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U. S. NAVAL PROVING GROUND  
DAHLGREN, VIRGINIA

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DEFINITION FOR U. S. NAVY ANTI-AIRCRAFT MACHINE GUNS, SYNOPSIS OF DEVELOPMENTS DURING WORLD WAR II AND SUGGESTED FIELDS FOR FURTHER IMPROVEMENTS.

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U. S. NAVAL PROVING GROUND  
DAHLGREN, VIRGINIA

REPORT NO. 1-46

AMMUNITION FOR U. S. NAVY ANTI-AIRCRAFT MACHINE  
GUNS, SYNOPSIS OF DEVELOPMENTS DURING WORLD  
WAR II AND SUGGESTED FIELDS FOR FURTHER  
IMPROVEMENTS.

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*David J. Hedrick*

DAVID J. HEDRICK  
CAPTAIN, U. S. NAVY  
COMMANDING OFFICER.

## PREFACE

### OBJECT

The object of this report is to summarize the developments in ammunition for U. S. Navy anti-aircraft machine guns from September 1, 1939 to date, to summarize the present status of such ammunition, and to suggest fields for further improvement. The components covered are cartridge cases and primers, propellants, projectiles, tracers, fuzes, projectile fillers, and assembled rounds for the 20mm/70 Caliber, 1W10/75 Caliber and 40mm/60 Caliber.

### ABSTRACT

Various changes ~~have been~~ <sup>made</sup> during World War II in the design and materials of ammunition components for U. S. Navy anti-aircraft machine guns in order to improve performances and reduce hazards. This report summarizes the history of such changes. Other desirable improvements have not as yet been achieved. Suggested fields for improvement are incorporated in this report.

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I. CARTRIDGE CASES AND PRIMERS

A.- 20mm/70 Caliber A. A. Gun

1. Short History of Initial Development, and Subsequent Developments, Changes and Improvements

(a) General

When the 20mm A. A. gun was introduced into this country late in 1940, quantities of Swiss ammunition accompanied the gun. The cartridge case of this Swiss ammunition was brass, wax-coated, and contained two small flash holes in the base. The anvil on which the primer would strike was an integral part of the cartridge case.

(b) Mark 2 Case

The first official Navy cartridge case to be used was the brass Mark 2 case (Buord Ammunition Dwg. #294336 dated 3 April 1941). This design was very similar to that originally furnished by the Swiss. The Mark 2 case had a double flash hole and a projection within the primer hole which acted as an anvil for the primer charge. With minor improvements taking place through the war years, large quantities of Mark 2 cases were produced and used, particularly in the early phases of the war. When assembled into complete rounds, it was necessary to grease the case prior to firing if satisfactory automatic operation were to be obtained. This procedure is a change from the Swiss practice of using a wax similar to beeswax for lubricating the case.

(c) Mark 30 Primer

The Mark 2 case employed the Mark 30 percussion primer (Buord Ammunition Dwg. #294312 dated 3 April 1941). The Mark 30 primer was essentially of the same design as the primer in the Swiss ammunition; it did not employ an anvil, since, as stated above, the anvil was integral with the Mark 2 case.

(d) Mark 3 Case, Mark 4 Case

It was recognized very early that the Mark 2 case could and should be improved. The difficult job of fabrication of the anvil and double flash holes in the base of the case prevented production output

from reaching the levels desired. In 1943, the Mark 3 case (Buord Ammunition Dwg. #330872 dated 16 January 1943) and the Mark 4 case (Buord Ammunition Dwg. #389272 dated 1 July 1943) were produced. Each case had a larger, single flash hole and a cylindrical primer hole with a flat base. These cases are identical except that the Mark 3 case is made of steel, and the Mark 4 case of brass. The Mark 3 steel case was developed during this period because of the relative scarcity of brass. Some difficulty was encountered in the production of a steel case which would not split or which would otherwise be satisfactory. The present Mark 3 case is relatively free of defects, but still exhibits a higher percentage of longitudinal splits and primer blowouts than the Mark 4 brass case.

(e) Mark 31 Primer

The Mark 3 and Mark 4 cases employ the Mark 31 primer (Buord Ammunition Dwg. #388903 dated July 1943) which is similar to the Mark 30 primer except that the anvil is part of the primers and a primer charge termed FA90a is used, for reasons of safety during manufacture, instead of the fulminate of mercury employed in the Mark 30 primer. Like the Mark 30, the Mark 31 primer is pushed into, and crimped by, the case.

2. Service Deficiencies of 20mm A.A. Cases and Primers

- (a) All 20mm A. A. Cases presently require grease lubrication to insure satisfactory automatic fire. This requirement makes cleanliness of ammunition of prime importance, because dirt, sand, etc. will foul the gun mechanism and thereby reduce gun efficiency. A project is presently underway to lubricate the case with a graphite suspension lacquer, thus eliminating the greasing operation.
- (b) Although not of serious concern, a rather high percentage of Mark 3 steel cases split at the mouth during firing. This longitudinal split is usually about one inch (1") long.
- (c) An appreciable number of instances of primer leakage or primer blowouts has been noticed with the Mark 3 case. A project is presently underway which provides for a grooved primer hole, allowing the fired primer to mold itself in the groove, preventing leakage.

3. Adequacy of Present Design of 20mm A. A. Cases and Primers

In most respects the present design of the 20mm case and primer is adequate to insure proper performance of ammunition. However, with the present design of case and primer it is necessary to crimp the case around the primer to prevent loose primers and primer blowouts. Change in the design of the case might eliminate the need for this crimping operation.

4. Adequacy of Present Effective Specifications

(a) Existing specifications applicable to the ballistic testing of 20mm cases and primers at the NPG are:

(1) Cases - O.S. 20 dated 18 January 1944 and O.S. 1317 dated 11 May 1943.

(2) Primers - O.S. 1413 dated 13 November 1943.

(b) One hundred (100) samples are taken from each lot of 50,000 cases or primers for ballistic tests at the Naval Proving Ground. Forty (40) cases are fired at proof charge and the balance at service charge. The sample primers are fired in service charge rounds. No case or primer must exhibit any defect after firing, except some allowance is made for longitudinal splits in Mark 3 steel cases. Retests of cases and primers generally provide for twice the number of original samples. These quantities of samples and tests are considered adequate for proof.

5. Suggested Fields for Improvement

It is suggested that:

(a) Research be continued to eliminate the greasing of 20mm rounds. Previous efforts to accomplish this have been generally unsuccessful.

(b) Investigation be continued toward the elimination of Mark 3 steel case defects with regard to splits and primer leakage.

(c) Redesign of Mark 3 and Mark 4 cartridge cases for elimination of loose or blown out primers be investigated further.

I. CARTRIDGE CASES AND PRIMERS

B. - 1.10/75 Caliber Gun

1. History of Initial Developments and Subsequent Changes

By January 1939 the cartridge case and primer for the 1.1 gun had been developed to the present condition. The case is Mark 1 (brass) case (Buord Ammunition Dwg. #163673 dated 8 August 1933) and the primer is Mark 19 Mods. 0, 1, 2 and 3 (Buord Ammunition Dwg. #281726 dated 28 January 1941). The Mark 19, Mods. 0, 1, 2 and 3 essentially the same, the modification symbol being simply a means of identifying the various manufacturers.

2. Suggested Fields for Improvement

Since the 1.1 gun is obsolete, it is suggested that no further investigation of 1.1 primers and cases be undertaken.

I.

CARTRIDGE CASES AND PRIMERS

C. - 40mm/60 Caliber A. A. Gun

1. Short History of Initial Development and Subsequent Developments, Changes and Improvements

(a) General

The bulk of the ammunition furnished for the 40mm A. A. gun when it was introduced into the United States in 1941 was of British origin. The cartridge case was brass with a tapped hole in the base to receive a threaded primer.

(b) Mark 1 Case

The first Navy 40mm cartridge case to be used was the brass Mark 1 case (BuOrd Ammunition Dwg. #294432 dated 7 May 1941) which was similar to the case of British design. This case and its modifications employed a screw-type primer, inserted into a tapped primer hole in the base of the case. This feature resulted in an extremely effective case, free from primer leakage troubles.

(c) Mark 21 Primer

The Mark 21 screw-type primer (BuOrd Ammunition Dwg. #299430 dated 14 May 1941) was used with the Mark 1 case. It was discovered that the Mark 21 Mod. 0 or 1 primer was dangerous, because the construction did not completely prevent premature firing of the 40mm round as it was catapulted into the gun chamber. Preventive measures were taken, with the result that at present the Mark 21 Mod. 3 primer is used with the Mark 1 case.

(d) Mark 2, Mark 3 Case

In the interim between the realization of the danger of the Mark 21 Mods. 0 and 1 primer, and development of the Mark 21 Mods. 2 and 3 primer, the Marks 2 and 3 cases were developed. These cases are identical except that the Mark 2 is brass and the Mark 3 is steel. The primer hole of each is cylindrical, and uses the push-fit Mark 22 primer. The method of inserting the Mark 22 primer (BuOrd Ammunition Dwg. #328952 dated 3 August 1942) into the Mark 2 case (BuOrd Ammunition Dwg. #329377

dated 28 January 1943) and Mark 3 case (Buord Ammunition Dwg. #330825 dated 9 January 1943) proved time-conserving and quite successful, except that there resulted a relatively high percentage of primer blowouts and primer leakage with the Mark 2 case, as compared with the Mark 1 case. As a solution, the Mark 2 Mod. 1 case was developed, with a longer primer hole. With this case the Mark 22 Mod. 1 primer which had a longer, tapered head than the Mark 22 Mod. 0 primer was used.

(e) Mark 22 Primer

The Mark 22 and the Mark 22 Mod. 1 primers are derived from the 1.10 primer Mark 19. The primer is simple, rugged, efficient and relatively safe. As stated above, the Mark 22 Mod. 1 primer has a tapered head which is longer than the cylindrical head of the Mark 22 Mod. 0 primer. This change was intended to reduce the frequency of primer blowout and leakage, and has succeeded in this respect.

2. Service Deficiencies of 40mm Cases and Primers Known to the Naval Proving Ground

- (a) The Mark 1 case functions quite satisfactorily, but considerable time is required for inserting the screw-type primer.
- (b) The Mark 2 Mod. 0 case involves a rather large percentage of primer leakage and blowout occurrences.
- (c) In isolated instances, the base of the Mark 3 case separates from the remainder of the case. This transverse split occurs about 1" to 3" from the case base.
- (d) There is the possibility that time of storage of primers, particularly the Mark 21 type, may adversely affect the stability of the primer.

3. Adequacy of Present Design of 40mm Cases and Primers

The Mark 2 Mod. 1 case and the Mark 3 case, when used with the Mark 22 Mod. 1 primer, provide reliable, effective and easy-to-assemble combinations.

4. Adequacy of Present Effective Specifications

- (a) Existing specifications applicable to the ballistic testing of 40mm cases and primers at the NPG are:
- (1) Cases - O.S. 20 dated 18 January 1944 and O.S. 1502 dated 18 January 1944.
  - (2) Primers - O.S. 3092 dated 23 August 1943 and O.S. 1407 dated 29 July 1943.
- (b) Sixteen (16) samples are selected from each lot of 20,000 40mm cases for ballistic tests. Twelve (12) cases are fired at service charge and four (4) cases are fired at proof charge. A complete post-firing examination is given the cases, and any seriously defective case is cause for rejection of the lot it represents. Any operational failures attributable to the cartridge case is also cause for rejection. At the end of the war, the percentage of rejections of cases failing ballistic tests was very low.
- (c) Primers are given a ballistic and/or catapult test for lots in production and surveillance. Forty (40) samples from each lot of 20,000 are selected for ballistic test, and five (5) primers from each fifth lot are selected for catapult test. The ballistic test is entirely a test for normal functioning, while the catapult test consists of catapulting a dummy round, assembled with the test primers, ten (10) times in a 40mm mechanism with firing pin removed, and then firing the primer in the normal manner.

5. Suggested Fields for Improvement

It is suggested that:

- (a) Investigation be continued to determine the effect of surveillance on stability of Mark 21 and Mark 22 primers.
- (b) Research be conducted to eliminate the defects peculiar to the Mark 3 (steel) case. These cases are fairly reliable but exhibit a higher percentage of base separations than do brass cases.

II.

PROPELLANTS

A. - 20mm/70 Caliber A. A. Gun

1. Short history of Initial Development and Subsequent Developments, Changes, Improvements

(a) General

The powder received with the 20mm Oerlikon anti-aircraft gun when it was introduced into the United States was a flake powder, single base, high nitrocellulose, containing diphenylamine and a coating of centralite. The first American powder designed for the 20mm A. A. gun was DuPont IMR powder #4356. The manufacturing formula was 100 parts of nitrocellulose, 1 part potassium sulphate and 0.6 part of diphenylamine. The characteristics and composition of the powder are given here:

Nitration	13.15%
DNT (coating)	6.04%
Diphenylamine	0.55%
Potassium Sulphate	0.68%
Total Volatiles	1.59%
Web	0.016

This was replaced soon by DuPont IMR powder #4831, a similar formula which was adopted for general use and has been used for all production lots. The changes from #4350 are indicated by the following data on IMR 4831:

98% of Nitrocellulose (13.15% N)  
1% of Potassium Sulphate  
1% of Diphenylamine  
Surface coating - Dinitrotoluene to give desired ballistics. Approximately 7 parts per 100 parts base grain.

Lot M/A 183, manufactured at Memphis for the British Purchasing Commission under the above formula, was chosen as the British Master Standard Powder. The service charge required to give 2725 ft/sec. at 70°F, was carefully determined in a number of guns. This charge was used also as a temporary standard for Navy production lots. Later, extensive firings were conducted with lots M/A 183, DSZ-2 and CDZ-27 to determine a service charge for 2725 ft/sec. at 90°F, and to select a master standard powder on the

basis of best velocity uniformity. DSZ-2 (SPDN-3025) was selected as the new master standard powder as a result of these firings. The service charge weight of SPDN-3025 was determined to be 423 grains. In July 1942 the service velocity of the 20mm A. A. gun was changed to 2740 ft/sec; the service charge weight of SPDN-3025 for this velocity was calculated to be 427 grains.

(b) Development of Test Procedure

Essentially, the method of determining the service charge of a production lot of powder has remained unchanged from the original scheme. This consisted first of establishing a velocity of the day by firing a certain number of service rounds of master standard powder; then a velocity vs. weight of charge curve was obtained by firing 10 rounds of the production lot at estimated service charge, 5 rounds at 100 ft/sec. below service, and 5 rounds at 50 to 100 ft/sec. over service. The service charge was determined by picking the point where the curve (a faired straight line) passed the velocity of the day. This procedure of matching the service charge of a master powder, was used in preference to the usual method (in other calibers), of determining a service charge for a definite service velocity by one firing in a new gun; this was done because it was recognized there were variations from gun to gun and variations from day to day in the same gun. Thus, what has come to be known as a "Matched Powder" procedure has always been standard practice in proving 20mm powder.

(c) Charge Determination for HE and HET Projectiles

From the beginning, charge determinations were fired with Mark 3, 123 gram projectiles, either inert or HE loaded. However, a complication arose in assigning powder charges for the assembly of service ammunition, because of the difference in weight between the Mark 3 HE projectile (123 grams) and the Mark 4, HET projectile (119 grams). If the same weight of charge were assigned to both projectiles the velocity of the HET projectile would be considerably higher. In consideration of this, separate charge determinations were made for each projectile so as to obtain the same velocity on all rounds. This arrangement quickly

proved to be unsatisfactory. The muzzle energy of the comparatively light HET projectile was considerably less than that of the HE projectile. This factor was of considerable importance to the functioning of the gun in automatic operation, as the muzzle energy directly affects the amount and length of the blowback of the recoiling bolt. Lesser energy associated with the light projectile interfered with the gun operation and caused failures to latch back and failures to eject the fired cartridge. This effect was aggravated by the service procedure of loading magazines with alternate HE and HET projectiles. A good part of the energy of the HET round was used up in absorbing the greater recoil of the preceding HE round, thus further reducing the recoil of the HET. The result of this experience was to assign the weight of charge determined for the HE projectile to both types of projectiles. In the interest of obtaining better gun operation, a difference in velocity and resulting range between the two types of projectile was tolerated. Even with this increased velocity the muzzle energy of the HET projectile remained appreciably lower than that of the HE projectile. Finally in June 1942 it was decided that the design of all 20mm A. A. projectiles be so modified as to make all projectiles 123 grams.

(d) Automaticity Test

These difficulties of gun operation were reflected in the powder proof specifications and procedures by the inclusion of an automaticity or automatic functioning, test. The service weight of charge having been determined, five service rounds were loaded with HE projectiles and five more with HET projectiles. These were loaded into a magazine so that they would be fired in alternate fashion, HE, HET, HE, HET, etc. Firing was conducted in a medium-worn barrel equipped with new barrel springs in order to insure a severe test. In the event of failure of the gun to operate satisfactorily during this test a similar ten-round alternate HE and HET burst was fired using the master standard powder. If this operated satisfactorily, the test powder was rejected; if it in turn failed, the automaticity test was repeated with the test powder under less severe conditions. This automaticity test was continued using alternate Mark 3 and Mark 4 projectiles on all production lots of powder until all

ammunition containing Mark 4 projectiles had been expended. At this time the test was modified by substituting the new Mark 7, 123 gram HET projectile for the old Mark 4, 119 gram HET projectile. Several hundred lots of powder were tested over the period of a year under the new conditions. No lot failed, even when fired in a gun worn considerably beyond the service life. Accordingly, the specifications were altered to abolish this automaticity test.

(e) Pressure

During the earliest firings with 20mm A. A. powders attempts were made to measure the chamber pressure. The measuring arrangement necessitated firing in a special, single-fire mechanism. Results were erratic, as the methods used involved a plunger piercing the cartridge case and then crushing a copper disc. The accuracy of results was questionable, and in addition it was felt that measurements in a single-fire mechanism did not accurately reflect the conditions existent in the automatic weapon. It was decided to discontinue attempts to measure chamber pressures in this fashion. At the same time it was demonstrated, by repeated firings without any gun casualties, that the cartridge case could be completely filled with powder and fired without causing pressures beyond the strength of the gun. This full load of approximately 490 grains was considerably higher than the service charge weight of approximately 420 to 440 grains. Hence, it was considered safe to operate the gun, without danger of excessive pressures from the propellant powder.

(f) Bolt Recoil

During 1942 a method was developed for measuring the bolt recoil of individual rounds in a burst. Such measurements were incorporated into the powder proof specifications as a substitute for pressure measurements. The requirement specified was that a ten round burst of each test lot of powder at the determined weight of charge give an average recoil which must not vary more than plus 5mm or minus 3mm from the average recoil of a group of service rounds of master standard powder fired at the same time. During this check of bolt recoils velocities were measured on all rounds, thus

obtaining a check on the accuracy of the original charge determination.

(g) Change of Service Velocity

The introduction of the Mark 3 and Mark 4 cartridge case to replace the Mark 2 in 1943 affected the muzzle velocities of all 20mm A. A. rounds. Because of the increased flash hole area, velocities were increased 25-30 ft/sec. At this time no adjustment was made in the service charge of the Master Standard Powder (SPDN-3025) so as to retain the 2740 f/s muzzle velocity. Instead, the service velocity was raised to 2770 ft/sec., and the service charge of SPDN-3025 remained unchanged at 427 grains.

2. Service Deficiencies

The major deficiency of the 20mm A. A. powder as it is now constituted is that it produces an objectionable amount of smoke. It is not too apparent when a single gun is firing, but there have been a number of complaints from the fleet to the effect that under battle conditions, when several 20mm A. A. guns in close proximity are operating, the cloud of smoke produced is often sufficiently dense to obscure the target. Omission of potassium sulphate from the powder reduced the smoke only slightly and introduced undesirable flashing characteristics.

3. Adequacy of Present Design

Except for the undesirable smoke characteristics, the present formula and design of smokeless powder are adequate.

4. Adequacy of Present Effective Specifications

(a) The specifications currently in effect for the proof of 20mm smokeless powder are:

BuOrd ltr S78/20mm (Pr6) dated 19 Jan. 1942.  
BuOrd ltr S89/20mm (Pr6a) dated 27 Jan. 1942.  
BuOrd ltr S78/20mm (Pr6a) dated 9 July 1942.  
BuOrd ltr S78-1(51) (Pr6a) dated 27 July 1942.  
BuOrd memo to Chief of Ordnance, War Dept.  
EW16/S78-1(51) dated 15 Aug. 1942.  
BuOrd ltr NP9/S78(Re2d) dated 19 Aug. 1943.  
BuOrd ltr NP9/S78(Re2d) dated 26 April 1944.  
BuOrd ltr NP9/S78(Re2d) dated 16 Sept. 1944.  
BuOrd ltr S78(20mm)(Re2a) dated 11 Aug. 1945.

- (b) These specifications appear to be adequate to produce the desired ballistic properties. Moreover, test data over the past year and a half indicate that the specification concerning bolt recoil is unnecessary, inasmuch as no lot of powder during that period of time has failed to match the recoil of the Master Standard Powder within the specification limits.

5. Suggested Fields for Improvement

It is suggested that:

- (a) Further investigation of powders of different chemical compositions be made in an attempt to achieve the ideal of a flashless, smokeless round.
- (b) The recoil check be eliminated from the powder proof specifications.
- (c) The various directives which comprise the specifications for proof of 20mm powder be combined in one Ordnance Specification.

II.

PROPELLANTS

B. - 1710/75 Caliber Gun

1. Short History of Initial Development and Subsequent Developments, Changes, Improvements

By 1 September 1939 the smokeless powder for the 171 gun had been developed to its present form. A representative composition is as follows:

Nitrocellulose	89%
Dinitrotoluene	10%
Diphenylamine	1.00%
Web thickness	.0315

The physical condition of the powder was and remains a single-perforated grain, graphite coated. There have been no changes in the formula of manufacture of the powder. New specifications regarding uniformity of velocity and pressure became effective in August 1943; the change increased the maximum allowable mean variations of velocity and pressure from 0.625% to 1% and from 3.125% to 5% respectively. Until May 1944 test lots of powder were proved by the "New Gun" method, calculating a service charge for a 2700 f/s velocity in a new gun. This method was superseded by the "Matched Powder" method in May 1944.

2. Service Deficiencies

171 powder gives rise to consistent and very large flashing. Rounds assembled with this type of powder also copper the barrel within 100 rounds, when lead foil or powdered lead is not added to the charge.

3. Adequacy of Present Design and Specifications

Except as regards flashing the present design produces a powder with the desired ballistic properties. The specifications are adequate to insure achieving the desired properties.

4. Suggested Fields for Improvement

In view of the fact that the 171 gun is obsolete, it is suggested that no further investigation of powder for this gun be undertaken

II.

PROPELLANTS

C. - 40mm/60 Caliber A.A. Gun

1. Short History of Initial Development and Subsequent Developments, Changes, Improvements

(a) General

The foreign powder furnished for the 40mm Bofors gun when it was introduced to the United States, was a single base, high-nitrogen nitrocellulose powder with diphenylamine stabilizer, and centralite as a coating material. It was in strip form, approximately 9"5 x 0"52 x 0"036. Various Army 37mm and 75mm powders and Navy 3"/23 and 6 pounder powders were fired in the 40mm Bofors and found unsatisfactory. During 1941 a number of special powders were developed for the gun. One sample of double-base (20% nitroglycerine, 75% nitrocellulose) powder was prepared in August 1941 by the Hercules Powder Company but was discarded. All the rest of these special powders were the FNH type of the following general compositions:

85% Nitrocellulose (NC)  
 10% Dinitrotoluene (DNT)  
 5% Dibutylphthalate (DBP)  
 1.05% Diphenylamine added

Some of the samples prepared contained 1% potassium sulphate for flash suppression. All were the cylindrical grain type with seven perforations; web size of the samples varied from "0176 to "0209.

(b) Production Samples

During September 1941 the following four samples of powder were tested at the Naval Proving Ground:

Sample	Web Size	Diphenylamine	Pot. Sulphate
EX-4848	"0209	1.05%	1%
EX-4849	"0207	1.05%	None
EX-4862	"0176	1.05%	1%
EX-4863	"0179	1.05%	None

The Naval Proving Ground letter S78(40mm)(B17273) dated 1 October 1941 reported that samples EX-4848 and EX-4849 were too slow for the 40mm gun and that EX-4862 and EX-4863 were satisfactory ballistically.

Subsequent tests at the Army Proving Ground indicated that EX-4862 was too fast. Accordingly, later experimental samples were made with web size of about #0195, which slowed down the powder. The formula used in the manufacture of lot RHU-1, the first production lot made specifically for the U. S. Navy was as follows:

Nitrocellulose	82.95
Dinitrotoluene	10.00
Dibutylphthalate	5.00
Potassium Sulphate	1.00
Diphenylamine	1.05
Web Size	#0185

This formula has been used for all subsequent 40mm powder production, with slight modification in the web size.

(c) Development of Proof Procedure

Proof of powder was conducted in accordance with O.P. 366 and Chapter 10 of the Proof Regulations of the Naval Proving Ground. The service velocity of the gun was established as 2890 f/s, the service pressure limits as 17.5 tons/sq.in. minimum and 19.5 tons/sq.in. maximum. The specifications for uniformity limits were .625% of the mean velocity and 3.125% of the mean pressure. These uniformity limits were changed by BuOrd letter NP9/S78(Re2d) dated 19 August 1943 to become .6% of the mean velocity and 5% of the mean pressure. The latter specifications are currently in effect. Originally the determination of service charge was accomplished by firing a Charge vs. Velocity curve in a new 40mm gun and picking off the service charge at 2890 f/s. This was known as the "New Gun" method. This was superseded in 1943 by the "Matched Powder" method wherein service rounds of a carefully calibrated Master Standard Powder (SPDN-3804) were fired to establish a service velocity and pressure, against which the service charge and pressure of the test lot of powder were calculated.

(d) Effect of Various Components on Smokeless Powder

The introduction of the Mark 11 tracer, which increased the weight of projectile from 1.97 to 1.985 pounds, and of the Mark 3 (steel) cartridge case, with greater wall thickness, which decreased the

effective chamber volume, necessitated slowing the powder down in order to keep the service pressure within the specification limits of 17.5 to 19.5 ton/sq.in. This was accomplished by increasing the web size and changing the drying procedure so as to retain a slightly higher percentage of residual volatiles. Inert loaded projectiles were originally used in powder proof determinations. However, it was discovered that the ballistic behavior of these projectiles was somewhat erratic. The procedure was changed, and TNT-loaded projectiles were substituted and are still used.

## 2. Service Deficiencies

The major deficiency of the 40mm A. A. powder as now constituted is that it produces an objectionable amount of smoke. Various steps have been taken in attempting to make the 40mm round smokeless. Omission of lead foil from the charge reduced the smoke somewhat. Omission of potassium sulphate from the 40mm powder likewise gave a consistent but small decrease in smoke. Substitution of 1#1 powder for the regular 40mm powder, together with the omission of lead foil, reduced the smoke to practically nothing; however, two serious difficulties were encountered, viz., extremely large and consistent muzzle flashes, and coppering of the gun barrel within 100 rounds. (Regular production 40mm powder can be used without lead foil for more than 6000 rounds without evidence of coppering).

## 3. Adequacy of Present Design

Except as regards the smoke producing characteristics, the present design and formula of 40mm smokeless powder appear to be adequate.

## 4. Adequacy of Present Effective Specifications

- (a) Following is a list of specifications now applicable to the proof of 40mm powder:

O.P. 366

Proof Regulations of the Naval Proving Ground,  
Chapter X.

BuOrd ltr NP9/S78(Re2d) dated 19 Aug. 1943.

BuOrd ltr NP9/S78(Re2d) dated 19 Feb. 1944.

BuOrd ltr NP9/S78(Re2a) dated 16 May 1944.

BuOrd ltr S78-1(50-40mm)(Re2d) dated 11 July 1944.

BuOrd ltr S78-1(51)(Pr6a) dated 7 Sept. 1944.

NPG ltr S78-1(50)(BMO 79790) dated 20 Dec. 1944.

BuOrd ltr NP9/S78(Pr6a-1) dated 12 Feb. 1945.  
BuOrd ltr EW16/S78(Pr6a-1) dated 16 Feb. 1945.  
BuOrd ltr S78-1(51)(Re2a) dated 5 May 1945.

- (b) These specifications appear to be adequate, except that specifications for lots of smokeless powder to be used with A.P. projectiles should be clarified.

5. Suggested Fields for Improvement

It is suggested that:

- (a) Investigation of powders of new chemical compositions be inaugurated in order to find a flashless, smokeless round.
- (b) Specifications for powder lots destined for use with A.P. projectiles be clarified.
- (c) The miscellaneous directives comprising the specifications for proof of 40mm powder be combined into an Ordnance Specification.

### III.

### PROJECTILES

#### A. - 20mm/70 Caliber A. A. Gun

#### 1. Short History of Initial Development and Subsequent Developments, Changes and Improvements

##### (a) HEI Projectile

The early stages of experimental work with 20mm projectiles were conducted using lend-lease ammunition obtained from the National Fireworks Company, which was at that time loading ammunition for the British. In January 1942 the British indicated that the incorporation of an incendiary element greatly improved the destructive effects especially against aircraft. Tests at the Proving Ground corroborated British findings. British methods of loading the incendiary consisted of inserting a small amount of black powder between the incendiary mix, which was the first increment of loading, and the second increment of tetryl. This method was quite complicated and was not readily adapted to production loading. Further experimenting was conducted in an effort to simplify the above procedure. It was determined that the black powder was unnecessary for propagation. Final loading of incendiary type ammunition using projectiles designated Mark 3 was as follows:

First Increment: Incendiary mix (64 grain pellet) consisting of Magnesium, Aluminum, Barium Nitrate, Paraffin and Graphite.

Second Increment: Tetryl pellets (2 or 3) - 128 grains total.

##### (b) Pentolite Loading

In June 1942, experiments were conducted to determine the suitability of Pentolite as a projectile filler for the HE type projectile. At this time there were a number of gang pelleting machines available for loading of Pentolite. Although test results with Pentolite were comparable to the standard tetryl loading, this filler was never adopted for production loading.

(c) HET Projectile

The Mark 4 projectile was the designation given the first tracer type of 20mm Oerlikon ammunition used in this country. This projectile was a replica of the British HET projectile. The Mark 4 projectile weighed approximately 60-70 grains less than the Mark 3 used for HE and HEI loading. This weight differential resulted in two unfavorable features in that this lighter projectile caused unsatisfactory gun performance because of short blowbacks and also had a range variation from the standard Mark 3. This difficulty was overcome by the design of the Mark 7 projectile which was similar to the Mark 4 but equal in weight to the Mark 3. The Mark 7 projectile was adopted for all HET loading after the fall of 1943.

(d) Armor-Piercing Projectile

The first type of armor-piercing projectile put in production by the U. S. Navy was designated Mark 8. The windshield used on this projectile was of a plastic composition which proved unsatisfactory because these windshields disintegrated in flight. The Mark 9 AP projectile with a steel windshield was then developed, proved satisfactory, and was put in production in the latter part of 1944. Development work was conducted also on a Mark 10 AP projectile. The main difference between the Mark 9 and 10 is in the size of the windshield. The windshield of the Mark 10 is slightly longer, and the after end serves as a bourrelet, whereas the projectile body of the Mark 9 acts as a bourrelet. Although the Mark 10 gave comparable performance to the Mark 9, the Mark 10 was never placed in production.

(e) Streamlined Projectiles

Since the middle of 1943 the Bureau has been in the process of developing streamlined projectiles that would be suitable replacements for the Marks 3, 7 and 9 projectiles. The most recent test was conducted during the spring of 1945. Comparative ranging tests were conducted using standard Marks 3 (HEI), 7 (HET) and 9 (AP). The streamlined HEI (Sk. #124288) and HET (Sk. #120560) projectiles had a range 300 to 400 yards greater than the standard projectiles when fired at low angles up to 5°

elevation. The streamlined AP (Sk. #140676) also had a greater range than the Mark 9 projectile, but had a significantly larger range dispersion. Present development of the experimental AP projectile is being conducted so as to improve the stability factor.

2. Service Deficiencies

The major service deficiency of present production 20mm A. A. and A. P. projectiles is the short effective range of the projectiles. This condition can be overcome to a considerable degree by the introduction of the new streamlined projectiles. However, before this substitution can be made for all types of projectile, the streamlined A.P projectile must be further developed to improve the stability factor, because in its present state the projectile has an unsatisfactory range dispersion.

3. Adequacy of Present Design

The design of the 20mm projectile now in use is inadequate because the external contours of the projectile are such as to cause a shortened range. The projectile has already been redesigned in this respect, and the new streamlined design represents a definite improvement. In addition the tracer cavity of the present Mark 7 projectile is larger than necessary for the amount of tracer pyrotechnic used; this necessitates insertion of a certain amount of inert material in the tracer cavity, which practice is considered objectionable.

4. Adequacy of Present Effective Specifications

(a) A. A. Projectiles

O.S. 2337 (Minor Caliber Projectiles) and BuOrd Drawings Nos. 294290 and 329164, for the Mark 3 and Mark 7 projectiles respectively, constitute the present effective specifications for 20mm explosive-loaded A.A. projectiles. These specifications are adequate to insure the proper performance of the projectiles within the limitations of the present design.

(b) A. P. Projectiles

O.S. 2806 (Minor Caliber Projectiles) and BuOrd Drawing No. 423661, for the Mark 9 projectile, constitute the present effective specifications for the 20mm A.P. projectile. O.S. 2806 is inadequate

and is in the process of being revised. Recommendations regarding this revision have previously been submitted to the Bureau by the Proving Ground.

5. Suggested Fields for Improvement

It is suggested that:

- (a) The present Mark 3, Mark 7, and Mark 9 projectiles be replaced by corresponding projectiles of streamline design.
- (b) Tracer cavity of the Mark 7 projectile or its streamlined replacement be redesigned so as to eliminate the necessity for placing inert material in the tracer cavity.
- (c) O.S. 2806 be revised.

### III.

### PROJECTILES

#### B - 1.1/75 Caliber Gun

#### 1. History of Developments, Changes and Improvements

##### (a) General

During the development of 1.10 ammunition two (2) types of projectiles Mark 1 and Mark 2 were utilized. Both projectiles were designed with an integral tracer. The Mark 2 was designed with greater wall thickness in the tracer cavity to withstand greater pyrotechnic consolidating pressures. Although the 1.10 gun was one of the most common small caliber A.A. guns at the time of the entry of the United States into World War II, the performance of the ammunition for this gun was unsatisfactory because of high percentages of tracer duds and premature explosions. Early in 1942 the Naval Ordnance Laboratory was directed to improve the tracer action, a project to be carried on with the development of the self-destruction feature.

##### (b) Redesign of Tracer Cavity

Experiments revealed that available pyrotechnics at this time required very high consolidation pressures to result in satisfactory performance. Since the tracer cavity walls of the Mark 1 was too thin to withstand these high consolidating pressures it was decided to redesign the Mark 1 projectile increasing this wall thickness. This design resulted in the Mark 2 projectile.

##### (c) Mark 2 Projectile

Numerous tests were conducted in the Mark 2 projectile utilizing the standard 1.10, U. S. Rubber Company and Triumph Explosive pyrotechnics, incorporating various loading techniques. As mentioned previously, the high loading pressures resulted in the best tracer performance. However, it was found that the maximum pressures obtainable using the Mark 2 projectile was 70,000 p.s.i. Pressures higher than this resulted in excessive swelling of the tracer stock, which in turn caused tracer duds, blowouts, and prematures.

(d) Mark 1 Projectile

While the above tests were in progress the Bureau of Ordnance decided that, because of the large quantity of Mark 1 projectiles on hand, it seemed advisable to develop a suitable tracer loading using the self-destruction feature in this projectile. With the Mark 1 projectile it was found that the maximum loading pressure that could be utilized in the hub of the tracer was 60,000 p.s.i. The tracer within the stock of the projectile body itself could withstand 100,000 p.s.i. Loading pyrotechnics under these two (2) pressures in two increments resulted in a very dim tracer. Production loading under these pressures was again unsatisfactory. In the fall of 1944 the tracer body was redesigned again increasing its size from O#660 to O#700. Firing of these projectiles loaded at approximately 80,000 to 100,000 p.s.i. under laboratory conditions resulted in satisfactory performance and it was thought that these projectiles would be satisfactory for production loading. However, at this time the 1.10 gun was rapidly being replaced by the 40mm gun and the project was officially closed prior to any production loading of these projectiles.

2. Suggested Fields for Improvement

Since the 1.1 gun is obsolete, it is suggested that no further investigation of 1.1 projectiles be undertaken.

III.

PROJECTILES

C. - 40mm/60 Caliber A.A. Gun

1. Short History of Initial Development and Subsequent Developments, Changes and Improvements

(a) General

Preliminary testing of 40mm ammunition was started in early 1941 in conjunction with tests on the Bofors gun itself. Early experimentation was conducted using British ammunition and by September of that year testing of projectiles, designated Mark 1, manufactured in this country was initiated. The Mark 1 projectile was comparable to the British ammunition used during initial tests.

(b) Mark 2 Projectile

In the latter part of 1943 the pilot lot of Mark 2 projectiles was tested at the Proving Ground. This projectile differed from the Mark 1 only in minor manufacturing changes. Shortly thereafter all production of high explosive type projectiles was concentrated on the Mark 2 projectile.

(c) Mark 3 Projectile

The Mark 1 and Mark 2 projectiles are designed so as to accommodate a threaded fuze on the forward end and either a threaded tracer or a base plug in the after end, according to the type ammunition desired. Because of the great demand for non-traced type of ammunition in the latter part of 1944, it was decided to design a projectile with a solid base thereby eliminating the necessity of a base plug and facilitating loading. The pilot lot of Mark 3 (solid base) projectiles was tested at the Proving Ground in the early part of 1945. Because of the rapid changes in service demands to dark tracer and delay ignition tracer at this time the Mark 3 was never put in production.

(d) A.P. Projectile

The armor-piercing type projectile used by the Navy is an Army design manufactured for the Navy to Navy specifications. This type projectile, designated M81A1, consists of a solid slug with steel windshield

attached, resulting in an overall projectile length slightly less than the explosive loaded projectiles. The base of the A.P. projectile is designed to accommodate an integral tracer. When no tracer is desired the cavity is filled with a wooden plug.

2. Service Deficiencies

At the present time the only service deficiency reported is an occasional unsatisfactory windshield crimp on the A.P. M81A1 projectile. In tests at the Naval Proving Ground the windshield crimping has been considered satisfactory, but there have been occasional complaints from the service about thrown windshields.

3. Adequacy of Present Design and Present Effective Specifications

(a) A.A. Projectiles

Present design and effective specifications for 40mm A.A. projectiles are given in BuOrd Drawings Nos. 328536 (Mark 2 Proj.) and 39380 (Mark 3 Proj.), and O.S. 2337 (Minor Caliber Projectiles). The design and specifications are adequate.

(b) A.P. Projectiles

Present design and effective specifications for 40mm armor-piercing projectiles are given in Army Ordnance Dept. Drawing 75-2-321 (M81A1 Proj.) and O.S. 2806. This Ordnance Specification is considered inadequate and is currently under revision by the Bureau. Recommendations regarding this revision have previously been submitted to the Bureau by the Proving Ground.

4. Suggested Fields for Improvement

It is suggested that O.S. 2806 be revised.

#### IV.

#### TRACERS

##### A. - 20mm/70 Caliber A. A. Gun

##### 1. Short History of Initial Development and Subsequent Developments, Changes and Improvements

##### (a) General

Initial testing of traced ammunition was conducted using igniters and pyrotechnics developed by the British. At the end of 1942 the Bureau of Ordnance received reports from the fleet that this type of traced ammunition gave too much muzzle flash and too bright a streak upon firing. During night firing this light created a double hazard in that it silhouetted the firing ship and blinded the gunners after a few seconds of firing. As a result of the undesirable characteristics of this type 20mm tracer the Bureau directed that a tracer be developed having a dark igniter that would not give more than a faint streak of light until the projectile reached a distance of 75 to 125 yards from the gun, at which point the tracer could be picked up and followed by the gunner. In addition the Bureau directed that substitute materials be found for the critical materials, chlorinated rubber and shellac, that were constituents of the standard tracer.

##### (b) Original Tracer Composition

The original 20mm tracer consisted of strontium nitrate and magnesium as a base, with shellac as a binder, beeswax as a lubricant and chlorinated rubber as a color intensifier. It was thought that a satisfactory mixture could be made by replacing the chlorinated natural rubber with similarly processed synthetic rubber, while at the same time replacing or eliminating the shellac. Several attempts were made, but the resulting mixtures were unsatisfactory either because of insufficient light, too much smoke, or failures to ignite. Additional experiments using Vinsol resin and hydrofol glyceride resulted also in unsatisfactory performance.

##### (c) Development of R-131 Pyrotechnic

Experiments with a Swedish mixture that used strontium tartrate produced a satisfactorily burning tracer, but was not suitable for production loading because of the

impossibility of forming the mixture into firm pellets. In addition this mixture was not sufficiently sensitive to flame. The pyrotechnic finally adopted for production loading in delayed ignition tracers was designated R-131. This mixture was made up by adding strontium tartrate to a basic strontium nitrate-magnesium mixture. Hexachlorobenzene was included to enrich the color. Stearic acid replaced the beeswax as a binder, eliminating the necessity of preparing the mixture hot, and in addition making it possible to pellet the mixture. The charcoal improved the ignitability of the mixture. Composition and percentages by weight of the R-131 pyrotechnic are listed below:

Magnesium	- 31.8%
Strontium Nitrate	- 30.9
Strontium Tartrate	- 27.3
Hexachlorobenzene	- 4.6
Charcoal	- 0.9
Stearic Acid	- 4.5

(d) Dark Ignition Tracer

Development of the dark ignition igniter proceeded from British mixtures which made use of potassium dinitrophenate as a fuel, barium peroxide as an oxidizing agent and bakelite varnish as a binder. Because this mixture required insertion of another mixture between it and the pyrotechnic to effect ignition of the latter, it was considered unsatisfactory. Mixtures containing barium peroxide and antimony sulfide were found to give a much faster rate of burning than the British mix and subsequent mixtures tested. Friction sensitivity caused a great deal of trouble in handling the barium peroxide-antimony sulfide mixture but was greatly decreased by the addition of a small amount of graphite. To give the slight streaking effect described heretofore required the addition of a small percentage of magnesium. The composition of the igniter, designated D.I.-149F, adopted for service use is listed below:

Barium Peroxide	- 78.4%
Antimony Sulfide	- 18.4
Magnesium	- 2.2
Graphite	- 1.0

Subsequent specification written to cover this type of ammunition specified that the total burning

time of the dark-ignition tracer should be from 3.5 to 4.5 seconds. The average burning time of the standard tracer when loaded in the Mark 7 projectile is approximately 6 seconds. To satisfy the dark-ignition tracer requirements it was necessary to load approximately 3 grams of an inert material so as to decrease the burning time.

2. Service Deficiencies

The only service deficiency of the 20mm tracer is the blinding effect of the original bright-streaking tracer on the gunner during night firing. This has been overcome by the substitution of the dark ignition tracer.

3. Adequacy of Present Design and Present Effective Specification

The design and formula of the dark ignition tracer, which has superseded the original bright-streaking tracer, together with manufacturing and testing specifications are included in O.S. 3425. These specifications and design are considered adequate.

IV.

TRACERS

B. - 40mm/60 Caliber Gun

1. Short History of Initial Development and Subsequent Developments, Changes and Improvements

(a) General

The tracer for 40mm high explosive projectiles differs from other U. S. Navy tracers in that it is required to inaugurate the self-destruction of the projectile after a prescribed time of flight. The tracer originally selected for the H.E. projectile assembly was of British design and was designated the Mark 8. This type tracer differed from standard Navy tracers in that it was sealed from contact with the flame of the propellant, ignition being accomplished by a percussion primer cap through set-back forces when the gun was fired.

(b) Mark 8 Tracer

Very unsatisfactory performance resulted during the testing of the Mark 8 tracers mainly because of the high percentage of prematures. This type tracer had additional disadvantages in that its complicated construction was not readily adaptable to mass production methods, and because of the hazard to personnel and equipment associated with the tracer parts expelled as the projectile left the gun muzzle. Tests revealed that it was possible for the lead sealing discs to penetrate 1/8" steel plate at a distance of 60 feet from the gun muzzle.

(c) Mark 10 Tracer

In the fall of 1942 the Mark 8 tracer was redesigned increasing the wall thickness in an effort to eliminate the high percentage of prematures. This new tracer was designated Mark 10. Although the Mark 10 was a definite improvement over the Mark 8 from the standpoint of performance and subsequently was used in the assembly of several million rounds of of service ammunition, it still retained the basic principles and consequently the disadvantages of the Mark 8.

(d) Mark 11 Tracer

Because of these disadvantages, the development of a direct ignition tracer was initiated early in 1943.

This tracer, designated Mark 11 was much simpler in design than its predecessors. The Mark 11 tracer is sealed with a brass disc which disintegrates on the explosion of the propellant charge. After rupturing of this disc the starter mixture is ignited which in turn burns through and ignites the pyrotechnic mixture. After a prescribed burning time the projectile is exploded through a small thermal relay containing black powder located in the base of the tracer body. Some difficulty was encountered during initial loadings of the Mark 11 tracer body because of inconsistent burning times, and some prematures and tracer duds. After successive experiments using various loading pressures and multi-shaped loading rams it was found that tracer performance was greatly improved under pyrotechnic loading pressures of 90,000 to 110,000 p.s.i., and using a stepped-face ram which increased the ignition surface.

(e) Special Types of Mark 11 Tracer

After attaining satisfactory results using the Mark 11 tracer body there was a demand from the fleet for "special" tracers as outlined below:

Dark-Ignition Tracer - should burn dark for a distance of about 200 yards after which tracer should burn normally to self-destruction with a minimum self-destruction time of ten (10) seconds.

Dark Tracer - should burn so as to be invisible from any point of observation during night firing having a minimum time to self-destruction of ten (10) seconds.

Daylight Tracer - having visibility in bright daylight of at least seven (7) seconds with the unaided eye and a minimum self-destruction time of ten (10) seconds.

Development of these three types of tracers was conducted simultaneously by the Naval Ordnance Laboratory and production loading plants. Experiments were conducted using various types of igniter and pyrotechnic mixtures, loading pressures and rams.

(1) Dark Tracer

By the spring of 1944 the Naval Ordnance Laboratory developed what appeared to be a

satisfactory igniter and pyrotechnic mixture that would meet the dark tracer requirements. Production loading of eleven (11) lots using this mixture resulted in very unsatisfactory results because of high percentage of duds. Early in 1945 a satisfactory mixture was developed for the dark tracer that could be successfully loaded by the production plants. The ingredients used in type and its designation are listed below:

Igniter (D.I.-152) - Barium Peroxide, Selenium and Graphite.

Pyrotechnic (D.T.-226B) - Barium Peroxide, Antimony Sulfide, Asphaltum and Graphite.

(2) Delayed-Ignition Tracer

In 1945 a satisfactory mixture, suitable for production loading, was developed for the delayed-ignition tracer. The ingredients and designation are listed as follows:

Igniter (D.I.-152) - Barium Peroxide, Selenium, and Graphite.

Pyrotechnic (R-132) - Strontium Nitrate, Strontium Tartrate, Magnesium, Carnauba Wax and Charcoal

(3) Daylight Tracer

Development of a satisfactory tracer having long visibility in bright daylight has been unsuccessful up to the present time. Experiments have been conducted using Mark 11 tracer bodies with an enlarged bore and a special long tracer body (BuOrd Sk. #140046) loaded with various types of tracer mixtures in an effort to increase the brightness qualities of the tracer. Although the demand for 40mm ammunition is now restricted to training and practice uses the Bureau of Ordnance has directed the Naval Ordnance Laboratory to continue development work on a tracer that will give visibility in bright daylight for approximately seven (7) seconds and burning time of twelve (12) to fourteen (14) seconds.

(f) Mark 14 Tracer

Early in 1945, the service requested a traced, non-self-destroying type of ammunition to be used for

bombardment attacks. To meet the immediate demands the self-destruction feature was eliminated by filling the tracer relay cavity in the standard Mark 11 tracer body with an inert material rather than the normal black powder charge. However, this did not result in 100% non-self-destruction performance, apparently because of leakage around the relay body. To remedy this situation, the Mark 11 tracer body was redesigned to the extent of eliminating the relay and making the base of the tracer body solid. This new tracer body was designated Mark 14 and was used in UL type (HEIT - no SD) ammunition assemblies after March 1945.

2. Service Deficiencies

The deficiencies encountered in the service use of the 40mm tracer are that the tracer is not visible for a sufficiently long time during bright daylight and the burning times of the dark tracer and delayed ignition tracers are too short.

3. Adequacy of Present Design and Present Effective Specifications

Design and specifications for the Mark 11 Tracer are furnished in BuOrd Drawings Nos. 423429 and 423430 and O.S. 2978. Except as noted in paragraph 2, above, the design and specifications are adequate. BuOrd Drawing No. 440297 establishes the design of the Mark 14 tracer. There is no Ordnance Specification available for this tracer.

4. Suggested Fields for Improvement

It is suggested that:

- (a) Development work on a tracer for visibility in bright daylight be continued.
- (b) An Ordnance Specification be prepared for the Mark 14 tracer.
- (c) Primary consideration in future development be given to a universal day and night dark-ignition tracer wherein the pyrotechnic (or several pyrotechnics in succession) burns dimly or invisibly to the point of changeover from igniter to pyrotechnic, but progressively brightens during flight.

V.

FUZES

A. - 20mm/70 Caliber AA Gun

1. Short History of Initial Development

The antiaircraft model of 20mm AA Oerlikon type gun, mount, ammunition and accessories was adopted by the U.S. Navy in 1941. Production was started on guns and ammunition made according to designs and drawings furnished by Great Britain, which country had previously adopted this gun as a Naval weapon. As late as 1940, the British were using a rotor type percussion fuze armed by centrifugal force and employing a plunger and striker forced inward on impact. However, the fuze adopted by the U.S. Navy was that of a later British design known as the "254" or "H.E. 254" which had no moving parts and was much simpler in construction. This fuze is of the air-column type, its action being initiated by impact. The American version of this fuze was assigned the designation Mark 26 Mod. 0.

2. Subsequent Changes, Developments and Improvements

(a) General

The Mark 26 fuze (and Mods.) was used exclusively on ammunition for the 20mm AA gun throughout World War II. Although two Mods. have been added to the original, the fuze has not been changed radically and it remains one of extremely simple construction. The action of the fuze was first believed to be initiated by heat resulting from compression of air in a channel above the detonator but later this theory was partially discarded, and it is considered that the action is primarily that of a shocking force which causes a direct disturbing action on the detonator. This fuze is an exception to the cardinal requirement of Navy fuzes that they be "detonator safe." The design incorporating a detonator permanently in line with the booster was accepted in the case of the fuze Mark 26 because of the relatively small amount of explosive filler in a 20mm projectile, resulting in relatively slight danger to personnel in case of a premature, and because the detonator contains straight azide and tetryl instead of supersensitive azide priming mixture. This design permitted maintenance of the necessary rate of production of vast quantities of ammunition and kept down the cost. The fuze is abnormal in one

other respect viz., the shape. The flat nose has been recognized as being detrimental to the best ballistics and preliminary tests have been conducted using a fuze with a streamlined body designated 6-c.

(b) Mark 26 Mod. 0

After the ballistic requirements were established, early experiments were directed toward increasing the sensitivity and percentage performance. Various modifications and loadings were tested, one of which later was developed into the Mods. 1 and 2 type. The design originally started out as the double detonator type in which the explosive charge was increased. A firing pin type also was tried but was discarded in favor of the double detonator type. Close cooperation was maintained with the British Technical Mission which did proof testing and development work of lend-lease ammunition at their range in this country. Production of the Mod. 0 fuze was discontinued in favor of the Mods. 1 and 2. The Mod. 0 fuze consisted of five parts as follows:

1. Body
2. Closing disc (spun into the nose of the body)
3. Rear disc (forms open channel to detonator)
4. Detonator (lead azide and tetryl)
5. Magazine

(c) Mark 26 Mods. 1 and 2

In the interest of simplification, experimental bodies of machined brass stock with a solid nose were manufactured and tested and found to be satisfactory. This fuze with other changes (magazine with intermediate charge and fuze with no rear disc) was later designated Mod. 2. In the same period the Mod. 1 fuze which differs only in material (zinc die cast body instead of brass) was developed. The Mods. 1 and 2 consist of four parts as following:

1. Body (solid-nose type)
2. Detonator (lead azide and tetryl)
3. Magazine
4. Magazine charge (tetryl)

The Mod. 1 is by far the most common type now in service. Since September 1944 this has been the only standard design under manufacture.

3. Service Deficiencies Known to the Proving Ground

The overall performance of the Mark 26 Mod. 1 fuze is considered very satisfactory, the percentage of any malfunctionings being very low.

4. Adequacy of Present Design

The Mark 26 Mod. 1 fuze as presently designed is considered satisfactory in that it has resulted in very good performance when fired against targets within 1000 yards range.

5. Adequacy of Present Effective Specifications

O.S. 2347 dated 2 August 1945 SPECIFICATIONS FOR THE MANUFACTURE, ASSEMBLY, LOADING AND INSPECTION OF POINT DETONATING FUZE MARK 26 MOD. 1 is presently adequate.

6. Suggested Fields for Improvements

It is suggested that further research be conducted using the streamlined fuze bodies mentioned in paragraph 2 (a) to obtain optimum characteristics in regard to functioning, sensitivity and safety.

V.

FUZES

B. - 1710/75 Caliber Gun

1. Short History of Initial Development and Subsequent Developments, Changes and Improvements

(a) Mark 12 Fuzes

In January 1939 the fuze used for 1710 ammunition was the Mark 12, Mods. 2 and 3. Production of the Mark 12 Mod. 2 fuze by the Naval Gun Factory and Pollak Manufacturing Company was started early in 1938. Mods. 2 and 3 differed only in the manufacturers of the inert parts. They contained additional safety features to prevent occasional prematures in the bore or close outside, which had been encountered in the use of the Mark 12 Mods. 0 and 1 fuzes. The firing pin was first "eared" to prevent its moving back against the detonator until impact and later a thin washer was placed between the forward part of the firing pin and the nose. On impact, both the "ears" and the washer must be deformed.

(b) Mark 34 Mod. 0

Because of the simplicity and the highly satisfactory performance of the 40mm point-detonating fuze Mark 27 Mod. 1, this design for the most part was copied in making a new fuze for the 1710 gun. The one important difference is the method employed to secure the rotor in the unarmed position. This is the only fuze in the U.S. Navy which employs the sliding setback block and shear wire feature for this purpose. The Mark 34 fuze superseded the Mark 12 type design. Production of Mark 34 fuzes was started in early 1943 by Triumph Explosives, Incorporated. Several contractors supplied inert parts and other contracts were let for loading and assembly, but production was terminated in 1944.

(c) Mark 34 Mod. 1

The Mod. 1 employs "hour-glass" firing pin detents. This type is more bore-safe than the earlier cylindrical type but, although the design and testing was completed, the manufacture and loading of the Mark 34 type fuzes was discontinued prior to the production of any of the Mod. 1 variety.

2. Service Deficiencies Known to the Proving Ground

(a) Mark 12 Fuzes

The most serious deficiency of these fuzes is the relatively high percentage of prematures. Considerable quantities of these fuzes are on hand in the Mod. 2 and 3 versions but data gathered during World War II was meager due to the program of replacing 1.10 guns by 40mm guns. Because of this and since a superior fuze has been developed in the form of the Mark 34, deficiencies are of small consequence except for evaluating the fuzes already on hand.

(b) Mark 34 Fuzes

Because of the replacement of the 1.10 gun by the 40mm gun and because of the recent introduction of this fuze into the Naval Service, data on its performance likewise is meager. As noted previously, the Mod. 1 type never got into production. However, because of the similarity with the Mark 27 fuze and the parallelism between Mods., it is assumed that the performance and likewise the deficiencies are similar.

3. Adequacy of Present Design

Inasmuch as the 1.10 gun is becoming obsolete and in view of sizeable quantities of useable fuzes on hand, this item does not merit further consideration.

4. Adequacy of Present Effective Specifications

(a) Nos. and Titles

- (1) O.S. No. 1001 ORDNANCE SPECIFICATION TO GOVERN THE MANUFACTURE, INSPECTION AND TESTING OF DETONATING FUZE MARK XII-2, REV. (B), dated 11 March 1938.
- (2) O.S. No. 2870 SPECIFICATIONS FOR THE MANUFACTURE, LOADING AND INSPECTION OF POINT DETONATING FUZE MARK 34 dated 24 May 1943.

(b) Comments

Since production has been stopped on both Mark 12 and Mk. 34 fuzes for sometime past and since no future production is anticipated, no specifications are presently in use. If commencement of production should again be planned, the specifications should be reviewed and modernized, especially O.S. No. 1001.

5. Suggestions

It is suggested that the 1710 gun (and ammunition including fuzes) be declared obsolete as the production and installation of 40mm gun permits.

V.

FUZES

C. - 40mm/60 Caliber Gun

1. Short History of Initial Development

The Bofors 40mm gun and ammunition of Swedish manufacture were first tested for the U.S. Navy at the Proving Ground in September 1940. Upon serious consideration of the adoption of this gun by the U.S. Navy, firing tests of American designs of ammunition components were conducted in September 1941 under orders of the Bureau of Ordnance. The fuze tested (in several variations) was designated Mark 27. The Mark 27 fuze is of the point detonating type designed to function on impact with the target. This fuze meets the cardinal Navy requirement of being "detonator safe" and contains two independent safety features to prevent prematures. These first fuzes employed a die-cast aluminum body. Such a body was practically new in fuze design but represented one of many features of the fuze designed by the Naval Ordnance Laboratory aimed at permitting mass production of a fuze simple but safe. The original foreign fuze furnished the basic design but was so complex that it did not lend itself to mass production with the critical shortage of machine tools. The need for a fuze was urgent, and fortunately the redesign was accomplished rapidly and was so satisfactory that the Mark 27, with but normal development improvements and with but only one change major enough to rate a new Mod. number, was used exclusively on 40mm ammunition throughout World War II. The estimated unit cost with the original complicated design was \$1.25. The fuze designed by NOL cost 71 cents to make when it first went into production. Mass production, design changes and improvement in technique made possible a reduction in unit cost to 37 cents by April 1945. Much of the early work in solving production problems was done by Triumph Explosives, Incorporated. Various experimental modifications have been tested and rejected. Among these, the most notable were a fuze with delay action and another with a detonator from a Mark 26 Mod. 1 fuze (20mm) substituted for the firing pin and hammer.

2. Subsequent Developments, Changes and Improvements

(a) General

Although considerable work has been done during development in determining the optimum dimensional and physical characteristics, there have been no radical departures from the original American design.

The one important modification made which was assigned the designation "Mod. 1" was the adoption of "Hourglass" detents to make the fuze more consistently bore-safe. The feature was jointly developed by the National Defense Research Council and the Naval Ordnance Laboratory. Testing was commenced in June 1943 and the design was officially approved in February 1944, with a conversion in production to the Mod. 1 following shortly. The general arrangement drawing for the fuze (BuOrd Dwg. No. 300423) was prepared in July 1941 and the extent of changes is shown by the list of revisions on it and on the detail drawings.

(b) Sensitivity

The sensitivity of the early Mark 27 fuzes was compared with that of the Mark 12 fuze (151) as a norm and found to compare favorably. However, when production expanded and parts were made by several contractors and assembled at several plants frequent poor functioning occurred and considerable testing was done on various schemes, loading methods, and material proposed to improve performance. Two items which were found to critically affect sensitivity were the shape or sharpness of the firing pin and the assembly of the booster pellet as regards density. Rigid requirements were included in the specifications designating that the firing pin have a sharp edge at the intersection of the flat end of the point and the conical surface and that the dense or hard end of the booster pellet be placed away from the booster lead-in. The value of an insensitive round (TNT loaded but plugged) was investigated and although it was conceded to have some superiority in damaging aircraft engines, the Proving Ground recommended against its use on the basis of the decreased value of the weapon because of the greatly reduced effective target area. The sensitivity for earth, water, heavy armor, newsprint and chipboard at various obliquity and velocities was determined.

(c) Safety

An alarming number of prematures, some in the bore, occurred early in the testing and service use of the Mark 27 fuze. A 40mm premature has been defined by the Bureau of Ordnance as "a high or low order detonation of the projectile in the gun barrel",

or, in service use, "at any point in flight within 400 yards of the muzzle of the gun". The fuze was investigated but it was found that the majority of prematures were initiated by the tracer or by a defect in the projectile itself. However, it was also found that the fuze was not as safe as had been supposed, since the cylindrical type firing pin detents were found to contribute almost nothing to the safety of the fuze as demonstrated by 80% prematures just inside the muzzle when firing fuzes with prearmed rotors. This condition led to the adoption of setback locking hourglass detents which keep the firing pin locked while in the bore, and for that distance beyond the muzzle of the gun that the velocity is increasing. They release the firing pin when set back has decayed to the point where the centrifugal force of the detents dominates, which occurs between 12 and 18 inches beyond the muzzle of the gun.

3. Service Deficiencies Known to the Proving Ground

The overall performance of the Mark 27 Mod. 1 fuze of recent production, including functioning, sensitivity, and safety, is very good. Although the percentage is low, prematures are still a hazard. It appears that they are not the result of inadequate design but of faulty components and assembly and can be held to a minimum by constant vigilance of the loading plants.

4. Adequacy of Present Design

The Mark 27 Mod. 1 fuze has proved adequate as a point detonating fuze. However, with the advent of larger, heavier, and more heavily armored enemy aircraft it appears that a fuze with delay action is desirable or better still that an explosive semi-armor piercing or armor piercing projectile be used, which projectile will require a base detonating fuze.

5. Adequacy of Present Effective Specifications

O.S. 2958, Rev. B, dated August 2, 1945 - SPECIFICATIONS FOR THE MANUFACTURE, ASSEMBLY, LOADING AND INSPECTION OF 40MM. DETONATION FUZE MK. 27 represents a recent rewrite and together with the drawings and applicable

specifications listed, is presently adequate. One change suggested for clarification of the title is the addition of the word "POINT" preceding "DETONATING" to designate type and the inclusion of information to show which Mods. are covered by O.S. 2958.

6. Suggested Fields for Improvement

It is suggested that the possibilities of a base detonating fuze be investigated.

VI.

PROJECTILE FILLERS

A. - 20mm/70 Caliber Gun

The History of the development of the types of projectile fillers used in the 20mm projectile is covered in Chapter III. Existing specifications for Assembled Rounds, listed in Chapter VII, adequately cover the loading of this size projectile. In the latter part of World War II all high explosive type ammunition, with the exception of that loaded with the dark ignition tracer, was loaded incorporating the incendiary pellet. As recommended in Chapter III, future experimentation with this size projectile should be conducted in an endeavor to include an incendiary pellet in the dark-ignition type projectile thereby increasing the lethal effects and standardizing loading procedures.

B. - 1710/75 Caliber Gun

In the period from 1939 until the time 1710 ammunition was no longer loaded, all high explosive loading was with explosive "D". Considerable difficulty was encountered with prematures during the above period, but as explained in Chapter IV, the cause of this malfunctioning was not associated with the projectile bursting charge, but was caused primarily by excessive tracer consolidating pressure which often cracked the projectiles. As this type ammunition is now obsolete no further comment in regard to design or specifications is applicable.

C. - 40mm/60 Caliber Gun

1. TNT loading

Initial loading of 40mm projectiles in this country used a high explosive charge of TNT. Because of the fact that a practically direct hit was required when using this size ammunition to do any appreciable damage it was decided to experiment with the possibility of incorporating an incendiary element within the projectile and thereby increasing the destructive qualities, especially when striking inflammable objects such as gasoline tanks and pipe lines.

2. TNT - Incendiary loading

With this objective of increasing the destructive quality in mind, extensive tests were conducted: first, to decide the proper position within the projectile to place the incendiary mix, which was of the same composition as that used in 20mm ammunition; and second, to determine the optimum amount of incendiary material to be incorporated. Initial placement of the incendiary mix in the center of the TNT charge as a core resulted in poor self-destruction flashes. Loading the incendiary mix as the first increment next to the tracer relay resulted in poor self-destruction performance also. The method finally adopted for production loading early in 1943 and the one that gave the most satisfactory results consisted of an incendiary ring pellet with a TNT core placed in the middle of the TNT charge. In early 1945 the loading technique was changed again substituting a solid pellet for the incendiary ring pellet to facilitate loading. This change was accomplished with no adverse results. The weight of the incendiary pellet adopted was approximately 18 grams.

3. Specifications

Existing specifications listed under Chapter VII covering the loading of all types of 40mm ammunition, are considered adequate.

VII.

ASSEMBLED ROUNDS

1. Types of Assembled Rounds

Following is a list of the various types of ammunition covered within this report, together with complete identification information:

20mm/70 Caliber Gun

<u>Lot Symbol</u>	<u>Type and Loading Assembly</u>	<u>Projectile Color</u>
ZA	HE	White
ZB	HE-T	Slate Gray
ZC	HE-I	Red
ZD	AF	Black
ZE	AP-T	Black with White Band
ZF	BL-T	Green with Yellow Band
ZG	BL-P	Green
ZH	HE-DI	Slate Gray with Red Band

HE - High Explosive	AP - Armor Piercing
HE-I - High Explosive Incendiary	BL - Blind Loaded
T - Tracer	P - Plugged (no tracer)
DI - Delayed Ignition Tracer	

40mm/60 Caliber Gun

<u>Lot Symbol</u>	<u>Type and Loading Assembly</u>	<u>Proj. Body</u>	<u>Color of Fuze Band</u>	<u>Fuze Nose</u>
UA	HE-P	Green	Green	Green
UB	HE-T	Green	White	Green
UC	AP	Black	-	-
UD	AP-T	Black	White Band on Windshield	
UE	BL-T	Red	White (Dummy Fuze)	Red
UF	BL-P	Red	Red (Dummy Fuze)	Red
UG	HE-I-T	Green	White	Red
UH	HE-SD(DT)	Green	Black	Green
UJ	HE-I-P	Green	Red	Red
UK	HE-I-SD(DT)	Green	Black	Red
UL	HE-I-T (no SD)	Green with White Black Band		Red
UM	HE-I-T-DI-SD	Green	Yellow	Red

HE - High Explosive  
 HEI - High Explosive, Incendiary  
 T - Tracer (standard)  
 AP - Armor Piercing  
 BL - Blind loaded  
 P - Plugged (no tracer)  
 SD - Self-destroying  
 DT - Dark Tracer (non-luminous)  
 DI - Delayed Ignition Tracer

100/75 Caliber Gun

<u>Lot Symbol</u>	<u>Type of Loading</u>
YA	AA - Explosive "D"
YB	AA-SD - Explosive "D"
AA - Anti-Aircraft	SD - Self-destroying

2. Adequacy of Present Effective Specifications

(a) Nos. and Titles

Following is a list of present day specifications applicable to the loading of 20mm and 40mm ammunition. Since 1710 is now obsolete no specifications are listed.

20mm/70 Caliber Gun

<u>O.S. No.</u>	<u>Title</u>
2806	Armor Piercing Projectiles (Minor Caliber) - Also applicable to 40mm ammunition.
2923	Loading, Assembly, Inspection and Packing of 20mm A.A. H.E., H.E.I. and H.E.T. Cartridges.
3425	Loading, Assembly, Inspection and Packing of 20mm A.A. H.E.T. Cartridges with Dark Ignition Tracer.

40mm/60 Caliber Gun

2990	Loading, Assembly, Inspection and Packing of 40mm A.A. (H.E.T. & H.E.I.T.) Cartridge with Tracer Mark 11 and Mods.
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(b) Comments

After revision of O.S. 2806, which is in progress, existing specifications for 20mm ammunition will be adequate. At present there are no specifications covering 40mm ammunition loaded with either the dark-ignition type tracer (UK) or the delayed-ignition type tracer (UM). After issue of specifications covering these two types of tracers the 40mm specifications will be considered adequate.

3. Suggested Fields for Improvement

- (a) In subsequent development of 20mm and 40mm ammunition it is suggested that efforts be made to standardize the identification colors. Because of the obsolescence of various types of straight HE loadings, the number of various types of assembled rounds will eventually be reduced by two in the

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case of the 20mm and three in the 40mm. This will still leave quite a large number of types of ammunition but with a standardization such as "Red" projectile color for incendiary loading for both 20mm and 40mm, much of the present confusion should be eliminated.

- (b) It is suggested that Ordnance Specifications be prepared to cover 40mm ammunition with Dark-ignition tracer (UK) and Delayed-ignition tracer (UM).

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