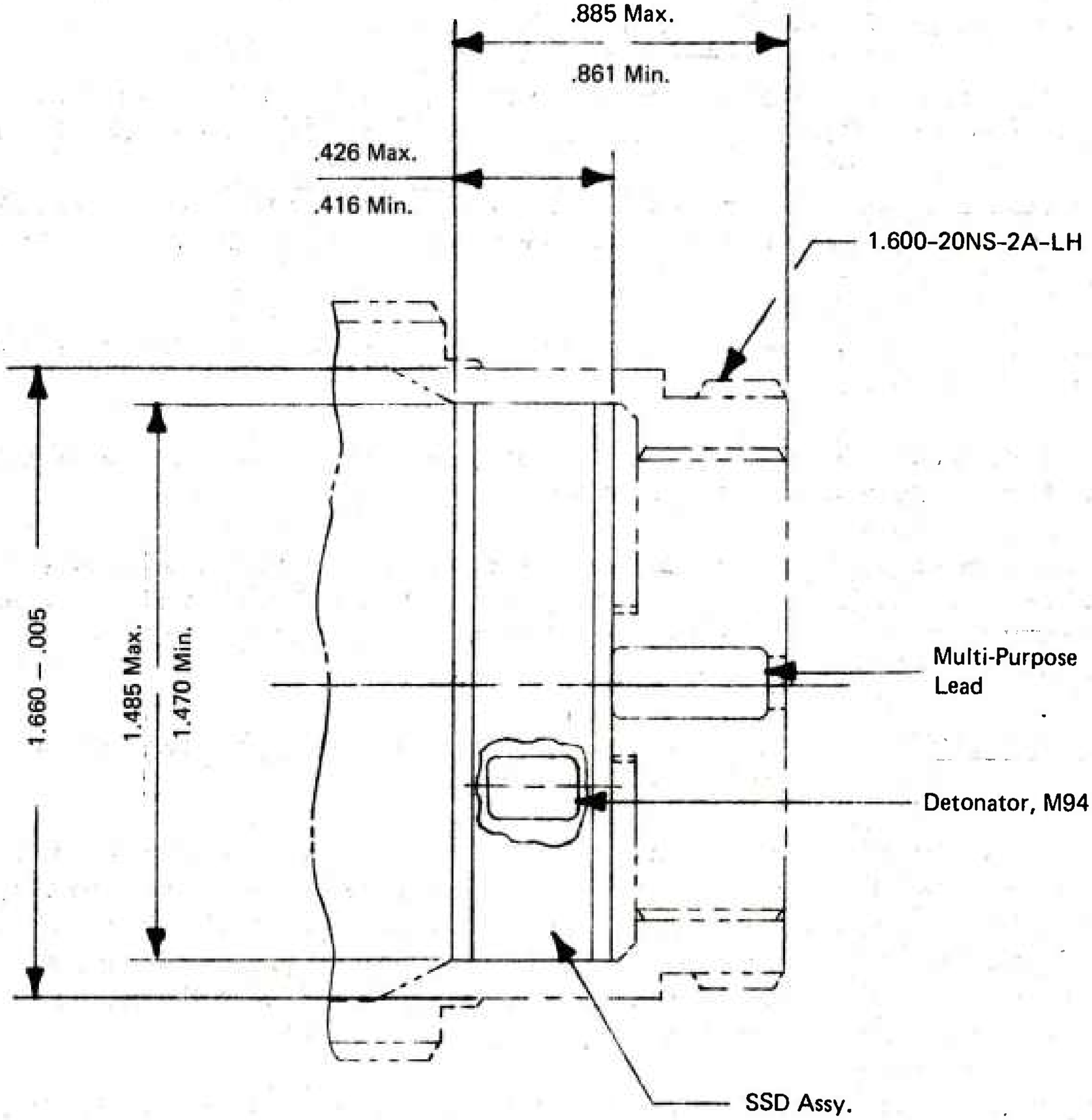

Figure 4. M577 SSD

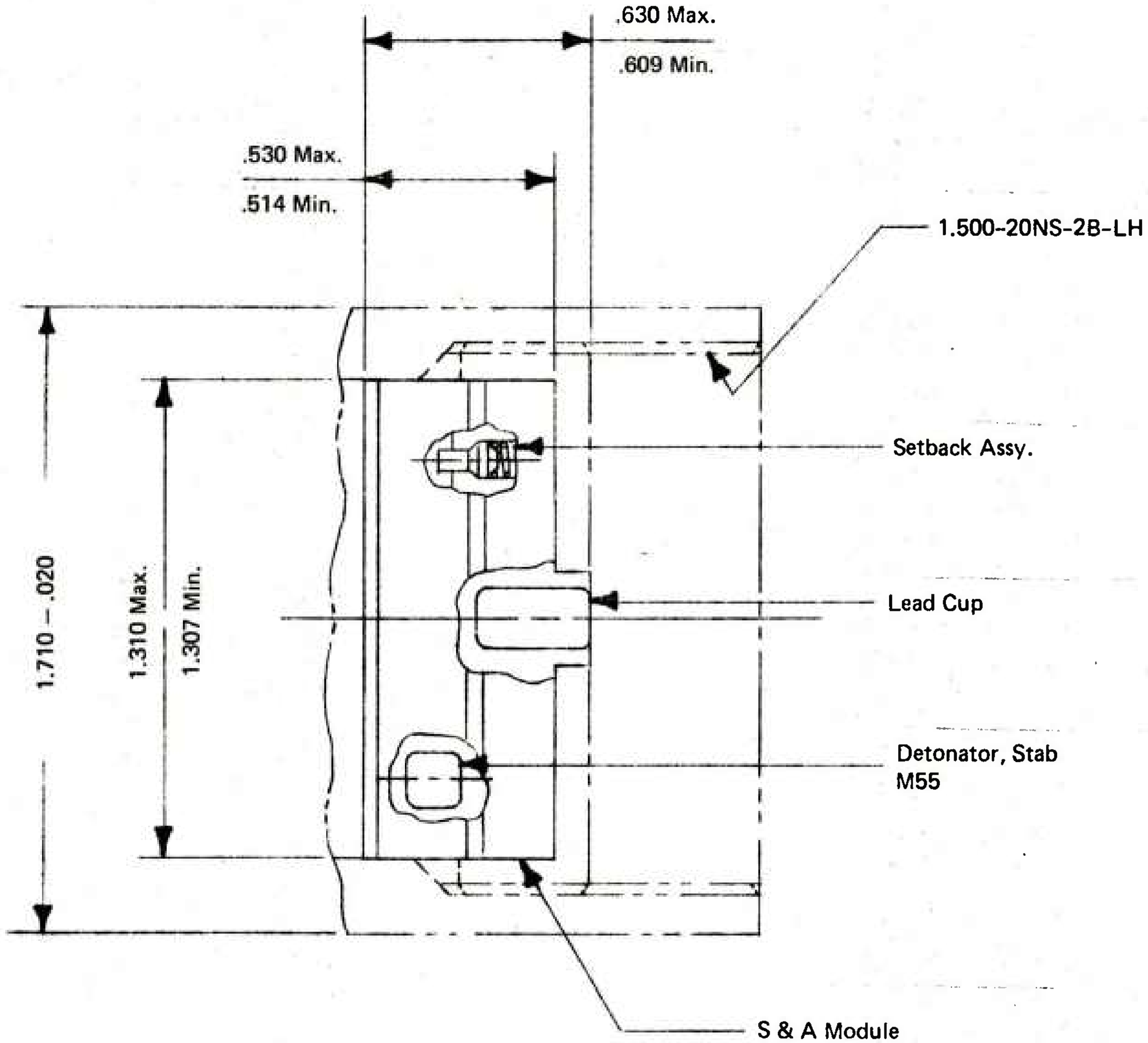

Figure 5. M572E2 S&A

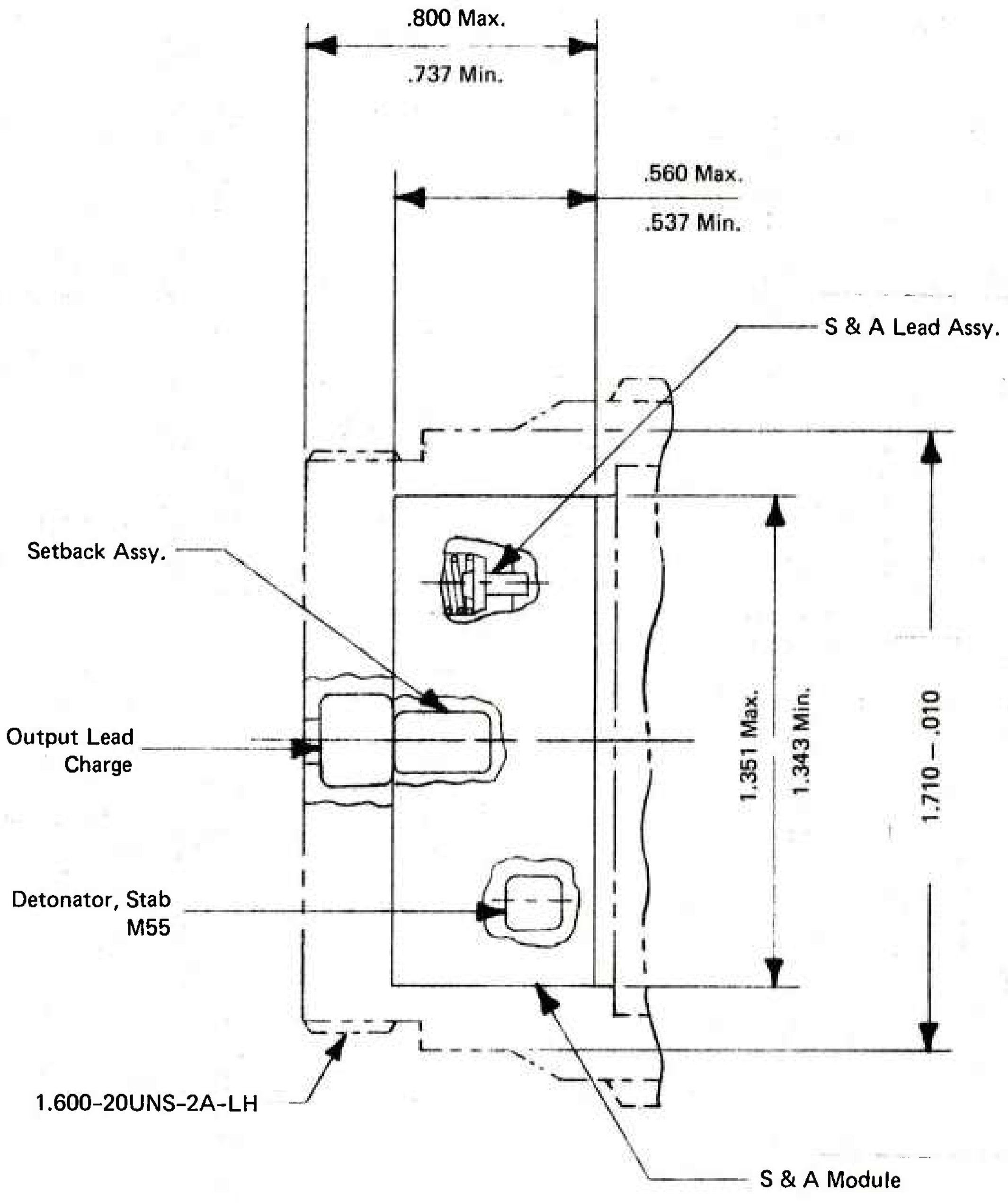

Figure 6. XM587E2 S&A

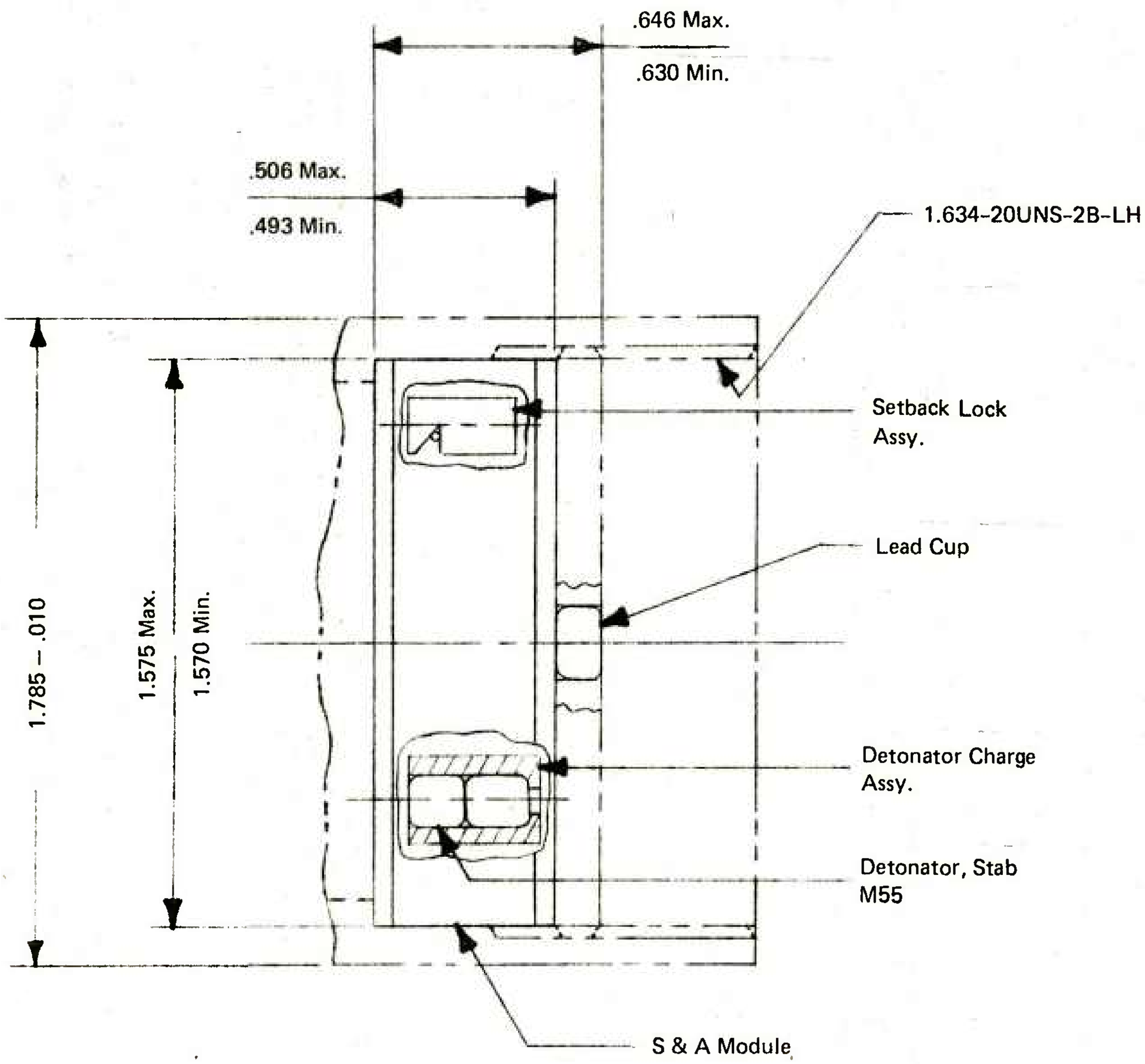

Figure 7. XM732 S&A

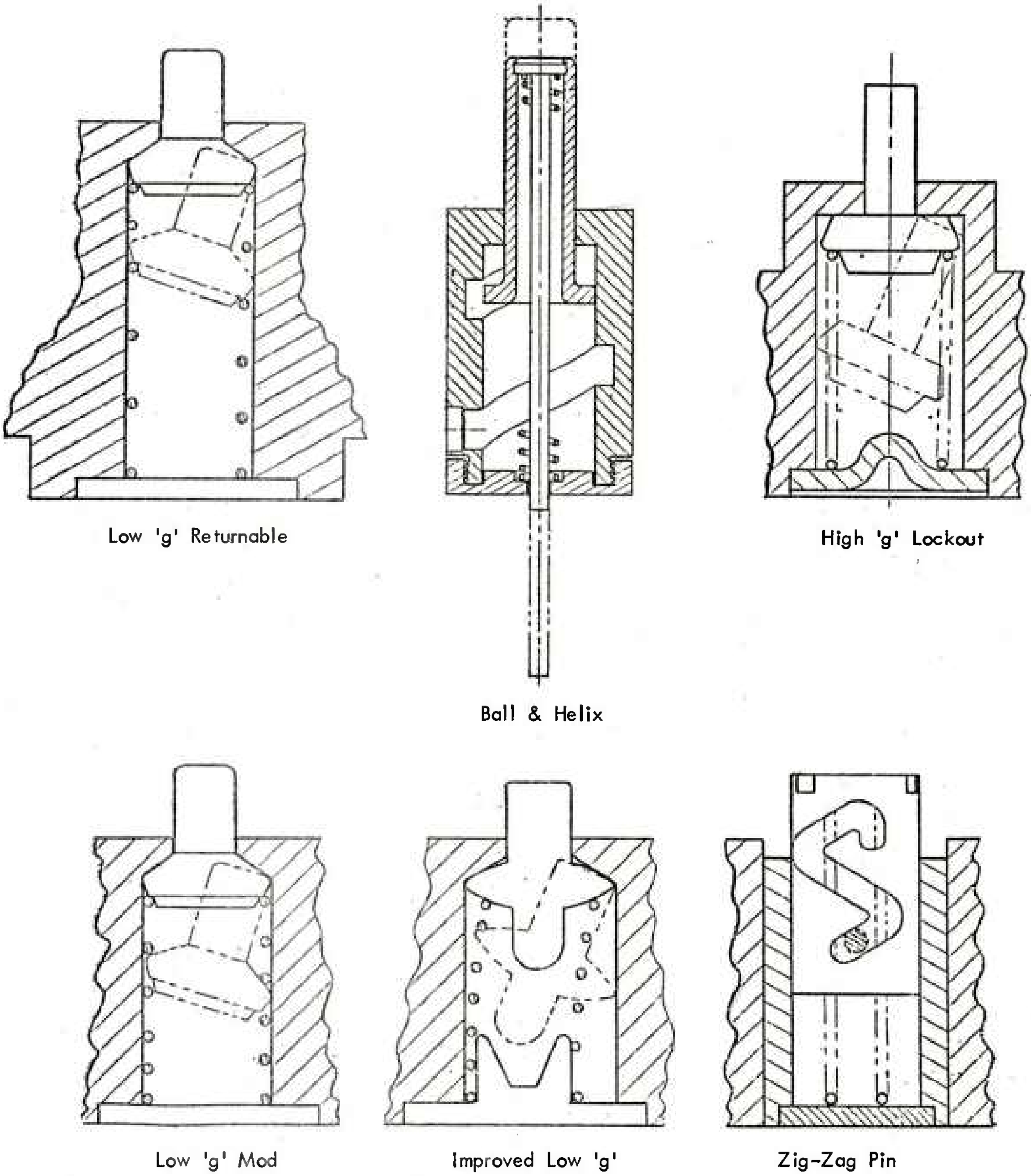

Figure 8. Setback Pins

The method of attack is to derive the Hamiltonian representing the system. The Hamiltonian of the system must take into account the linear and radial acceleration of the setback pin mechanism. With the Hamiltonian the equations of motion can be derived, and the relationship between the coordinates and coordinate transformation will reduce the equations of motion to an elementary system. This process of finding a suitable coordinate transformation is the most difficult part as there is no set procedure to follow.

Once an analytic solution to the equations of motion has been found, the system parameters may be systematically investigated and optimal values determined.

An alternative to finding an analytic solution to the derived equations of motion may be attempted. Here, using numerical approximation techniques, a solution would be attempted by computer analysis. As in the analytical solution, the system parameters would also be studied by this method to determine optimal values.

The turns to arm concept study provides new tools for expressing values for arming requirements and gun characteristics. This study, Report R-2006, provides the means to design and evaluate escapements and to determine the optimum design. The equation formulated for the concept expressing arming in calibers and the turns to arm follows:

$$S = Knd$$

S is Distance in Feet
K is Turns to Arm
n is the Rifling Twist. Caliber/Turn
d is Dia. of Gun Bore Ft/Caliber

Arming in Calibers, 400 non-arm/800 arm. For each weapon; example, 75mm Gun.

$$S = d \times \text{Calibers}$$

$$= .075\text{m} \times 400 \text{ Cal.} \times 3.28 \text{ m/Ft} = 98.4 \text{ Ft.}$$

$$= .075 \times 800 \times 3.28 = 196.8 \text{ Ft.}$$

Turns to Arm.

$$K = S/nd,\ n = 1 \text{ Turn in 20 Calibers},\ nd = \text{Ft/Turn}$$

$$= 98.4/.075 \times 3.28 \times 20$$

$$= 20 \text{ Turns Non-Arm}$$

$= 196.8/.075 \times 3.28 \times 20$

≈ 40 Turns to Arm

Tables 2, 3 and 4 show the characteristics for the Army and Navy Weapon systems in terms of calibers and turns to arm. The characteristics are detailed in Figures 9 to 13 inclusive.

The primary purpose of an S&A device is to provide safety and in turn maintain the reliability of the basic fuze. An evaluation of the S&A devices would be based on the safety and reliability capabilities. Fault tree analyses were conducted on the safety and reliability on the seven S&A's. As the devices were in various stages of development, assessments were based on data obtained and on predictions. An initial draft of the safety and reliability fault tree analyses of the existing S&A devices was released on March 1975. Predictions based on calculations of point estimates are listed on Table 5, a copy from released draft**.

Independent Government Cost Estimates were compiled on the S&A devices based on 100,000 units/month. Cost data on each component part of each S&A were obtained, however, time and funds were lacking to complete the units cost estimates.

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*Ballistic data in final report, Methodology Investigation, by Leo. D. Heppner, September 1974.

**Draft of Report on Safety and Reliability Fault Tree Analyses, by Anthony Perugini QAA-R, March 1975.

Table 2. Weapon Ballistics

U.S. ARMY WEAPONS

Cal/Type mm	Model	Twist Turn/Cal	Rate Ft/Rev	Arming Calibers Distance 400	Distance 800	Turns 400	Turns 800
75 How	M1A1	1/20	4.92	98.4	196.8	20.0	40.0
75 RR	M20	1/22	5.41	98.4	196.8	20.0	40.0
75 AA	M35	1/25	6.15	98.4	196.8	16.0	32.0
90 G/AA	M1	1/32	9.45	118.0	236.0	12.5	25.0
90 Gun	M41	1/25	7.38	118.0		16.0	32.0
105 How	M103	P1/35-18	6.2	137.8	275.6	22.0	44.0
105 How	M2A1/2	1/20	6.89	137.8		20.2	40.4
106 RR	M40A1	1/20	6.89	132.1	278.1	20.0	40.0
4.2 MTR	M30	0-1/20	7.00	140.0	280.0	20.0	40.0
120 AA	M1	1/30	11.75	157.4	314.8	13.4	26.8
120 Gun	M58	1/25	9.79	157.4		16.0	32.1
152 Gun	XM38	1/41.2	20.60	199.4	398.8	9.6	19.3
155 How	M1/M2	1/25	12.71	203.4	406.8	16.0	32.0
155 Gun	M126	1/20	10.17	203.4		20.0	40.0
175 Gun	M113	1/20	11.48	229.7	459.4	20.0	40.0
8" Gun	M1	1/25	16.67	266.6	533.2	16.0	32.0
8" How	M2	1/25	16.67	266.6		16.0	32.0
240 How	M1	1/25	19.68	314.8	629.6	16.0	32.0
280 Gun	M66	1/20	18.37	367.4	734.8	20.0	40.0
8" How	M198	1/20	13.33	266.6	533.2	20.0	40.0
155 Gun	XM109	1/20	10.17	203.4	406.8	20.0	40.0
105 Gun	XM204	P1/35-18	6.20	137.8	275.6	22.0	44.0
76mm Gun	M1	1/40	9.97	99.7	199.4	10.0	20.0
76mm Gun	M1A2	1/32	7.98	99.7	199.4	12.5	25.0
8" How	M110A1	1/20	13.33	266.6	533.3	20.0	40.0
8" How	M110A1E1	1/20	13.33	266.6	533.3	20.0	40.0

Table 3. Weapon Ballistics

U.S. NAVY WEAPONS

Cal/Type in	Model	Twist Turn/Cal	Rate Ft/Rev	Arming Calibers Distance 400	800	Turns 400	800
3/50		1/32	8.0	100.0	200.0	12.5	25.0
3/70		1/20	5.0	100.0	200.0	20.0	40.0
5/38 AAC		1/30	12.5	166.6	333.2	13.3	26.6
5/54		1/25	10.42	166.6	333.2	16.0	32.0
6 47		1/25	12.50	200.0	400.0	16.0	32.0
8 55		1/25	16.67	266.6	533.2	16.0	32.0
12 50HC		1/25	25.0	400.0	800.0	16.0	32.0
14 50HC		1/25	29.17	466.6	933.2	16.0	32.0
16 45HC		1/25	33.3	533.3	106.6	16.0	32.0
16 50HC		1/25	33.3	533.3	106.6	16.0	32.0

Table 4. Weapon Ballistics

HEPPNER REPORT — NAVY INFORMATION

ARMY

Weapon Cal	Weapon Type	Weapon Model	Twist Cal/Turn	Muzzle Velocity FPS Min	Muzzle Velocity FPS Max	Spin RPM Min	Spin RPM Max	Linear Max 'g'	Chamber PSI Max	Turn Rate Ft/Rev	Arm Distance 400 Cal	Arm Distance 800 Cal	Turns to Arm 400 Cal	Turns to Arm 800 Cal	Land Dia Inches	Area '□' Inches
75	HOW	M1A1	1/20	700	1250	8540	15300	16200	3400	4.92	98.4	196.4	20.0	40	2.95	7.00
75	RR	M20	1/22	990	1400	1100	16000	7900	9800	5.41	98.4	196.4	20.0	40	2.95	7.00
75	AA	M35	1/25		2800		27300	23900	44000	6.15	98.4	196.4	16.0	32	2.95	7.00
76	GUN	M1	1/40	1550	2700	4190	16200	23360	43400	9.97	99.7	199.4	10.0	20	3.00	7.30
76	GUN	M1A2	1/32	2700	3400	20250	25500	34500	46900	7.98	99.7	199.4	12.5	25	3.00	7.30
90	GUN	M1	1/32	2700	3825	17100	24290	34420	48500	9.45	118.0	236	12.5	25	3.54	10.15
90	GUN	M41	1/25	2400	4000	1810	15240	38240	50500	7.38	112.0	236	16.0	32	3.54	10.15
105	HOW	M103	1/32-18	420	2200	4060	21300	19800	42600	6.20	157.8	275.6	22.0	44	4.12	13.00
105	HOW	M2A1	1/20	650	1550	5660	13500	15290	37800	6.89	137.8	275.6	20.2	40.4	4.12	13.00
106	RR	M49A1	1/20	1440	1550	1080	14240	9130	11300	6.89	139.1	278.1	20.0	40	4.17	13.70
42	MTR	M30	0-1/20	315	1035	5060	8870	9530	14300	7.00	140	280	29.0	40	4.20	14.21
120	AA	M1	1/30		5100		15800	13800	45500	11.75	157.4	314.8	26.8	26.8	4.70	17.71
120	GUN	M58	1/25		2500		15500	13100	41400	9.75	157.4	314.8	16.0	32	4.70	17.71
152	GUN	XM38	1/41.2		2240		5520	24700	36800	20.60	199.4	398.8	9.6	19.2	6.00	28.87
155	HOW	M1A2	1/25	580	1850	3210	11080	11490	39000	12.71	203.4	406.8	16.0	32	6.10	29.82
175	GUN	M113	1/20	1675	3000	8750	15700	10760	44000	11.47	229.7	459.4	20.0	40	6.89	38.19
8"	GUN	M1	1/25	2600	2850	9360	10300	8350	44000	16.67	266.6	533.2	16.0	32	8.00	51.32
8"	HOW	M2	1/25	820	2200	2950	7920	8990	38500	16.67	266.6	533.2	16.0	32	8.00	51.32
240	HOW	M1	1/25	1500	2300	4570	7010	7490	39700	19.68	314.8	629.6	16.0	32	9.45	71.55
280	GUN	M66	1/20	1380	2500	4510	8160	5800	39000	18.57	367.4	734.8	20.0	40	11.02	97.39
8"	HOW	M198	1/20	2240	2240	13200	13200	11300	37000	16.67	266.6	533.2	16.0	32	8.00	51.34
155	GUN	M109	1/20		2710		10000	16800	55000	10.17	203.4	406.8	20.0	40	6.10	29.94
105	GUN	XM204	1/35-18	648	2170	6270	21000	18650	44700	6.20	137.8	275.6	22.0	44	4.12	13.65
105	HOW	M2A2	1/20	394	1630	3450	14240	11810	25000	6.89	137.8	275.6	20.0	40	4.12	13.05
155	GUN	M185	1/20	680	1850	4000	10900	10790	49700	10.17	203.4	406.8	20.0	40	6.10	29.82
8"	HOW	M110A1	1/20	833	2330	3747	10450	7600	30000	13.33	266.6	533.3	20.0	40.0	8.00	51.32
8"	HOW	M110A1E1	1/20	833	2550	3747	11500	9300	37000	13.33	266.6	533.3	20.0	40.0	8.00	51.32

NAVY

Weapon Cal	Weapon Type	Weapon Model	Twist Cal/Turn	Muzzle Velocity FPS Min	Muzzle Velocity FPS Max	Spin RPM Min	Spin RPM Max	Linear Max 'g'	Chamber PSI Max	Turn Rate Ft/Rev	Arm Distance 400 Cal	Arm Distance 800 Cal	Turns to Arm 400 Cal	Turns to Arm 800 Cal	Land Dia Inches	Area '□' Inches
3-/50			1/32	2575	2700	20888	19260	20627	38000	8.0	100	200	12.5	25	3	7.07
3/70			1/20	3250	3400	32640	27300	25000	38000	5.0	100	200	20.0	40	3	7.07
5/38		AAC	1/30	1025	2600	12480	4920	14335	42000	12.5	166.8	333.2	13.3	26.6	5	19.64
5/54			1/25	1025	2650	15240	5880	9000	38000	10.42	166.8	333.2	16.0	32	5	19.64
6/47			1/25	1860	2650	12780	9900	9012	41500	12.50	200.0	400.0	16.0	32	6	28.27
8/55			1/25	1925	2700	9720	7800	7796	42600	16.67	266.6	533.2	16.0	32	8	50.26
12/50		HC	1/25	1625	2650	6300	4560	4717	3900	25.00	400.0	800.0	16.0	32	12	113.10
14/50		HC	1/25	1885	2820	5760	4140	9867	4200	29.17	466.6	933.2	16.0	32	14	153.94
16/45		HC	1/25	1745	2625	4500	3360	4268	4200	33.33	533.3	106.6	16.0	32	16	201.06
16/50		HC	1/25	1745	2690	4860	3600	4268	3800	33.33	533.3	106.6	16.0	32	16	201.06

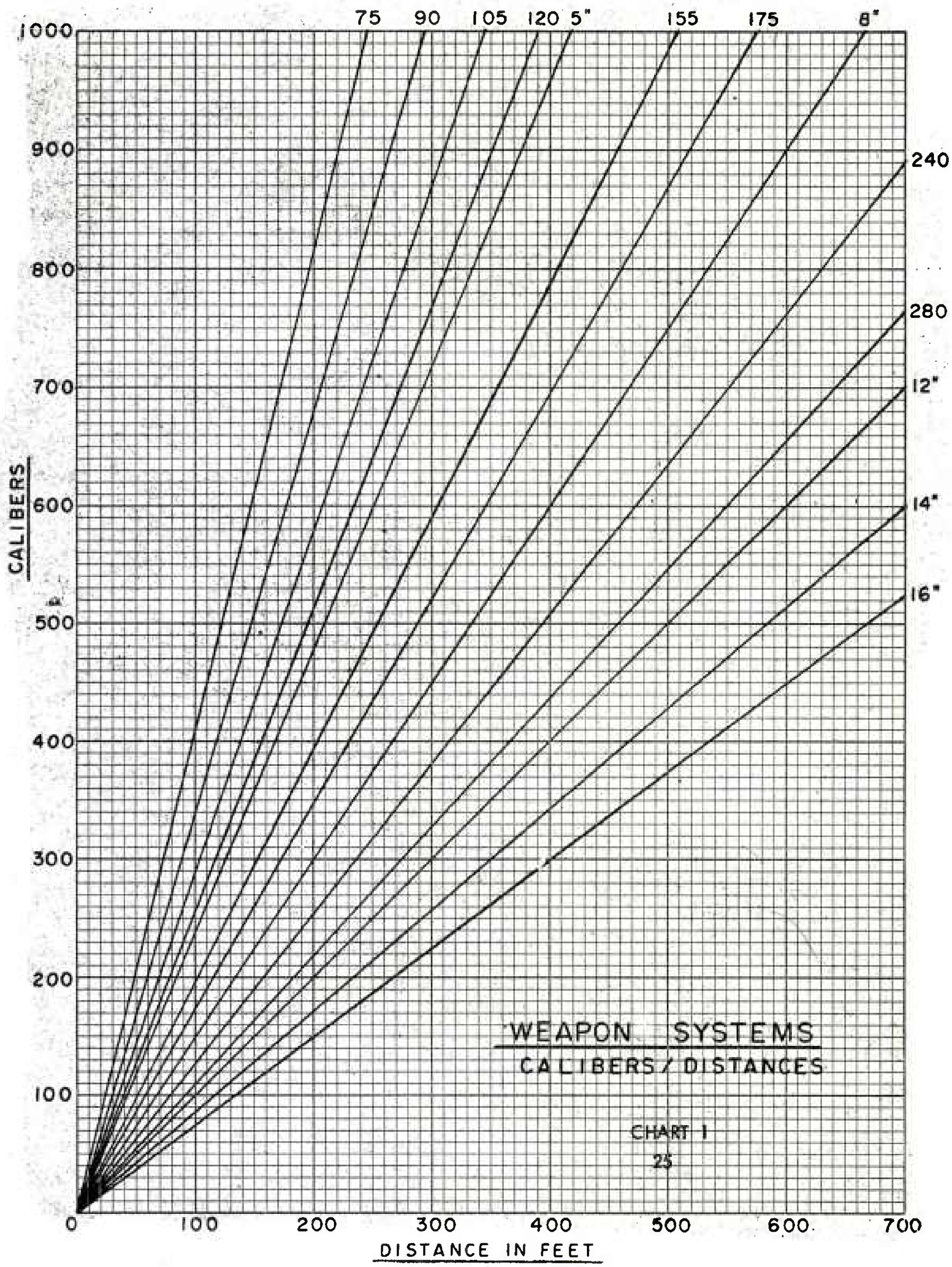

Figure 9. Calibers/Distances

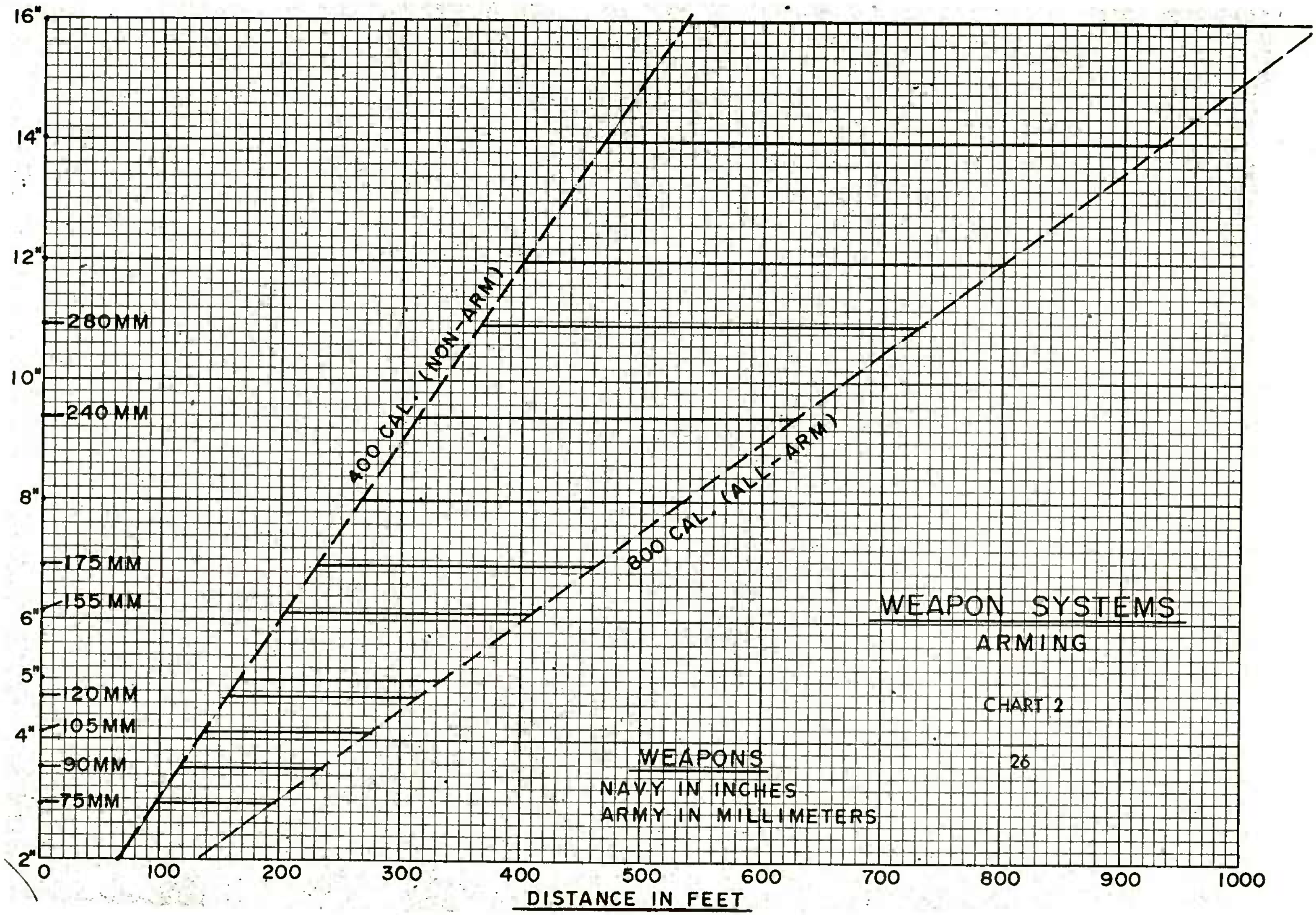

Figure 10. Arming

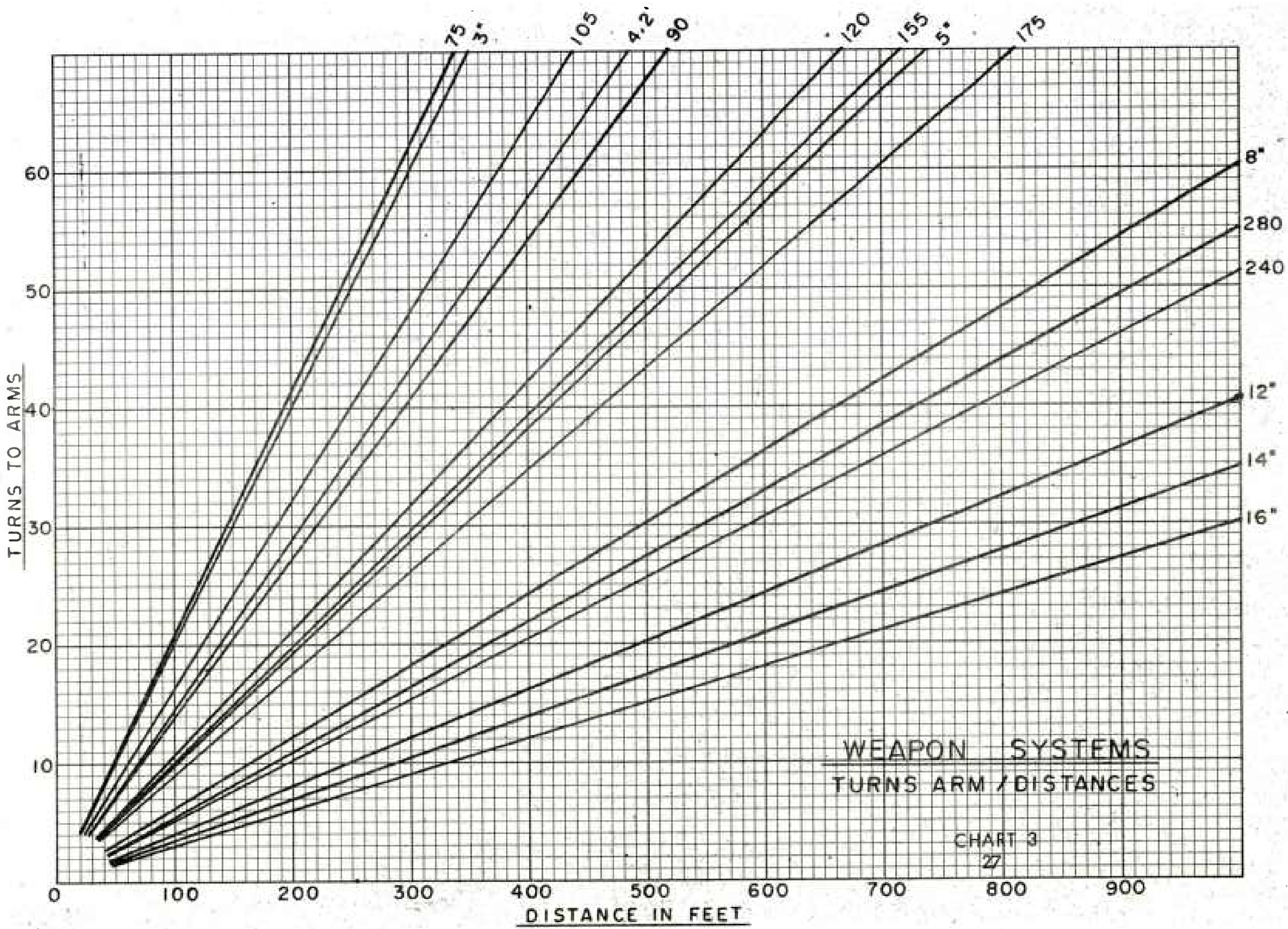

Figure 11. Turns to Arm/Distances

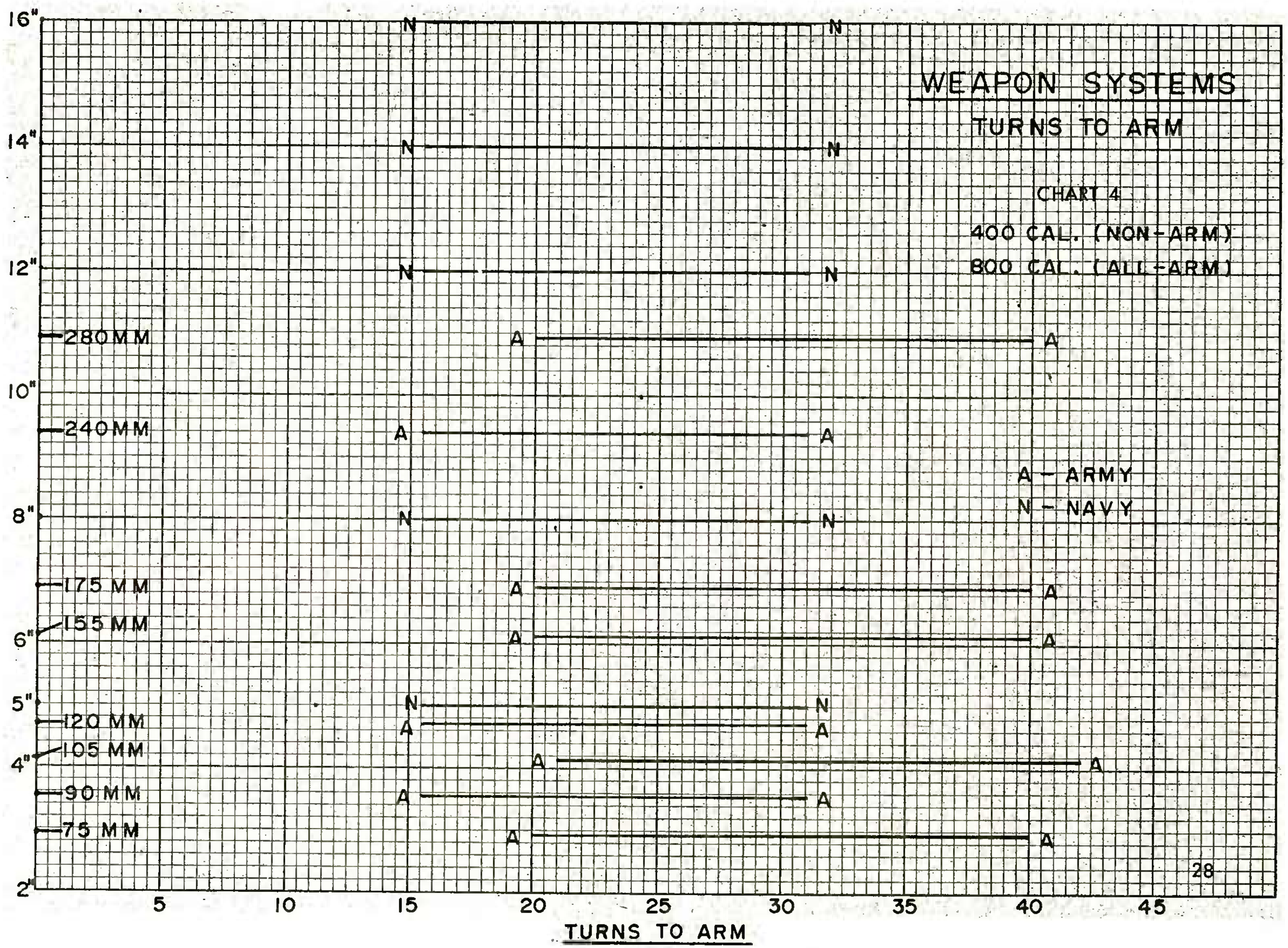

Figure 12. Turns to Arm

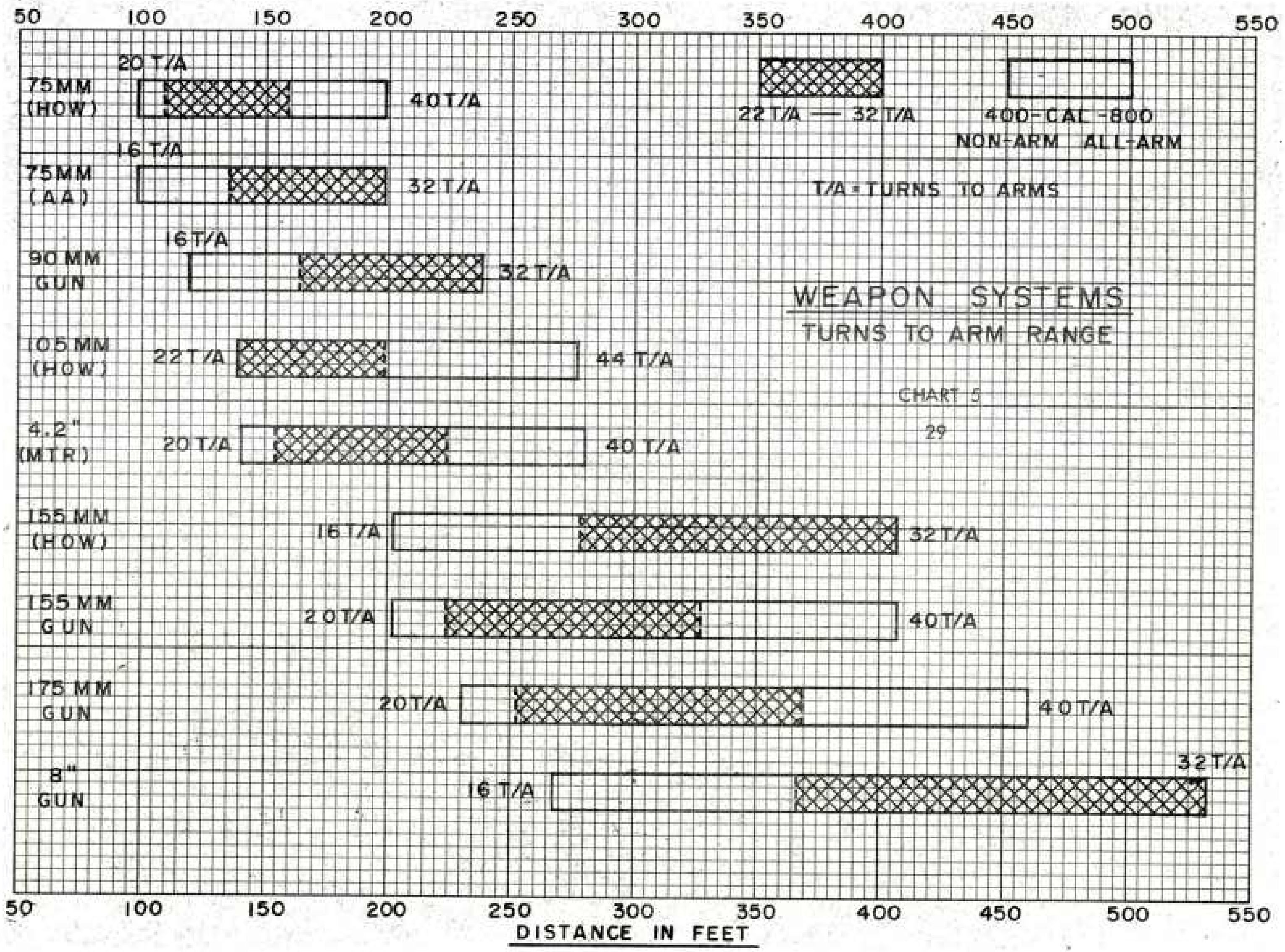

Figure 13. Turns to Arm Range

Table 5. Malfunction Probabilities and Safety Failure and Reliability Function Predictions

S&A Device	S&A Arms Prematurely: Malfunction Probability	S&A Arms Prematurely: Safety Failure Prediction	S&A Fails to Provide Proper Function: Malfunction Probability	S&A Fails to Provide Proper Function: Reliability Function Prediction
M125A1	4.711×10^{-8}	$1/21.23 \times 10^{6}$	$.90 \times 10^{-3}$	99.91%
M125A1 (ALT)	4.711×10^{-8}	$1/21.23 \times 10^{6}$	$.90 \times 10^{-3}$	99.91%
M57E2	4.711×10^{-8}	$1/21.23 \times 10^{6}$	2.7×10^{-3}	99.73%
M732	32.35×10^{-8}	$1/3.09 \times 10^{6}$	1.2×10^{-3}	99.88%
M577	6.511×10^{-8}	$1/15.358 \times 10^{6}$	$.90 \times 10^{-3}$	99.91%
Gearless	1.451×10^{-8}	$1/68.92 \times 10^{6}$	1.2×10^{-3}	99.88%

CONCLUSIONS AND RECOMMENDATIONS

The task to develop and standardize on S&A device was curtailed and held in abeyance at end of FY74 until further notice. The data, information and results obtained during this study justified the approach taken and work developed to accomplish the task. Preliminary studies of the interface factors, explosive components, setback pins and escapements indicate the feasibility of a common S&A. Technical advances indicate optimum designs of setback pins and escapements will improve performance.

The proposed requirements are realistic, common to the basic fuze and adaptable to an item of military material. The turns to arm concept assures commonality in expressing arming distance for the various weapon systems and the arming rate for the S&A.

It is recommended that the development and standardization of the S&A be completed. A kit, can be supplied with adapters, developed to overcome interface problems until modifications to the fuzes can be adopted.

Confirmation of the requirements by other Government agencies should be attained.

APPENDIX A

PROPOSED REQUIREMENT FOR AN ARTILLERY SAFING AND ARMING MECHANISM (S & A)

I. STATEMENT OF REQUIREMENT

1. Statement of Requirement

   a. CARD Para 112f, OCO Ammunition.

   b. The objective is to develop and standardize the safing and arming mechanism (S&A) of fuzes for use on spin stabilized artillery ammunition.

   c. The purpose is to replace existing S&A mechanisms by a single device thereby minimizing proliferation and gaining the economic and logistic benefits derived from standardization.

   d. The primary function of an S&A mechanism is to prevent an unintended detonation and in turn allow the propagation of the explosive train of the munition after the munition has reached the proper point in time or space.

   e. The S&A mechanism is to be used and employed with the standard and developmental fuzes and projectiles for spin stabilized artillery weapon systems.

2. Operational/Organizational/Logistical Concepts

   a. United States Forces will employ the S&A/fuzes in all types of terrain and climates, including operations in any geographical areas under the categories 1 through 7 and 8 (desired) as defined in Chapter 2 Section II of AR70-38.

   b. The S&A/Fuzes will be used in all Field Artillery and Tank Weapon Systems either standard or under development for essentially the same missions as current S&A/Fuzes.

   c. The S&A mechanism shall be governed by the existing logistic requirements of each of the designated fuzes.

II. CHARACTERISTICS

1. General Characteristics

   a. The S&A mechanism shall withstand the internal, external and terminal ballistic environments including forces resulting from high speed mechanical loaders/rammers conforming to advances in Weapon and Ammunition Technology and the forces of transport in tactical vehicles over rough terrain without special handling.

   b. The S&A, Packaged with Fuze shall be capable of storage without maintenance for 10 years in open storage and 20 years in covered storage without degradation of performance under climatic conditions defined in Chapter 2, AR70-38.

   c. The S&A shall contain the explosive material compatible for use in designated fuzes for spin stabilized Artillery Munition and conform to U.S. Army Standards.

   d. The performance of the S&A is to be consistent with that currently being achieved in existing fuze application.

   e. The S&A shall utilize non-critical and standard materiel, and shall be suitable for automatic production and inspection.

2. Physical Characteristics

   a. The size, weight and configuration of the S&A must conform to the interface and contour requirements of the designated fuzes and boosters.

   b. The size must be:

      Length ________________

      Diameter ______________

      Weight ________________

   c. The S&A mechanism shall include the explosive lead charge, the Setback Pin Assembly, Spin Detents and ______________________________.

3. Safety Characteristics

   a. The S&A shall contain at least two safety features and design safety criteria in compliance with MIL-STD-1316A.

b. The S&A shall have the detonator out-of-line and provide static detonator safety.

c. The S&A shall contain safety features which will prevent omission of parts, and/or MAL assembly resulting in an armed and unsafe unit.

d. The S&A shall be bore safe and provide the minimum arming delay of 400 calibers in all designated weapon system.

e. The safety failure rate of the S&A within the minimum arming distance (400 calibers) shall not exceed one in 2.5×10^6.

f. The S&A shall be compatible with the overhead safety requirements assigned to existing fuzes.

4. Technical Performance Characteristics

a. The S&A shall arm and function with the required reliability when fired in the appropriate artillery, 4.2 mortar and tank weapon systems.

b. The S&A shall arm and perform with a functional reliability of %.

c. The non-arming rate for the S&A shall not exceed 1 in 1000.

d. The S&A shall function reliably throughout the temperature range of -50°F to 125°F. The climatic categories 1 thru 7 as defined in Chapter 2, Section II of AR70-38. The S&A shall function reliably after storage temperature range of -50° to 160°F.

e. The S&A shall not disarm upon graze or target impact.

f. The S&A shall be fully armed at 800 calibers trajectory distance from the weapon.

g. The S&A shall not arm when subjected to a setback force of ______g, and shall arm under a setback force of 1500 g.

h. The S&A shall not arm when subjected to a spin of 1000 RPM and shall arm at 1700 RPM.

i. The S&A, for growth potential shall be operable under the launch conditions of 40,000 g's, axial, 20,000 g's lateral 35,000 RPM spin; 4000 ft/sec. muzzle velocity of .075 eccentric spin.

j. The S&A shall withstand set forward accelerations up to 1500 g's during manual and automatic loading, and ramming operations based on current artillery systems.

III. ENVIRONMENTAL

1. Environmental and Performance Tests

a. The S&A, with Fuze, shall comply with MIL-STD-331 when subjected to the following:

(1) Jolt Test	Test No. 101
(2) Jumble Test	Test No. 102
(3) Forty Foot Drop	Test No. 103
(4) Transportation and Vibration	Test No. 104
(5) Temperature and Humidity	Test No. 105
(6) Fungus resistance	Test No. 110
(7) Five Foot Drop	Test No. 111
(8) Extreme Temperature Storage	Test No. 112
(9) Rough Handling	Test No. 114
(10) Static Detonator Safety	Test No. 115
(11) Muzzle Impact Safety	Test No. 207
(12) Impact Safe Dist.	Test No. 208
(13) Air Delivery, Simulated	Test No. T213

IV. VULNERABILITY

1. Nuclear Effects

The S&A, compatible with the fuze, shall be invulnerable to nuclear effects that are fatal to humans and/or be capable of decontamination for disposal.

2. CBR Vulnerability

Inherent design of S&A, Fuze and sealed container shall provide for either decontamination for use or rendered safe for disposal.

3. Electromagnetic Radiation

The S&A shall be immune to electromagnetic radiation from emmitter, nuclear or lightning sources.

RATIONALE

SAFING & ARMING MECHANISM (S&A)

1. Statement of Requirement.

Rationale: The statement of requirement cites the OCO providing guidance for non-system advanced development effort and defines the objectives, purpose, function and use of the S&A Mechanism.

2. Operational, Organizational, Logistical Concepts

Rationalc: These concepts define the mission profile depicting the intended use, arcas and types of operations to be conducted by the various military with the S&A Fuzes.

II. CHARACTERISTICS

1. General Characteristics

Rationale: The general characteristics emphasize the structural integrity of thc S&A to ensure reliable performance by providing resistance to damage in handling and in the use of loaders and rammers, provide adequate strength to survive ballistic forces and prevent deterioration in storage. Compatibility of the explosive elements and use of standard items eliminate extensive testing, ensure reliability and reduces cost.

2. Physical Characteristics

Rationale: The size, weight and configuration of the S&A must be compatible with the designated fuzes thereby maintaining the same ballistic match of the complete round.

3. Safety Characteristics

Rationale: The safety characteristics prevent accidental initiation of the ammunition during the pre-launch cycles of assembly, handling, transportation, storage and loading: and in the operational use including consideration of bore safety, prematures, early bursts and non-arming distance. Thesc features ensure safety to handling personnel, gun crew, troops, equipment and weapon.

4. Technical Performance Characteristics

Rationale: The specified technical characteristics will ensure high probability of mission success. The capability to achieve the required reliability under the rigors of transportation, the pre-launch conditions of loading and ramming, the launch conditions of the weapon systems and the environmental conditions of climate will enhance the performance of the S&A. The degree of reliability, as specified, consistent with the current state of the art, provides maximum safety and mission success under all possible combinations of weather, climate and terrain.

III. ENVIRONMENTAL

1. Environmental and Performance Tests

Rationale: Consideration of the Laboratory and field tests of MIL-STD-331 provide engineering information on the performance of the S&A and components under controlled environmental and natural conditions from assembly to final use. Conformance to the test criteria ensure the ruggedness, safety, operability and reliability of the S&A under rough handling, transportation and climatic environments. The field tests will ensure safety of crew and weapon.

IV. VULNERABILITY

1. Nuclear Hardening; 2. CBR; 3. EMR

Rationale: Immunization to these hazards will ensure handling personnel and troop safety and will permit continued operational use of munitions during these attacks.

DRAFT PROPOSED OPERATIONAL CAPABILITY OBJECTIVE (OCO)

I. TITLE: Advanced Artillery Fuzing/Artillery Safing and Arming (S&A).

II. SECURITY CLASSIFICATION: UNCLASSIFIED

III. DATE SUBMITTED TO ACSFOR:

IV. RECOMMENDED CARDS FUNCTIONAL AREA: Ammunition

V. THIS OCO IS DERIVED FROM OR SUPPORTS:

Card, OCO 112 Para f. Ammunition

VI. STATEMENT OF OBJECTIVE:

The objective is to develop and standardize a safing and arming mechanism capable for use on spin stabilized artillery HE rounds. The task is to replace existing Safing and Arming mechanism by a single multi-purpose device, minimize proliferation and gain the economic and logistic benefits derived from standardization. A four year time frame is required to complete the non system (6.3) Advanced Development Effort for this program.

VII. JUSTIFICATION:

There are, currently several safing and arming (S&A) mechanisms of various designs and in various stages of development for use on spin stabilized rounds fired in the same weapon systems. The primary function of an S&A is to prevent an unintended detonation, provide the safe non-arm and the all arm features for the fuze. Although a delay element is common to all, the design of the various S&A mechanisms was influenced by the contour and scope of each inherited fuze. As no requirement existed for an independent and common S&A the result is a lack of commonality in geometry and in arming delay. The proposed safing and arming mechanism will meet the performance characteristics established for a common device and conform to the interface requirements for each fuze. The requirements will be coordinated with the concerned Government Agencies, to obtain full concurrence and achieve commonality in performance and geometry. This OCO will provide the basis for the non system Advanced Development Effort of the program to standardize the S&A mechanism.

VIII. COORDINATION:

Frankford Arsenal was tasked by ARMCOM, AMSAR to develop the S&A and as requested coordinated efforts with other developers, Picatinny Arsenal and Harry Diamond Labs. Likewise the U.S. Army Field Board and School at Fort Sill provided guidance and information on Arming requirements.

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