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SOME ASPECTS OF PYROTECHNIC DELAYS ,

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03.0	"Check List for Establishing a Testing Schedule for Guided Missile Fuzes and Safety and Arming Mechanisms"	1-18-56
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05.0	"Safety and Operability Test at Upper Service Extremes of Accelerations, for Use in Develop- ment of Projectile Fuzes"	6-20-56
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SOME ASPECTS OF PYROTECHNIC DELAYS

1. PURPOSE

The purpose of this article is to present to the fuze designer a composite picture of the "state of the art" of pyrotechnic delays. This article is intended to illustrate the merits of pyrotechnic delays and their limitations and should be helpful to designers in the choice of a delay system. It is not intended to be all inclusive but to act only as a guide.

2. INTRODUCTION

Both "present day" weapon systems and those of the future will involve radical changes in fuze design. These changes are necessary because of space, weight and reliability requirements. One particular area of fuzing which can be improved from the standpoint of reducing space and weight is in time-delay systems. A time-delay device may be defined as one which interposes a predetermined fixed time between any one and a subsequent event. Some of the more common ways of obtaining a time delay are:

a. Mechanical methods:

clock mechanisms

diaphragms

hydrostats

b. Electrical methods:

RC circuits

syncro motors

c. Chemical methods:

pyrotechnic

chemical reactions other than pyrotechnic

It is the intent of this paper to describe and summarize the advantages and disadvantages of pyrotechnic time delays specifically for the fuze designer. In the past, there has been some reluctance, on the part of many designers of fuzes and ordnance devices, to use pyrotechnic delays. In part, this reluctance may be because pyrotechnic items are one-shot devices, i. e., they can be tested only once and therefore the statistical reliability is believed to be unsound. (This is an erroneous assumption. ¹) In addition pyrotechnic devices require special handling and fabrication. These constitute legitimate concerns. However, it is the opinion of those who design and develop pyrotechnic-delay devices that this attitude is a result of a lack of adequate information on the actual utility and reliability of this type device. ¹ To help correct this attitude an examination of the

pyrotechnic-time-delay field will be made and discussed. Particular emphasis shall be placed on delay design, delay compositions and the reliability of pyrotechnic-delay devices.

There is no universal delay mechanism suitable for all applications. Selection of a delay device for use in a fuze or weapon must be based on the overall requirements of the particular weapon in which it will be used. In general, the advantages in using a pyrotechnic-delay are as follows:

- a. Normally, they contain no moving parts.
- b. Time delays are available ranging from microseconds to several minutes.
- c. By comparison, they are smaller and lighter than equivalent mechanical and electrical delays.
- d. These devices are rugged and can pass the standard military rough-handling tests.
- e. Large amounts of energy are available in small weights and volumes.
- f. Usually, the fabrication cost is lower than complicated mechanical and electrical-delay devices.

It is pertinent to emphasize at this time that pyrotechnic-delay devices are not the ultimate answer to all delay problems. There are some disadvantages which are apparent in particular situations. In general, pyrotechnic-delay

devices possess the following disadvantages:

- a. They contain pyrotechnic and explosive material and therefore require explosive safety precautions.
- b. The explosive materials are sensitive to humidity and temperature and therefore controls must be maintained in processing, storage, and application.
- c. Time reproducibility at a given temperature is about $\pm 5\%$. However, rapid gains are being made to reduce this spread.

3. DELAY DESIGN

Most pyrotechnic-delay devices in use today consist of three major elements housed in one body. These elements are: the initiator, the delay column and the base charge. Each element can be considered as an entity in the design of a particular delay device. In considering the ignition system, the method of initiation is important, i. e., whether initiated mechanically by a firing pin or electrically. A design consideration for the delay column is whether it shall be obturated or vented, i. e., whether to contain the gases produced by the chemical reaction or to vent them to a larger volume. The base charge is usually a straightforward application of a particular type explosive to produce a specific effect. The three elements which make up a delay device will be discussed separately so that the characteristics of each may be better understood.

4. THE INITIATOR

The purpose of the initiator assembly, whether it is mechanically or electrically activated, is to produce hot gases and particles which will impinge on the delay column. The initiator assembly (in Navy-designed items) usually contains a charge-holder which falls into one of two categories, either the conventional or the chimney type charge-holder. The former sits directly on top of the delay column allowing very little or no free volume. The chimney type charge-holder may or may not sit directly on the delay column but provides for a free volume in which to vent gases. It also directs and concentrates the hot gases and particles on a definite area. Figures 1A and 1B are typical conventional and chimney type charge-holders used with electrical initiator plugs. The conventional type charge-holder can be modified by placing a ring between it and the delay column, thereby providing a free volume. The design of the charge-holder is dependent upon the type of initiation (mechanical or electrical), the baffling used in the delay column and whether the system is obturated or vented. References 2, 3, 4, and 5 describe and illustrate applications where the charge-holders mentioned above have been used.

The Army Ordnance design of pyrotechnic delay assemblies frequently uses a different configuration employing a primer-holder subassembly in which only the initiating primer is held securely. This subassembly is then screwed into, staked into, or otherwise held rigidly in the main delay assembly. The igniter charge is made a part of the main pyrotechnic delay column.

5. THE DELAY COLUMN

There are numerous design parameters which affect the delay time in a particular delay device. Reproducible delays with small variations are greatly dependent upon the design and construction of the delay column. Satisfactory performance depends on the following design parameters:

- a. Delay composition
- b. Free volume
- c. Heat sink
- d. Igniter material
- e. Loading conditions

A desirable delay composition is one which has good long-term storage characteristics, relative insensitivity, low gassing, high ash retention and can be easily reproduced. Table 1 lists several delay compositions and their delay-time range currently being used in Navy ordnance devices.^{6, 7, 8, 9, 10, 11} Table 2 lists delay compositions used by the Army and commercial loading facilities.⁷ These compositions have been used quite extensively and each has special characteristics which may be desirable for a given application. The decision to use a particular delay composition must be based on its known characteristics and the application for which it will be used. For example, the degree of gassing should be known since the more gas evolved the greater the internal pressure will be resulting in

a greater time variation. 12, 13, 14 Past experience has shown that vented delay systems and those with large internal free volumes result in more uniform delay times.

The quality of materials for the body or subassembly immediately surrounding the delay column is critical. If there is an occasional chance of porosity (e. g. die cast metals) within this surrounding envelope, or of a contamination on the interface between the delay column and the surrounding body, this could cause occasional erratic performance due to traces of entrained gas-forming impurities.

The body in which the delay composition is loaded is important in that it conducts and transfers heat away from the reacting composition. Thus, the body becomes a heat sink. It is desirable to have a body which acts as an infinite heat sink, i. e. , it is sufficiently massive enough to transfer at a constant rate enough of the heat generated so that the temperature at the burning front of the delay column remains approximately constant. Due to size considerations, this may not always be feasible. However, the device in which the delay element is housed may act as an additional heat sink. Figure 2 is a typical curve illustrating the change in delay time vs the mass of metal about the delay column. When the heat sink (about the delay column) is not massive enough, greater variations in delay time will be experienced due to variations in burning temperature. These variations will become more pronounced as the delay time becomes longer. For

very short delay times (a 0.1 second or less) the effect of the heat sink becomes less significant.

To insure reliable ignition of the delay powder an igniter mixture more sensitive than the delay powder is loaded on top of the delay column. In addition to being more thermally sensitive than the delay composition such igniter mixtures produce larger heat outputs. In general, igniter mixtures consist of a metal/metal oxide composition so that high temperatures can be attained with a small degree of gassing. A popular ignition material used by the Navy is Gasless Ignition Powder (MIL-P-22264), formerly A-1A Ignition Powder. Table 3 is a list of commonly used igniter mixes and some of their properties. The selection of an igniter mixture is dependent upon its compatibility with the delay composition it is to ignite. Other important factors to consider are thermal sensitivity, burning temperature, gas production and slag retention.

An important consideration in the design of a delay column is the manner in which its integrity is maintained. It has been observed that forces such as spin, set-back, shock, and internal gas pressure can cause separation of the delay column and can result in failure.

Usually separation occurs while the delay column is burning and at the burning front. At this front the material is usually molten and any of the above mentioned forces can cause the column on either side of the burning front to separate. Various experimental methods have been utilized to

maintain the column configuration. These include devices such as putting threads on the delay column I. D. wall, and the use of retainer rings and discs.² However, a very successful design has been to baffle both ends of the delay column. The baffles can be in the form of slotted discs, washers or porous metal discs. A typical baffled delay column is shown in Figure 3. The baffles (2 to 5 mils oversize) are always force fitted into the delay body. The loading pressure and therefore the density of the delay composition, must be carefully controlled because the density has an appreciable effect on the burning rate of most mixtures. Thus it is necessary to know the burning characteristics vs loading pressures of a given delay composition. Then a loading pressure can be chosen which gives the least variation in the burning rate as the pressure changes. Another consideration is the loading sequence of a delay column. The procedure should be such that the delay composition is loaded before any of the more sensitive materials. The reasoning is that if the igniter mix is loaded first, followed by the delay composition, it is very possible that some of the igniter mix will adhere to the entire length of the walls of the delay body. Upon ignition, this could cause a blow-by of the delay column and result in a premature output. Another cause of premature functioning is a delay column of insufficient length. This can be minimized by proper baffling.

6. THE BASE CHARGE

The type of output for a delay device is dependent upon the next operation

in the system. There is no restriction on the type of base charge material provided it is compatible with the other components in the device. It should be noted that while the delay column is burning, heat is being transferred through the metal body. In cases of long delay times (five seconds or greater) where a heat sensitive base charge is used, it may be necessary to insulate the base charge from the delay body. This can be accomplished by loading the base charge in a cup or ring of suitable insulating material.

7. THE ASSEMBLED UNIT

The three major elements of an explosive-delay device discussed above usually are integrated into one body or housing. It is good practice to design for hermetic sealing. However, where venting is necessary it is not practicable to hermetically seal the delay item. There is an exception with stab-initiated delay devices in that the item is sealed and obturated until initiation. The puncture caused by the firing pin allows venting. In some Army percussion-initiated delays, venting, if required, may be obtained by use of blow-out discs.¹⁵ A system of double cups has been employed in electrically-initiated devices which allows them to be hermetically sealed until initiated. At this time one of the cups which has a thin wall is preferentially punctured by the initiator output allowing the gases to be vented. On some occasions hermetic sealing is required in addition to external venting. In these instances the delay device can be sealed into a tube or container of sufficient volume which will permit both hermetic sealing and

provide an adequate vent volume. Figures 4, 5 and 6 are typical examples of a stab-initiated delay, an electrically-initiated delay and venting of a delay into a specific sealed volume, respectively. See also reference 16. for recent delay primer developments.

8. RESEARCH AREAS

The use of pyrotechnics to obtain controlled delay times has increased greatly since World War II. However, there are many aspects of this field which require further improvement. The design and mechanism of pyrotechnic-delay devices are well understood. The area of compounding delay compositions having good surveillance and reproducibility characteristics is still an art. Limited research and development are currently being carried out by both government and industry to produce delay compositions which will meet the stringent requirements of both present and future needs. To summarize, efforts are being made to prepare ignition and pyrotechnic-delay compositions with the following characteristics:

- a. Withstand long term high temperature, high humidity storage,
- b. Have a small standard deviation of burning time at a given temperature,
- c. Have a small time spread over the temperature range -65°F to 160°F.
- d. Produce minimum volume of gas.
- e. Have improved homogeneity and reproducibility

Other areas where important data are meager are the effect on delay time due to reduced atmospheric pressure and the compatibility of delay compositions with metals and plastics. Also needed is a better understanding of the mechanism of reaction between the various constituents. This should aid in determining which physical and chemical variables require more control, and to determine the tolerances which should be imposed on each specified control variable. Even if the reaction mechanism is not easily determined, it is believed important to identify and establish these various control factors by laboratory investigations and methods, rather than by trial-and-error methods as in the past, which identified this field as an "art".

9. SUMMARY

A general review of the "state of the art" of pyrotechnic-delay devices has been presented. This is by no means a complete picture of pyrotechnic-delay devices but rather an introduction for designers who may have a need for such basic knowledge. It has been indicated that with proper design, suitable materials, and adequate manufacturing controls a reliable delay device can be fabricated. Moreover, reliable and reproducible delay time devices having high energy outputs also can be attained. The limitations of these systems and the research currently being conducted to overcome the present deficiencies have also been discussed. Due to the relatively small weight and size of pyrotechnic-delays it is believed that there is a great future for these devices.

TABLE 1
NAVY DELAY COMPOSITIONS IN CURRENT USE

Compositions	Inverse Burning rate range (sec/in)	Reference
1. Manganese,		
Barium Chromate,	2 - 14	6, 7, 10, 12
Lead Chromate		
2. Molybdenum,	0.1 - 32	8
Barium Chromate,		
Potassium		
Perchlorate		
3. Tungsten,	0.4 - 40	8, 9
Barium Chromate,		
Potassium Perchlorate		

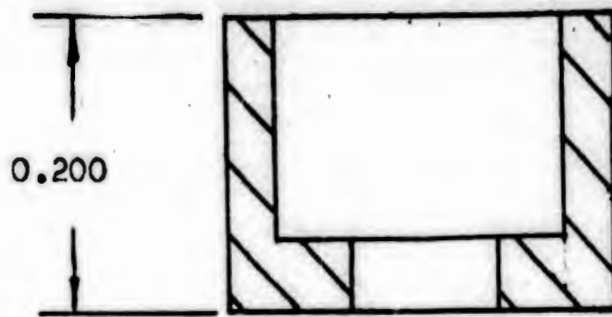
TABLE 2
DELAY COMPOSITIONS

Composition	Inverse Burning rate range (sec/in)	User	Reference
Barium Chromate, Boron	5	Army	7
Potassium Perchlorate, Barium Chromate, Zirconium-Nickel alloy	5-12	Army	7
Silicon Fuel Compositions			
B2-53	4-12	Army	7
Nickel, Zirconium, Potassium Perchlorate, Barium Chromate		Catalyst Research Corporation	7
HP-25	7		
T-2	11		
Barium Peroxide, Selenium, solder	1	Hercules Powder Co.	

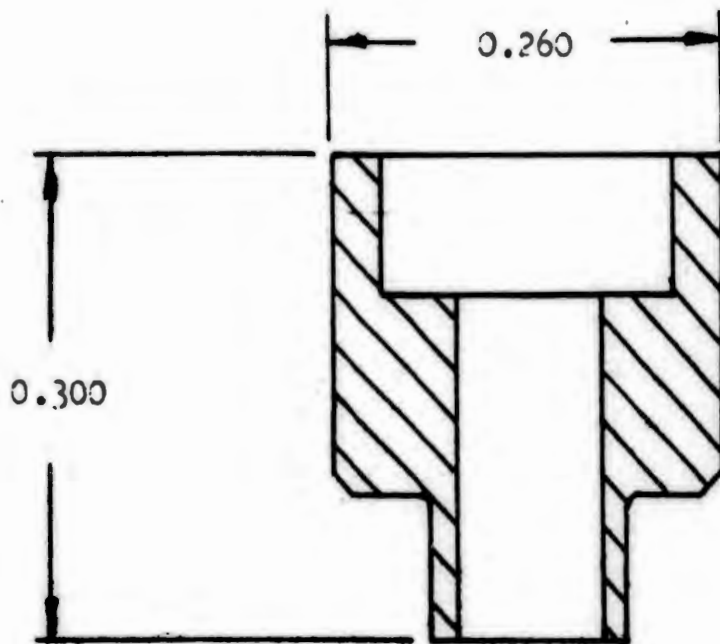
TABLE 3

IGNITER MATERIALS

<u>Material</u>	<u>Composition</u>	<u>Percent Funct. at -54°C</u>	<u>Inverse Burning Rate Milliseconds/inch</u>	<u>Percent Slag Retention</u>	<u>Spark Sensitivity Percent Firing at 20,000 ergs</u>
1. Gasless Ignition Powder (formerly A-1A) MIL-P-22264	65% Zirconium 25% Ferric Oxide 10% Superfloss	100	160	98	100
2. Boron/Barium Chromate Delay Composition PA-PD-1215	10% Boron 90% Barium Chromate	100	81	49	0
3. Boom Powder B2-50 Chem Corps	17 1/2% Zirconium 32 1/2% Titanium 50% Ferric Oxide 1.8% Binder added	100	88	76	0
4. F 33 B (no specification available)	41% Zirconium 49% Ferric Oxide 10% Superfloss	100	375	50	--



A- Conventional Type Charge Holder



B- Chimney Type Charge Holder

Figure 1- CHARGE HOLDERS

Constant I.D. 0.203
Delay mix- Manganese Delay Composition

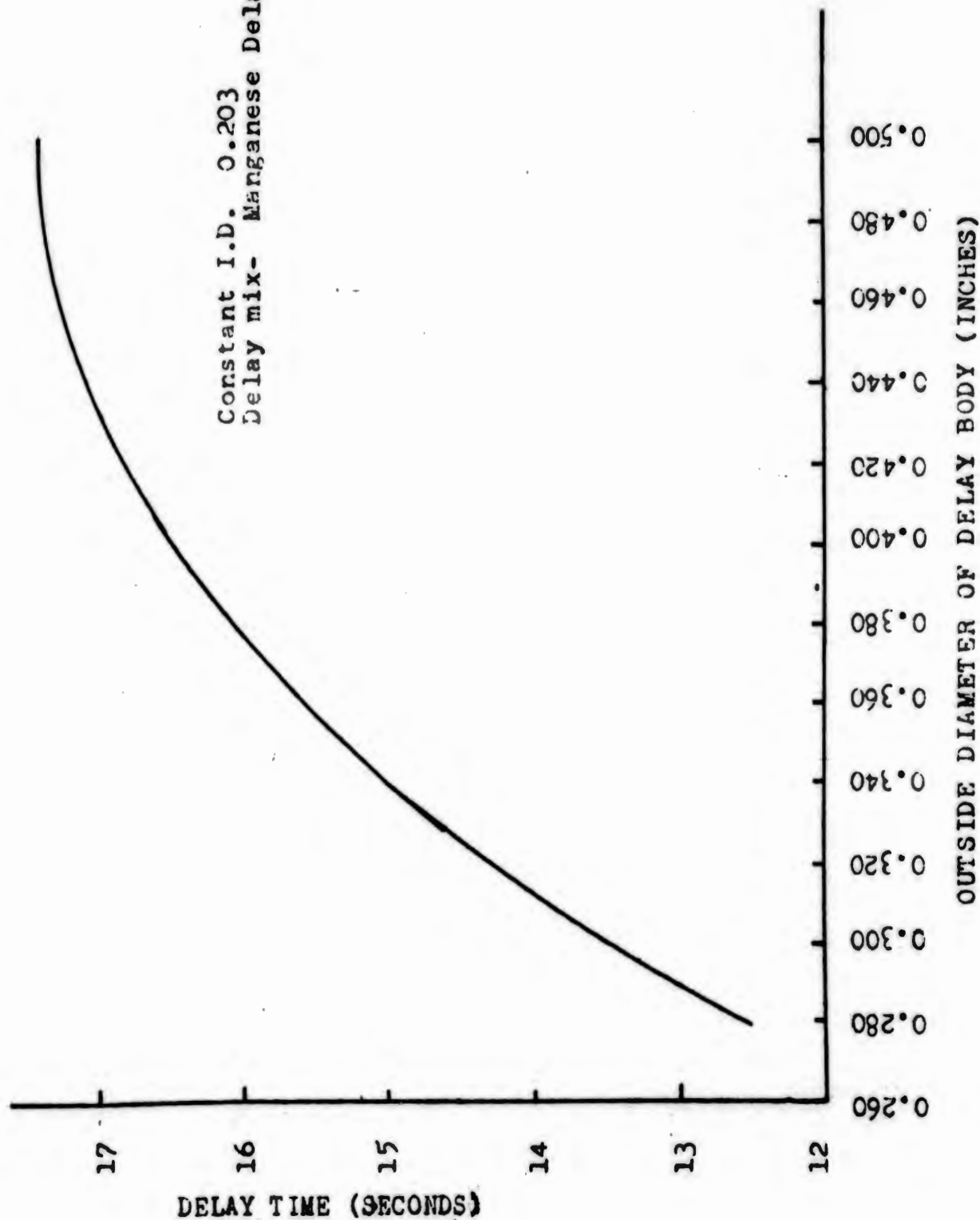


FIGURE -2 DELAY TIME VS OUTSIDE DIAMETER

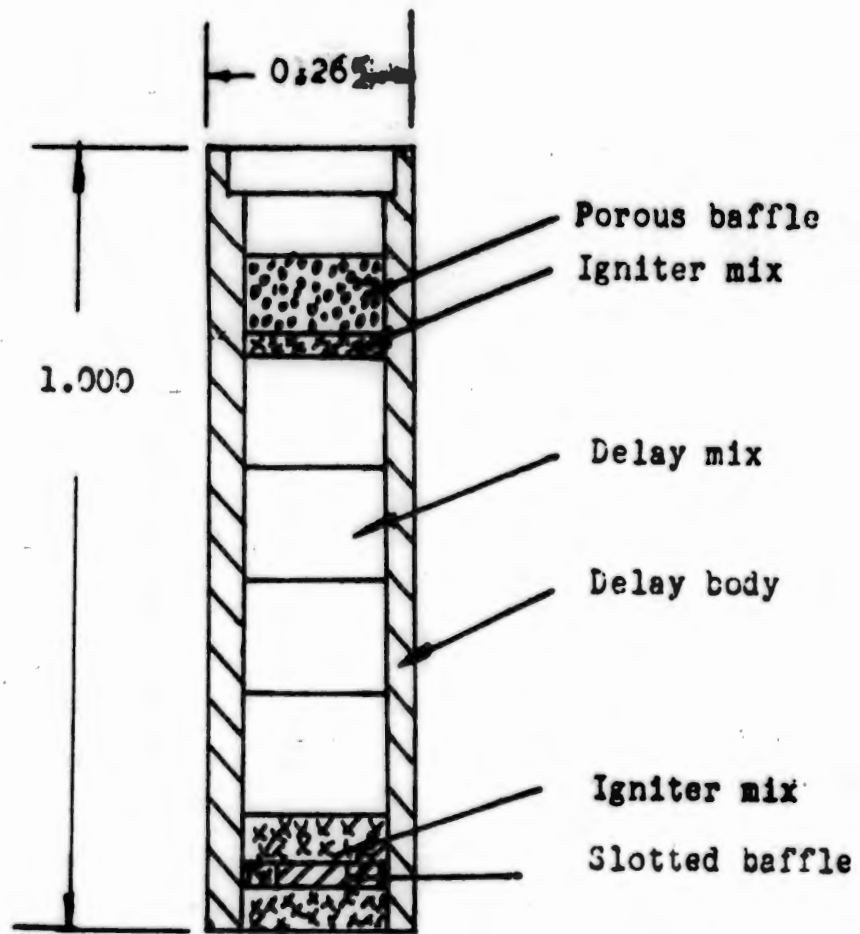


FIGURE 3- TYPICAL BAFFLED DELAY COLUMN

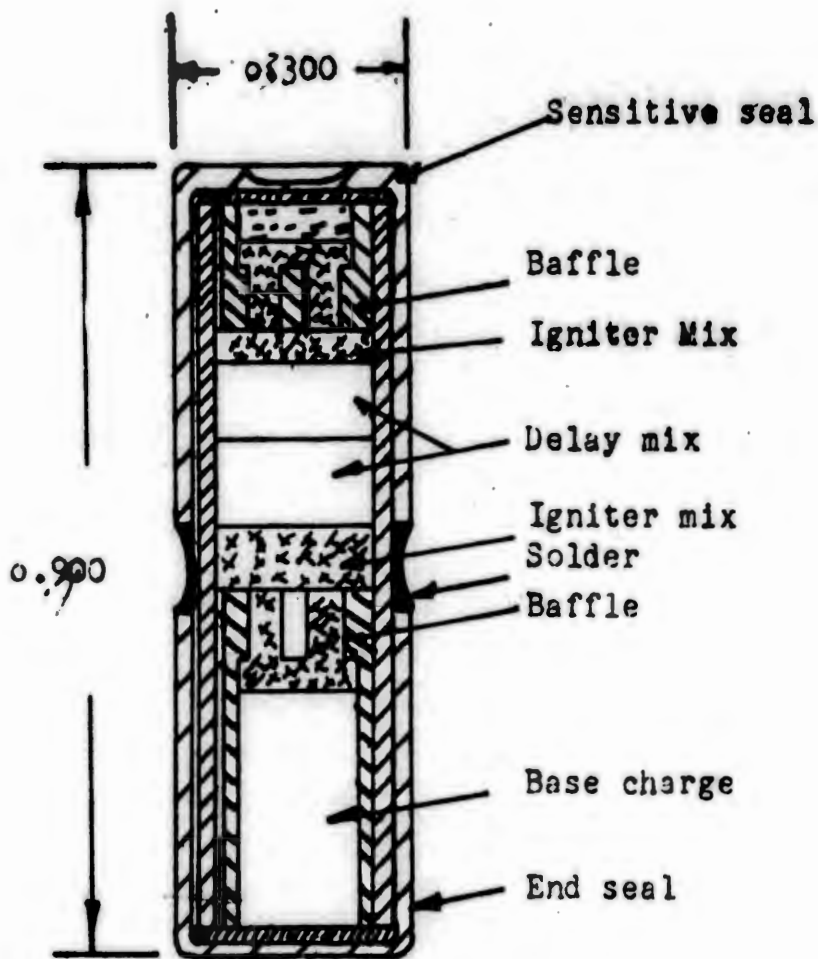


FIGURE 4- WOX-28A DELAY ACTUATOR

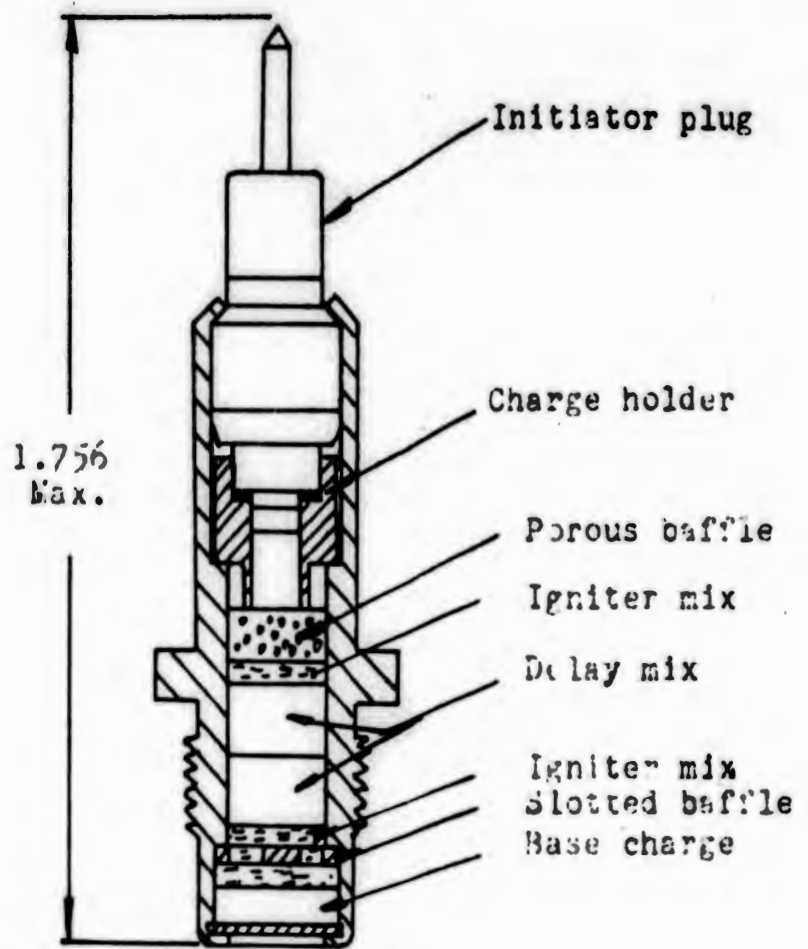


FIGURE-5 MK-14-O DELAY ACTUATOR

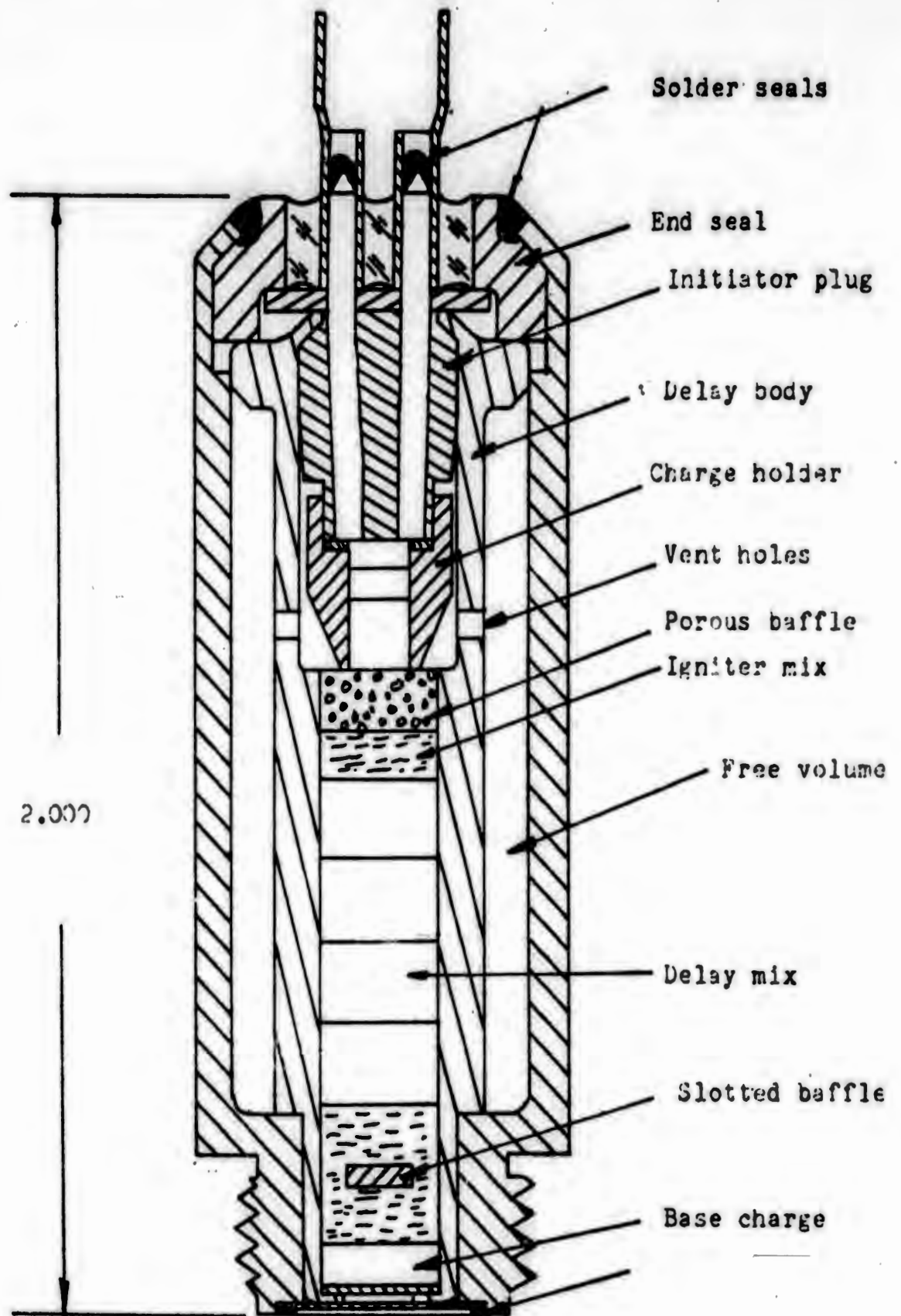


FIGURE -6 WOX-22A DELAY ACTUATOR

REFERENCES

1. **Pyrotechnics in Missile Design** by Leonard Katz, Ordnance, September-October, 1959, Vol XLIV, No. 236.
2. NavOrd Report 4204 "The Development of a Delay System for the XE-2, XE-3, and XE-9 Delay Actuators and the XE-26 Delay Primer", B. B. Herman, B. Bernstein, I. Kabik, 1955 (Conf.)
3. NavOrd Report 4463 "Development of the XE-29A - Low Energy Low Resistance Electric Gasless 0.250 Second Delay Primer", C. M. Cormack, Jr., 1955 (Conf.)
4. NavOrd Report 6088 "Primers XE-66A, XE-67A, XE-70A for Hotpoint", V. J. Menichelli, 1958.
5. NavOrd Report 6092 "The Development of the XE-57B Delay Primer for the Picket Boat Depth Charge Pistol", E. E. Kilmer, 1958 (Conf.)
6. **Military Specification Manganese Delay Composition.** MIL-M-21383 (Nord)
7. NavOrd Report 5671 "A Comparative Study of Five Pyrotechnic Delay Compositions", M. F. Murphy, 1958.
8. **Universal Match Corporation, Summary Report No. 2, Contract Nord 13466, Task 2, 1958**
9. NavOrd OS 11131, **Descriptions and Requirements Tungsten Delay Composition, 1960.**
10. NavOrd Report 1775 "Manganese and Cobalt Delay Mixtures", R. H. Corwyn and R. Skelton, 1951.

11. NavOrd Report 2261 "Burning Characteristics of Manganese, Barium Chromate and Lead Chromate Mixtures", E. E. Elzufon, 1952.
12. NOLR 1111, Ordnance Explosive Train Designers' Handbook
13. DOFL Report R-320-61-2, "Investigation of Environmental Effects on Tungsten Delay Compositions", Norman L. Martin, 1961.
14. DOFL Report R-320-61-16, "Engineering Test Data for 4-8 Second T5E3 Pyrotechnic Delay Element", Norman L. Martin, 1961.
15. DOFL Purchase Descriptions X-TL-PD-15 and X-TL-PD-16
16. NavOrd Report 6883 "Development of WOX-73A and WOX-74A Primers", E. E. Kilmer, 1960.

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