TMJ
OT
O-19

NS/rk

U. S. NAVAL TECHNICAL MISSION TO JAPAN
CARE OF FLEET POST OFFICE
SAN FRANCISCO, CALIFORNIA

DECLASSIFIED IAW DOD MEMO OF 3 MAY 1972, SUBJ: DECLASSIFICATION OF WWII RECORDS

6 February 1946

RESTRICTED

From: Chief, Naval Technical Mission to Japan.
To : Chief of Naval Operations.

Subject: Target Report - Japanese Projectiles - General Types.

Reference: (a)"Intelligence Targets Japan" (DNI) of 4 Sept. 1945.

1. Subject report, dealing with Target O-19 of Fascicle O-1 of reference (a), is submitted herewith.

2. The investigation of the target and preparation of the report were accomplished by Comdr. G. R. Dolan, RN, and Lt. Comdr. M. R. Herman, USNR, assisted by Lt.(jg) Robert Boggess, USNR, and Lt.(jg) K. C. Lamott, USNR, as interpreters.

C. G. Grimes

C. G. GRIMES
Captain, USN

30645

JAPANESE PROJECTILES
GENERAL TYPES

"INTELLIGENCE TARGETS JAPAN" (DNI) OF 4 SEPT. 1945

FASCICLE O-1, TARGET O-19

FEBRUARY 1946

U.S. NAVAL TECHNICAL MISSION TO JAPAN

SUMMARY

ORDNANCE TARGETS

JAPANESE PROJECTILES

Common Projectiles: These are not particularly novel or interesting but show considerable variety in the methods of manufacture. Incendiary shrapnel of two types are designated Common Projectiles, Models 3 and 4.

Incendiary Shrapnel: The Japanese Navy placed great faith in the effectiveness of incendiary shrapnel as an anti-aircraft weapon. It is considered probable that they rather overestimated its value as compared to HE.

Anti-Submarine Projectiles: These projectiles appear to be the type showing the greatest originality in design. It is difficult to obtain any true picture of their effectiveness during the war.

Illuminating Projectiles: The original Japanese starshell had no parachute and was not very effective. Later illuminating projectiles are largely copies of foreign designs.

Rocket Projectiles: The shaped charge projectiles designed for use against tanks showed considerable progress. The remaining projectiles were of HE or incendiary shrapnel type.

Armor Piercing Projectiles: In the design of AP projectiles the Japanese concentrated on the possiblity of striking the enemy ship below the waterline and therefore possibly below the armor belt. To achieve this the projectiles were designed to continue an undisturbed trajectory under the water. (It is debatable whether success in this attempt will give an increased number of hits below the water level at long ranges.)

The fuze delay was adjusted to give satisfactory functioning after being initiated in striking the water and then passing through the water and the ship's side (0.4 seconds). The fire control stressed the desirability of getting short misses, and the Japanese claimed that even projectiles that missed the enemy ship would have a certain mining effect.

It would appear that, to some extent, they sacrificed the effectiveness of their AP projectiles on occasions of direct hitting (particularly against light armor) in order to achieve a doubtful hit through the water or a mining effect for which an AP projectile is singularly poorly designed.

The most recently designed Japanese AP projectiles, Type 91, were produced in calibers ranging from 15.5cm (6.1") to 46cm (18.1"). The major caliber projectiles of this design have true armor piercing caps; the medium caliber have only a small cap-head. In both sizes, the projectile is designed to have an "undisturbed underwater trajectory" by allowing the forward section to break off on water impact, leaving a flat forward surface.

The projectiles have a weight ratio, $2M/D^3$, of about 1.08 and are approximately 4.3 calibers long. The major caliber projectiles have an analysis consisting roughly of 0.50% carbon, 3.8% nickel, 0.7% chromium, and 0.5% molybdenum. The medium caliber projectiles have lower nickel and higher chromium, a concerted effort having been made to conserve nickel. The projectiles were decrementally hardened, the major calibers by a decremental quench as well as decremental temper; the medium caliber by a decremental temper. The chemical analysis and the surface hardness gradient were stipulated in the specifications. The isoscleric lines in the interior pattern were nearly normal to the axis except at the tip of the nose. The maximum nose and cap hardnesses of the major caliber projectiles exceeded 80 shore hardness; the medium caliber noses were somewhat softer.

Ballistic tests were based on a corrected DeMarre formula. The required projectile performance was similar to the U.S. Navy specifications: a complete penetration with cavity effective.

* * * * *

TABLE OF CONTENTS

Summary .... Page 1

List of Enclosures .... Page 2

List of Illustrations .... Page 3

References .... Page 4

Introduction .... Page 5

The Report

Part I Common Projectiles .... Page 7
Part II Incendiary Projectiles .... Page 8
Part III Anti-Submarine Projectiles .... Page 12
Part IV Illuminating Projectiles .... Page 18
Part V Rocket Projectiles .... Page 18
Part VI Armor Piercing Projectiles .... Page 29
Part VII Miscellaneous Projectiles .... Page 55
Part VIII Machine Gun Ammunition .... Page 59

* * * * *

LIST OF ENCLOSURES

(A) 15cm Common Projectile .... Page 61

(B) 14cm Type 2 Common Projectile .... Page 62

(C) 10cm Common Projectile for Type 98 Gun .... Page 63

(D) 36cm Model 3 Common Projectile .... Page 64

(E) 20cm Model 3 Modification 1 Common Projectile .... Page 65

(F) List of Documents Forwarded to WDC Through ATIS .... Page 66

LIST OF ILLUSTRATIONS

Figure 1. Common Projectiles (Diagrams) .... Page 10

Figure 2. Common Projectiles (Photographs) .... Page 11

Figure 3. Common Projectiles , Model 3 (Mod. 1) .... Page 14

Figure 4. Common Projectiles, Model 4 .... Page 15

Figure 5. Incendiary Projectile .... Page 16

Figure 6. Anti-Submarine Projectiles .... Page 17

Figure 7. Miscellaneous Projectiles .... Page 19

Figure 8. Illuminating Projectile "A" (Star Shell) .... Page 21

Figure 9. Illuminating Projectile "B" .... Page 22

Figure 10. Illuminating Projectile "B" .... Page 23

Figure 11. Star and Illuminating Projectiles .... Page 24

Figure 12. Heavy Rocket Projectile .... Page 26

Figure 13. 12cm Incendiary-Shrapnel Rocket .... Page 27

Figure 14. 8cm Shaped Charge Rocket (Photograph) .... Page 28

Figure 15. 8cm Shaped Charge Rocket (Diagram) .... Page 28

Figure 16. Armor Piercing Projectile, Type 91 .... Page 31

Figure 17. Thermal Cycles Prior to Quenching Type 91 Bodies .... Page 36

Figure 18. Tempering Furnace for the Type 91 Bodies .... Page 37

Figure 19. Thermal Cycles for Tempering Type 91 Bodies .... Page 38

Figure 20. Location of Hardness Test Points on Type 91 Bodies .... Page 42

Figure 21. Interior Hardness Patterns of Major Caliber AP Projectiles Type 91 .... Page 44

Figure 22. Thermal Cycles Prior to Quenching Major Caliber Caps (After Preheat) .... Page 46

Figure 23. Location of Test Points, Major Caliber Caps .... Page 47

Figure 24. Armor Piercing Projectiles .... Page 54

Figure 25. Practice and Target Projectiles .... Page 56

REFERENCES

Location of Target:

Navy Technical Department, TOKYO.
Yokosuka Naval Arsenal.
Ikego Magazines.
The First Naval Technical Arsenal, KANAGAWA.
The Naval Technical Research Institute, MEGURO.
Sagami Arsenal.
Hiratsuka Powder Factory.
Imperial Navy Proving Ground, KAMEGAKUBI.
KURAHASHISHIMA in Japan Inland Sea near KURE.
Ordnance and Steel Making Sections, Kure Naval Arsenal.

Japanese Personnel Who Assisted in Gathering Data:

Captain IWASHIMA, Head of Gun and Projectile Section of the Technical Department of Navy Ministry, TOKYO.

Captain OHIRA, in charge of steel manufacture and treatment. Attached to the Technical Department of Navy Ministry (experienced in steel manufacture).

Captain YAGIMA, employed in projectiles, cartridge case, and primer design under Captain IWASHIMA.

Technical Commander TAKAGI, attached to the Technical Department of Navy Ministry on design of explosive components, explosive trains, and primers.

Kikuo NISHIDA, Ex-Technical Lieutenant, Kure Naval Arsenal (about six years experience in ammunition components and design, a physicist by profession).

M. KANERO, Civilian Engineer, KAMEGAKUBI Proving Ground and Kure Naval Arsenal (many years experience in ballistic testing of armor and AP projectiles).

Kazuo HORIKAWA, Ex-Technical Lt. Comdr., Kure Naval Arsenal Experimental Laboratory (about 10 years at KURE, research metallurgist).

TAKANASHI, Ex-Technical Lt. Comdr., Kure Naval Arsenal (about five years at KURE, a projectile production metallurgist).

Kazuo NAKAMAE, Ex-Technical Commander, Chief metallurgist, Kure Naval Arsenal (many years experience in heat treatment of alloy steels).

INTRODUCTION

At the first interrogations, Japanese officers stated that all drawings and books on projectiles had been destroyed by orders from headquarters. There were two principal localities in which interrogation could most profitably be carried out: in the TOKYO area and at Kure Naval Arsenal.

As far as possible, figures have been checked by getting information from two or more sources, but the absence of documentary proof in many cases (except for pamphlets produced since August 1945, very largely from memory) has made the collection of accurate data difficult, if not impossible.

There are undoubtedly errors in details, but it is believed that the general picture is fairly correct.

THE REPORT

Part I - COMMON PROJECTILES

In the Japanese Navy, the term "common projectiles" is sometimes misleading. The Japanese included under this term some semi-armor-piercing projectiles, several different kinds of high explosive projectiles manufactured in different ways, and also what they termed Model 3 Common Projectiles and Model 4 Common Projectiles. These last two types were really incendiary projectiles and were painted red; all other common projectiles were painted maroon.

There is nothing particularly interesting or novel in the high explosive common projectiles in the Japanese Navy. The different types are shown in sketches in Figure 1. The differences between these types of projectiles were largely due to manufacturing requirements and the limiting powers of available presses. At times drawn tubes were headed to form common projectiles.

During the war, developments tended both towards reducing the standard of the material from which common projectiles were made and improving the ballistic performance.

With regard to improving the performance of shells, major emphasis was placed on anti-aircraft projectiles. The projectile itself was made more pointed with a caliber radius head of 13. More care was also taken in making the fuze blend to the shape of the projectile. At the end of the war, the following types of anti-aircraft shells had completed tests:

1. 50 cal/12.7cm (5") (see Table I). The new type projectile was increased in length to 21.6 inches with a weight of 61.6 lbs and a bursting charge of 4.84 lbs. The caliber radius of the head was 13 and it was boat-tailed (angle 5½°). The range increased to 25,180 yds and the maximum height of trajectory increased to 16,420 yds at 90°.

2. 45 cal/12cm (4.7") (see Table I). The length was increased to 20.28 inches with a weight of 49.5 lbs and a bursting charge weight of 4.07 lbs. The head and tail were shaped as for the 12.7cm projectile. The range was increased to 22,430 yds and the height of trajectory at 75° to 14,220 yds.

3. 50 cal/10cm (4") (see Table I). The length was increased to 17.7 inches with a weight of 29.7 lbs and a bursting charge of 2.4 lbs. The head and tail were shaped as for the 12.7cm. The range was increased to 21,340 yds and the height of trajectory at 80° to 14,220 yds.

It is understood that although experiments had all been completed satisfactorily, only the 12cm shell had actually gone into production.

Increased range of anti-aircraft projectiles had also been achieved in the case of projectiles used with the Type 98 gun by an increase in the caliber length of the guns and increased muzzle velocity.

A few dimensioned drawings of common projectiles are shown in Enclosure (A), Enclosure (B), and Enclosure (C).

With regard to reduction in the standard of material required for projectiles, some experiments were carried out on making projectiles out of cast iron instead of steel. These projectiles were designed first for use in land fighting or for firing from ships against troops. Later in the war, they were intended for use against aircraft and experimental tests were carried out on shells for the short 12cm gun and the 45 cal/12cm anti-aircraft gun. In the case of the former, gun experiments had been completed and shells were in course of production.

Experiments were also carried out to save copper by using steel instead of copper for driving bands. These experiments were successful in the opinion of the Japanese Navy, and it was decided that the use of steel bands did not cause any greater rate of wear on guns and were equally satisfactory from the ballistic point of view. The steel driving bands are cut in sections from cylinders, and the section is split before the steel driving band is pressed on to the shell. There is little difference between the copper and steel driving bands in regard to shape, except that the grooves in the steel bands are larger and deeper.

The specification for the steel is as follows:

C	0.03	Ni	0.01
Si	0.01	Cr	0.01
Mn	0.01	Cu	0.01
P	0.005	Al	0.03
S	0.04		

Yield point	14.2 kg/mm^2
Tensile strength	22.2 kg/mm^2
Elongation	43.4%
Reduction of area	74.1%
Izod impact value	2.9 to 3.1 ft lbs
Brinell hardness	61.8

It is understood that the Japanese obtained their first information on steel driving bands from Germany, but they claim that the methods of production, manufacture, and details of dimensions were worked out in Japan.

At the end of the war experiments had been completed and preparations had been made for mass production of steel driving bands for the 12.7cm anti-aircraft gun and the short 12cm gun.

A list of common projectiles and their characteristics (other than Model 3 and 4, which are included in the incendiary shell list in Part II) is given in Table I.

Figure 2 shows photographs of miscellaneous common projectiles. The photographs in the top row are of obsolete types.

Part II - INCENDIARY PROJECTILES

Incendiary shells fall into the following categories:

1. Common Projectiles, Model 3
2. Common Projectiles, Model 4
3. Incendiary Projectiles

The composition and steel specifications for incendiary shells are shown in Table II.

1. <u>Common Projectiles, Model 3</u>. These projectiles were designed for anti-aircraft fire and are referred to by the Japanese indiscriminately as incendiary, or as shrapnel, or as common projectiles, Model 3. These shells are filled with steel tubes containing an incendiary mixture with a piece of quickmatch in the center. Arrangement of the tubes and shell characteristics are given in Table III and Figure 3. Shell burst is initiated by a time mechanical fuze. The incendiary tubes ignite about one-half second later and burn for five seconds at 3000°C, giving a flame about 17 feet long.

TABLE I
HE AND COMMON PROJECTILES

	Diagram in Figure 1	Caliber (inches)	Explosives (lbs)	Shell Steel Specifications											Exterior Ballistic Information (including shape of head)						Fuzes Used	Effective Radius (yds)	Use
				Chemical							Mechanical												
				C	Si	Mn	P	S	Ni	Cr	Yield Point (kg/mm^2)	Tensile Strength (kg/mm^2)	Elong. (%)	Izod (ft/lbs)	Size of Cavity (% of shell)	Total Length (in)	Total Weight (lbs)	Maximum Range (yds)	Max. Ht. of Trajectory (yds)	Muzzle Velocity of Gun (ft/sec)			
C.P. Type 0	A	18.1/45 cal	136 Trinitroanisol	.4/.5	< .35	.3/.7	<.035	<.035	1.5/2.0	.2/.6	> 55	80/100	> 10	> 10	18.7	63	2992	35,600	10,940	2640	Time Fuze, Type 4, Mark 0, Nose	74.4	AA
C.P. Type 0	A	16/45 cal	97.7 Trinitroanisol	.4/.5	< .35	.3/.7	<.035	<.035	1.5/2.0	.2/.6	> 55	80/100	> 10	> 10	19.36	55.1	2069	33,930	9,850	2640	Time Fuze, Type 4, Mark 0, Nose	64.1	AA
C.P. Type 0	A	14/45 cal	65.1 Trinitroanisol	.4/.5	< .35	.3/.7	<.035	<.035	1.5/2.0	.2/.6	> 55	80/100	> 10	> 10	19.36	47.25	1369	30,650	7,660	2640	Time Fuze, Type 4, Mark 0, Nose	54.9	AA
C.P. Type 0	B	8/50 cal	18 Trinitroanisol	.4/.5	< .35	.3/.7	<.035	<.035	1.5/2.0	.2/.6	> 55	80/100	> 10	> 10	25.4	34.64	276.5	31,650	10,940	2740	Time Fuze, Type 4, Mark 0, Nose	32.05	AA
C.P.	E	8 (Howitzer)	30 Trinitroanisol	.45/.65		.45/.80	<.05	<.05			> 35	65	> 12		66.2	22.06	103.4	6,900	4,380	1000	Anti-Sub. Fuse, Type 1, Nose	26.3	AA Sub.
C.P. Type 0	B	6.1/65 cal	6.8 Picric acid	.4/.5	< .35	.3/.7	<.035	<.035	1.5/2.0	.2/.6	55	80/100	> 10	> 10	21.86	25.64	123	30,000	10,940	3020	Time Fuze, Type 4, Mark 0, Nose	25.2	AA
C.P. Type 0	B	6/50 cal	6.35 Picric acid	.35/.45	.05/.40	.8/1.4	<.045	<.045		.5/1.0	> 50	> 70	> 12	> 10	24.8	22.85	99.8	23,000	8,760	2790	Time Fuze, Type 4, Mark 0, Nose	21.2	AA
C.P. Type 4	C	6/50 cal	5.85 Picric acid	.4/.5	< .35	.3/.7	<.035	<.035	1.5/2.0	.2/.6	> 55	80/100	> 10	> 10	23.06	22.5	99.8	23,000		2790	Perc. Fuze, Type 13, Mark 1, Base		Surface
C.P. 1	F	6/40 cal	11.4 Picric acid	.35/.45	<.05/.40	.8/1.4	<.045	<.045		.5/1.0	> 50	> 70	> 12	> 10	38.6	20.87	99	14,800	4,380	2300	Perc. Fuze, Type 13, Mark 1. Base		AA
C.P. with cap*	D	5.5/50 cal	4.44 Picric acid	.55/.65	< .40	< .3	<.03	<.03	2.5/3.0	2.0/2.6	>35/70	70/100	> 10		21.27	21.65	83.5	18,930		2790	Perc. Fuze, Type 13, Mark 1, Base		Surface
C.P. Type 0	B	5.5/50 cal	6.31 Picric acid	.4/.5	< .35	.3/.7	<.035	<.035	1.5/2.0	.2/.6	> 55	80/100	> 10	> 10	28.6	21.8	83.5	19,700	5,470	2790	Time Fuze, Type 4, Mark 1, Nose	28.6	AA
C.P. Type 2	C	5.5/50 cal	5.72 Picric acid	.4/.5	< .35	.3/.7	<.035	<.035	1.5/2.0	.2/.6	> 55	80/100	> 10	> 10	26.45	21.8	83.5	18,600		2790	Perc. Fuze, Type 13, Mark 1, Base		Surface
C.P.	C	5.5/40 cal	7.33 Picric acid	.35/.45	.05/.40	.8/1.4	<.045	<.045		.5/1.0	>50	> 70	> 12	> 10	32.0	21.65	83.5	17,500		2300	Perc. Fuze, Type 13, Mark 1, Base		Surface
C.P. Type 1.AA	F,G	5/50 cal	4.86 Trinitroanisol	.45/.65		.45/.80	<.05	<.05			> 35	> 65	> 12		30.05	17.2	50.8	20,100		2860	Time Fuze, Type 4, Mark 3, Nose	20.6	
C.P. AA	F,G	5/50 cal	4.15 Picric acid	.45/.65		.45/.80	<.05	<.05			> 35	> 65	> 12		30.05	17.2	50.6	20,150		2990	Time Fuze, Type 4, Mark 1, Nose	20.6	Surface
C.P. AA	F,G	5/40 cal	4.15 Picric acid	.45/.65		.45/.80	<.05	<.05			> 35	> 65	> 12		30.05	17.2	50.6	15,870	10,300	2360	Time Fuze, Type 4, Mark 1, Nose	20.6	AA
C.P. AA	F,G	4.7/45 cal	3.76 Picric acid	.45/.65		.45/.80	<.05	<.05			> 35	> 65	> 12		30.55	16.3	44.85	17,500	10,940	2710	Time Fuze, Type 4, Mark 1, Nose	19.84	AA
C.P. Type 1.AA	F,G	4.7/45 cal	4.10 Trinitroanisol	.45/.65		.45/.80	<.05	<.05			> 35	> 65	> 12		30.55	16.0	44.85	17,500	11,000	2790	Time Fuze, Type 4, Mark 3, Nose		
C.P.	F,G	4.7/45 cal	3.76 Picric acid	.45/.65		.45/.80	<.05	<.05			> 35	> 65	> 12		30.55	16.0	44.85	17,500		2710	Perc. Fuze Type 13 Mark 1, Base	19.84	Surface
C.P.	E	4.7 (Howitzer)	5.56 Trinitroanisol	.45/.65		.45/.80	<.05	<.05			> 35	> 65	> 12		54.0	13.4	28.6	5,800	3,283	950	Perc. Fuze, Type 88, Mark 2, Nose	18.3	Ground & AA
C.P. AA	G	65 cal/4 (Type 98)	2.1 Trinitrotoluene	.35/.45	.05/.40	.8/1.4	<.045	<.045		.5/1.0	> 50	> 70	> 12	> 10	27.52	16.15	28.6	21,350	14,225	3280	Time Fuze, Type 4, Mark 2, Nose	14.88	AA
C.P.	G	50 cal/4 (Type 88)	2.1 Picric acid	.35/.45	.05/.40	.8/1.4	<.045	<.045		.5/1.0	> 50	> 70	> 12	> 10	27.0	15.0	28.6	17,730	12,260	2860	Time Fuze, Type 4, Mark 2, Nose	14.88	AA
C.P. AA	F,G	60 cal/3 (Type 98)	0.84 Trinitrotoluene	.35/.45	.05/.40	.8/1.4	<.045	<.045		.5/1.0	> 50	> 70	> 12	> 10	24.8	12.8	13.18	14,800	9,300	2960	Time Fuze, Type 4, Mark 2, Nose	14.88	AA
C.P. AA	F,G	3 (40 cal)	1.0 Picric acid	.45/.65		.45/.8	<.05	<.05			> 35	> 65	> 12		29.06	11.22	13.18	11,820	7,860	2230	Time Fuze, Type 3, Mark 4, Nose	13.72	AA
C.P.	G	3 (Howitzer)	1.0 Trinitroanisol	.45/.65		.45/.8	<.05	<.05			> 35	> 65	> 12		29.6	11.22	12.74	8,430	5,145	1480	Perc. Fuze, Type 88, Mark 2, Nose		Surface
C.P.	F	2	Picric acid	.45/.65	.05/.40	.45/.8	<.05	<.05			> 35	> 65	> 12				5.98	4,925		1840	Perc. Fuze, Type 88 Mark 2, Nose		Surface
C.P.	F	1.8	Picric acid	.45/.65	.05/.40	.45/.8	<.05	<.05			> 35	> 65	> 12			6.7	3.3	4,380		2000	Perc. Fuze Type 88 Mark 2, Nose		Surface

*Cap is secured by soldering.
Note: Color marking is maroon in all cases.

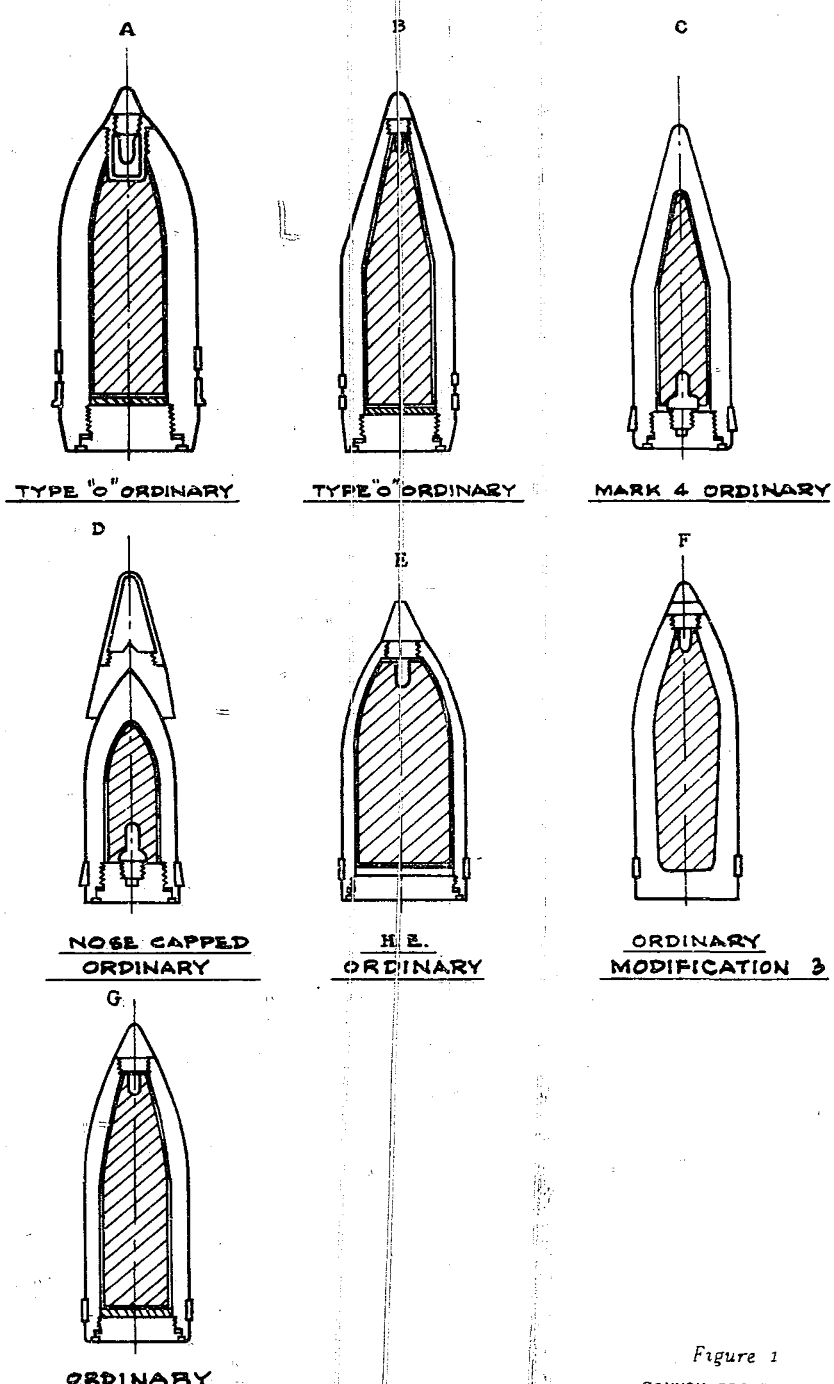
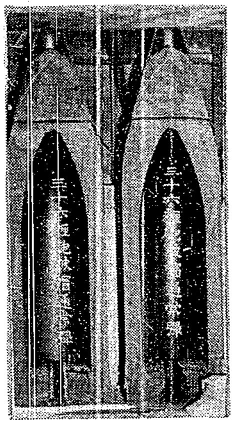
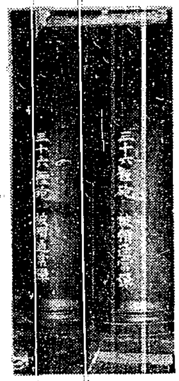


Figure 1
COMMON PROJECTILES

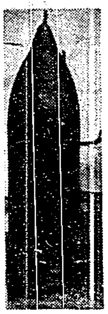


36cm CAPPED (Old)



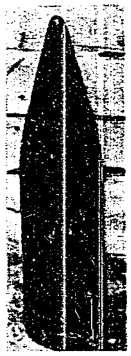
36cm CAPPED (Old) Section Models

30cm (Very Old)



15cm

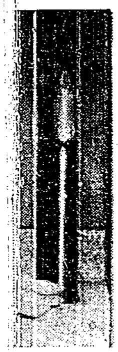
15cm



14cm

14cm COMMON

14cm



8cm

6cm

Figure 2

COMMON PROJECTILES

2. Common Projectile, Model 4. These projectiles are similar in purpose to Model 3 but differ in certain characteristics, being filled with phosphorus. The tube arrangement and statistics are shown in Table IV and Figure 4.

3. Indendiary Projectiles. These are in many ways similar to the two types described above. They vary in the arrangement of the tubes and in having a wider dispersion angle after bursting. The arrangement of the incendiary composition and statistics are shown in Table V and Figure 5.

It was generally considered by gunnery officers at sea that the above types of incendiary projectiles were more effective than common projectiles in anti-aircraft fire directed at approaching targets, owing to the continuation of the tubes and fragments in an effective cone after the burst.

Many arsenals were turned over to manufacture of one of these types in the months before the Guadalcanal campaign. The following description by a Japanese officer can scarcely be bettered for brevity:

"The shell is bursted at the optimum points of the trajectory by fuze, and after that the energetic splinters sprint about igniferously."

It is likely, however, that the Japanese naval officers were misled by the impressive appearance of the bursts in the sky into overestimating the efficiency of this type of projectile, as used in the Japanese Navy.

Effective use of this projectile would necessitate consideration of the differences in ballistic coefficient between it and common projectiles. It would also seem desirable that the position of burst should be raised above the line of sight between the gun and the target, since shrapnel drops towards the earth.

It is understood that this problem was to some extent appreciated by the naval technical officers responsible for fire-control design, who produced ballistic charts and cards showing the corrections required when these special projectiles were used. Even so it is not clear that they made full allowance for the necessity of bursting shrapnel shell higher than HE shell in addition to calculation for normal ballistic corrections.

It is very doubtful whether the gunnery officers of ships were in all cases able to make the necessary corrections, or, indeed, that they were fully cognizant of the problem involved. In many ships, some guns in each turret were loaded with HE and some with incendiary shrapnel to be ready for either approaching or croning targets, which would make the control problem even more complicated.

Dimensioned drawings of Model 3 Common Projectiles are given in Enclosure (D) and Enclosure (E).

Part III - ANTI-SUBMARINE PROJECTILES

Considerable effort was directed by the Japanese Navy to develop projectiles which would continue an undisturbed trajectory after striking the water.

The Japanese did not devote much thought to development of long projectiles for this purpose, but decided as the result of experiment that a flat-nosed projectile in which the area of the flat front was equal to half the area of the base was most efficient. These were adopted after extensive tests in 1943.

The first type, shown in Diagram A of Figure 6, was an adaptation of an HE common projectile, onto the shoulder of which a water penetrating cap was screwed.

TABLE II
INCENDIARY PROJECTILES

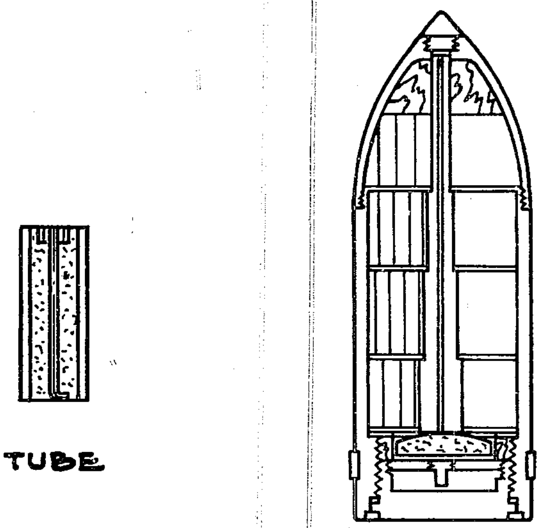
	Caliber	Pyrotechnic Ingredients (%)	Shell Steel Specifications: Chemical: C	Si	Mn	P	S	Ni	Cr	Mechanical: Yield Point (kg/mm^2)	Tensile Strength (kg/mm^2)	Elongation (%)	Impact Izod (ft/lbs)	Fuze Used	Muzzle Velocity (ft/sec)
Common Projectile Model 3	18"/45 cal		.4/.5	.35	.3/.7	.035	.035	1.5/2.0	.2/.6	55	80/100	10	10	Time Fuze, Type 4, Model 0, Nose	2640
	16"/45 cal	Polisulphide Synthetic Rubber 9.3 Natural Rubber 5 Stearic Acid 0.2 Sulphur 0.5 $Ba(NO_3)_2$ 40 Electron Metal 45	.4/.5	.35	.3/.7	.035	.035	1.5/2.0	.2/.6	55	80/100	10	10	Time Fuze, Type 4, Model 0, Nose	2740
	14"/45 cal		.4/.5	.35	.3/.7	.035	.035	1.5/2.0	.2/.6	55	80/100	10	10	Time Fuze, Type 4, Model 0, Nose	2710
	8"/50 cal		.4/.5	.35	.3/.7	.035	.035	1.5/2.0	.2/.6	55	80/100	10	10	Time Fuze, Type 4, Model 0, Nose	2770
	5"/50 cal		.35/.45	.05/.40	.8/1.4	.045	.05		.5/1.0	50	70	12	10	Time Fuze, Type 4, Model 1, Nose	2940
	5"/40 cal		.35/.45	.05/.40	.8/1.4	.045	.05	1.5/2.0	.5/1.0	50	70	12	10	Time Fuze, Type 4, Model 1, Nose	2310
Common Projectile Model 4	8"/50 cal	Yellow Phosphorous 100	.4/.5	.35	.3/.7	.035	.035	1.5/2.0	.2/.6	55	80/100	10	10	Time Fuze, Type 4, Model 1, Nose	1000
	5"/50 cal		.35/.45	.05/.40	.8/1.4	.045	.05		.5/1.0	50	70	12	10	Time Fuze, Type 4, Model 1, Nose	2940
	4.7"	Polisulphide Synthetic Rubber 9.3 Natural Rubber 5 Stearic Acid 0.2 Sulphur 0.5 $Ba(NO_3)_2$ 30 Electron Metal 10 Fe_3O_4 25 Aluminum 20	.35/.45	.05/.40	.8/1.4	.045	.05	1.5/2.0	.5/1.0	50	70	12	10	Time Fuze, Type 4, Model 1, Nose	2710
Incendiary Projectile	8" (Howitzer)		.45/.65		.45/.80	.05	.05			55	65	12		Time Fuze, Type 4, Model 1, Nose	1000
	5.5"		.35/.45	.05/.40	.8/1.4	.045	.05		.5/1.0	50	70	12	10	Time Fuze, Type 4, Model 1, Nose	2790
	4.7"		.35/.45	.05/.40	.8/1.4	.045	.05	1.5/2.0	.5/1.0	50	70	12	10	Time Fuze, Type 4, Model 1, Nose	2710

NOTE: Composition of electron metal: magnesium 90%; aluminium 3%; copper 3%; zinc 1→2%; silicon approx 2%.
Color marking is red in all cases.

TABLE III

CHARACTERISTICS OF COMMON PROJECTILE
MODEL 3 (MOD. 1)

Shell	Fuse	Total Length (mm)	Gross Weight (gm)	No. of tubes and stays Tubes	Stays	Total	Angle of dispersion (°)	Effective diameter of burst (m)	Dimensions of tube (mm)
94/46	Type 9 Model 1 Type 4 Mod. 0	1,600	1,360	996	504	1,500	15	242	25 x 90
45/40		1,400	940	735	375	1,110	15	213	25 x 90
45/36		1,200	622	480	199	679	15	152	25 x 90
50/20		860	126	198	57	255	13	100	25 x 90
50/12.7		437	23	43	23	66	10	54	20 x 50
40/12.7		437	23	43	23	66	10	54	20 x 50



TUBE

Figure 3

COMMON PROJECTILES, MODEL 3 (MOD. 1)

TABLE IV

CHARACTERISTICS OF COMMON PROJECTILES
MODEL 4

Shell	Fuse	Total Length (mm)	Weight (kg)		Tubes		Effective diameter of burst (m)
			Gross	Explosive	Number	Angle of dispersion	
short 20cm	time	560	47	0.5	144	40°	30
50/12.7cm	Type 4	437	23	0.3	48	25°	13
45/12cm							

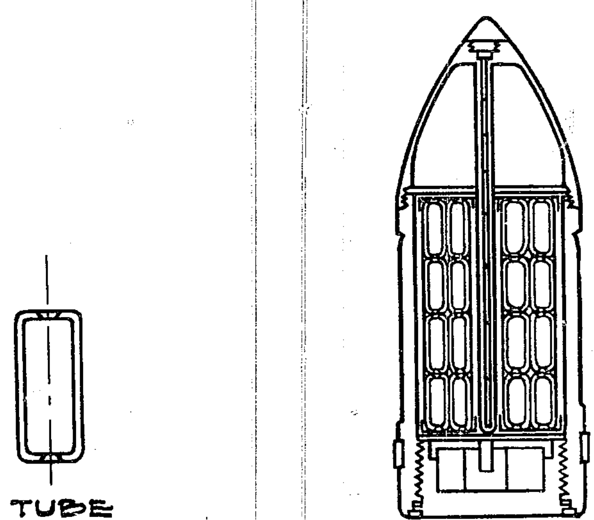


Figure 4
COMMON PROJECTILES, MODEL 4

TABLE V

CHARACTERISTICS OF INCENDIARY PROJECTILE

Shell	Fuse	Total Length (mm)	Weight (kg)		Tubes		Effective diameter of burst (m)
			Gross	Explosive	Number	Angle of dispersion	
short 20cm	time	560	47	0.6	72	60°	8
40/14cm	time	550	38.8	0.4	30	60°	21
45/12cm	Type 4	406	20.4	0.3	18	60°	

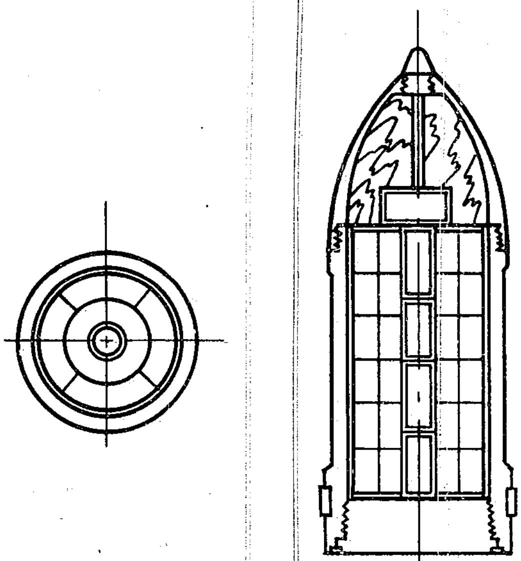


Figure 5
INCENDIARY PROJECTILE

TABLE VI
ANTI-SUBMARINE PROJECTILES

Shell For	Diagram in Figure 6	Specifications				Capabilities			
		Diameter (mm)	Total Length (mm)	Weight		Muzzle Velocity (m/sec)	Maximum Range (m)	Minimum Range* (m)	Underwater Effect
				Gross (kg)	Bursting Charge (kg)				
50, 45, 40 Caliber 15cm gun (6 inch)	A	151.6 (5.97")	approx 600 (23.64")	51.383 (113.0 lbs)	2.875 (6.44 lbs)	250 (820 ft/sec)	4200 @ 40° (4590 yds)	800 (875 yds)	Will penetrate 8mm (.3115 inch) D.S.** armor plate at depth of 8 meters (26.22 ft)
50, 40 Caliber 14cm gun (5.5 inch)	A	139.2 (5.485")	approx 573 (22.5")	41.998 (92.4 lbs)	2.860 (6.29 lbs)	250 (820 ft/sec)	4200 @ 40° (4590 yds)	800 (875 yds)	
50, 40h Caliber 12.7cm gun (5 inch)	B	126.3 (4.975")	approx 437 (17.2")	21.000 (46.2 lbs)	3.983 (8.775 lbs)	250 (820 ft/sec)	4300 @ 40° (4705 yds)	800 (875 yds)	Will penetrate 250mm (9.85 inches) D.S.** armor plate at depth of 8 meters (26.22 ft)
45, 45h Caliber 12cm gun (4.7 inch)	B	119.4 (4.71")	approx 415 (16.35")	16.400 (36.3 lbs)	3.771 (7.185 lbs)	250 (820 ft/sec)	4000 @ 40° (4375 yds)	750 (820 yds)	
40, 40h Caliber 8cm gun (3 inch)	B	75.6 (2.98")	approx 285 (11.23")	5.300 (11.66 lbs)	0.668 (1.47 lbs)	250 (820 ft/sec)	3200 @ 40° (3500 yds)	700 (766 yds)	Will penetrate 115mm (4.53 inches) D.S.** armor plate at depth of 8 meters (26.22 ft)

*To avoid ricochets.
**D.S. - Dusol Steel, roughly equivalent to U.S. Navy High Tensile Steel.

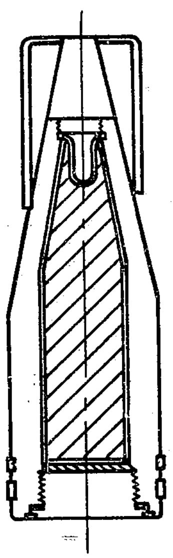


DIAGRAM "A"

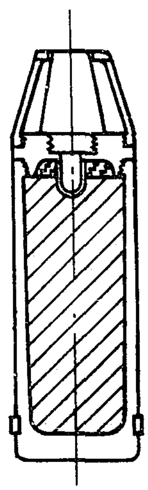


DIAGRAM "B"

ANTI-SUBMARINE PROJECTILES

Production was later switched to the type shown in Diagram B in Figure 6, which was designed solely as an anti-submarine shell. Characteristics of the shell are given in Table VI.

Photographs of two anti-submarines projectiles are shown in the bottom left corner of Figure 7.

Part IV - ILLUMINATING PROJECTILES

The Japanese Navy's original illuminating projectiles, called HOSEIDAN, were of a very elementary type. They were starshells without parachutes, and naturally their illumination was of very short duration. The name of these shells was later changed to SHOMEIDAN A.

An improved type of illuminating shell was designed using a form of double emission (as shown in the U.S. Naval Bomb Disposal School's publication, "Japanese Ammunition", page 301). These projectiles were named SHOMEIDAN B. Some illuminating projectiles were also made with single emission and were designated SHOMEIDAN B-1.

Characteristics of illuminating projectiles of various calibers are shown in Table VII and sketches are given in Figures 8, 9, and 10. Japanese personnel repeatedly stated that all drawings of shells were destroyed by burning in August, and though some drawings of other types of shells have been found, very few drawings of illuminating projectiles have been discovered.

An American illuminating projectile of about five-inch caliber was recovered by the Japanese during the war, and they used it as a model for designing their projected shell, some of which were used in service. For this purpose, they scaled it up for larger calibers and intended to manufacture 18 inch illuminating projectiles. They stated that this size was not actually made though some 16 inch illuminating projectiles were in service.

From remarks made during interrogations by shell designers and fuze designers, it appears that the major caliber illuminating shells were probably dynamically unstable, as a large number of blinds could be attributed only to reclosing of the centrifugal block during flight.

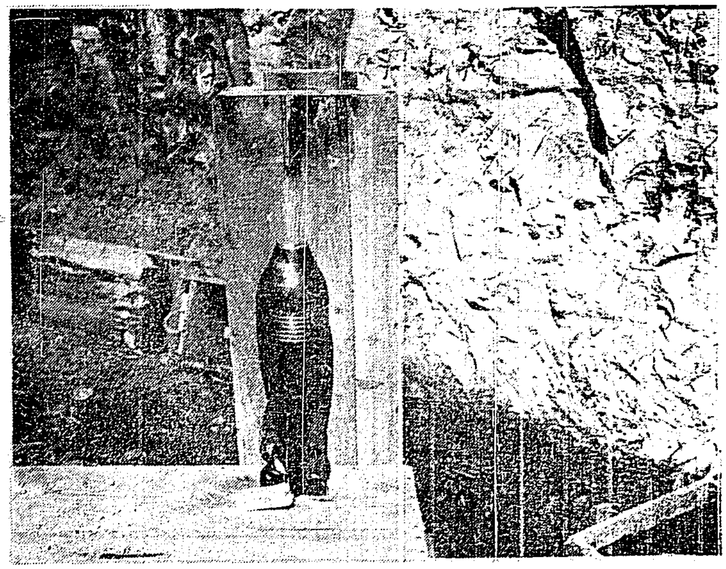
The fuze used for these shells was a time mechanical fuze. In the case of the larger caliber shells, a Type 4 Model 0 of 100 seconds possible setting time was used. The centrifugal block in this fuze was so pivoted that both the force of acceleration and centrifugal force tended to keep it open, and if it closed during flight, it would appear probable that the large caliber illuminating projectiles had a considerable precession about their trajectories.

The development of these large caliber illuminating projectiles for use from the main armament guns of battleships was pursued as a temporary expedient to enable the Japanese Navy to fight at long ranges at night, as they considered that their radar was not effective at ranges that could be used by Allied Forces.

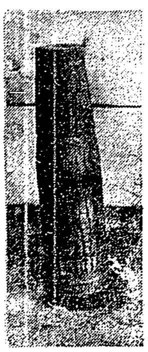
Figure 11 shows some photographs of illuminating projectiles, and also of some of the older type starshells (without parachutes) which can be distinguished by their lighter color (bluish grey).

Part V - ROCKET PROJECTILES

The Japanese developed rocket projectiles for anti-aircraft use, (for use in conjunction with multiple launchers) and for land operations. The former were 12cm incendiary shrapnel (see Figure 13) and the latter were either HE or shaped charge HE for use against tanks. A list of rocket propelled projectiles is given in Table VIII.

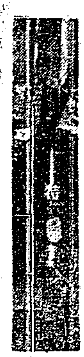


15cm MORTAR

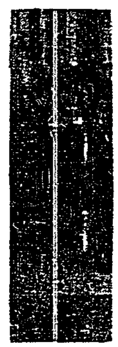


14cm A/S

12.7cm A/S



8cm A/S



8cm AA

Figure 7
MISCELLANEOUS PROJECTILES

TABLE VII
ILLUMINATING PROJECTILES

Type		Pyrotechnic Ingredients		Shell Steel Specifications											Fuse Used	Candle Power (x 10⁴)	Muzzle Velocity (ft/sec)	Maximum Range (yds)
				Chemical							Mechanical							
		Composition %	Weight (lbs)	C	Si	Mn	P	S	Ni	Cr	Yield Point (kg/mm²)	Tensile Strength (kg/mm²)	Elongation %	Impact Izod (ft/lbs)				
16"/45 cal	B_1	Magnesium 53 Barium Nitrate 42.5 Beeswax 3.5 Sodium Oxalate 1.0 (Experiments with sodium oxalate up to 10% gave good results.)	38.4	.4/.5	<.35	.3/.7	<.035	<.035	1.5/2.0	.2/.6	>55	80/100	>10	>10	Time Fuze, Type 4, Mark 0	530	2300	24,200
8" No. 2 50 cal	B		11.3	.4/.5	<.35	.3/.7	<.035	<.035	1.5/2.0	.2/.6	>55	80/100	>10	>10	Time Fuze, Type 4, Mark 0	160	2330	24,700
8" 50 cal	B_1		10.7	.4/.5	<.35	.3/.7	<.035	<.035	1.5/2.0	.2/.6	>55	80/100	>10	>10	Time Fuze, Type 4, Mark 0	170	2330	23,700
6.1"/65 cal	B		5.03	.4/.5	<.35	.3/.7	<.035	<.035	1.5/2.0	.2/.6	>55	80/100	>10	>10	Time Fuze, Type 4, Mark 1	95	2460	23,600
6.1"/65 cal	B_1		5.70	.4/.5	<.35	.3/.7	<.035	<.035	1.5/2.0	.2/.6	>55	80/100	>10	>10	Time Fuze, Type 4, Mark 1	160	2460	23,600
6"/50 cal	B		4.57	.4/.5	<.35	.3/.7	<.035	<.035	1.5/2.0	.2/.6	>55	80/100	>10	>10	Time Fuze, Type 4, Mark 1	95	2330	17,500
6"/50 cal	B_1		5.20	.4/.5	<.35	.3/.7	<.035	<.035	1.5/2.0	.2/.6	>55	80/100	>10	>10	Time Fuze, Type 4, Mark 1	126	2330	17,500
5.5"/50 cal	B		3.58	.4/.5	<.35	.3/.7	<.035	<.035	1.5/2.0	.2/.6	>55	80/100	>10	>10	Time fose, Type 4, Mark 1	76	2330	19,700
5.5"/50 cal	B_1		3.93	.4/.5	<.35	.3/.7	<.035	<.035	1.5/2.0	.2/.6	>55	80/100	>10	>10	Time Fuze, Type 4, Mark 1	109	2330	19,700
5"/50 cal	B_1		2.28	.35/.45	.05/.40	.8/1.4	<.045	<.05		.5/1.0	>50	> 70	>12	>10	Time Fuze, Type 4, Mark 1	68	2460	17,000
5"/40 cal	B_1		2.43	.35/.45	.05/.40	.8/1.4	<.045	<.05	1.5/2.0	.5/1.0	>50	> 70	>12	>10	Time Fuze, Type 4, Mark 1	68	2360	15,900
4.7"/45 cal	B_1		1.72	.35/.45	.05/.40	.8/1.4	<.045	<.05	1.5/2.0	.5/1.0	50	> 70	>12	>10	Time Fuze, Type 4, Mark 1	60	2300	15,400

NOTE: Type B is double emission; Type B_1 is single emission.
Color marking is red in all cases.

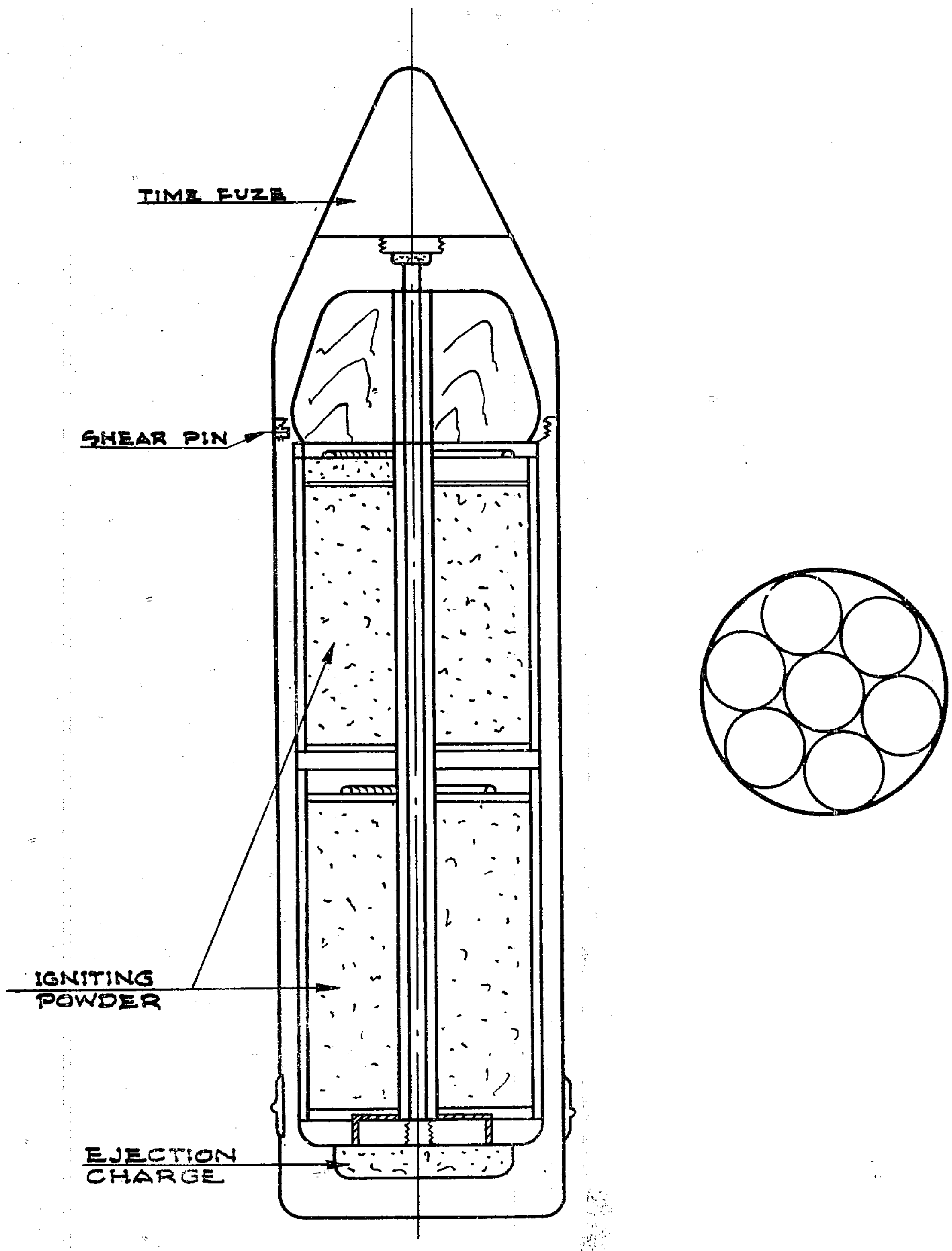


Figure 8
ILLUMINATING PROJECTILE "A" (STAR SHELL) SHOMEIDAN "A"

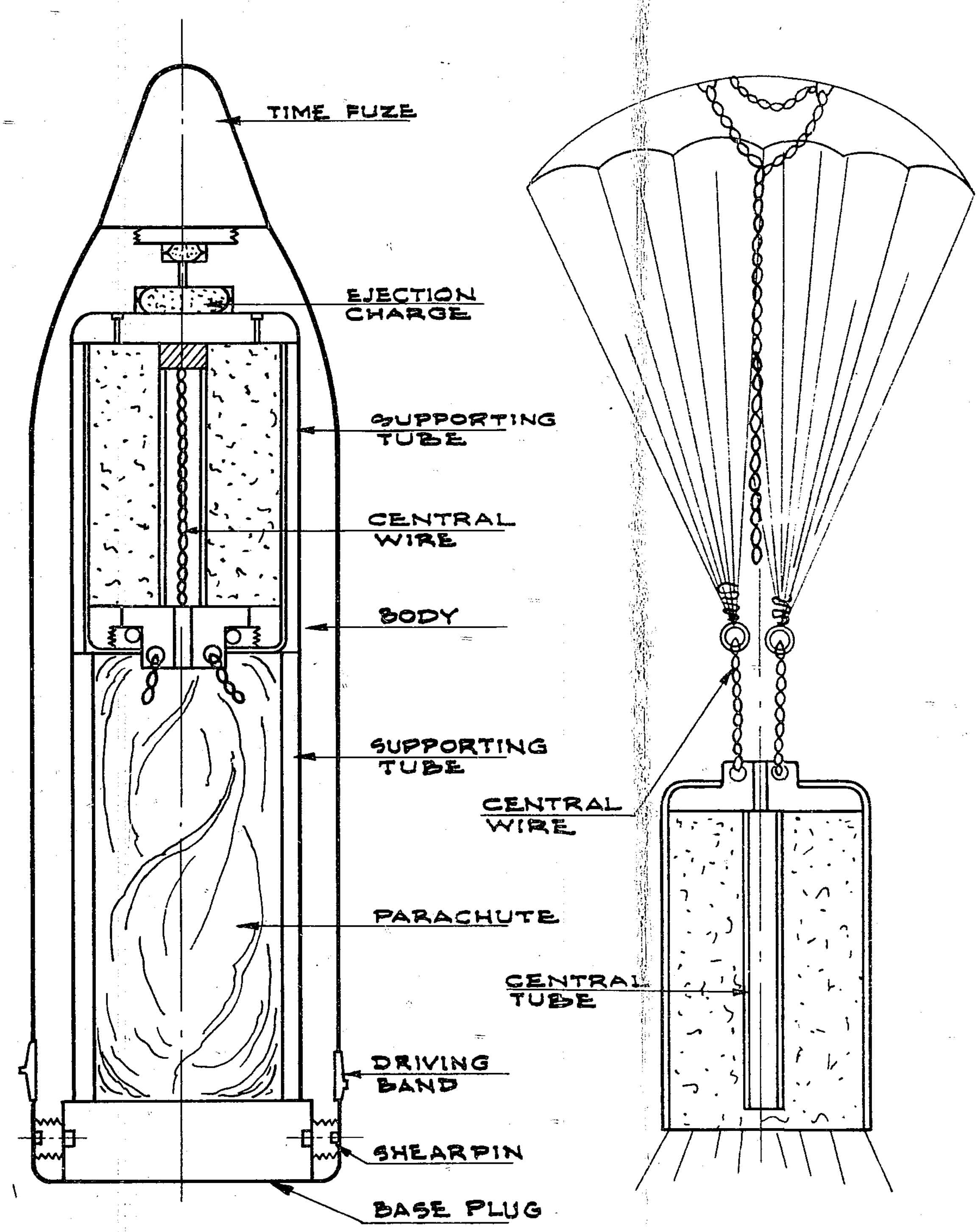


Figure 9
ILLUMINATING PROJECTILE "B"

Types Used: 36cm, 20cm, 15cm, 14cm, 12.7cm, 12cm

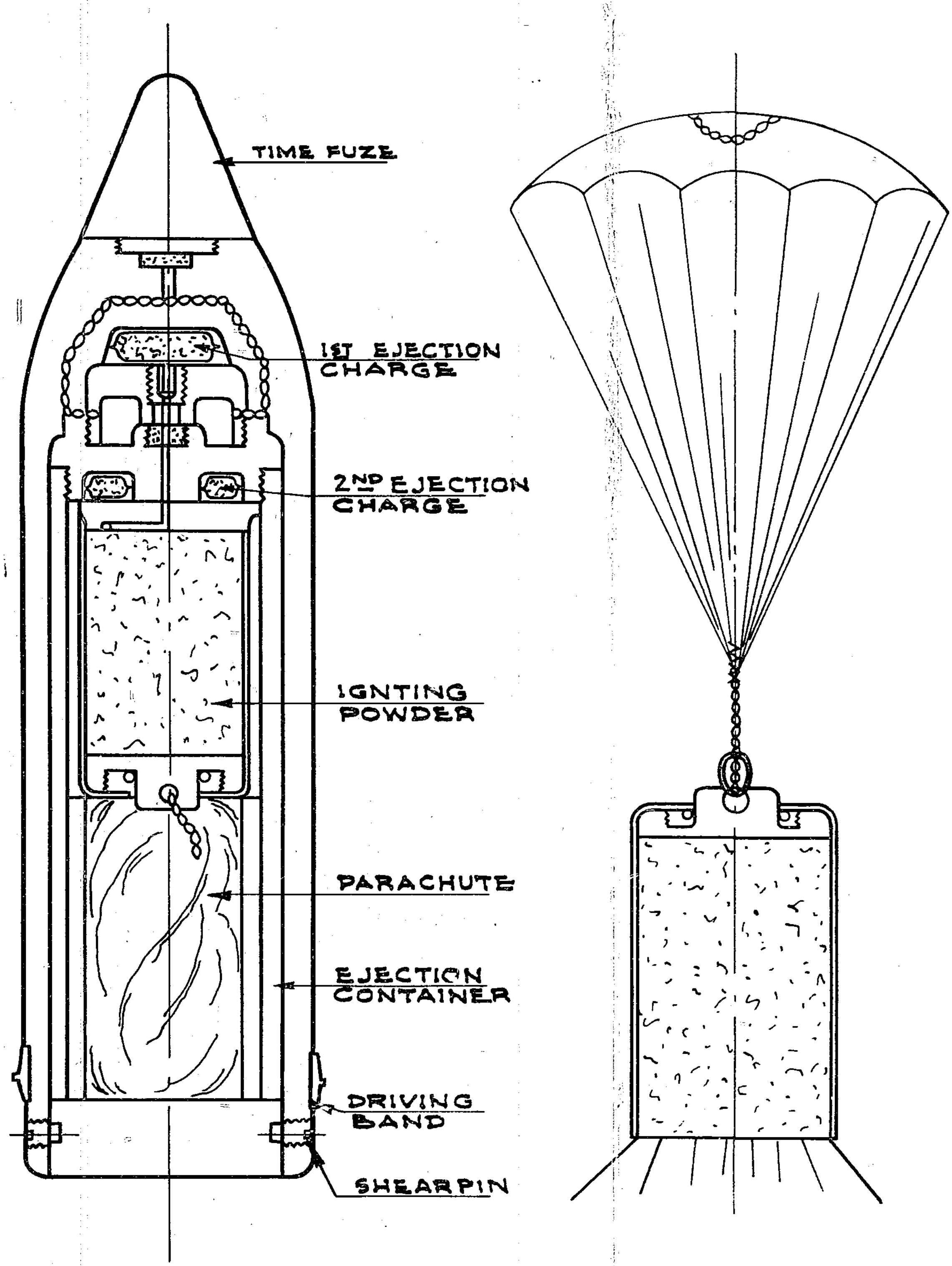


Figure 10

ILLUMINATING PROJECTILE "B"

Types Used: 20cm, 15.5cm, 15cm, 14cm

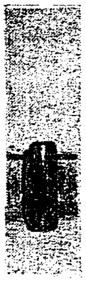
14cm ILLUMINATING

14cm STAR SHELL

12.7cm STAR SHELL

12.7 ILLUMINATING

15cm STAR SHELL



8cm ILLUMINATING

Figure 11

STAR AND ILLUMINATING PROJECTILES

TABLE VIII
ROCKET PROJECTILES

	Characteristics													Performance				Use
	Overall			Bursting Charge of Weight	Rocket Charge*					Nozzle Diameter		Fuze	Primer	Angle of Inclin. (°)	Angle of Diver. (°)	Time of Burning (sec)	Max. Range (yds)	
	Dia. of Projectile	Total Length	Total Weight (lbs)		(Inches) de	(Inches) di	Length (in)	Length No.	Weight (lbs)	(in)	No.							
Heavy	17.7"	5' 9.3"	1320	220	2.29	0.4	15.4	37	130	1.52	6	Percussion	Percussion	20	7.5	1.6	1600	For land battles
8" Common	8.0"	3' 6.5"	200	37	2.29	0.4	11.4	7	18.5	0.57	6	Percussion	Percussion	25	0.0	1.6	2000	For land battles
8" Common Modified	8.0"	3' 4.9"	176	26	2.29	0.4	15.8	7	26	0.65	6	Percussion (or time)	Pull out	25	0.0	2.0	3300	For land battles
8" V	8.0"	2' 8.6"	104	15	1.38	0.2	6.7	19	10	0.535	6	Percussion	Pull out	25	0.0	1.0	1300	Anti-tank
4.7" Common No. 2	4.7"	2' 5.8"	53	5.5	1.38	0.2	14.2 10.9	6 1	7.7	0.45	6	Percussion	Pull out (or perc.)	25	10	1.0	5200	For land battles
4.7" Shrapnel (containing sulphur)	4.7"	2' 5.8"	53	10	1.38	0.2	14.2 10.9	6 1	7.7	0.45	6	Time	Elec.	25	10	1.0	5200	AA
4" V	4.0"	1' 5.1"	23	3.3	1.18 1.18	0.2 0.4	4.5 2.4	6 6	1.9	0.246	6	Percussion	Pull out	30	0.0	0.8	1300	Anti-tank
3" V	3.0"	1' 3.0"	13	1.2	0.79 0.97	0.2 0.35	4.7 2.4	7 1	1.0	0.216	6	Percussion	Percussion	30	0.0	0.4	1300	Anti-tank
No. 25 (Bomb-Rocket) Mod. 3, Type 2	11.8"	5' 11"	400 (R) 770 (R&B)	155	3.10	0.4	15.8	18	110	3.55	1	Percussion	Elec.	0	7.5	4	5500	For land battles
No. 6 (Bomb-Rocket) Mod. 3, Type 2-3	7.9"	3' 7"	130 (R) 220 (R&B)	45	2.29	0.4	15.8	7	26	1.58	1	Percussion	Elec.	0	10	2	2700	For land battles

NOTE: Propellent charges used for these rockets are the tube-formed smokeless powder named "Special DT6" or "Special FDT6". The composition of the powder is as follows:

	Nitro-glycerin	Gun-cotton	Centra-lite	Mononitro naphtalin	Nitro-kalium
Special DT6	30	60	3	7	
Special FDT6	27	60	3	7	3

At the bottom of the rocket, six nozzles are situated, at equal distances on a circle concentric with the axis of the projectile. The axes of the nozzles are inclined to the axis of the rocket with an angle of 20° or 30°. The rocket Model 3 is designed to propel bomb from the rear in land battles. There is only one nozzle for the rocket Model 3 and its axis is on the axis of the rocket. Fins are fitted on the rear of rocket Model 3 to stabilize it.

*Under the heading Rocket Charge, de and di represent the exterior diameter of the propellant slick and the diameter of the central hole through the slick respectively.

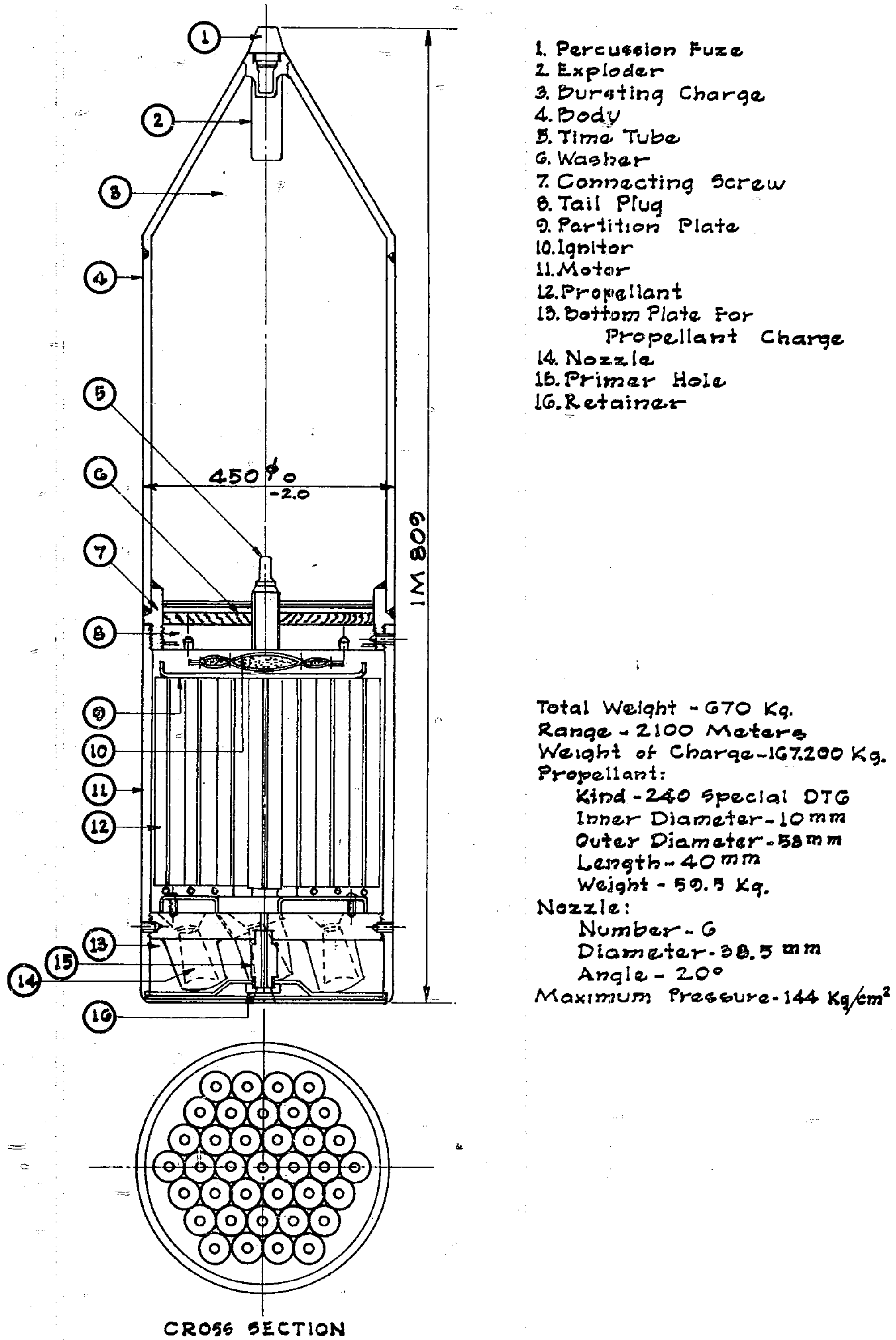
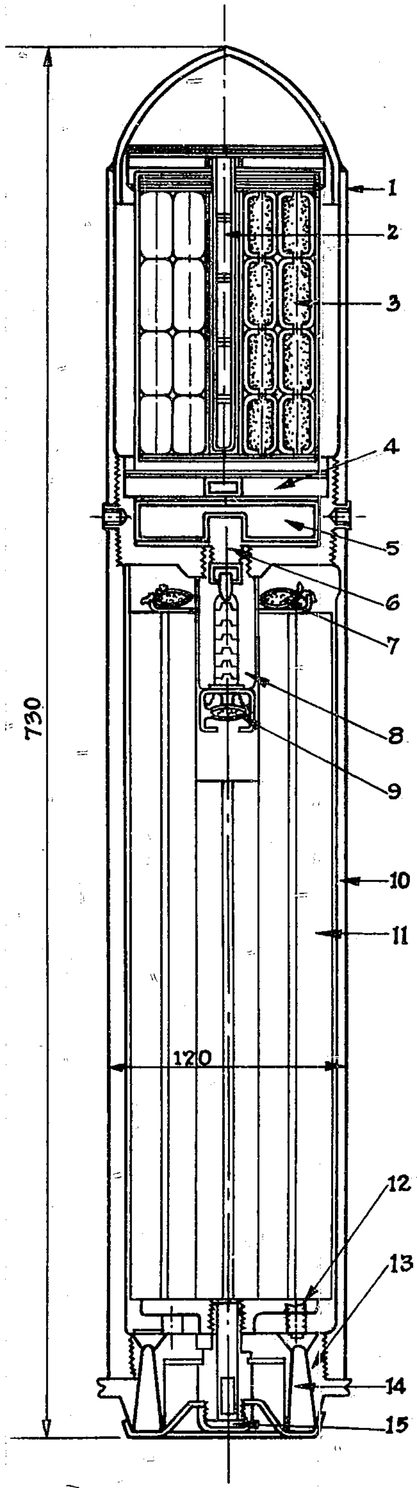


Figure 12

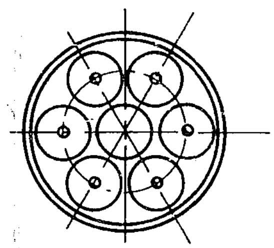
HEAVY ROCKET PROJECTILE



TOTAL WEIGHT - 22.5 KG.
RANGE - 4800 METERS
WEIGHT OF EXPLOSIVE - 0.78 KG.
PROPELLANT CHARGE:
- KIND - 150 SPECIAL DT 6
- INNER DIAMETER - 5 MM
- OUTER DIAMETER - 30 MM
- LENGTH - 360 MM
- WEIGHT - 3.4 KG.

NOZZLE
- NUMBER - 6
- DIAMETER - 11.5 MM
- ANGLE - 25°

MAXIMUM PRESSURE - 196 KG/CM²



CROSS SECTION

1. BODY
2. CENTRAL EXPLOSIVE
3. SHRAPNEL
4. SUPPORTING PLATE FOR SHRAPNEL
5. BOTTOM EXPLOSIVE
6. CAP
7. FIRE TRANSFERING POWDER
8. DELAY TUBE
9. LEAD-IN
10. PROPELLANT CHARGE CHAMBER
11. PROPELLANT CHARGE
12. SUPPORTING PLATE FOR PROPELLANT
13. NOZZLE RING
14. NOZZLE
15. PRIMER

Figure 13

12cm INCENDIARY-SHRAPNEL ROCKET

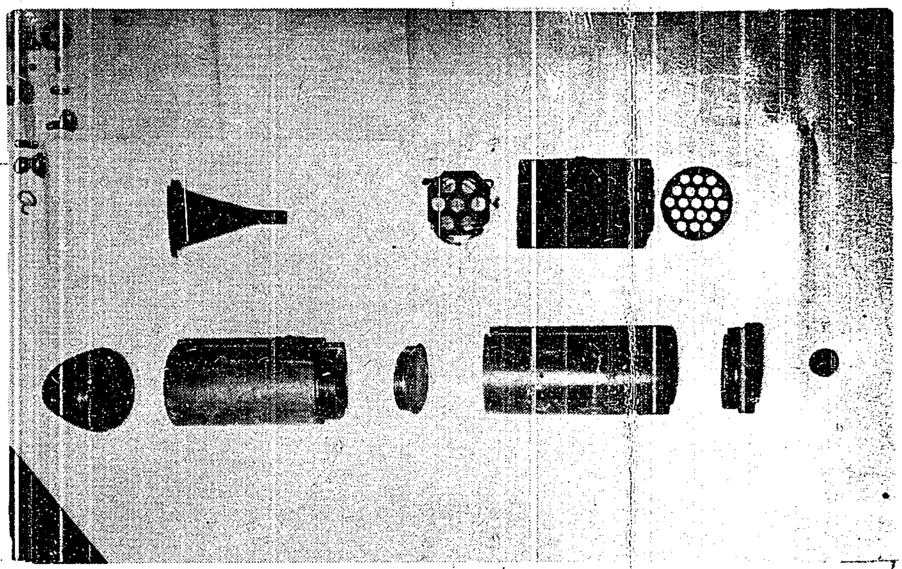


Figure 14

8cm SHAPED CHARGE ROCKET

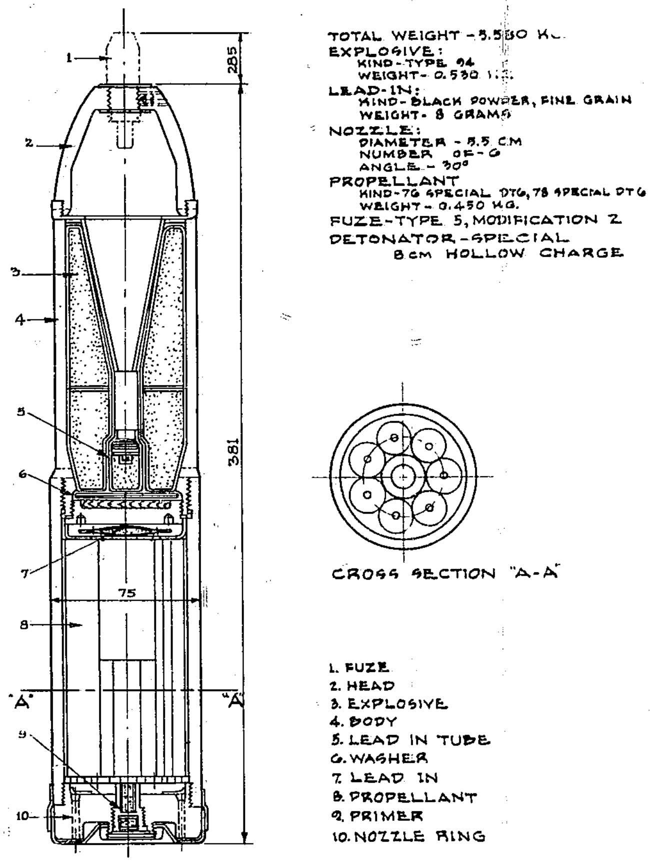


Figure 15

8cm SHAPED CHARGE ROCKET

The fundamental principles of shaped charge projectiles were obtained from Germany and a considerable amount of research was carried out by the Japanese. A comprehensive study of the mathematical and experimental research carried out is contained in Report No. 158 by the Air Technical Intelligence Group of Advanced Echelon Far Eastern Air Force. (See NavTechJap Report, "Japanese Demolition Methods," Index No. 0-35.)

In the case of conical cavities of 30° angle the "stand off" height was one diameter; with a 40° angle the "stand off" was 3/4 of the diameter. In the case of a semi-spherical cavity the "stand off" height was two to four times the diameter.

The penetrating power of the shaped charge projectile against armor was claimed to be as follows:

20cm rocket projectile .... 10 inches
10cm rocket projectile .... 2.3 inches
8cm rocket projectile .... 2.3 inches

A Type 5, Model 2 percussion fuze was used with the shaped charge projectiles, and the flash was taken down a central hole to the fuze of the charge. Experiments were in progress to shape the booster of the fuze to give "shaped charge" effect.

The separation plate at the surface of the cavity was made of three layers of 1.6mm steel plates.

All the rockets were spin-stabilized except the 20cm (8 inch), and when the war ended experiments were still being carried out to modify the shape of the "fins" on the 20cm rocket to improve its ballistics.

Figure 12 is a sketch of the "heavy rocket"; Figure 13 shows the anti-aircraft 12cm incendiary shrapnel rocket projectile; and Figures 14 and 15 show the 8cm shaped charge projectile.

The Japanese work TA indicates a shaped charge and the word RO indicates rocket propulsion. ROTSU is a rocket-propelled shaped charge projectile.

Part VI - ARMOR PIERCING PROJECTILES

A. General.

The Japanese claim that practically all blueprints and data on this subject which were not destroyed by the air raids were subsequently burned or otherwise disposed of before the occupation. In most cases, there was little evidence to discount this claim insofar as the knowledge of the individuals interviewed was concerned. Consequently, the information contained herein is based primarily on the data supplied by the Japanese technicians from their memory and a few documents which they supplied from their private sources. It is believed that the information contained herein, except when otherwise noted, is authentic to the best knowledge of the Japanese personnel interviewed. Whenever possible, the data on equipment was checked by inspection of the shops and testing areas involved.

All available information on the manufacture and testing of the Armor Piercing Projectiles, Type 91, is given here. Certain information which was not available may be obtained from examination of specimens shipped to the United States. The principal data lacking are the details of the dimensions and weights of the projectile components. The major caliber projectiles were so located as to make weighing as well as breaking down of the caps, plugs, etc., impractical.

B. Summary of Design.

1. Distinguishing Characteristics.

The most recent Japanese armor piercing projectile is designated as Type 91 (i.e., originally designed in 1931). It superceded the earlier Type 88 design. The Type 91 projectile was designed so that if it struck water short of the target, its trajectory would remain undisturbed, with the target being the lower side belt below the water-line. This was accomplished by weakening the forward section of the projectile so that when it struck water it would separate, leaving a flat end. For the major caliber projectiles (46, 40, and 36cm) the armor piercing cap was divided transversely into two parts: a small forward part known as the cap-head, and the cap proper. The after face of the cap-head and the forward face of the cap were flat and were assembled flush. They were secured to each other only by the windshield threading which screwed on to both parts as shown in Figure 16. The windshield had an internal circumferential groove at the cap and cap-head interface which weakened the connection sufficiently so that the cap-head and windshield broke off on water impact. The cap was soldered and crimped to the body.

The medium caliber (20cm and 15.5cm) Type 91 service projectiles had no cap. The body had a flat forward end and a cap-head which was secured to the body in the same manner as the cap and cap-head were secured in the major caliber projectiles. Strictly speaking, the medium caliber Type 91 projectiles were not armor piercing by American standards, since they lacked a true cap. The outer contour of the medium caliber Type 91 projectiles was essentially the same as the major caliber. There were capped 20cm and 15.5cm (Type 91 Mod. 1) projectiles which were used for experimental purposes and armor development only. They were proportioned in all respects after the major calibers but were never used in service.

All Types 91 projectiles were boat-tailed. They contained a base plug with an adapter.

2. Dimensions and Weights, Type 91 Projectiles.

TABLE IX

	Diam. of Bourrelet (inches)	Total Length (inches)	Weight Lbs.	Filler(TNA)		Cap & Windshield		Initial Vel. (ft/sec)
				Lbs.	%Wt.	Lbs.	%Wt.	
40cm Type 94	18.07	77.0	3215	52.6	1.6	?		2560
40cm	16.11	68.4	2242	32.8	1.5	358	16.	2560
36cm	13.97	60.1	1480	24.5	1.7	229	15.5	2530
20cm	7.96	35.7	277	6.85	2.5	17	6.	2740
15.5cm	6.07	26.7	123	2.54	2.1	?		3020

The data for "Cap and Windshield" include all three components where applicable: the cap, cap-head, and windshield. Data for the individual pieces were not found. Furthermore, the data given are approximations to the nearest pound.

The 40cm, Type 94, was so designated for security purposes. It was actually a 46cm (18.1") projectile. The Type 94 refers to the gun. The projectile was nevertheless a Type 91 design. The above projectiles will

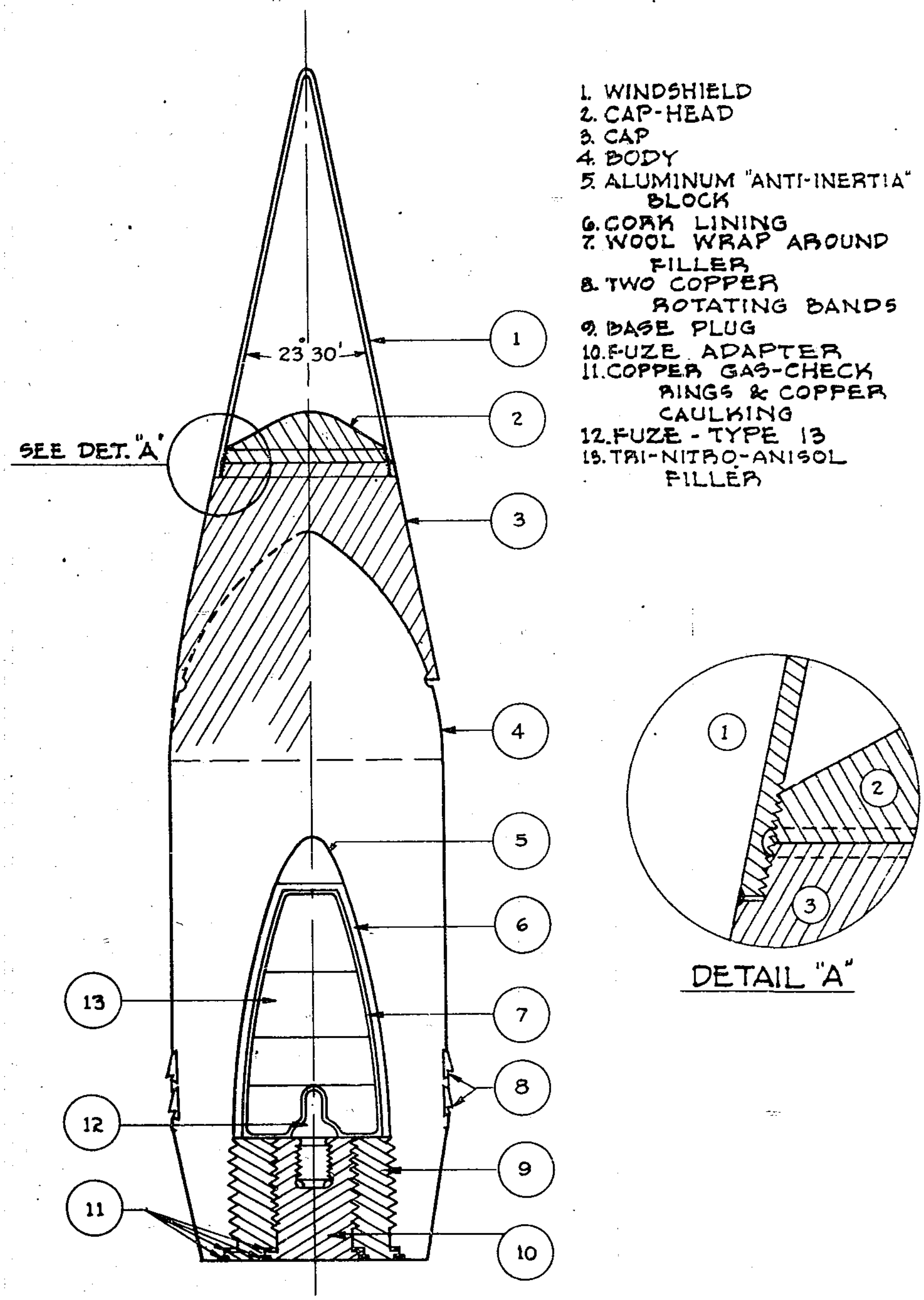


Figure 16

ARMOR PIERCING PROJECTILE, TYPE 91

be referred to as 18", 16", 14", 8", and 6", respectively, in this report. As noted in the last section, an experimental 48cm (19") projectile had also been produced.

3. Painting and Marking.

All AP projectiles are supposed to be white all over with an orange band at the center of gravity. If loaded, the end of the windshield is painted green. If base-fuzed, the windshield has a red tip forward of the green. If dye loaded, a band of the same color as the dye is painted just aft of the green. Some of the projectiles found in storage were not fully painted and had only an orange-red protective coating. In any case, the whole projectile including the bourrelet and base was painted with the exception of the two rotating bands. The characters for "9" and "1" (for Type 91) were painted on the windshield.

C. Fuze Technique.

1.

Projectile	Fuze	Delay Time (sec)
18"	Type 13 Mk. 5	0.4
16", 14", 8"	Type 13 Mk. 5 with wood "cap"	0.4
6"	Type 13 Mk. 3	0.08

The pre-formed T.N.A. fillers for the 16", 14", and 8" projectiles were made to receive the fuze Type 13, Mk 4, which is somewhat longer than the Mk 5. The Mk 5 had the same delay time and was similarly designed, but was stronger and had better materials. Hence, the Japanese changed over to the Mk 5 for all major caliber projectiles and had to add a wooden "cap" to occupy the otherwise vacant space in the 16", 14", and 8" fillers. The most recent fillers for the latter projectiles were pre-formed to receive the Mk 5 fuze, but very few of these ever were sent to service.

2. All fuzes were usually assembled aboard ship by removing the adapter, inserting the fuze in the adapter, and returning the assembly to the base of the projectile. The use of the aluminum "anti-inertia" block at the forward end of the cavity, the cork lining, the lacquered cavity, and the wool wrapping of the filler were all safety features. The aluminum and cork were principally to prevent premature deflagration of the filler on impact.

3. The long fuze delay of the Type 13, Mark 5 (0.4 sec) was used to allow time for penetration of the lower side belt after the fuze action was initiated on water impact, for a short near-miss. The same idea doubtlessly guided the delay time for the 6" fuze on a smaller scale.

D. Inspection.

All of the armor piercing projectiles for the Imperial Japanese Navy were produced at the ordnance plant in Kure Navy Arsenal. The inspection of the projectiles during and after manufacturing was conducted by Ordnance Section personnel attached to the yard, unlike the armor plate, which was controlled by a central bureau in TOKYO. The projectiles were ballistically tested at the Kamegakubi Proving Ground located on KURAHASHISHIMA in the Inland Sea near KURE. The Proving Ground was supervised by personnel attached to the Ordnance Section of the Navy Yard. It is believed, however, that the inspection of the projectiles during the manufacturing process was rigorous in view of the large number of personnel employed by the inspection department. This is not to say that the inspection methods were particularly good nor the specifications severe, merely that the standards which were set up were probably adhered to. The details of the control are given herein wherever data were available in the chronological order in which they were applied.

E. Melting and Ingot Practice for Bodies.

1. A basic electric furnace, Heroult type, with a 13,000 pound capacity was used.

2. A highly oxidizing slag for the first stage helped to reduce phosphorus and a high carbide content in the slag kept the sulphur down. The scrap was high grade with low P and S content to start with.

3. Charge of metal:

Cold scrap .... 50 to 60%
Premelted "wash-metal" scrap .... 40 to 50%
Pig .... *less than 10%

*Added in the last stage to adjust the carbon content.

4. The mold was the rough shape of the projectile body, a circular section with a slight taper, an ogive shaped bottom with the customary bottom sprue. The ingot ran approximately 45% heavier than the finished body. The mold for the 18" projectile was 19.9" in diameter at the top. The Japanese claim the ingot shrank about 0.2" on cooling. Only one projectile was made from each ingot for all calibers.

5. The bodies were numbered by using the chronological number of the heat, followed by a fraction which indicated the ingot number. Thus, 67021 2/6 indicates heat number 67021, the second of 6 ingots from the heat. This number usually appeared on the bottom of the base ring, painted in black.

TABLE X

LADLE ANALYSES

	Specification SL4, for 18", 14", and 16"		Specification SL3, for 8" (prior to July 1945)		Specification SL6, for 8" (during July 1945)	
	Specifications	Averages	Specifications	Average	Specifications	Average
C	.45/.55	.45/.55	.55/.65	.60	.45/.55	.50
Mn	under .40	.15/.30	under .45	.15	.8/1.2	1.0
Si	under .45	.25/.35	under .45	.30	under .45	.30
P	under .025	.01	under .025	.015	under .025	.020
S	under .025	.006/.01	under .025	.007	under .025	.015
Ni	3.5/4.0	3.5/4.0	2.5/3.0	2.8	1.5/2.0	1.7
Cr	.5/1.0	.5/1.0	2.0/2.6	2.3	2.0/2.6	2.3
Mo	.3/.8	.3/.8	none	none	.20/.50	.30
Cu	under .2	.1/.15	under .25	.20	under .25	.20

6. During the spring of 1945, the substitute analysis (SL6) for 8" projectiles was developed which was claimed to result in an equally satisfactory product to the SL3 analysis although somewhat more difficult to heat treat. The purpose of the substitution was, of course, to conserve nickel. It went into production in July but since the plant was bombed in the latter part of the month and ceased operations, not many rounds were produced and certainly none ever went to service.

7. The 6" projectile, Type 91, had not been in production for about ten years for the following reasons:

a. Large stocks on hand.

b. Change in the tactical use of the 15.5cm (6") gun. This gun was apparently used in recent years principally as secondary or broadside battery on ships which also carried major caliber main batteries. The principal use for the gun in this status was anti-aircraft.

c. For smaller combat vessels, the 15cm (5.9") gun was used rather than the 15.5cm whenever a gun of this size was required. There was no AP projectile made for the 15cm gun, only a hooded common for armor penetration.

Since this projectile had been out of production so long, records could not be found and the metallurgists interviewed could not recall the details.

F. Annealing and Shaping.

1. The ingot was annealed as follows: Heat to 780°C, hold for 5 to 15 hours (depending on caliber); furnace cool to 300°C, heat to 680°C, hold for 8 to 20 hours, and furnace cool.

2. The ingot was cropped off by sawing cold after the anneal. Approximately 30 to 35% from the top of the ingot was sawed off. The hot top alone weighed about 20% of the ingot. The bottom of the ingot was not cropped except for the sprue.

3. The ingot was then heated to from 1080° to 1150°C and was pierced in a hydraulic press. The process required two strokes, the first, applied to the whole top of the ingot, served to press the ingot into the chamber of the press, the second to pierce the cavity. The major caliber projectiles were pierced by a horizontal press, the 8" projectiles by a vertical press.

4. The piercing operation was the only hot working applied to the body. The following table summarizes the data:

TABLE XI

Projectile Caliber	Force on Piston, Metric Tons		Forging Ratio
	Press Stroke	Pierce Stroke	
8"	?	?	1.5
14"	1600	500	1.8
16"	2000	700	1.6
18"	2200	1300	2.1

5. Following the piercing stroke, the body was returned to the furnace and slowly cooled to below 300°C. The body was then rough machined nearly to the finished dimensions.

G. Heat Treatment and Physical Tests.

1. The body was heated in a vertical cylindrical gas-fired (by-product coke gas from city supply) furnace using a slightly reducing atompshere. The body was suspended nose down and was slowly rotated (about 1 RPM). 8", 14", and 16" projectiles were usually heated in groups of four. The 18" projectiles were heated one to a furnace.

2. The temperature cycles are given in Figure 17. Pt-Pt/Rd thermocouple was pressed against the forward tip of the cavity from which the temperatures noted in Figure 17 were read. During air-cooling (see below) a "Wanner" optical pyrometer was used.

3. The ripples in the diagrams at 850°C indicate a withdrawal into open air from the furnace three times during the holding period for one minute each in the case of 14" and 16" bodies, and two minutes each in the case of 18" bodies. This air cool was an equalizing operation to reduce the thermal gradient. The 8" bodies received no air cooling. The shaded area in the diagram for the 18" body indicates a preheat in a separate furnace.

4. The Quench.

a. For the 14", 16", and 18" bodies, a decremental quench was used. The body was transferred as quickly as practicable from the furnace into a water tank, where it was suspended nose down. It was rotated and the water was circulated for agitation. The temperature of the water was kept at 30°C. The quenching times were as follows:

14"	40 min
16"	60 min
18"	90 min

The water level was gradually lowered from the base of the projectile to the forward bourrelet during the above periods. The cavity was not exposed to cooling medium.

b. The 8" body was quenched in agitated rape-seed oil until the forward tip of the cavity reached 150°C (by thermocouple), which took about 40 minutes. It was a uniform quench. The cavity was not exposed to the oil.

c. The hardness at the surface of the major caliber bodies after the quench was:

Nose	550 BHN (3000 kg: 10mm steel ball)
Base	450 BHN

No data were available on the 8" body after quenching.

5. The Temper.

a. The projectile body was suspended nose down in a direct-fired furnace (see Figure 18) using a slightly reducing atmosphere. The furnace had 24 burners in 8 vertical rows of 3 each. The nose of the body was immersed in circulating water during this operation with an overflow to maintain the precise level.

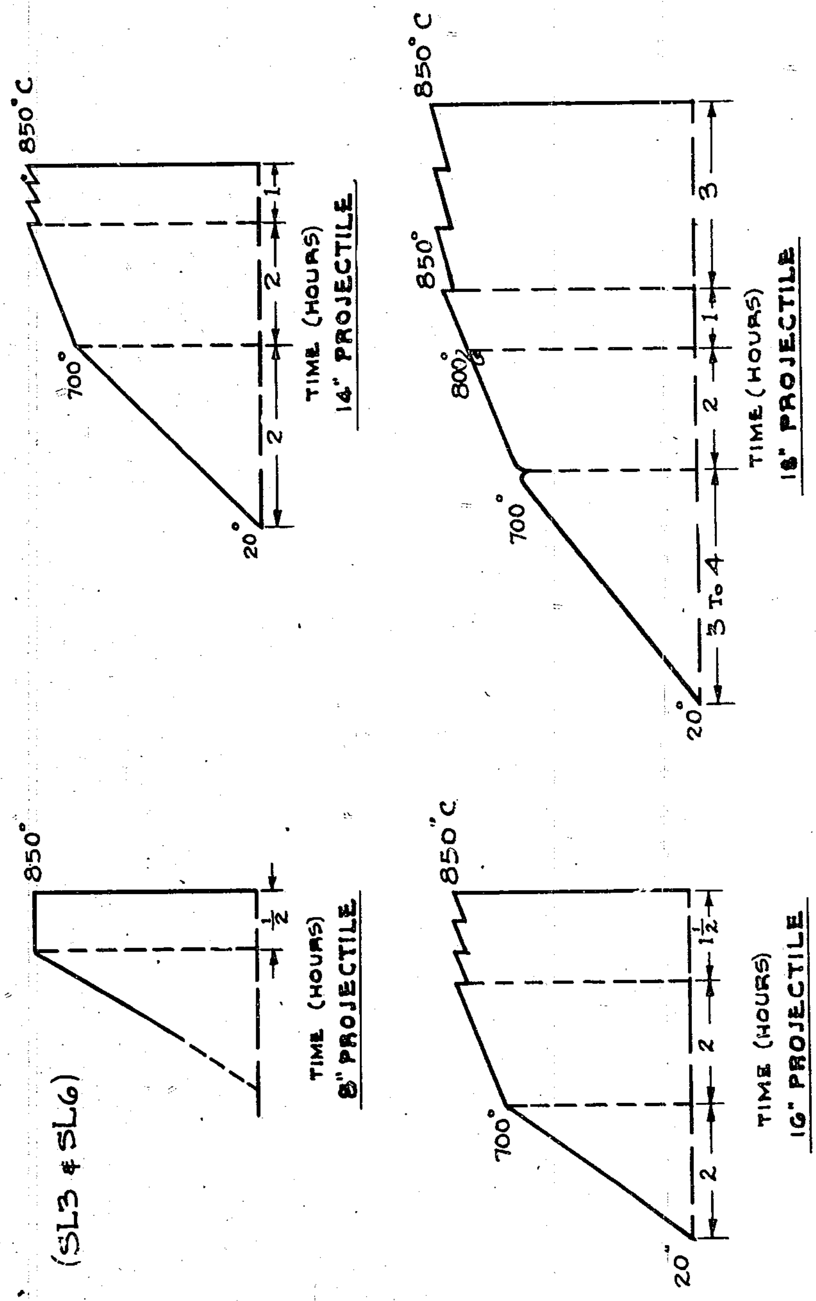


Figure 17

THERMAL CYCLES PRIOR TO QUENCHING TYPE 91 BODIES

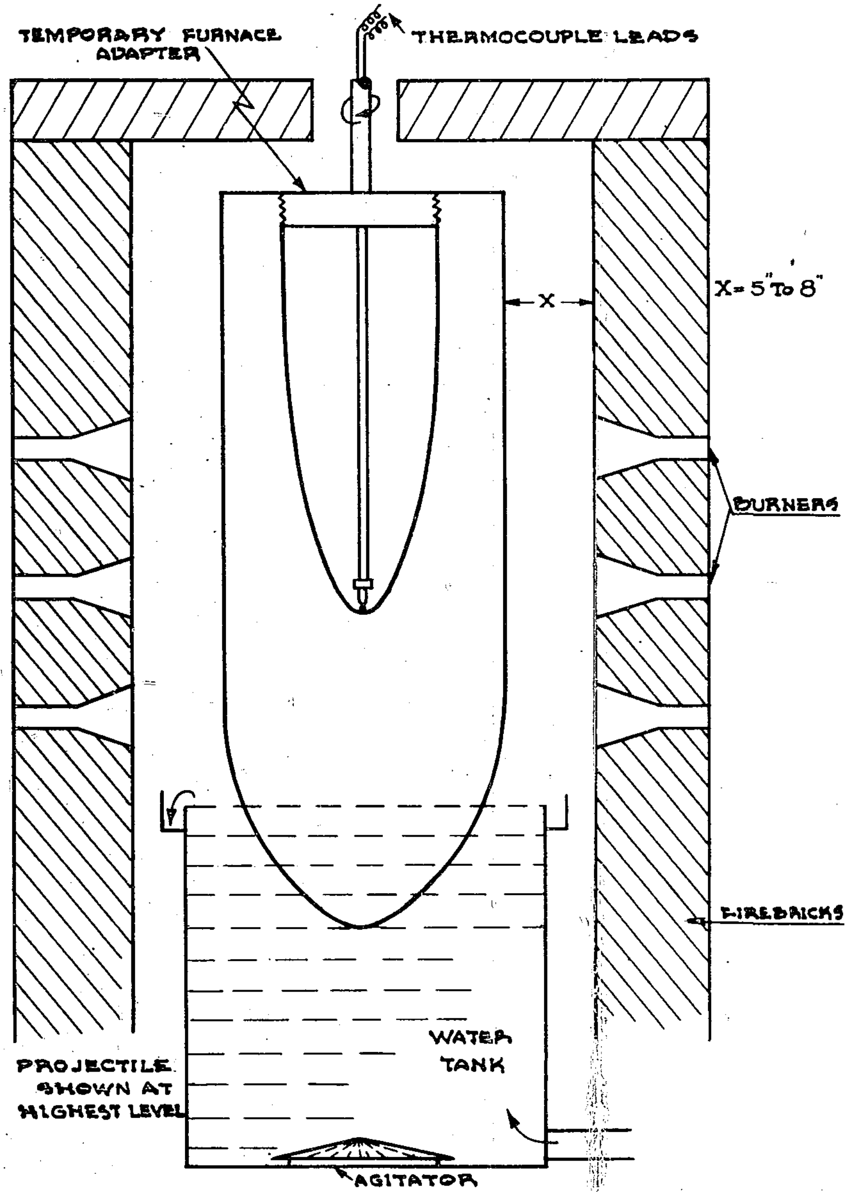


Figure 18

TEMPERING FURNACE FOR THE TYPE 91 BODIES

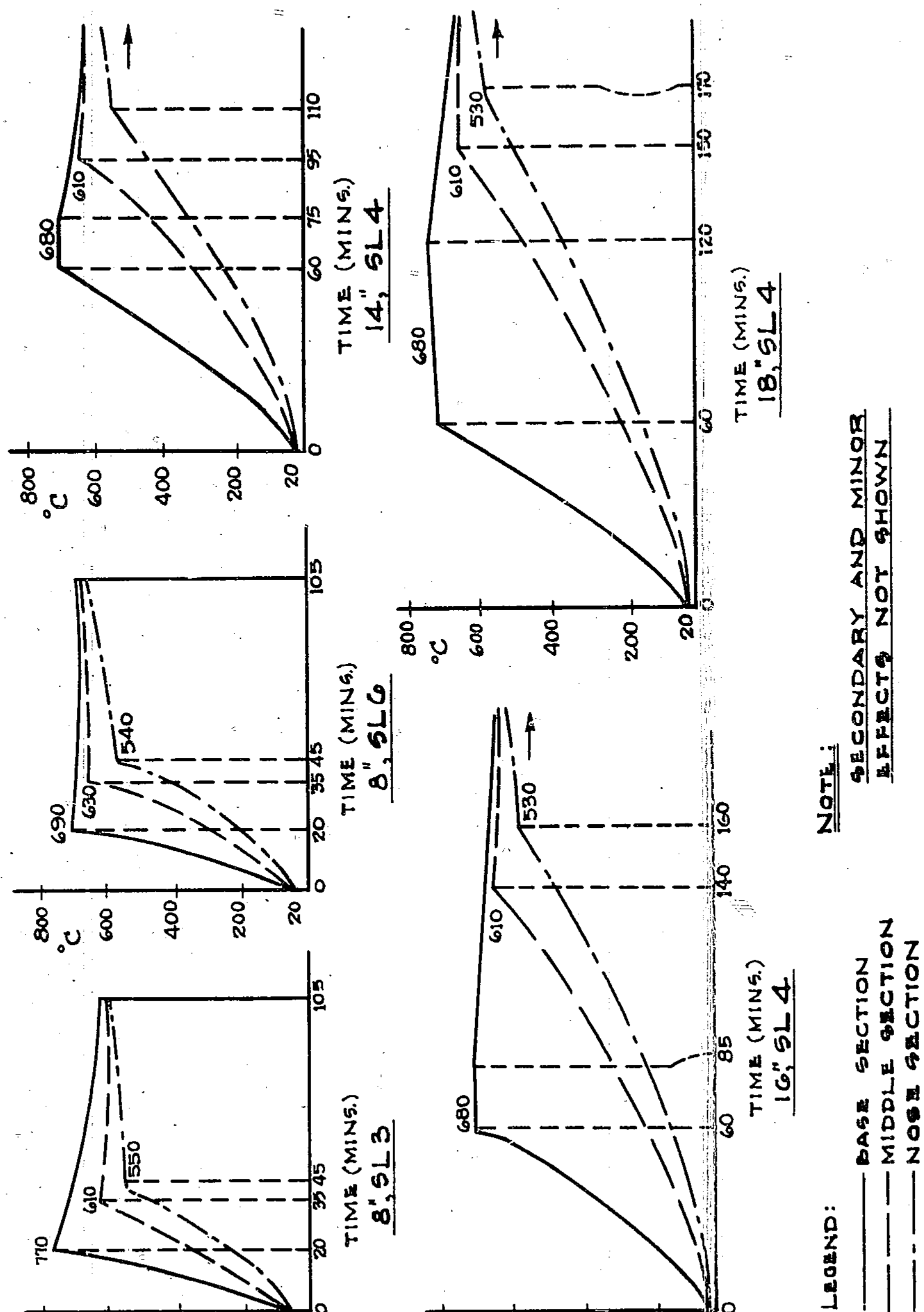


Figure 19
THERMAL CYCLES FOR TEMPERING TYPE 91 BODIES

b. The temperature readings during the operation were obtained by poking a thermocouple through the burner openings and pressing it against the side of the body. The body was rotated about its axis. A thermocouple junction was also located at the forward tip of the cavity.

c. The body was arranged to permit elevating it during the process so that the level of the water with respect to the body could be decreased. The water levels were as follows:

Projectile	Level A	Level B	Level C
8"	3" from end of nose.	1" from end nose.	not used
14", 16", 18"	about even with tip of cavity	about fwd. bourrelet	14"-5.7" from end of nose 16"-6.3" from end of nose 18"-8.1" from end of nose

d. The projectile body was divided into three sections from a heating control viewpoint, the base section which was uppermost, the middle section, and the forward section. Three levels of burners were used as noted above. In addition to elevating the position of the projectile at certain times, the top, middle, and bottom burners were successively cut off. The thermal cycles are given in Figure 19 and the times at which the above changes were made are given in the following table:

TABLE XII

	Time in minutes (total elapsed)			
	8"	14"	16"	18"
Raised from Level A to B	35	60	60	60
Raised from Level B to C		95	140	150
Top burners cut off	20	75	85	120
Middle burners cut off	35	95	140	150
Lowest burners cut off	45	110	160	170

e. The body was allowed to remain in the furnace until, for the major calibers, the thermocouple at the tip of the cavity read 300°C, and for the 8" projectile a total period of 105 minutes had elapsed (by which time it may be presumed that the cavity was down to 300°C). During the cooling period the projectile remained in water at the same level (B for 8", C for the others).

f. The body was then transferred to a large open tank and air cooled with nose still immersed in water at the same lowest level, until the body was cooler than the melting point of the cap-securing solder, about 140°C.

g. While the depth of immersion in water for the 8" body may appear small, attention is invited to the fact that the 8" body, unlike the major calibers, had a flat nose. The level B, in this case, barely covered the windshield thread shoulder.

h. The heat treatment of the major caliber projectile bodies was complete at this point. However, the 8" body was further treated by immersing the nose one inch in molten lead at 400°C for a period of 30 minutes and air cooling. The hardness data, given below, reflects this low temperature draw in a softer nose for the 8" projectile. The Japanese were questioned on the reason for softening the nose but the answers were so vague and variable as to make them untrustworthy.

6. Hardness Specifications and Data.

a. Standard Brinell and Shore Scleroscope readings were taken on the surface of each body. The locations of the readings are shown schematically in Figure 20 and tabulated in the following table.

TABLE XIII

	Distance from Base in Inches			
	8"	14"	16"	18"
Location				
1	1.0	1.0	1.0	1.0
2	6.5	5.9	6.3	7.9
3	11.0	15.0	16.1	20.1
4	15.5	21.2	22.8	28.8
5	18.1	23.6	25.6	31.9

Locations A, B, C, D, and E were determined by gauged jigs which were not found. But the method of locating the points is shown in Figure 20. Point C was located in each case except for the 8" body at the lowest water level on tempering (level C). Point D on the 8" body corresponds to the lowest water level.

b. The Brinell readings were taken, after grinding off a fraction of a millimeter, on a machine mounted on a dolly with a V-shaped bed. The screw was mounted on a movable frame which traversed the length of the bed. The screw was depressed by turning a wheel under which was located a force gauge. The machine itself was crude and subject to errors, but it was calibrated after each six projectiles so that the readings were probably fairly accurate. The scleroscope readings were obtained with a dial-type unit.

TABLE XIV

Location	Test	ANALYSIS		
		SL4 (Major Cal.)	SL3 (8" old)	SL6 (8" new)
1	BHN, 3000kg., 10mm ball	262-302	217-255	262-302
2		285-321	241-285	285-321
3		302-341	285-321	302-341
4		341-375	341-375	341-375
5		375-415	375-415	375-415
A,B	Shore Scler.	over 80	70-75	70-75
C		70-75	70-75	70-75
D		65-70	70-75	70-75
E		55-60	57-62	57-62

c. The odd numbers for the Brinell readings were used because they correspond to even readings for the ball impressions in millimeters, thus simplifying inspection. A failure of the specifications for any one location was cause for reheat-treatment. The average Shore reading for points A and B on the major caliber bodies was 83 SHN according to the Japanese, which is approximately the same or even slightly higher than the standard nickel-chrome American AP nose. However, uniformity of Japanese and American instruments is doubtful. The Japanese also placed an upper hardness limit to the nose of the 8" projectiles.

d. For the major caliber projectiles, after the first hardness test, the projectile body is "seasoned" by boiling in water for 24 hours. The object of this is to encourage cracking, if the body is liable to crack, and otherwise to toughen it by changing the alpha martensite to beta martensite. This operation was conducted at too low a temperature to be considered a true stress relief. The examination for cracks was visual; no magnafluxing was used.

e. The hardness data, crack test, ladle analysis, and dimensional inspection were the only specification requirements other than ballistic to which the body was subject. However, subsequent to final inspection and acceptance, but prior to issuing for service use, all armor piercing projectiles were given a weathering test for six months to a year (depending upon fleet requirements of delivery). While the Japanese would admit no violation of this requirement, the other evidences of speeded production and urgency indicate that the weathering test was reduced or even eliminated during the war.

f. The next section summarizes the available data on other tests which were occasionally conducted for information but which were not set up in the specifications.

7. <u>Other Physical Tests</u>.

a. The standard of comparison for tensile and impact values was set up by the following arbitrary conditions:

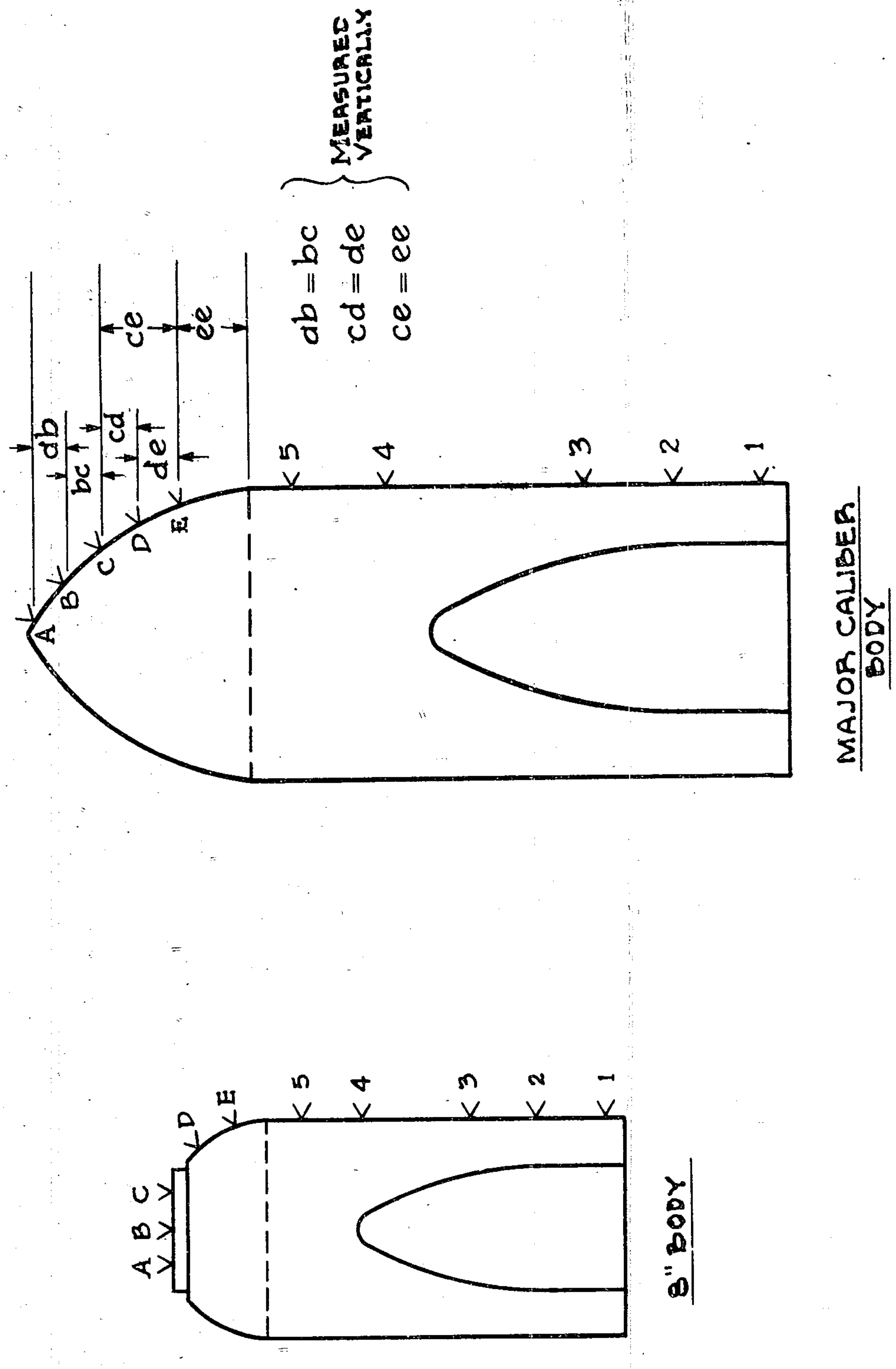


Figure 20

LOCATION OF HARDNESS TEST POINTS ON TYPE 91 BODIES

(1) A 50 kg (110 lb) ingot was poured from a high freque y induction crucible with the following analysis: (SL4 specification).

C	0.50	Ni	3.60
Mn	0.17	Cr	0.82
Si	0.27	Mo	0.68
P	0.014	Cu	0.32
S	0.013		

(2) The ingot was oil quenched from 850°C after a long hold. It was cut and tempered at four different temperatures with the test results as shown in the following table:

TABLE XV

Temper Temp., °C	Tens. Str. kg/mm²	Yield Pt. kg/mm²	Elong. % in 50mm	R.A. %	BHN (std.)	Izod ft-lbs
400	171.6	149.0	11.6	32.5	501	9.2 to 8.9
500	156.0	154.0	11.6	35.4	441	10.5 to 9.3
600	124.3	115.8	16.0	48.0	363	26.1 to 25.1
650	105.0	91.1	19.0	49.5	318	43.2 to 41.2

The tensile specimen had a 50mm gage length and 14mm diameter. The Izod specimen was a standard 10mm section with a V-notch 2mm deep and with a .25mm bottom radius. The Japanese could offer no data on how closely the actual projectile steel matched the above standard, but indicated that the projectile steel usually was somewhat superior, due mostly to the fact that the above ingot was not hot worked and the copper and sulfur were on the high side, the copper being above the specification limit. No standard was used for the 8" steels.

b. Interior Hardness Patterns. The accuracy of the data available on this subject is probably questionable due to the very few times that bodies were split and valid data obtained, as well as the fact that these data were claimed to be from memory. The patterns for bodies, caps, and cap-heads are given in Figure 21 for the major caliber projectiles.

H. Major Caliber Cap.

1. The same analysis (specification SL4) was used as for the body. Only one cap was made from each ingot. The ingot was short, stout, and had a round bottom with the customary sprue.

2. It was annealed with the following cycle:

a. Heat to 700°C in approximately 10 hours.
b. Hold at temperature for 40 hours.
c. Furnace cool to 300°C, discharge.

3. Following the anneal, the top 25% of the ingot was sawed off, cold. The bottom was not cropped except for removing the sprue.

4. The cap ingot was then heated to 1080-1150°C, the bottom of the ingot pressed flat (cap has a flat forward surface), and then pierced in a hydraulic press similarly to the body. A 4000 metric ton vertical

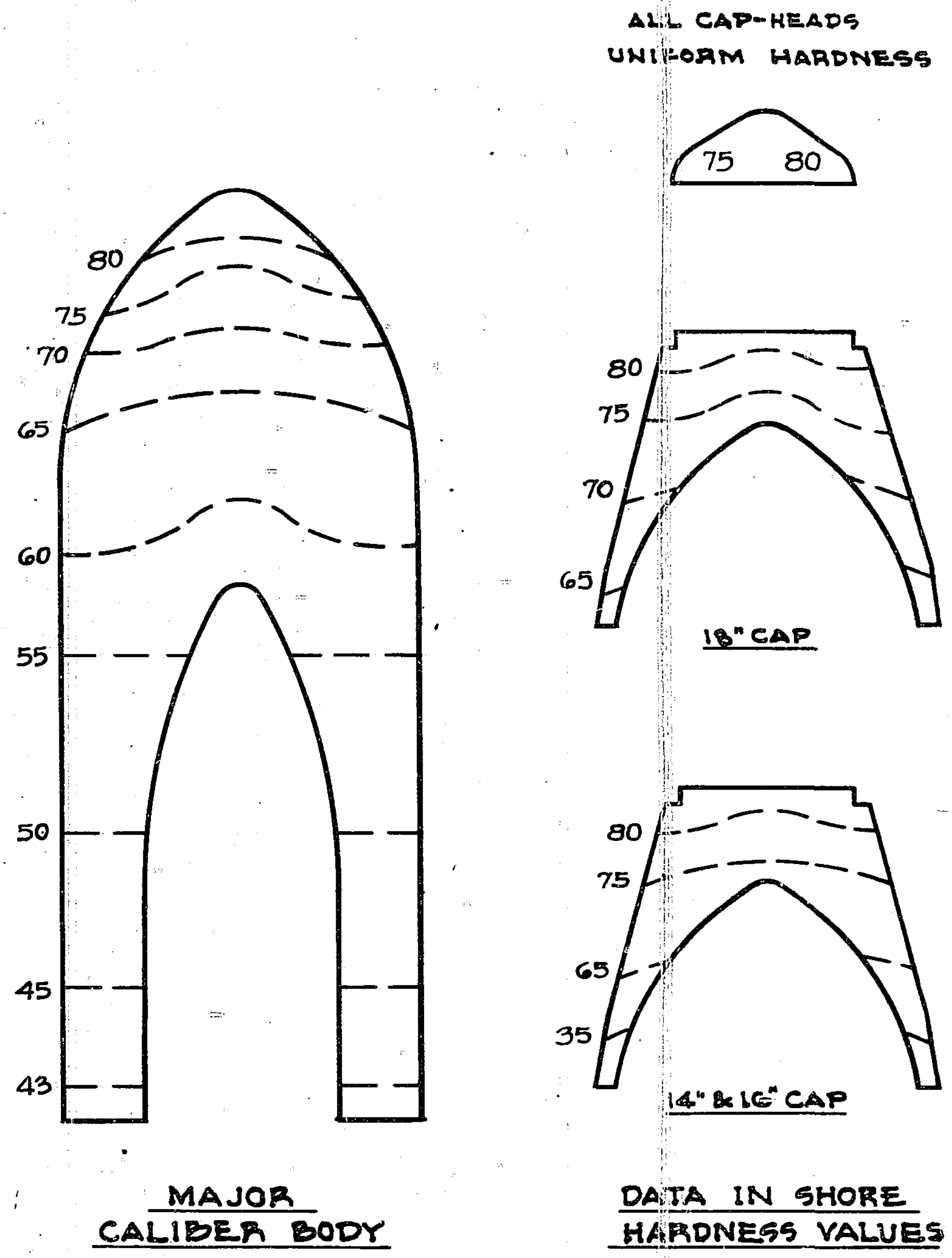


Figure 21

*INTERIOR HARDNESS PATTERNS OF MAJOR CALIBER
AP PROJECTILES, TYPE 91*

Armstrong heading press was used with a press stroke and pierce stroke as shown in the following table:

TABLE XVI

Cap for Projectile Caliber	Force of Stroke, metric tons	
	Press	Pierce
14"	1800	1000
16"	2000	1200
18"	2100	1500

Following the piercing operation, the cap was returned to the furnace and slowly cooled to below 300°C. It was then rough machined to nearly the finished dimensions. While no data on the forging ratio were obtained, it is certain that this value far exceeded that of the projectile body.

5. Heat Treatment.

a. Preheat in a gas-fired, direct-flame, vertical, cylindrical furnace:

14" and 16" cap .... in one hour to 650°C
18" cap .... in two hours to 650°C

b. Transfer to vertical cylindrical muffle furnace containing a number of burners arranged in an upper level and a lower level. The 14" and 16" caps were suspended nose down and lowered into the furnace until the after edge protruded 100mm (4"), i.e., so that only the forward portion of the cap was inside the furnace. The 18" cap, on the other hand, was heated wholly within the furnace. In any case, the cap was slowly rotated during the heating. A thermocouple junction was affixed to the tip of the "cavity" and, for the 18" cap, an additional thermocouple was affixed to the thread shoulder. The thermal cycles are shown in Figure 22. Each ripple during the holding period represents withdrawal from the furnace into open air for a period of one minute, the total period between withdrawals being:

14" .... 5 minutes
16" .... 9 minutes
18" .... 15 minutes

As for the projectile body, this short aircool was to reduce the thermal gradient.

c. The caps were water quenched in the same manner as the bodies. The data on this process is as follows:

Cap for proj. cal. .... 14" ... 16" ... 18"
Initial water level* .... 2.4 ... 3.9 ... 1.0
Water level at end .... Base of thread shoulder
Time in water (min) .... 20 .... 30 24

*Inches from edge of cap.

During this operation the cap was slowly rotated, with the forward end down, and the inner surface not in contact with water. The water level was kept constant and circulated, the temperature being

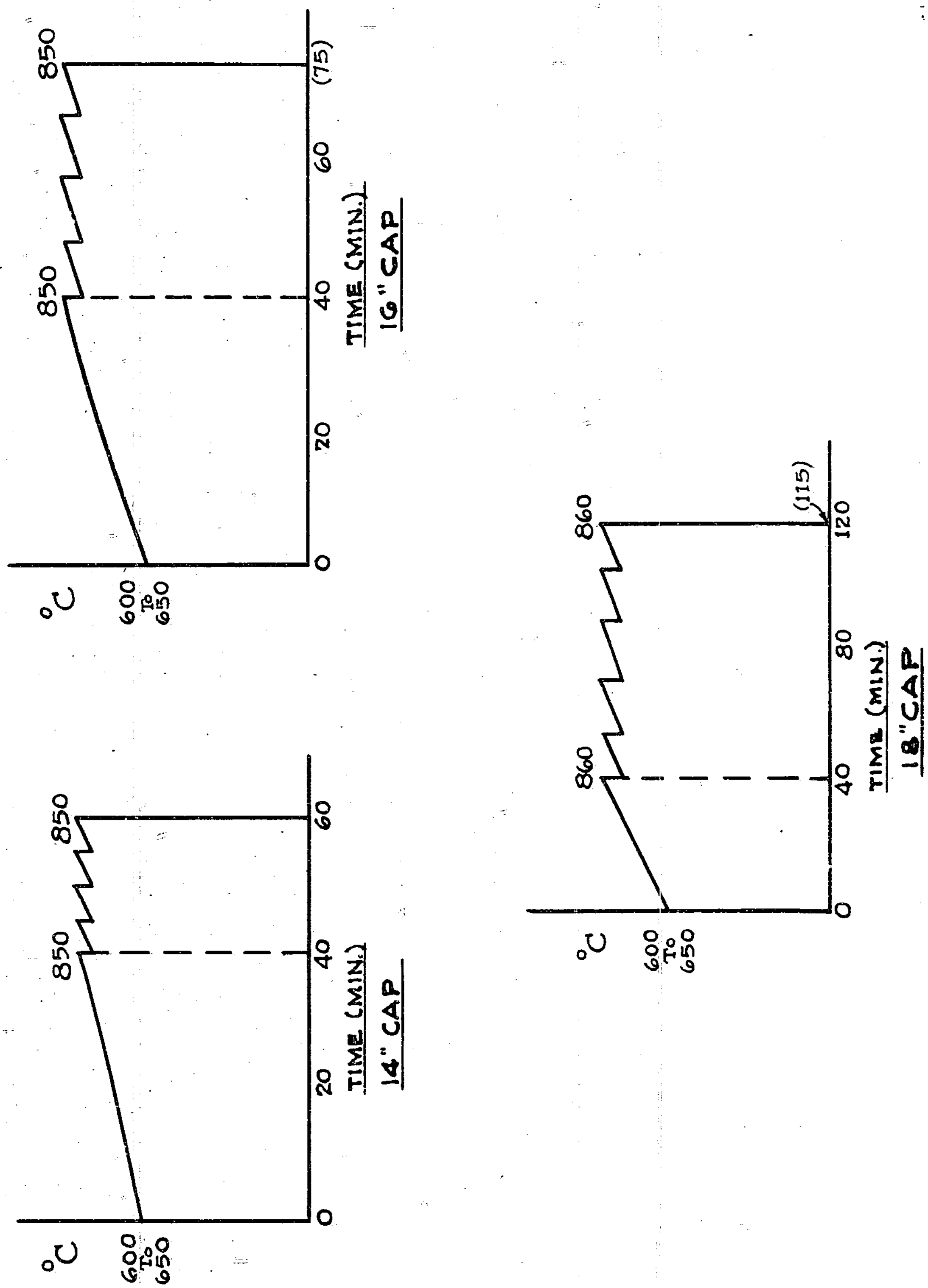


Figure 22
THERMAL CYCLES PRIOR TO QUENCHING MAJOR CALIBER CAPS
(After Preheat)

maintained at 30°C. The cap was gradually lifted out of the water as indicated above.

d. The capskirt was tempered by inserting the cap, forward end up, into a molten lead bath, under the following conditions:

Cap for proj. cal.	14" ...	16" ...	18"
Bath temp., °C.	650 ...	650 ...	380
Time immersed, (min)	5	7	7
Depth immersed*	2.4 ...	3.9 ...	4.3

*Inches from after edge cap.

This temper obviously resulted in considerably softer skirts on the 14" and 16" caps than on the 18" cap as reflected in the hardness specifications noted below and the hardness patterns shown in Figure 21. It may also be observed that the quenching technique for the 18" cap did not follow the same lines as for the 14" and 16" cap, as noted above. The higher hardness and more concave pattern for the 18" cap was determined by ballistic tests to be superior to the softer cap similar to the 14" and 16" which was first tried on the development tests. However, the softer cap continued to be used for the 14" and 16" projectiles because "time did not permit extensive ballistic tests in order to effect an improvement in 14" and 16" cap."

6. Cap Hardness.

a. Location of test points.

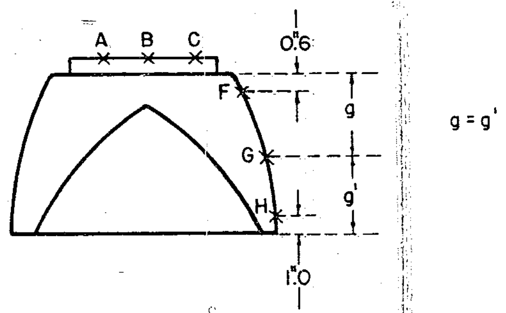


Figure 25

LOCATION OF TEST POINTS, MAJOR CALIBER CAPS

b. Specifications:

Location of point	Cap for Projectiles		
	14"	16"	18"
A, B, C		over 75	over 75
F	514-601	75-80	75-80
G	415-477	65-70	67-73
H	229-269	30-35	57-63

Note: Hardness test - BHN for 14", SHN for 16" and 18".

c. Failure of specifications at any location required reheat treatment. Both Shore and Brinell tests were used as indicated, although no explanation for the use of both tests at the same levels was found. A special supporting jig was required for the Brinell test, but since it was too small for the 18" cap, no specification was provided therefor.

7. Finishing.

a. The forward surface was machined and ground by a rotary process until it was flat to within close tolerances.

b. The threads for securing the windshield were ground.

c. The inner surface of the cap was machined and then lapped on to the nose of the specific body assigned to it.

I. Cap Solder and Cap Security.

1. Composition: Cadmium 18%, Zinc 32%, Lead 50%.
Melting Point: 138 to 142°C.

(NOTE: There was a difference of opinion among the Japanese interviewed concerning the solder composition. More than one analysis may have been used. The melting point was not disputed.)

2. The cap was soldered and crimped in a manner similar to that used by American producers, except that the quantity of solder used was somewhat less due to the lapped fit.

3. No pull test was used, but each cap was "rung" after crimping. About one cap from every 500 assembled projectiles was severely hammered transversely. There appeared to be no quantitative specification to this test. The Japanese claimed very little trouble with cap security.

J. Cap-Head.

1. The cap-head had the same analysis as the body of the projectile, and the same melting practice was used.

2. A rectangular ingot was poured and was forged roughly to a circular section. It was annealed at 700°C followed by furnace cooling to below 300°C. It was then rough turned nearly to the finished maximum diameter.

3. The forging was then heated to 1100 to 1150°C and cut into discs in a 500 metric ton hydraulic press. The discs were returned to the furnace and maintained at temperature until ready for shaping.

4. The disc was die forged to shape in the same press and furnace cooled to below 300°C. The cap-head was then rough-machined nearly to the finished dimensions.

5. Heat Treatment.

a. The major caliber cap-heads were preheated as follows:

18" cap-head: In an electric resistance furnace at 300°C for one hour, followed by molten lead bath at 700°C for 40 minutes.

14" and 16": Directly into molten lead bath at 650°C for one hour.

The 8" cap-head was not preheated.

b. The cap-heads were then transferred (8" cap-head from ambient temperature) to another molten lead bath at 850°C and held for the following times:

8", 14", 16"	30 min
18"	40 min

c. The cap-heads were uniformly quenched in agitated rape-seed oil for the following times:

8"	5 min
14"	15 min
16"	20 min
18"	30 min

They were then air-cooled to room temperature.

d. The heat-treatment of the major caliber cap-heads was complete at this point. The 8" cap-head was tempered at 380°C in an oil bath bath, held for about seven minutes, and air-cooled. The hardness specifications were as follows:

Major caliber	477-601 BHN
8" cap-head	70-75 SHN

(NOTE: The specified tolerance for hardness was apparently excessive. The average cap-head for major calibers was claimed to be over 550 BHN.)

The hardness test was performed on the flat after surface. The cap-head was presumably of uniform hardness throughout.

6. The cap-head was finish-ground on the after flat surface and for the windshield threads. A concentricity test with the assembled cap and body was performed at this point.

K. Base Plug and Adapter.

1. A rectangular 5300 pound ingot was poured with an analysis similar to that used for the Mark Gl inner tubes of the 12cm built-up gun barrels for which the same chemical specification was applied:

C	0.30	Ni	3.50
Si	0.25	Cr	0.70
Mn	0.50	Cu	under 0.20
P	under 0.035	Mo	none
S	under 0.035		

It was forged into a roughly circular section and the top and bottom 10% of the forging were cut off and examined for piping or other unsoundness. If satisfactory, the forging was hot cut by hydraulic press into sections of the proper length, which were then die forged at 1150°C to the rough shape.

2. The plug (or adapter) was annealed at 700°C, furnace cooled to below 300°C, and discharged. It was rough machined and drilled out to receive the adapter or fuze,

3. It was quenched from 850°C into agitated rape-seed oil, tempered at 650°C and oil cooled. It was then finish machined.

4. Prior to 1942, the axes of the plug and adapter were made normal to the axis of the ingot to insure that piping would not result in gas leakage at high firing pressure. However, the improvement of melting, pouring, and inspection practices subsequently made this unnecessary and the later plugs and adapters were co-axial with the ingot.

L. Rotating Bands.

The Type 91 projectile has two rotating bands of 99.85 to 99.90% copper which were cold pressed into the band scoring. The band scoring is of the circumferential wavy ridge variety. The press contained four dies which, when closed in to the end of the stroke, met and formed a complete circle.

M. Ballistic Test.

1. For purposes of the ballistic selections, 14" and larger projectiles were grouped in lots of 200 rounds, and the medium caliber projectiles in lots of 300. The last lot was allowed to vary somewhat at the discretion of the plant inspector.

2. From examination of the various physical and chemical data, the inspector selected two projectiles. Only one round was required for the ballistic test, but a second one was held in reserve in case the first round was not recoverable after the impact. In a few cases where a precise decision on the acceptability of the projectile after impact was difficult, two other rounds were fired, and both were required to pass.

3. Ballistic selection was made after finish-machining, but the risk of failure was claimed to be small compared to the time factor, since failures occurred very seldom. In fact, the Japanese claimed that no failures occurred except on the 18" projectiles (see below).

4. Strictly speaking, failure of the one projectile tested was supposed to be final and the lot was scrapped. In actual practice, the matter was usually studied at length and the specification altered on the premise that it was too severe. No provision was made for retest in the specifications.

5. The specification required a complete penetration with the explosive cavity intact. The firing officer determined whether the cavity was intact (i.e., capable of producing a high order detonation) by visual inspection. (The test round was, of course, blind loaded.)

6. The details of ballistic testing are more thoroughly described in NavTechJap Report, "Japanese Heavy Armor", Index No. O-16. In brief, the plate was leaned backward against a steel butt at the desired angle, the butt was open in the back, and the projectile after penetration passed through the butt into the ground behind. If the projectile bounced off the ground, it was usually caught by a natural hill about 500 yards behind the butt. The gun emplacements were located about 480 feet in front of the butts. The mean velocity was measured by a pair of boulenge chronographs. No electronic or galvanometric equipment was used for this purpose. However, the Japanese claimed that the boulenge chronograph had been constructed to provide a high degree of accuracy, a statement which is discounted by the writer after examination of the gauges, drop-tubes, and magnetic gear involved. The baseline between screens was about 50 feet. The angle of obliquity was measured with a quadrant equipped with a telescopic sight, and a vernier scale; the accuracy obtainable was doubtless in excess of useful significance.

7. The velocity specification tables were not found. However, a summary of the nominal conditions and the velocities specified therefor are given below. These tables were based upon two factors: (a) The DeMarre Critical Velocity and (b) The Figure of Merit. A detailed discussion of these factors is given in NavTechJap Report, "Japanese Heavy Armor," Index No 0-16. They are summarized below:

a. The DeMarre Critical Velocity:

$$V_d = \frac{1530 \quad D^{0.75} \quad T^{0.70}}{P^{0.50}}$$

Where V_d is the Critical Velocity, meters/second
D is the projectile diameter, decimeters
T is the thickness at impact, decimeters
P is the projectile weight, kilograms.

This formula, converted to English units, becomes approximately

$$V_d \cong \frac{1020 \quad D^{0.75} \quad T^{0.70}}{P^{0.50}}$$

Where D and T are in inches
P is in pounds
V_d is in feet/second.

The formula does not correct for obliquity, and in fact, does not represent the true limit velocity. It provides only a value to which a table of corrections known as "Figures of Merit" may be applied. The Figures of Merit are actually expressions of the $\%V_d$ applicable to a given set of conditions.

b. A complete set of data giving F.M. values for the average limit velocities over a wide set of conditions was prepared over a period of years, but was claimed to have been destroyed. Fragmentary portions of these data have been found which, when translated and pieced together, may provide a fair picture of Japanese terminal ballistics. There are two types of F.M. values: (a) those representing the limit velocity (in terms of $\%V_d$) at which a projectile will just penetrate a plate with zero remaining velocity, and (b) those representing a specification test, labeled $F.M._s$. For the Type 91 projectile specifications, the $F.M._s$ exceeds the F.M. by roughly 10% (somewhat more in the case of the 18" projectile).

8. Two types of armor were used for testing Type 91 projectiles:

a. VH armor: "Vickers" face hardened, non-cemented, with about 30% chill.

b. NVNC armor: "New Vickers" homogeneous armor.

The details of the above armor were given in NavTechJap Report, "Japanese Heavy Armor," Index No. 0-16.

9. The specification nominal conditions are summarized in Table XVII.

10. In actual practice, only a few of these conditions were used. The shock test for major caliber projectiles against NVNC armor was seldom used. Some of the conditions were too severe from a viewpoint of rupture-on-penetration. Consequently, the following of the conditions shown in Table XVII were regularly used, and these are given in detail:

18" Proj. 410mm (16.12") VH plate at 30° obliquity
V_s = 525 m/s (1723 f/s)
V_d = 337.8 m/s (1109 f/s)
$F.M._s$ = 1.554

16" Proj. 380mm (14.96") VH plate at 20° obliquity
V_s = 480 m/s (1575 f/s)
V_d = 350.1 m/s (1149 f/s)
$F.M._s$ = 1.371

14" Proj. 330mm (13.0") VH plate at 20° obliquity
V_s = 485 m/s (1591 f/s)
V_d = 353 m/s (1154 f/s)
$F.M._s$ = 1.378

8" Proj. 100mm (3.94") NVNC plate at 30° obliquity
V_s = 350 m/s (1148 f/s)
V_d = 232 m/s (761 f/s)
$F.M._s$ = 1.509

6" Proj. 75mm (2.95") NVNC plate at 30° obliquity
No accurate data available. $F.M._s$ about same as for 8" projectile.

TABLE XVII

Projectile	VH Armor			NVNC Armor		
	Thickness		Obliquity	Thickness		Obliquity
	mm	inches		mm	inches	55°
18"	560	22.0	16.5°	200	7.9	55°
	420	16.5	37°, 33°, 30°	125	4.9	70°
	410	16.1	37°, 33°, 30°			
	380	15.0	37°, 33°, 30°			
	350	13.8	45°			
16"	380	15.0	20°	150	5.9	55°
14"	410	16.1	16.5°	125	4.9	55°
	330	13.0	30°, 20°			
8"				165	6.5	30°, 15°
				140	5.5	45°, 30°, 15°
				100	3.9	45°, 30°, 15°
6"				100	3.9	30°, 15°
				75	3.0	45°, 30°, 15°

11. The 18" projectile, under the specifications first set up (37° obliquity, $F.M._s$ = about 1.38), failed more often than it passed, either by being rejected due to the nose being chewed or broken or by rupturing into the cavity through the after edge of the rear band score, probably

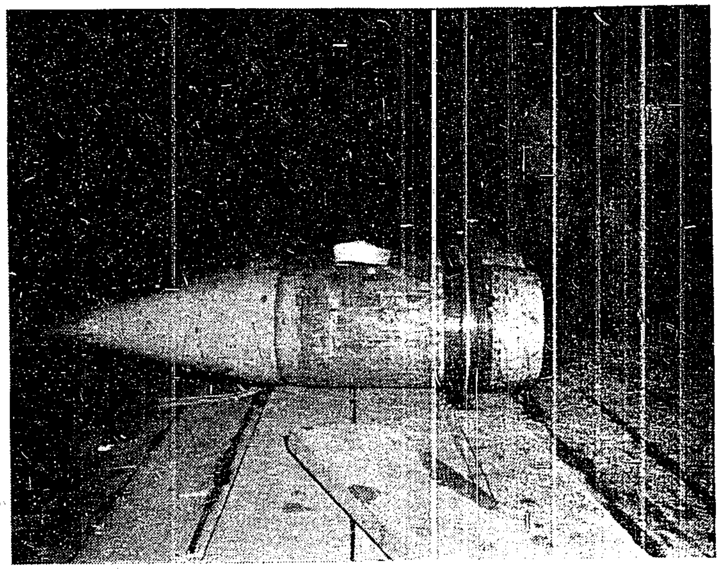
TABLE XVIII
ARMOR PIERCING PROJECTILES

Caliber (in)	Explosives (lbs)	Shell Steel Specifications: Chemical: C	Si	Mn	P	S	Ni	Cr	Mo	Mechanical: Yield Point (kg/mm²)	Tensile Strength (kg/mm²)	Elongation (%)	Reduction of Area (%)	Method of Securing Cap	Fuze Used
A.P. Model 1 18.1/45 cal	Trinitroanisol 52.6	.45/.65	<.40	<.3	<.03	<.03	3.4/4.0	.6/1.0	.4/.8	40/70	70/100	> 8	>10	Soldering	Perc. Fuze, Model 13, Type 5
A.P. Model 1 16.1/45 cal	Trinitroanisol 32.8	.55/.65	<.40	<.3	<.03	<.03	2.5/3.0	2.0/2.6		35/70	70/100	>10	>20	Soldering	Perc. Fuze, Model 13, Type 4
A.P. Model 1 14.0/45 cal*	Trinitroanisol 24.5	.55/.65	<.40	<.3	<.03	<.03	2.5/3.0	2.0/2.6	.4/.8	35/70	70/100	>10	>20	Soldering	Perc. Fuze, Model 13, Type 4
A.P. Model 1 8.0/50 cal*	Trinitroanisol 6.85	.55/.65	<.40	<.3	<.03	<.03	2.5/3.0	2.0/2.6	.4/.8	35/70	70/100	>10	>20	Screw	Prec. Fuze, Model 13, Type 4-1
A.P. Model 1 6.1/65 cal	Trinitroanisol 2.54	.55/.65	<.40	<.3	<.03	<.03	2.5/3.0	2.0/2.6	.4/.8	35/70	70/100	>10	>20	Screw	Prec. Fuze, Model 13, Type 5

Gun Caliber (in)	Size of Cavity (% of shell)	Muzzle Velocity (ft/sec)	Specifications: Diameter (in)	Total Length (in)	Total Weight (lbs)	Penetrating Capabilities: Maximum Range (yds)	Armor Type (Vickers)	Armor Thickness (in)	Mean Impact Velocity (ft/sec)	Striking Angle	Use
18.1/45 cal	7.4	2560	18.1	77	3,212	44,700	Hardened	22.05	1,822	16.5	Against armor plate
16.1/45 cal	6.5	2560	16.1	68.5	2,242	41,900	Cemented	18.1	1,610	22	Against armor plate
14.0/45 cal	7.4	2530	14.0	60.0	1,480	38,800	Hardened	16.15	1,763	16.5	Against armor plate
8.0/50 cal	9.5	2740	7.97	35.7	276	31,620	New Non Cemented	6.5	1,553	30	Against armor plate
6.1/65 cal	9.1	3020	6.075	26.74	123	30,000	New Non Cemented	3.94	2,224	60	Against armor plate

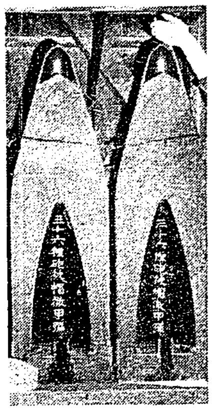
*Hardness of shell steel was as follows:

	Head of cap Shore No.	Cap (Brinnel No.): Shoulder	Middle	Base	Body (Brinnel No.) and Distance from Base (mm): 20	30	165	250	288	395	415	466	590	690
14.0/45 cal 8.0/50 cal	79 70	555	496	304	241	285	291	293	317	363	323	390	343	388

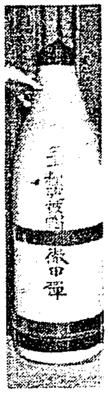


46cm CAPPED

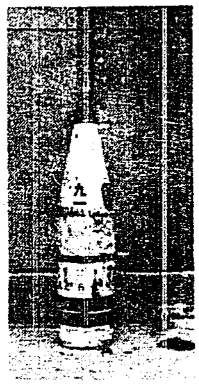
36cm CAPPED



36cm CAPPED Sectioned Models



30cm CAPPED (Very Old)



15.5cm

Figure 24
ARMOR PIERCING PROJECTILES

due to severe base slap on the hard face. The former difficulty was remedied by increasing the $F.M._s$ to 1.554 and the latter difficulty by decreasing the obliquity from 37° to 33° and later to 30°. Since the 14" and 16" projectiles were tested at 20° obliquity from the start, no such difficulties were encountered. The nose deformation of the 18" was also claimed to have been reduced by using the harder cap as noted in a previous section. Attention is invited to the relatively mild test conditions for the 8" projectile.

12. The specification velocities were claimed to be approximately 40 m/s or 130 f/s above the limit velocity except for the 18" projectile which had close to 200 f/s margin. The Japanese claimed that a tolerance for obtained velocity of 2.5 m/s or 8 f/s from the desired velocity was permitted. However, it was explained that a higher obtained velocity was tolerated provided the projectile travelled a considerable distance beyond the plate, and a lower velocity was, of course, acceptable if the projectile passed the test. Examination of a number of specific test records indicated, however, that velocity control was good.

N. <u>The 48cm Projectile</u>.

1. The Japanese produced an experimental 48cm (19") gun in the early 1920's. As noted in a separate report on this subject, (NavTechJap Report, "Japanese 18" Guns and Mounts," Index No. 0-45 (N)) the gun was not approved for service but did serve to provide certain information upon which the construction of the 18" gun Type 94 was subsequently based. The 19" gun was apparently used in recent years for experimental tests, since an armor piercing projectile Type 91 of that caliber was found in a magazine at Kamegakubi Proving Ground. The outer dimensions are approximately as follows:

<u>48cm Projectile, Type 91</u>

Length	81"
Diameter	19"
Estimated weight	3800 lb

2. The projectile was made, according to the Japanese, in 1941. No data on test results for this projectile was found. It appeared to have the same design characteristics as the other major caliber projectiles Type 91 except that it had only one large rotating band instead of two bands.

O. <u>Japanese Tests of Allied Projectiles</u>.

No American armor piercing projectiles have been tested by the Japanese. A few old design English Hadfield projectiles, copied (Japanese Mk. 5) and later abandoned by the Japanese, had been tested many years ago, according to the personnel interviewed.

Part VII - MISCELLANEOUS PROJECTILES

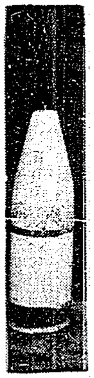
A. <u>Practice Projectiles</u>.

Practice projectiles were painted black, and, if converted from another type of projectile, had a yellow nose. Time practice projectiles had holes around the nose of the projectile to facilitate the emission of smoke which was produced by a smoke box situated near the front of the projectile cavity. These projectiles were also used for proof of time fuzes.

Photographs of a few time practice and practice projectiles are shown in Figure 25.

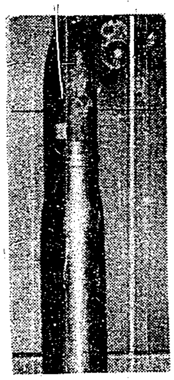
30cm PRACTICE
(Very Old)

VERY OLD
TARGET



20cm TARGET

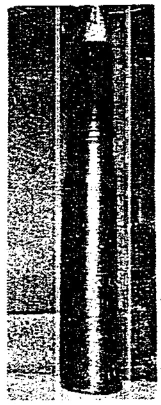
15.5cm TARGET H.A.



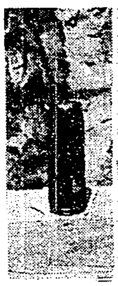
12cm TARGET

14cm TIME
PRACTICE

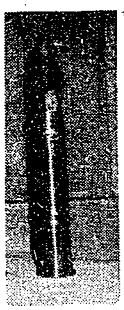
10cm TIME
PRACTICE



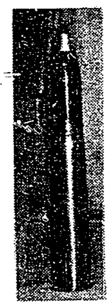
10cm PRACTICE



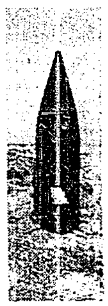
8cm PRACTICE



8cm PRACTICE



8cm TIME
PRACTICE



8cm TIME
PRACTICE

6cm PRACTICE

Figure 25
PRACTICE AND TARGET PROJECTILES

B. Research on External Ballistics.

Research on the external design of projectiles was carried out at the Naval Technical Research Institute (MEGURO), where there was a supersonic wind tunnel.

The wind tunnel was of the following design:

I Machine number 1.2 - 3.0
II Observation chamber diameter 300mm
III Type-Gottingen, closed circuit
IV Ventilators: Turbo blower of two stages 1000 hp (variable speed).
Turbo blower of two stages 700 hp (variable speed).
Turbo blower of two stages 1050 hp (variable speed).

These three blowers were used in series, maximum electric power 1200 hp. It is understood that full information about the tunnel and all experiments carried out were furnished by Mr. SUGIMOTO of the Institute to Dr. Griggs of the Economic & Scientific Section of Technical Intelligence in October 1945 and taken to the United States for translation.

Research on projectiles in the wind tunnel was confined until about 1941 to measuring pressures on the front and sides of conical and ogival projectiles, The conclusion reached was that conical projectiles had a better performance than ogival ones at high speeds but were unsatisfactory at lower velocities.

After 1941 experiments were begun on stability of projectiles, i.e., pressures on the front and sides were measured at varying degrees of yaw. No results were obtained as research was switched to investigation of rocket ballistics. These experiments were interrupted by bombing and were inconclusive.

C. Research on Anti-Aircraft Projectiles Containing Wire.

Some rather amateurish experiments were carried out to determine the effect of wire on airplane wings if struck by an airplane in flight.

A model airplane wing was shot out of a mortar against a wire at various velocities; some success was obtained in damaging the model wing.

The difficulty of expelling the wire from a rotating projectile made them decide that it would be a practicable weapon only if shot from a mortar. At the same time experiments were in process to overcome the difficulty through a device for spreading fins to reduce angular velocity before the shell was opened. Experiments were abandoned for lack of wire.

D. Tapered Bore Gun.

Experiments were being carried out with a tapered bore gun. The bore reduced from 19.5mm to 13mm and the projectiles had wing-shaped driving bands. Some success was obtained in obtaining high velocities, but excessive muzzle pressure caused inaccuracy in flight. At the end of the war experiments were held up waiting for the design of a more suitable propellant charge.

The idea was copied from the Gerlicht type gun (See NavTechJap Report, "Japanese Ordnance Research, Article 2 - Experimental Research on Super High Velocity Guns and Projectiles," Index No. 0-39-2).

TABLE XIX
CARTRIDGE AMMUNITION FOR MACHINE GUNS

Kind of MG	Vo and Pm	Nature of Bullet	Length of Bullet (mm)	Weight of Bullet (gm)	Weight of Cartridge (gm)	Total Length (mm)	Length of Cartridge Case (mm)	Base Diameter of Cartridge Case (mm)	Bursting charge (%) (Wt. of charge in grams)	Fuze	Remarks	History
40mm MG — Type V	890 m/s 28 kg/mm^2	Bursting & Tracer		1000	2300	446.5	310.5	62	TNT 60 sl power 40	fuze for 25mm MG	Color yellow, tracing time 10 secs	From Bofors
		Bursting & Incendiary	179.2						TNT 60 sl power 40 (phosp. 62)			
		Armor-piercing	156.3									
		Tracer										
		Drill	179.2									
25mm MG	900 m/s 26 kg/mm^2	Bursting	114.15	252	900	233	163.5	42.7	TNT 60 sl power 40 (17.1)	fuze for 25mm MG	Penetrates 20mm thick D.S. steel plate at V = 250 m/s	From Hotchkiss
		Bursting & Tracer (Reformed) Tp. 2)		246					TNT 60 sl power 40 (8.7)		Color yellow, tracing time more than 60 secs	
		Bursting & Tracing Tp 3	110.15	about 250							Color yellow, self-bursting type distance = 4000 m	
		Bursting & Incendiary	114.15	about 250					TNT 60 sl power 40 (phosp. 12)		At 450 m/s attacking velocity it can burn petroleum tank through thin plate at 5 m apart from the tank	
		Armor-piercing	97.8	282							At 450 m/s attacking velocity it can penetrate 25mm D.S. steel	
		Tracing & Signaling	110.15	245					TNT 60 sl power 40 charge from coloring "Flourescence"		Color yellow, colors the sea water green, can be discovered 1000 m apart	
		Tracer		246							Color yellow	
		Drill	114.15	252								
13mm MG	805 m/s 35 kg/mm^2	Incendiary Type I	.62	49.6	116.685	136.6	99.15	20.3	Phospher (3.5)		Penetrates 3mm thick HTS Va ≧ 610 m/s & angle of attack = 0°. Puts petroleum tank afire at Va = 590 m/s & AofA = 0°. Through 3mm plate at 100mm apart from tank. Tracing time 13 secs	From Hotchkiss
		Incendiary Type II	58.8	44.5	112.6	134.4	99.15	20.3	Pentrit 50 Hexogen 50 Hexogen 50 Al Powder 50		At 350 m range puts petroleum tank afire through 1mm duralumin plate set at 100mm apart from tank.	
		Armor-piercing	.62	51.8	118.5	136.6	99.15	20.3			Penetrates 28mm thick HTS at Va = 300 m/s and angle of attack = 0°	
		Tracer		46	113						Color yellow, tracing time more than 3 secs	
		Drill		51.8	118.5							
7.7mm		Incendiary Type I	36	9.6		78	56	13.5	Phospher		Penetrates 3mm HTS at 500 m range & angle of attack = 0°. Puts petroleum tank afire at 200 m.	From Vickers
		Incendiary Type II	33,7	9,7	24	76.2	56	13.5	Pentrit 50 Hexogen 50 (0.24) Hexogen 50 Al powder 50 (0.28)		Penetrates 2mm HTS at 500 m range & 0° angle of attack. Puts petroleum tank afire at 300 m. Through 0.8mm thick duralumin plate set at 500mm apart from the tank.	
		Armor-piercing	35	11.2	25.5	78	56	13.5			Penetrates 10mm thick HTS at Va = 300 m/s and angle of attack = 0°	
		Tracer	36	9.5	24						Color red and yellow, tracing time 2.6 secs	
		Drill	33	11.2	25.5							

E. Particular Projectiles Mentioned in "Intelligence Targets Japan," Fascicle 0-1, Target 0-19.

No trace could be found to the projectile designated as "HE AA Circular Layered Projectile." The Japanese officers interrogated could only suggest that it might be either an Army projectile unknown to them, or an experimental type of not much use which they tried to make after receiving a rather mutilated code message from Germany by wireless. This projectile was filled with circular discs of steel. Each disc had five holes in it filled with incendiary filling and the discs were weakened so that they split into five segments. They were in effect another form of incendiary shrapnel.

The Mk 5 AP projectile was the Japanese copy of Hadfield's AP projectile and was replaced by the Japanese Type 88. The Type 88 was replaced by the Type 91, which was the type in service.

Part VIII - MACHINE GUN AMMUNITION

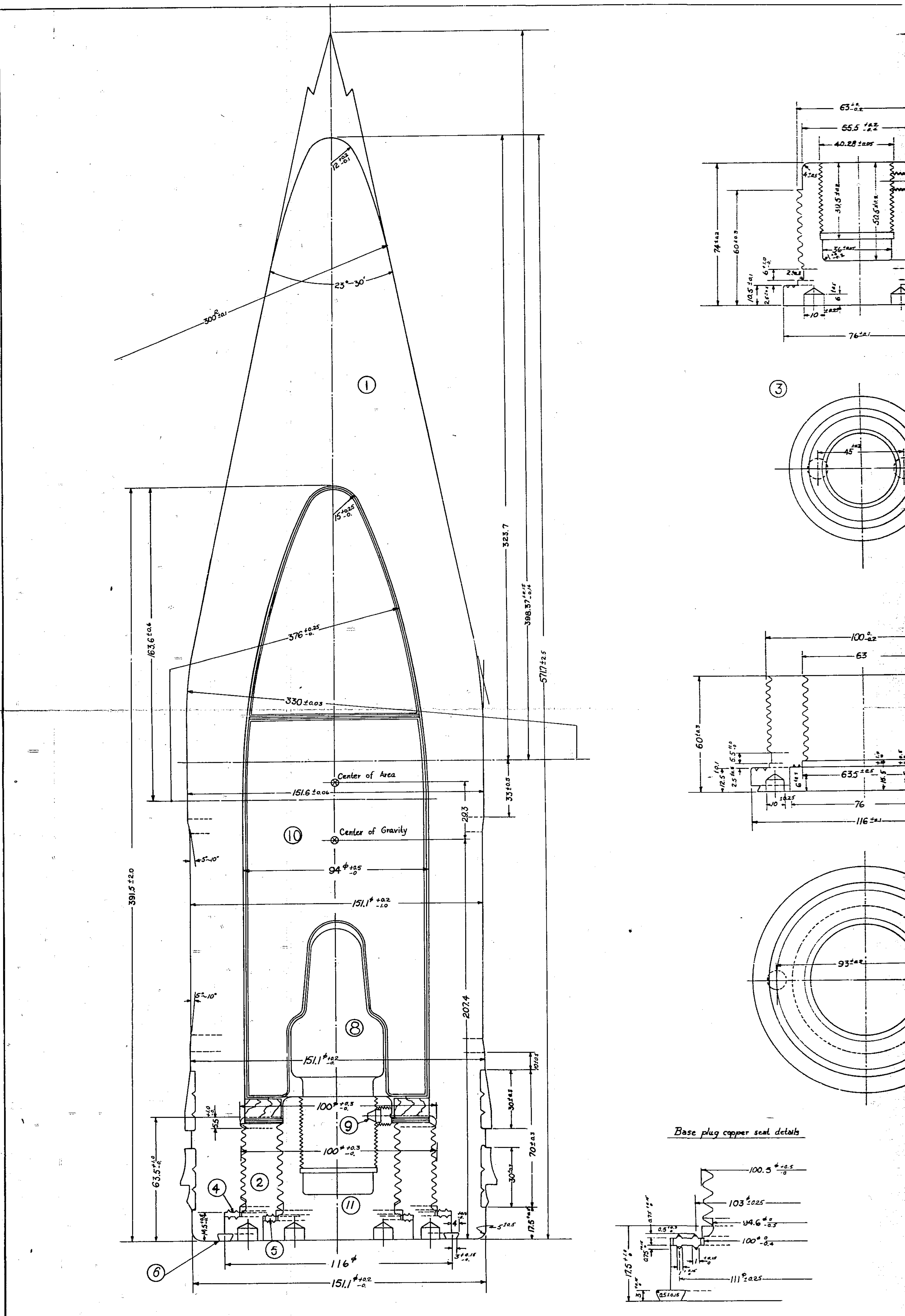
Machine gun ammunition used by the Japanese Navy was, with very few exceptions, of standard design and produced in the following calibers: 40mm, 25mm, 20mm, 13mm, 7.9mm, and 7.7mm, with several models and modifications for each. The 7.9mm was not in general use.

Designs were copied from Bofors, Hotchkiss, Vickers, and Oerlikon ammunition.

The 25mm vari-colored tracer round is fully described in NavTechJap Report, "Japanese Tracers," Index No. 0-22.

Characteristics of the ammunition used is given in Table XIX.

15cm COMMON PROJECTILE

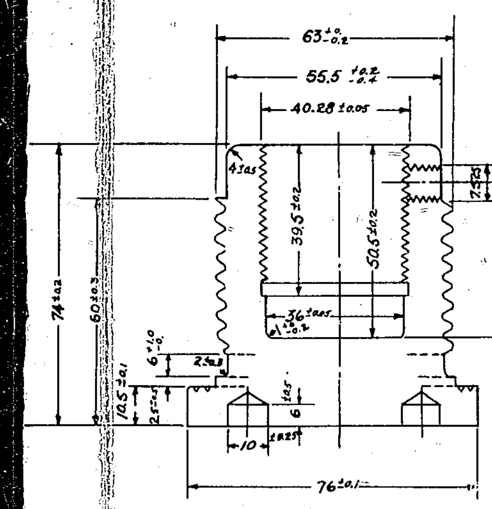


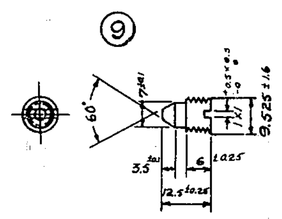
ENCLOSURE (A)

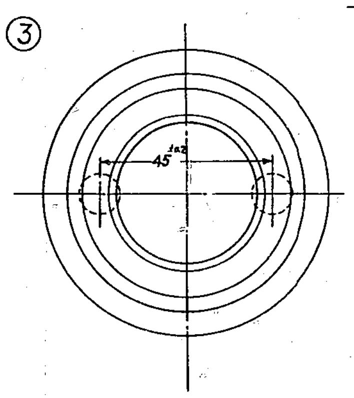
No.	Name	Material	No. Pieces	Weight	Total Weight
1.	Shell Case	H.E. Shell Special Steel	1	37.082	45.300
2.	Base Plug	"	1	2.268	Kg.
3.	Double Base Plug	"	1	1.225	(±)
4.	Copper Seal	Cap. 22	1	0.062	1%
5.	Same as above	"	1		
6.	Copper Filling	Cap. 20	1	0.067	
7.	Rotating Band	C.R.	1 Set	1.060	
8.	Fuze	TYPE 13 MARK 2	1	0.950	
9.	Set Screw	SDB 4	1	0.004	
10.	Main Charge	Separate Plan	1 set	2.642	
11.	Fuze Plug	Same as above	1		

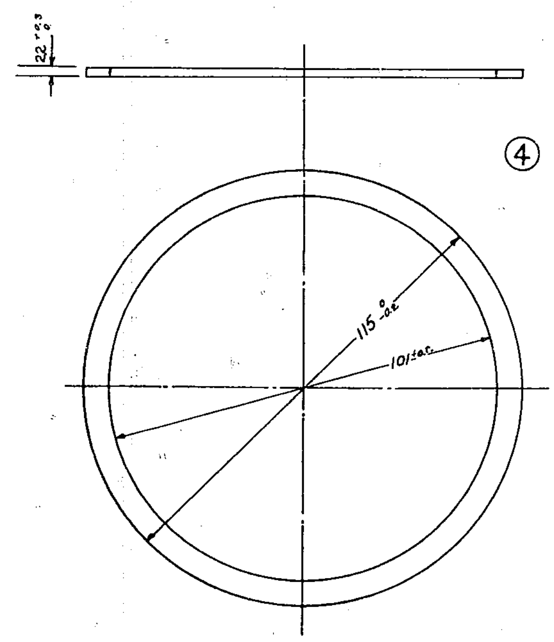
H.E. SHELL SPECIAL STEEL SPECIFICATIONS

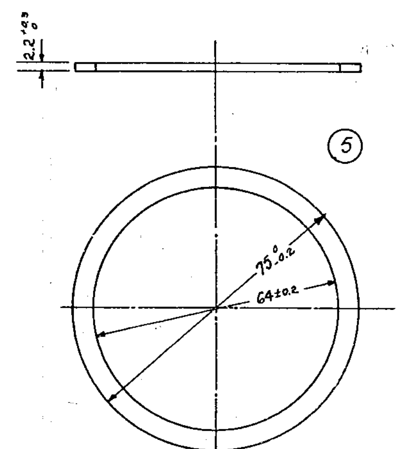
COMPONENTS	
C (%)	0.40 ~ 0.50
Si "	0.35 or less
Mn "	0.30 ~ 0.70
P "	0.035 or less
S "	0.035 or less
Ni "	1.50 ~ 2.00
Cr "	0.20 ~ 0.60

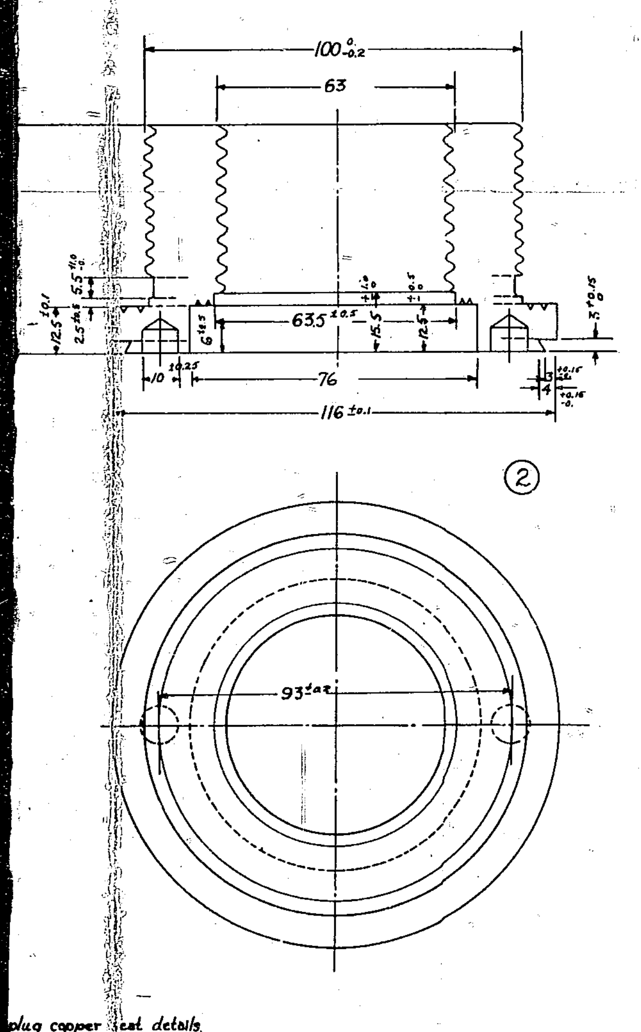




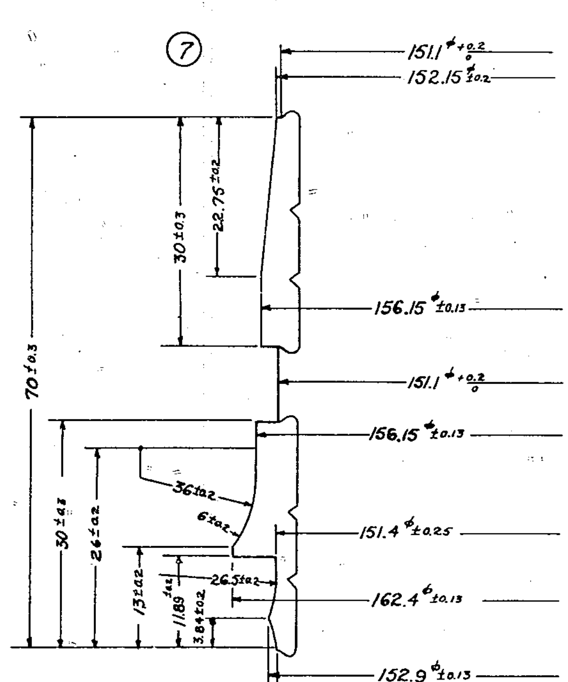




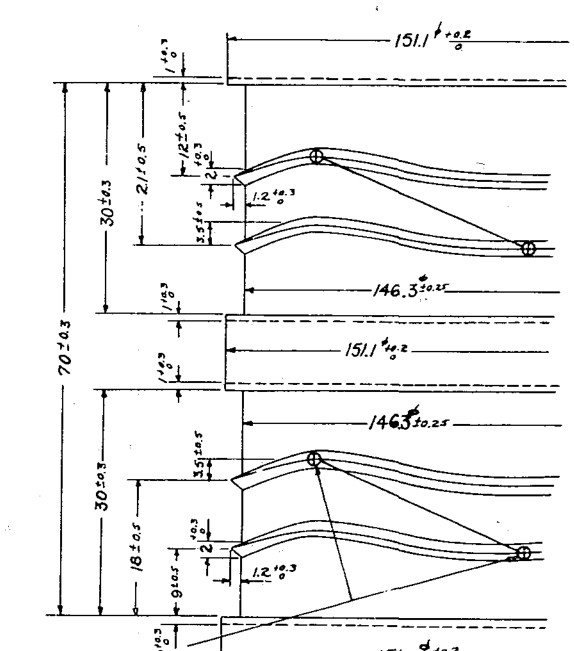




Rotating Band (2/1)

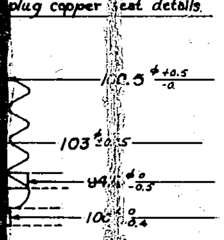


Curved Rotating Band (2/1)

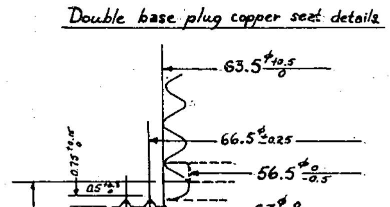


Contact is made at 6 places on the circumference.

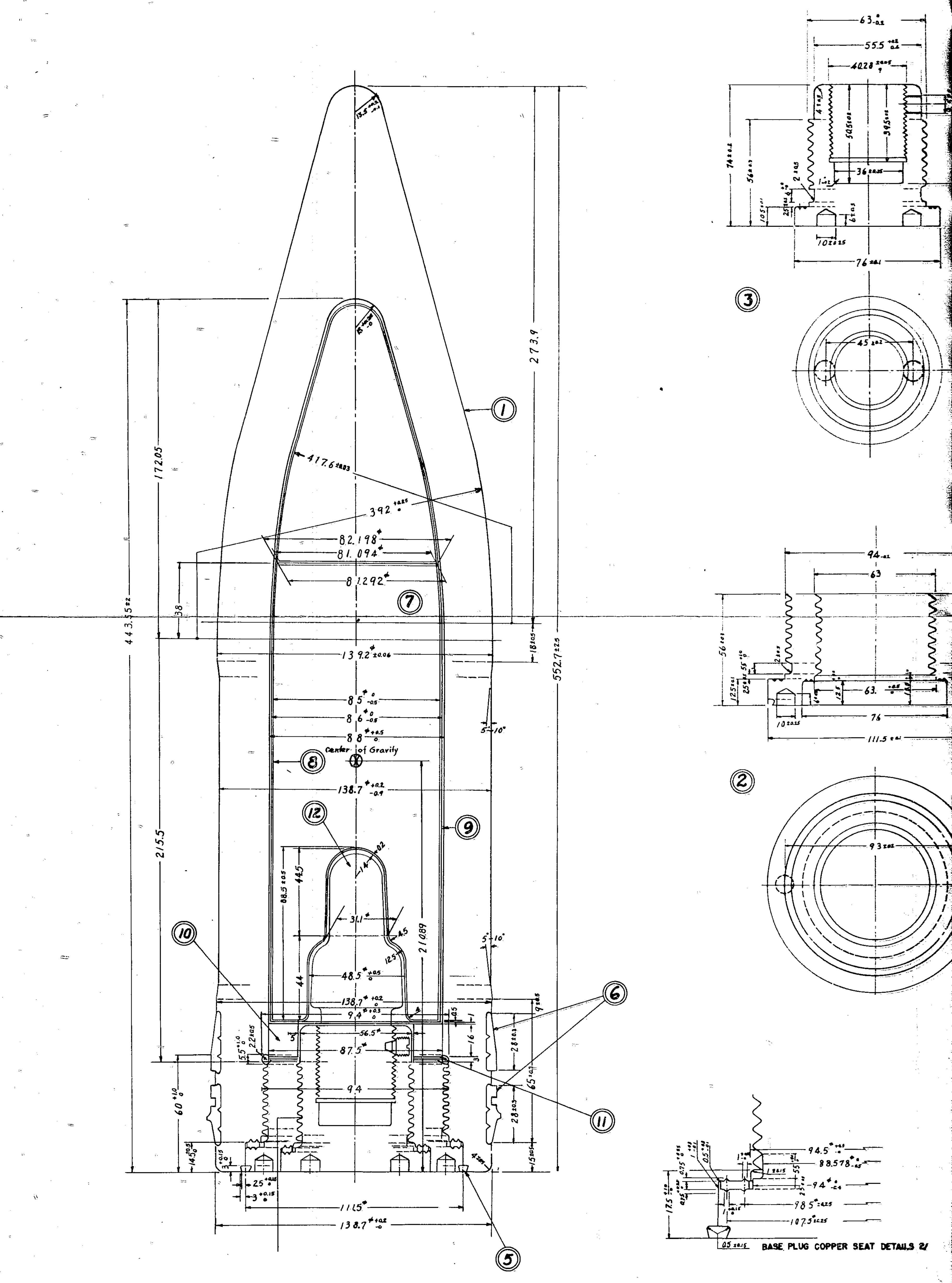
...plug copper seat details



Double base plug copper seat details

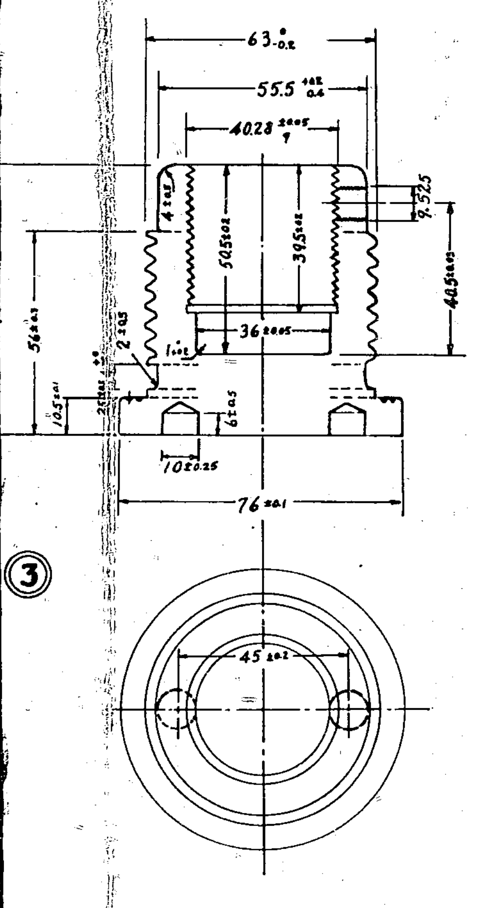


14cm TYPE 2 COMMON PROJECTILE

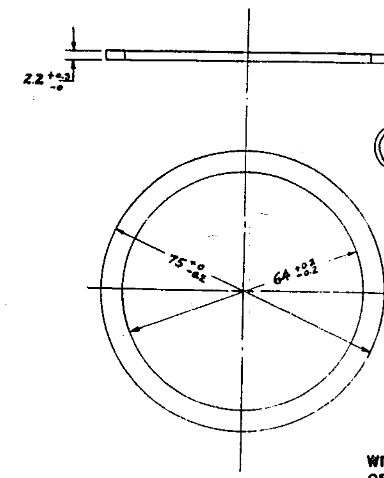


62

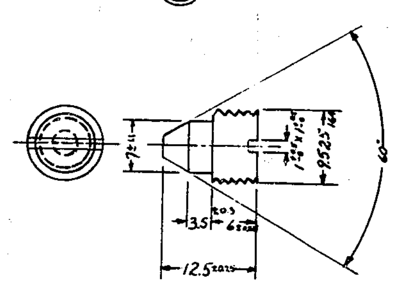
ENCLOSURE (B)



③

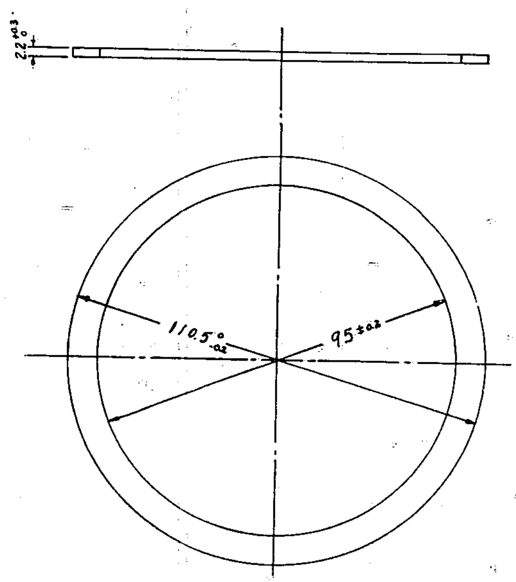


⑭

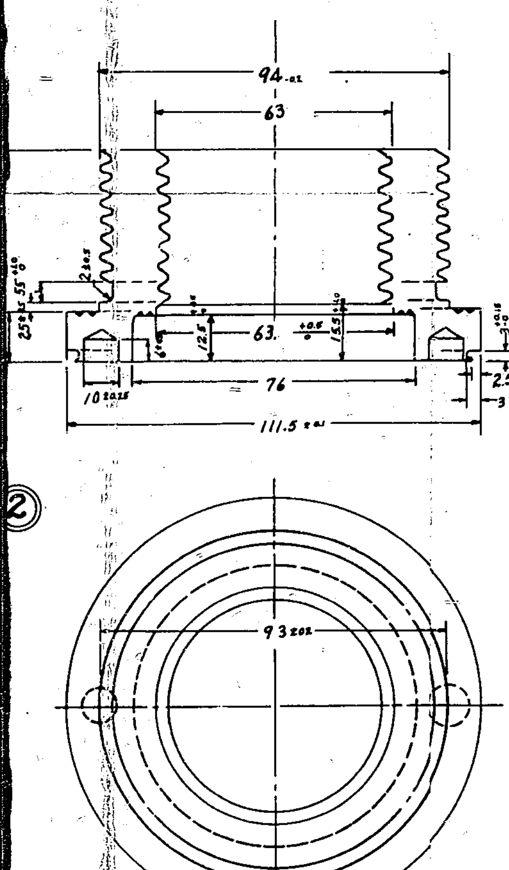


⑬

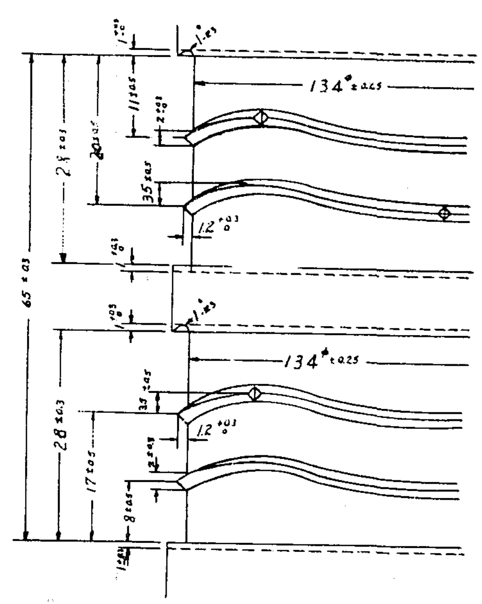
WITH EXCEPTION OF ROTATING BAND THE OUTER CONSTUCTION IS PAINTED



④

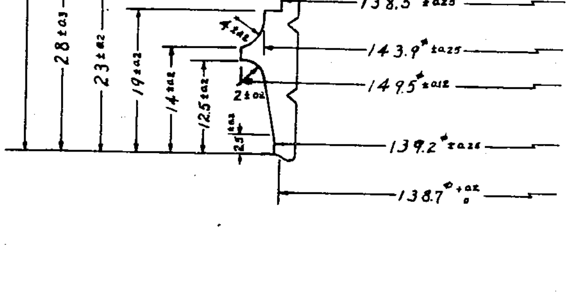


②

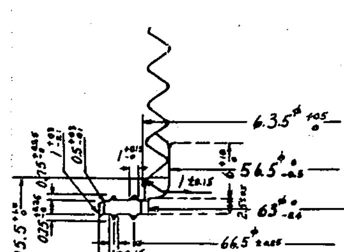


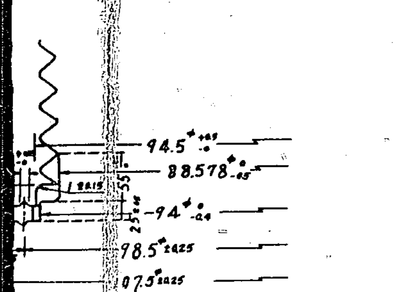
⑥

ROTATING BAND



DOUBLE BASE PLUG COPPER SEAT DETAIL

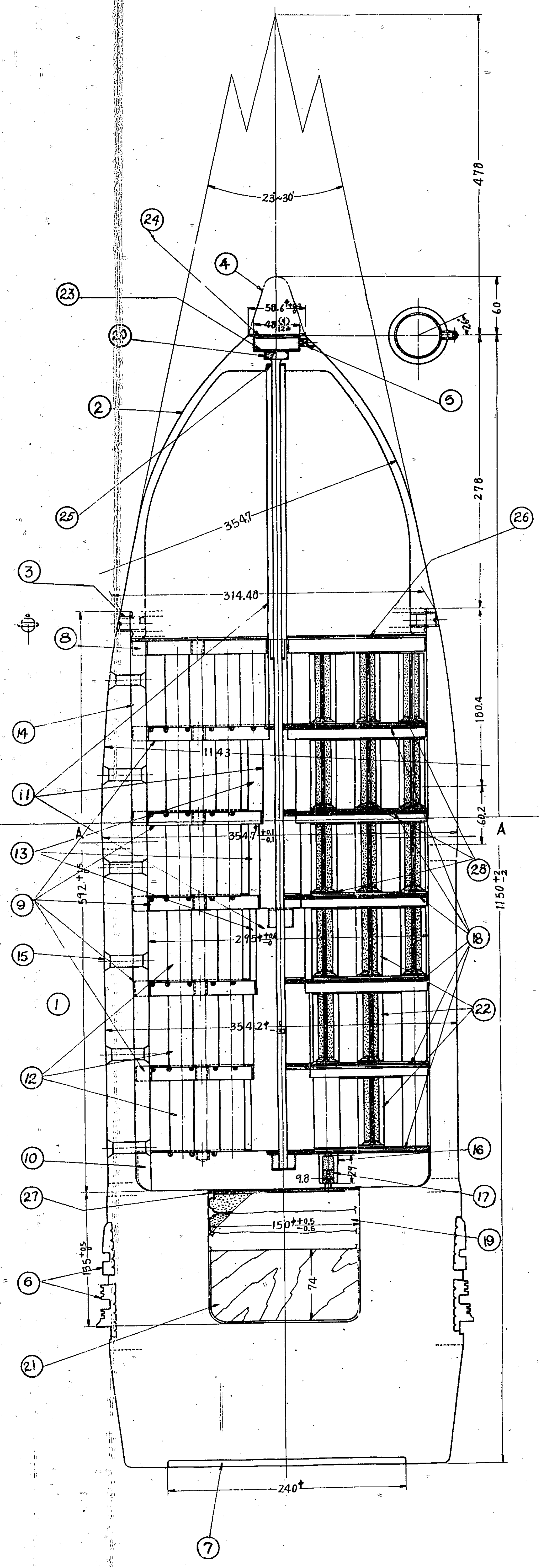




BASE PLUG COPPER SEAT DETAILS 2/

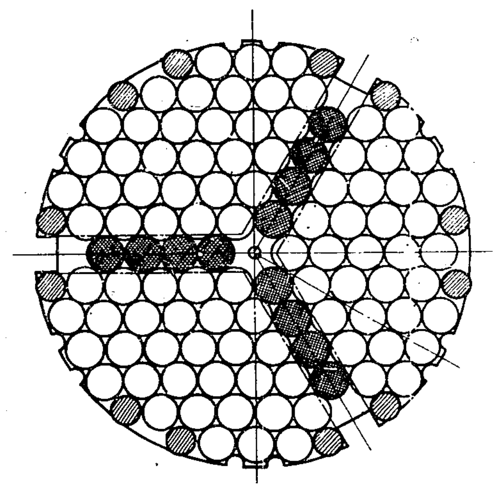
TOLERANCE ± 1% TOTAL WT. 38,000 KG

NO.	NAME	MAT.	NO. PIECE	WEIGHT
1	SHELL CASE	H.E. SPEC STEEL	1	30.491
2	BASE PLUG	"	"	1.745
3	DOUBLE BASE PLUG	"	"	1.232
4	COPPER SEAL	CuP_{22}	"	0.004
5	COPPER FILLING	CuB_{20}	"	0.051
6	ROTATING BAND	CR	1 SET	0.820
7	MAIN CHARGE	POWDER	"	2.554
8	PAPER CYLINDER FOR CHARGE		"	0.018
9	PAPER BAG		1	0.019
10	BOTTOM SEAT	SPECIAL GASKET	1	0.044
11	FILLER	30 RUN PAPER		0.008
12	FUZE	TYPE 13 MK	1	0.950
13	FUZE SET SCREW	SOBM OF SM 4 IN	1	0.004
14	COPPER SEAT	CuP_{22}	1	0.064
15	FUZE PLUG	SEPARATE PLAN		

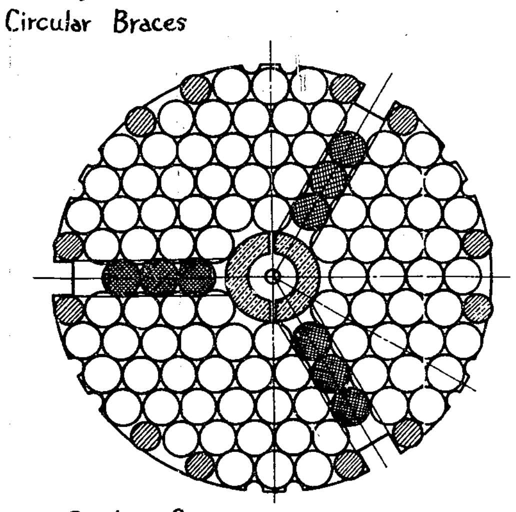


No.	Name	Material
1.	Shell Case	
2.	Projectile Head	
3.	Projectile Head Set Screw	
4.	Fuze	Type ó Time
5.		
6.	Rotating Band	
8.	Dividing Ring	
9.	Fuze Plate (1)(2)(3)(4)(5)	
10.	Base Block	
11.	Speed Fuze Rod (Top)(Center)(Bottom)	
12.	Circular Braces (A)(B)(C)	
13.	Split Braces (A)(B)(C)	
14.	Rotating Rod	
15.	Rotating Attachment Rivet	
16.	Delayed Action Case	
17.	Delayed Action Charge	Black Powde
18.	Quick Match	Paper Contamin
19.	Ejecting Charge and Powder Bag	Black Powder
20.	Priming Charge and Powder Bag	Black Powder
21.	Wooden Seat	
22.	Clusters	
23.	Filler Lining	Waxed Paper
24.	"	Fiber or Boru
25.	"	Perforated B
26.	"	Waxed Pap
27.	"	Perforated B
28.	"	Flannel
29.	"	Separate Pla

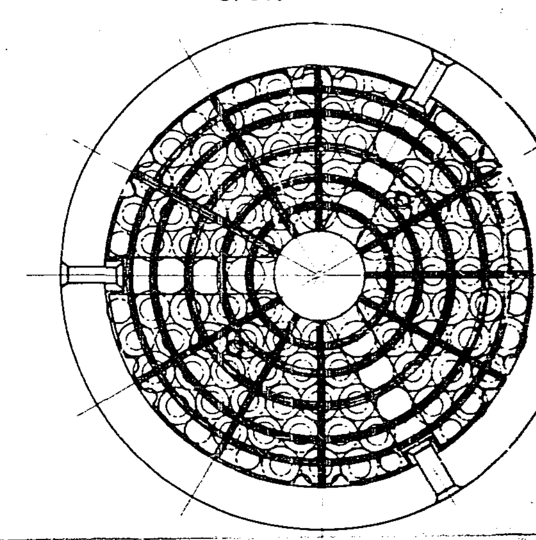
Total Weight and Tolerance 533Kg 000



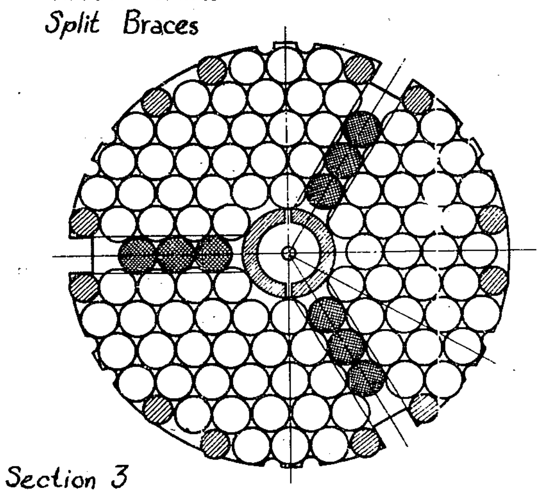
Section 1
Clusters
Circular Braces



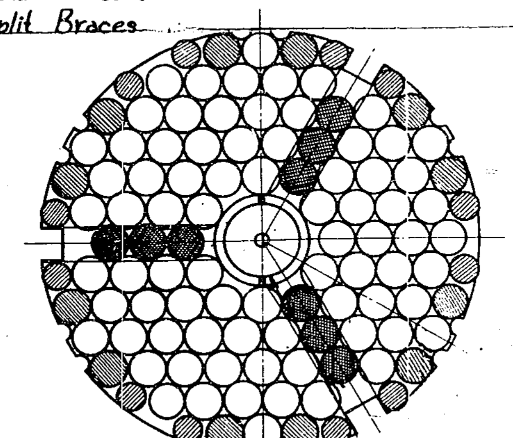
Section 2
Clusters
Circular Braces
Split Braces



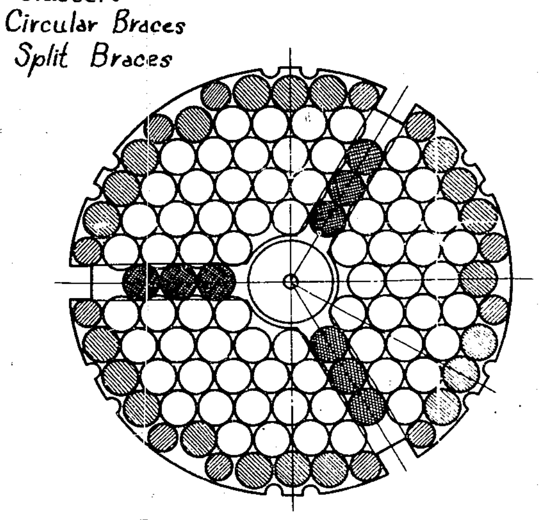
Cross Section AA



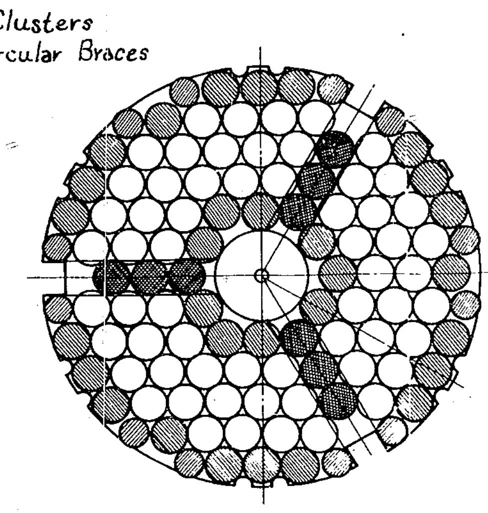
Section 3
Clusters
Circular Braces
Split Braces



Section 4
Clusters
Circular Braces
Split Braces



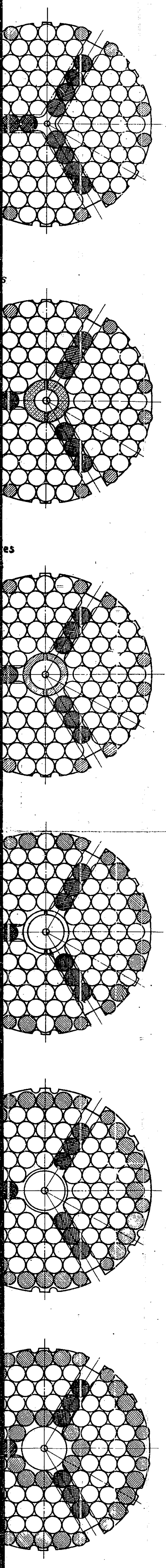
Section 5
Clusters
Circular Braces



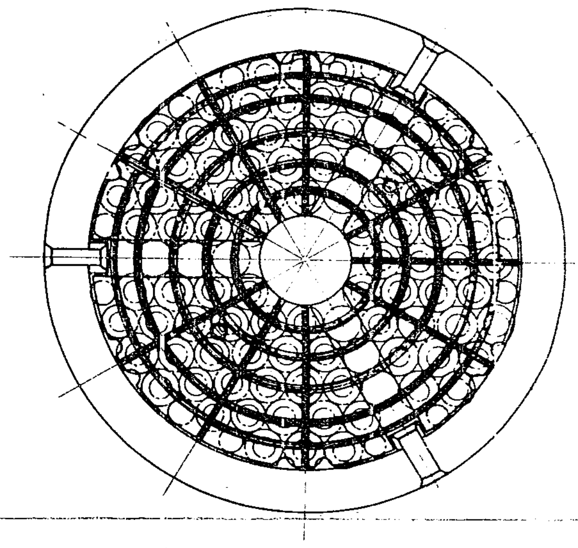
Section 6
Clusters
Circular Braces

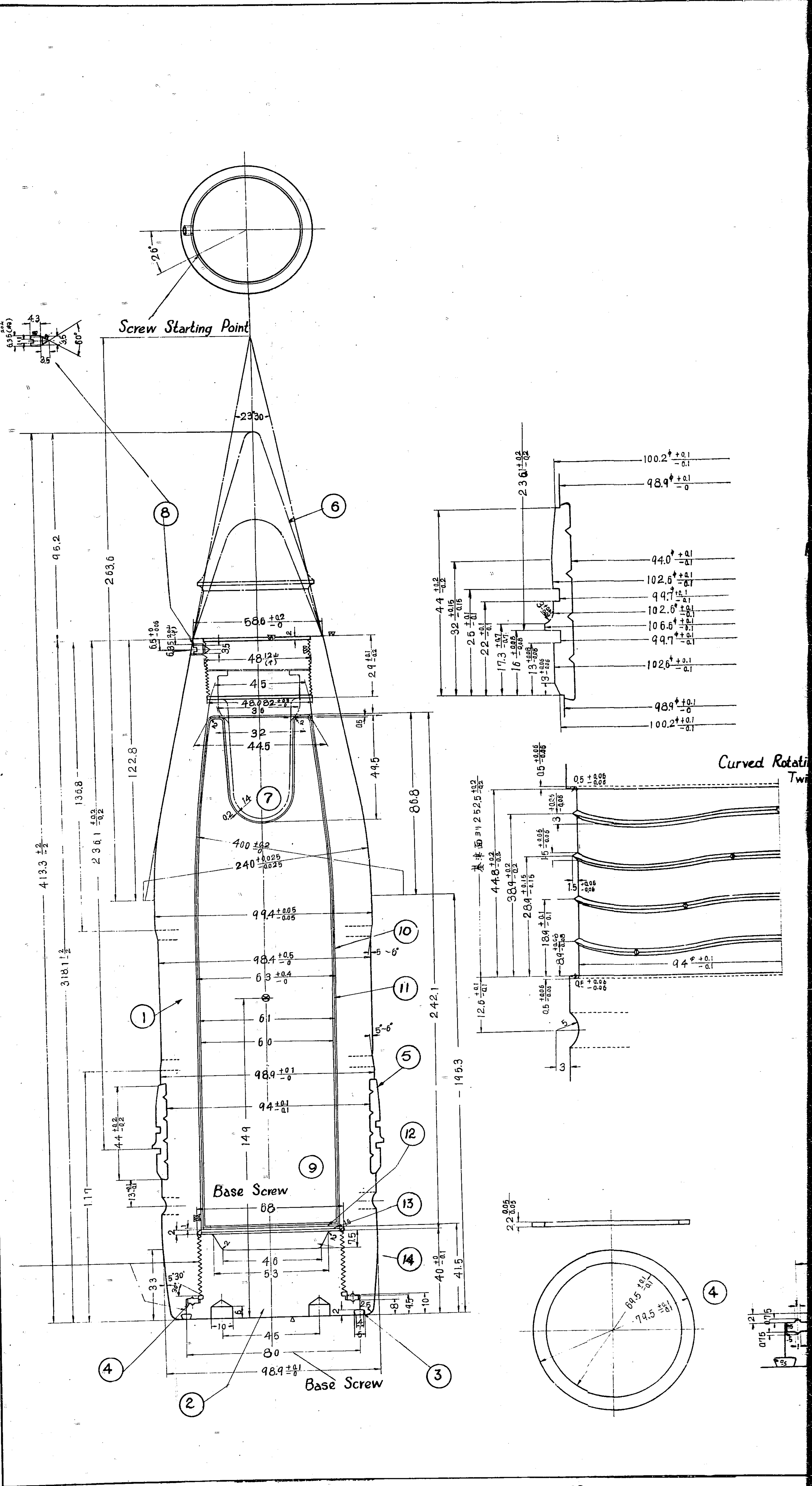
No.	Name	Material	No. Pieces
1.	Shell Case		
2.	Projectile Head		
3.	Projectile Head Set Screw		
4.	Fuze	Type ϕ Time	–
5.			
6.	Rotating Band		1 Set
8.	Dividing Ring		
9.	Fuze Plate (1)(2)(3)(4)(5)		
10.	Base Block		
11.	Speed Fuze Rod (Top)(Center)(Bottom)		
12.	Circular Braces (A)(B)(C)		
13.	Split Braces (A)(B)(C)		
14.	Rotating Rod		
15.	Rotating Attachment Rivet		
16.	Delayed Action Case		
17.	Delayed Action Charge	Black Powder	
18.	Quick Match	Paper Containing Quick Match	
19.	Ejecting Charge and Powder Bag	Black Powder	
20.	Priming Charge and Powder Bag	Black Powder	
21.	Wooden Seat		
22.	Clusters		
23.	Filler Lining	Waxed Paper	
24.	"	Fiber or Boru* Paper	
25.	"	Perforated Boru* Paper	
26.	"	Waxed Paper	
27.	"	Perforated Boru* Paper	
28.	"	Flannel	
29.	"	Separate Plan	

Total Weight and Tolerance 533kg 000gr ± 1.5%

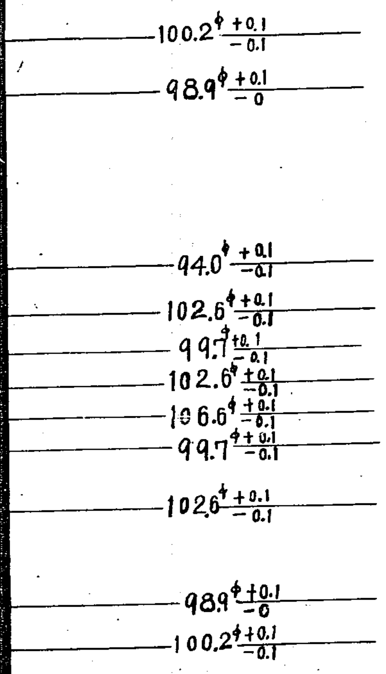


Cross Section AA



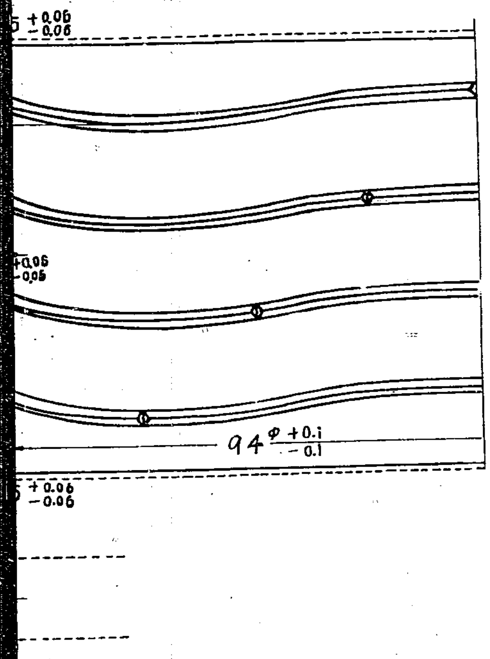

Screw Starting Point
Base Screw
Base Screw
Curved Rotati
Twi
1
2
3
4
5
6
7
8
9
10
11
12
13
14
413.3 ±2
318.1 ±2
263.6
236.1 ±0.2
136.8
122.8
95.2
242.1
195.3
86.8
49.5
117
99.4 +0.05 −0.05
98.4 +0.5 −0
98.9 +0.1 −0
94 +0.1 −0.1
63 +0.4 −0
61
60
68
46
53
45
80
149
58.6 +0.2 −0
44.5
32
400 ±0.2
240 +0.025 −0.025
100.2 +0.1 −0.1
98.9 +0.1 −0
94.0 +0.1 −0.1
102.6 +0.1 −0.1
99.7 +0.1 −0.1
106.6 +0.1 −0.1
69.5 +0.1 −0.1
79.5 +0.1 −0.1

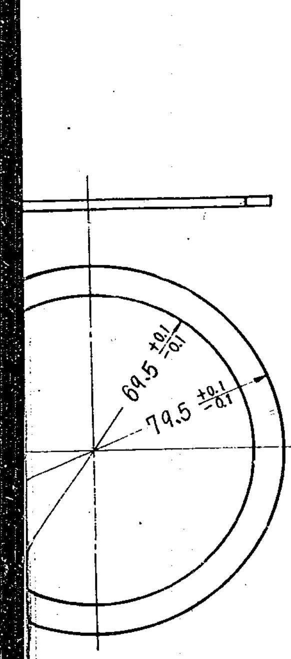
No.	Name	Material
1.	Shell Case	
2.	Base Plug	
3.	Copper Filling	
4.	Copper Seat	
5.	Rotating Band	
6.	Fuze (Type 88)	Type 99 Time
7.	Primer	
8.	Fuze Set Screw	Type 91
9.	Main Charge	Type 92 Explosive
10.	Main Charge Bag	Cotton Flannel
11.	Main Charge Paper Cyclinder	
12.	Base Cover	Cotton Flannel
13.	Base Seat	Paper
14.	Base Seat	Special Filler



Rotating Base
Twice Size

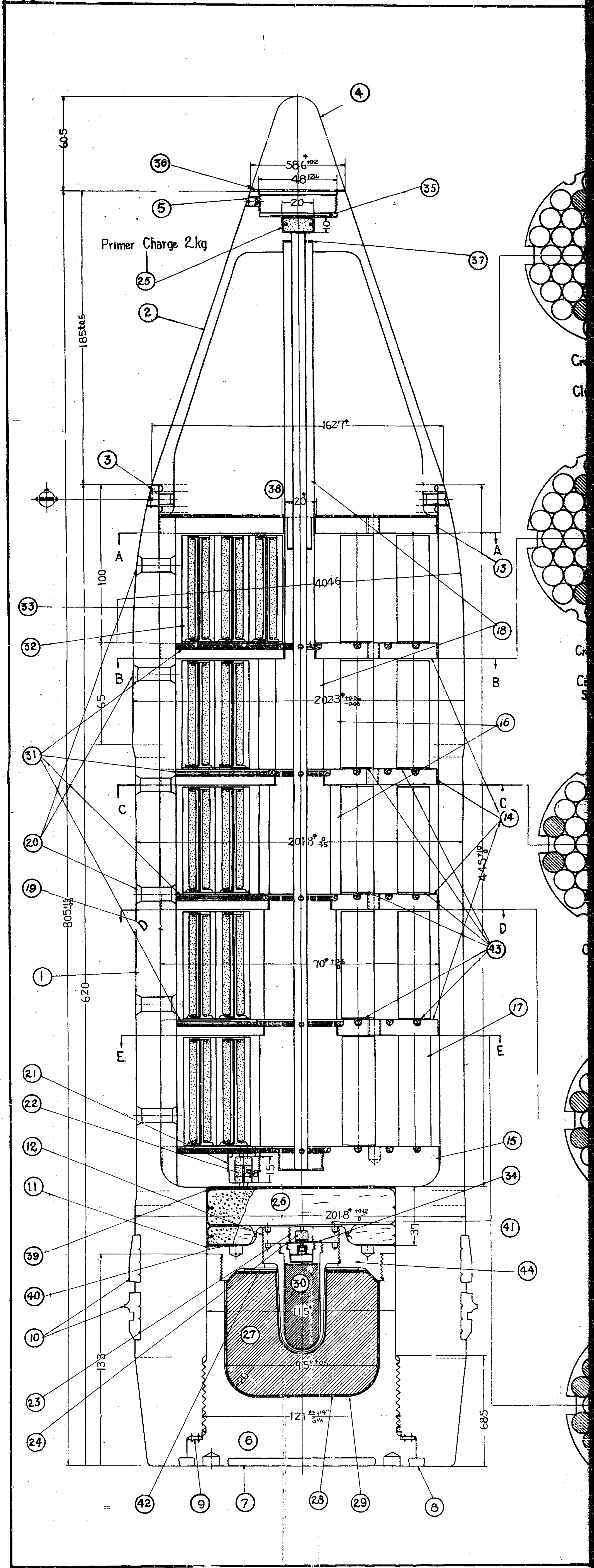
Curved Rotating Band Construction
Twice Size





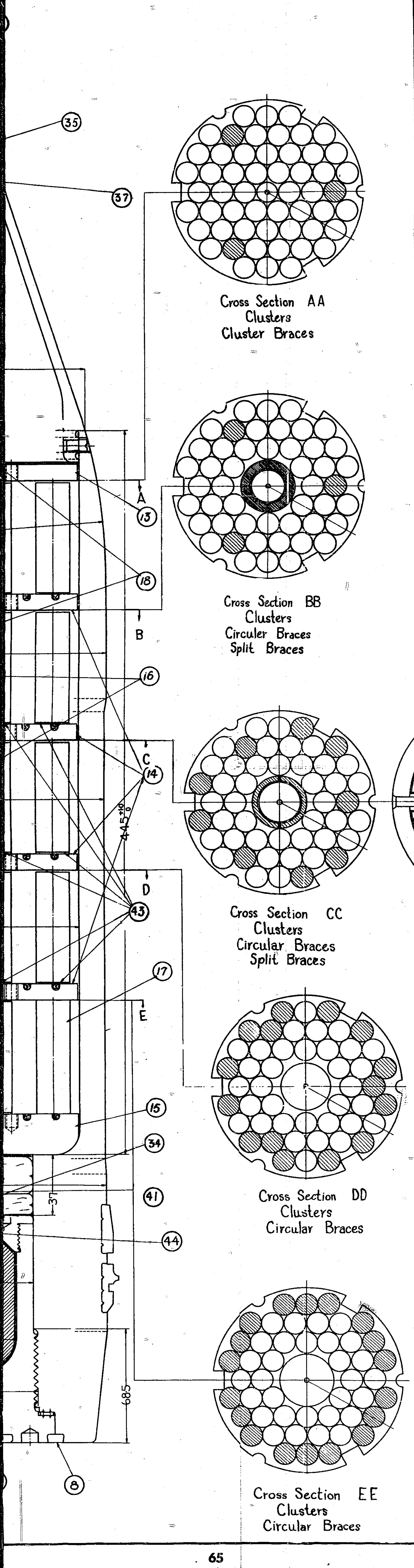
4

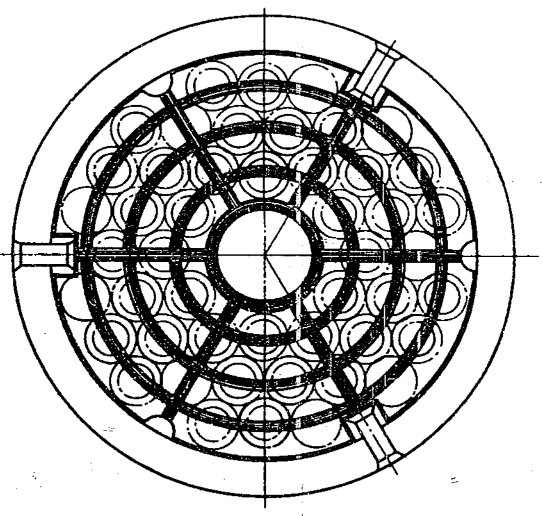
Twice Size


Primer Charge 2kg
A
B
C
D
E
58.6
48
20
10
1627
20
4046
2023
2018
445
70
2018
37
115
95
121
805
620
185
605
100
65
133
685
15
18

No.	Name	Material	No Pieces
1.	Shell Case		
2.	Projectile Head		
3.	Projectile Head Set Screw		
4.	Fuze	Type 91 Time	
5.	Fuze Set Screw		
6.	Base Plug		
7.	Base Plate		
8.	Copper Filling		
9.	Copper Seat		
10.	Rotating Band		1 Set
11.	Adapter Screw		
12.	Restraining Screw		
13.	Dividing Ring		
14.	Fuze Plate (1) (2) (3) (4)		
15.	Base Block,		
16.	Split Braces (1) (2)		1 Pr. Each
17.	Circular Braces		
18.	Speed Fuze Rod (Upper) (Lower)		
19.	Rotating Stop Rivet		
20.	Rotating Attachment Rivet		
21	Delayed Action Case (1)		
22.	Delayed Action Charge	Black Powder	
23.	Delayed Action Case (2)		
24.	Delayed Action Charge	Black Powder	
25.	Priming Charge and Powder Bag	"	
26.	Ejecting Charge and Powder Bag	"	
27.	Main Charge		
28.	Main Charge Wrapper	Paper	
29.	Priming Case	Type 91 Mod. 1	
30.	Quick Match	In Paper Case	
31.	Main Charge Cover	Flannel	
32.	Clusters		
33.	Cluster Charge		
34.	Lining		
35.	"	Bind Paper	
36	"	Fiber Paper	
37.	"	Perforated	
38.	"	"	
39.	"	"	
40.	"	"	
41.	"	Waxed Bind Paper	
42.	"	Perforated	
43.	"	Flannel	
44.	Tail Plug	Separated Plan	

Total Weight and Tolerance 120kg 000 gr ±1%





ENCLOSURE (F)

LIST OF DOCUMENTS FORWARDED TO WDC THROUGH ATIS

NavTechJap No.	Title	Atis No.
ND50-3820	Blueprints (seven prints of mortar projectiles)	3997
ND50-3821	Blueprints (six prints of HE projectiles)	3998
ND50-3822	Blueprints (six prints of general purpose projectiles)	3999
ND50-3823	Blueprints (three prints on pyrotechnic projectiles, two star shells, one illuminating)	4000
ND50-3824	Blueprints (seven prints on rocket projectiles)	4001
ND50-3825	Blueprints (four prints on armor piercing projectiles)	4002
ND50-3826	Blueprints (one print on hollow charge projectile)	4003
ND50-3827	Blueprints (one print on forging and heat treatment formulas)	4004
ND50-3828	Blueprints (nine prints on practice, dummy and target projectile)	4005
ND50-3829	Report on the experimental results of projectiles for exercise or training use	4006
ND50-3830	Outline of the process of filling the Type 92 HE shell for the fourth year Type 15cm Howitzer	4007
ND50-3831	Number 3 firing test or land battle ammunition	4008
ND50-3832	Device for roughening out surface of medium caliber projectiles	4009
ND50-3833	Experiment on illuminating shell	4010
ND50-3834	Navigation target shell Mod. 1	4011
ND50-3835	Matching of shells	4012
ND50-3836	Storage of Type 91 booster-1939	4013
ND50-3837	Experiment on common shell manufactured from drawn pipe - Part 2 (together with experiment on cartridge case)	4014
ND50-3838	Investigation on the method of statical explosion test of small and medium caliber projectiles	4015
ND50-3839	Experiment of special projectile and chemical weapon	4016
ND50-3840	Experimental report on 50 cal/15cm gun Mk III HE shell equipped with with Type 13 Mk 1 fuze	4017
ND50-3841	Filling of 45 cal/36cm gun Type 91 armor piercing shells	4018
ND50-3842	Various types practice shells	4019
ND50-3843	Studies on air resistance of round shells and air drag of conical shells	4020
ND50-3844	Air resistance of shells	4021
ND50-3845	Research on chemical shells	4022
ND50-3846	Capped HE shell (14cm) Modification 1	4023
ND50-3847	Type 98, 10cm DP shell loading	4024

ENCLOSURE (F), continued

NavTechJap No.	Title	Atis No.
ND50-3848	15cm and 24cm shell tests	4025
ND50-3849	Power test of ordinary shell of 15cm gun No. 4	4026
ND50-3850	Test of safety factor for use of smoke shell in sea surface	4027
ND50-3851	Type 93, 15cm mortar experimental Mk 3 shell and experimental incendiary shell, and the Type 94 light mortar temporary designated smoke shell	4028
ND50-3852	Report on improvement of lacquering of interval cavity of projectiles Part III	4029
ND50-3853	Notes on headings of projectiles	4030
ND50-3854	12cm, AA gun, experiments of common shell manufactured from drawn pipe - Part 3	4031
ND50-3855	Report on improvement of lacquering of external cavities of projectiles	4032
ND50-3856	Investigation report on booster charge which did not cause any failures	4033
ND50-3857	Greater Japan Ordnance, Ltd. Shonan Factory Tools Experimental Report	4034
ND50-3858	Tooling work on medium caliber projectiles	4035
ND50-3859	Investigation into manufacture of base plugs for projectiles	4036
ND50-3860	Studies on prevention of explosive deflagration (in projectile cavities)	4037
ND50-3861	Chemical ordnance in cold areas	4038
ND50-3862	Report on moistrue proof qualities of filling materials used as plugs	4039
ND50-3863	14cm projectiles hydraulic pressure tests	4040
ND50-3864	Charss on cartridge cases	4041
ND50-3872	12cm AA common shell experiments	4049
ND50-3865	Strength of steel wire against anti-aircraft	4042
ND50-3866	Tests on experimental signal "ENKA"	4043
ND50-3887	Blueprints (one print of common projectile)	4102
ND50-3888	Blueprint (one print of armor piercing projectile)	4103
ND50-3889	Blueprint (one print of mortar projectile)	4104
ND50-3890	Blueprint (three prints of semi-armor piercing projectile)	4105
ND50-3891	Blueprint (three prints of chemical liner projectiles)	4106
ND50-3892	Blueprint (six prints of pyrotechnic projectiles, four star shell, two illuminating)	4107
ND50-3893	Blueprint (eight prints of high explosive projectile)	4108
ND50-3894	Blueprint (two prints of incendiary-shrapnel projectile)	4109

ENCLOSURE (F), continued

NavTechJap No.	Title	Atis No.
ND50-3895	Blueprints(three prints of practice projectile)	4110
ND50-3896	Documents and prints of experiment on air pressure and resistance of projectiles	4111
ND50-3897	Research concerning prevention of corrosion in cartridge cases	4112
ND50-3898	Investigation on manufacturing of paper container of cast-charge which doesn't require the casting mold used formerly	4113
ND50-3899	15x12cm special chemical shell firing tests	4114
ND50-3962	Actual tests of smoke ordnance	4172
ND50-3935	Abrasion and Slipping of 14cm Rotating Bands	4379
ND50-3111	Various Types of Machine Gun Ammunition	4364