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

Subject: Target Report - Japanese Interior Ballistics.

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

1. Subject report, covering Target O-21 of Fascicle O-1 of reference (a), is submitted herewith.

2. The investigation of the target and the target report were accomplished by Lt. Comdr. J.R. Lyman, USNR, assisted by Lt. Comdr. R.A. Hay, USNR.

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JAPANESE INTERIOR BALLISTICS

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

FASCICLE O-1, TARGET O-21

FEBRUARY 1946

U.S. NAVAL TECHNICAL MISSION TO JAPAN

SUMMARY

ORDNANCE TARGETS

JAPANESE INTERIOR BALLISTICS

Japanese developments in interior ballistics and such related problems as flash, erosion, coppering and blast are herein discussed.

TABLE OF CONTENTS

REFERENCES

Location of Target:

Kure Naval Arsenal and Kamegakubi Proving Ground, HIROSHIMA Prefecture.

Yokosuka Ordnance Library, Yokosuka Navy Yard.

Japanese Personnel Who Assisted in Gathering Documents:

Lt. Comdr. J. ICHONOI, IJN.

Japanese Personnel Interviewed:

Capt. N. IWASHIMA, IJN, O-in-C of Guns and Powder Section, Naval Technical Department.

Capt. M. MITSUI, IJN, O-in-C of Ordnance Experimental Department, Kure Naval Arsenal.

Mr. J. MINATO, 20 years a ballistician, Kure Naval Arsenal.

Mr. M. KANERO, seven years an ordnance engineer, Kure Naval Arsenal.

LIST OF ENCLOSURES

(A) List of Japanese Documents Forwarded Through ATIS to Washington Document Center.

INTRODUCTION

Under the general heading of "Interior Ballistics" a study was made of various problems concerning naval guns and ammunition.

After interviewing key personnel at TOKYO, a visit was made to the Japanese Naval Proving Ground at KAMEGAKUBI, KUREHASHISHIMA, near KURE, and personnel were interviewed there and at Kure Arsenal. Unfortunately, virtually all written records in the KURE area had been destroyed, either deliberately or through bombing and typhoon action. An important source of written material, however, was discovered in YOKOSUKA, yielding reports far too numerous to be translated and digested in Japan. These reports have been listed and classified in Enclosure (A) and have been forwarded to the Washington Document Center.

THE REPORT

I. BALLISTICS IN GENERAL

One noteworthy feature of Japanese ballistics was the supplying of reduced charges for nearly all guns, for use in target and training work. This practice probably arose from the fact that with full service charges the guns had relatively very short accuracy lives. Two types of low-velocity charges were usually provided: "weak", rated at one-half of an equivalent service round, and "reduced", rated at one sixteenth. A few guns had "specially reduced" charges, which gave even lower velocities.

The following table summarizes charge data for various guns and the velocities obtained. The velocities are apparently computed for a new gun under optimum conditions and are about 5 m/s higher than figures given in other Japanese sources.

Gun			Service Charge			Weak Charge			Reduced Charge		
cm	in	cal	Index	Wt(kg)	MV(m/s)	Index	Wt(kg)	MV(m/s)	Index	Wt(kg)	MV(m/s)
40	16.14	45	$102DC_1$	219	785	$102DC_1$	167	655	85 DC	111	505
36	14	45	85DC	144	775	85DC	113	665	53 DC	65	505
20	8	50	53DC	33.8	840	53DC	26.3	715	30 DC	13.5	515
15.5	6.10	60	$36DC_2$	19.5	925	$36DC_2$	14	755	30 DC	7.5	555
15	6	50	37DC	12.4	855	37DC	8.9	715	30 DC	5.9	515
14	5.51	50	37DC	11.0	855	--	--	--	30 DC	4.5	515
14	5.51	40	30DC	6.9	705	--	--	--	20 C3	2.9	455
12.7	5	50	30DC	7.7	915	30DC	5.7	755	20 C3	2.8	555
12	4.72	45	30DC	5.5	830	30DC	4.3	705	20 C3	2.0	505
10	3.94	50	30DC	4.1	895	30DC	3.0	715	20 C3	1.4	515
8	3	40	20C3	.93	685	--	--	--	10 C3	.42	450
8	3	43	10C3	.4	455	--	--	--	---	--	--

("Specially reduced" charges for 14cm/50, 12cm/45, 8cm/40 cal. guns, index and weight not stated, gave 300 m/s muzzle velocity.)

Japanese naval doctrine called for the use of full service charges in all actions. An exception, however, was made in the Guadalcanal operations in 1942, when "reduced" charges were used in shore bombardments with 36cm and 20cm (14 inch and 8 inch) guns.

An examination of the above table shows that the identical granulation, designated 30 DC, was used for service charges for all sizes of gun between 14cm/40 cal. (chamber volume 915 cu. in.) and 10cm/50 cal. (chamber volume 488 cu. in.), including 12.7cm/50 cal. (chamber volume 976 cu. in.). Obviously, a poor powder fit was obtained with some of these guns, and the Japanese noticed this toward the end of the war in the case of the 12cm/45 cal. gun. By changing the powder type from long, solid rods to short, singly perforated grains (designated "short tubite") and simultaneously increasing the projectile weight from 45 to 49.7 lbs., the same bore pressure and muzzle velocity were attained, but the maximum range was increased from 16,000 to 20,000 meters.

In general, there was little of interest or novelty in Japanese research on the theory of interior ballistics. Enclosure (A) lists a report on mathematical theory, two on practical measurements relating to shape of powder grains and water content of powder, and a study of the interior ballistics of catapults which takes into account the high frictional forces, large heat lo losses, and low velocities.involved.

II. VELOCITY

The velocity equipment used at the Japanese Naval Proving Ground, KAMEGAKUBI, for powder proof, for ranging, and for armor penetration studies, was the Boulenge chronograph, which is too well known to merit further description. For some work, where contact with screens might have seriously disturbed projectile flight, a microphonic switch was used instead of screens; but this was apparently the only refinement attempted in the system.

A pamphlet found at YOKOSUKA (NavTechJap Document No. ND50-3970, ATIS No. 4295) discusses the accuracy of Japanese muzzle velocity measurement.

III. PRESSURE

Pressures during gun proof and powder proof were obtained by using copper cylinder crusher gauges, quite similar to those used in other countries. An interesting point in connection with the copper gauges is that the Navy obtained the cylinders and their calibration from the Army Arsenal at OSAKA. This assured uniformity between the services; however, before the end of the war the Navy was attempting to become independent of the Army and to calibrate its own gauges.

For lower pressures than those of high-powered guns, the Japanese found the normal gauges with cylindrical crusher erratic and insensitive; accordingly they modified the gauges to incorporate a ball, similar to that of a Brinell hardness machine. With copper cylinders, they found the ball-gauge satisfactory over a pressure range of about 0.10 to 10 kg/sq.mm (.06 to 6.4 long tons/sq.in.). For still lower pressures, the copper cylinder was replaced with a lead cylinder, which was used with cylindrical crushers over the pressure range of 0.01 to 2 kg/sq.mm (.006 to 1.2 long tons/sq.in.) and with ball-type crushers for still lower pressures. Such low-pressure gauges were used in work with howitzers, bomb-shooting guns, catapults, etc.

It is reported that piezo gauges were sometimes used in experimental work at KAMEGAKUBI, but no trace of the equipment was found there, and no personnel located were able to evaluate the results obtained. Several reports concerning pressure measurement are listed in Enclosure (A). Most of these deal with crusher gauges, but one pamphlet (NavTechJap Document No. ND50-3456, ATIS No. 4248) describes use of a manganin-wire gauge.

IV. POWDER TEMPERATURE

Japanese range tables are stated to have included a table of correction to muzzle velocity for change in temperature from the standard, 21°C (69.8°F). This standard was chosen since the annual mean temperature of the Japanese Empire is around 70°F. All powder for proof work was stored in a magazine at this temperature for 72 hours before being used.

Unfortunately, no Japanese naval range tables have yet been recovered, and so the temperature coefficient of muzzle velocity used is unknown. A firing table for 20mm aircraft machine guns (SWPA Trans. & Int. Sect. Enemy Pub. #256) gives a velocity decrease of 0.72 m/s per 1°C (1.3 f/s per 1°F). Work done on 8cm (3 inch), 12cm (4.7 inch) and 15cm (5.5 inch) guns in connection with the development of the 8cm (3 inch) aircraft cannon, which was designed to be operated at extremely low temperatures, is stated to have yielded a figure of 1.5 m/s per 1°C (2.8 f/s per 1°F) over the range of 20 to -50°C (68 to -58°F). The decrease in maximum bore pressure over the same range was 0.15 kg/sq.mm per 1°F (0.05 tons/sq.in. per 1°F). A report found at YOKOSUKA (NavTechJap Document No. ND50-3437, ATIS No. 4231) indicated rather widely varying temperature coefficients of velocity, depending chiefly on the kind of propellant, and to a lesser extent of the size of gun and the type of charge (i.e., service or weak).

V. FLASH

A large amount of work was done by the Japanese Navy on the suppression of flash of gunfire, for the purpose of concealment during night firing. The documents listed in Enclosure (A) indicate the scope of their research. For service ammunition, 8% K_2SO_4 and 8% hydrocellulose were incorporated into the powder before granulation. This gave good flashlessness, but increased the smoke somewhat (no Japanese powder was entirely smokeless), and also increased the charge weight about 30%. The flash-suppressing quality of this kind of powder was attributed by the Japanese to the lowering of the temperature of combustion.

Many studies were made by the Japanese on methods of measuring and recording flash photoelectrically. However, much of this work is open to the criticism that it was done not with actual guns and service ammunition but by burning the powder being tested in a special mortar or bomb.

VI. FLAREBACK

Japanese experience with flareback was apparently negative as far as casualties with their own ships are concerned. They were, however, aware of turret accidents in other navies attributable to this cause and independently conducted investigations of their own on the subject, with a view to determining the temperature and nature of combustion products of smokeless powder, and the possibility of introducing inert gases in the bore immediately after firing and before opening the breech. Two reports on this subject are listed in Enclosure (A).

VII. BLAST

The standard gun-blast measuring instrument in the Japanese Navy was a lead-disk gauge. A circular sheet of lead 1mm (occasionally 0.5mm) thick and 50mm in diameter was supported around the edge by a steel ring, the center part being free to deflect with a pressure differential. The gauges were calibrated hydrostatically. Samples of this type of gauge, a piston type gauge occasionally used for high blast pressures, and the lead disks have been sent to O.I.L., Indianhead, Maryland (NavTechJap Equipment No. JE50-3160).

The locus of points in a single plane around the muzzle of a gun having equal blast pressures was found to be cardioid. No formula was derived for computing blast from muzzle velocity, muzzle pressure, weight of charge, or other properties of a gun. The maximum blast pressure which personnel were able to withstand without injury was determined to be 1 kg/sq.cm. (14 lbs/sq. in.), as measured with the lead plate gauge.

Several drawings showing the position of blast measurements made aboard actual vessels, and the recorded values of blast at these points, were recovered at YOKOSUKA, and have been forwarded to the Washington Document Center as NavTechJap Document No. ND50-3482 (ATIS No. 4573). A set of standard blast curves for various guns and combinations, issued in 1936, appears in NavTechJap Document No. ND50-3403 (ATIS No. 4255).

VIII. EROSION AND GUN LIFE

It was the observation of the Japanese Navy that if a gun were fired repeatedly with full service charges at a given elevation, a progressive decrease in range resulted, but that eventually a time was reached when a shot would fall far short of the previous one, owing to wearing away of the gun barrel and consequent failure of the rifling and rotating band to perform their functions. The number of full service rounds that could be fired before this point was reached varied for different types of gun but, in general, was less for the larger caliber guns.

Accompanying the decrease in range, and, in fact, actually causing it, was a decrease in muzzle velocity. It was the Japanese observation that a new gun might show a rapid decrease in muzzle velocity in the early part of its life, but that as the gun became more worn the rate of decrease of velocity became less, and that a plot of velocity loss vs. number of rounds at this stage would be nearly a straight line, until the end of life was reached, and the erratic behavior mentioned in the previous paragraph was observed. Some types of gun, chiefly case guns, however, showed an initial slight <u>increase</u> in muzzle velocity during the early part of life, a trend which soon reversed itself, so that the later stages showed a relatively rapid decrease in velocity merging into a long period of almost linear relationship between velocity loss and rounds fired. No reasonable explanation was forthcoming from any of the Japanese personnel interviewed as to why a gun should show an increased muzzle velocity after firing a few dozen rounds; but the fact was regularly observed with case guns.

The "weak" and "reduced" charges mentioned in section I of this report were rated at 1/2 and 1/16 of a full charge respectively in computing the number of rounds fired by a given gun. These were figures based on experience, and there is no indication that the Japanese Navy used any formula for reducing rounds to equivalent service rounds on the basis of charge weight, time in bore, or muzzle velocity. It was stated that at the Proving Ground, when guns were fired with charges of varying weight, as for example, in armor penetration work where a certain velocity had to be attained, the round was rated as either 1, 1/4 or 1/16 full charge, depending on whether the actual charge weight used was nearer the "full" charge, the "weak" charge, or the "reduced" charge.

Two semi-empirical formulae were proposed by Japanese ballisticians to account for the observed behavior of guns with respect to accuracy life. Both assumed the life, $\underline{N}$, to be inversely proportional to erosion, $\underline{e}$, the amount of wear as measured by stargauge at a given point near the origin of rifling. By the first formula

$$e = K\,w\,V/d^3\,P$$

where $\underline{K}$ is a constant for the gun, $\underline{w}$ is charge weight, $\underline{V}$ is muzzle velocity, $\underline{d}$ is caliber, and $\underline{P}$ is maximum bore pressure.

By the second formula

$$e = C\,t\,P\,w/d^3$$

where $\underline{C}$ is another gun constant, $\underline{t}$ is the time the projectile spends in the bore, and $\underline{P}$, $\underline{w}$, and $\underline{d}$, are the same as above. The second formula is stated to yield better results.

IX. DECOPPERING

Deposits of copper in the bore of guns, left by the rotating bands of projectiles, were observed in the Japanese service but were not regarded by the Japanese Navy as a serious problem. No depending material was incorporated in naval service ammunition, unlike some kinds os Army artillery ammunition, which included tinfoil for decoppering purposes. Naval ammunition always used pure copper rotating bands.

Acting on information received from the German Navy, the Kamegakubi Proving Ground conducted some experiments using tinfoil (or tin-lead foil) and alloys made into wire form, but no definite conclusions were arrived at as to the proper composition, form or quantity to be used, should service experience show a need for such material.

Graphite was also tried as a bore lubricant to prevent coppering, but the results are stated to have been unsatisfactory.

A chemical method of removing copper deposits from the barrels of guns is described in a pamphlet, NavTechJap Document No. ND21-3417 (ATIS No. 4237). It involved the use of ammoniacal ammonium chloride and was claimed to be superior to either the Vickers ammonium persulfate treatment or electrolysis.

X. CHROME PLATING

No major caliber Japanese naval guns were chrome-plated for service use. A few experimental chrome-plated guns were manufactured, but no superiority over bare steel was detected, and the idea was abandoned.

NavTechJap Document No. ND50-3442 (ATIS No. 4220) deals with chrome-plated machine-gun barrels.

XI. POWDER BAGS AND CASES

Powder bags used in the Japanese Navy from the time they adopted cordite until 1942, were made of shaloon, a coarse woolen fabric. Ignition ends were sometimes of silk. In 1942, with the supply of Australian wool cut off, domestic silk was adopted for powder bags. Both silk and wool are stated by the Japanese to leave no embers in the bore after combustions.

The inside of Japanese cartridge cases was invariably lacquered, and often the cordite was enclosed in a silk or woolen bag. Both procedures were adopted to prevent contact of the cordite and bare metal. It was stated that an extensive series of surveillance tests revealed no deleterious effect from permitting direct contact between the cordite grains and a brass case; nevertheless, cases were always lacquered as a precaution against some effect possibly not revealed by the tests.

XII. RIPPLE SALVOS

As a result of investigation of methods of improving the salvo pattern of large caliber guns, extending over a period of ten years, it was determined that a slight delay introduced in the firing circuit of one gun of a turret had a decidedly beneficial effect, and around 1942 interval firing equipment was furnished to all 20cm (8 inch) twin turrets and larger mounts.

For the 46cm (18.1 inch) triple mount, the center gun was delayed 0.08 sec.; for the 40cm (16.1 inch) triple, the center gun was delayed 0.06 sec.; and for the 20cm (8 inch) twin mount, one gun was delayed 0.04 to 0.05 sec.

ENCLOSURE (A)

LIST OF PERTINENT DOCUMENTS
FORWARDED THROUGH ATIS TO WDC

NavTechJap No.	ATIS No.	Title (Contents) and Date
BALLISTICS IN GENERAL		
ND50-3443	4218	Solutions of differential equations in interior ballistics. 1934.
ND50-3474	4360	Comparison of elliptical powder grains and tubular grains of various internal diameters. 1938.
ND50-3415	4266	Effect of powder moisture on muzzle velocity and bore pressures. 1941.
ND21-3421	4238	Interior ballistic studies of catapults. 1944.
ND50-3480	4571	MS sheet of ballistic data, on guns. 1945.
VELOCITY		
ND50-3970	4295	Reliability of measurement of muzzle velocity. 1934.
PRESSURE		
ND50-3456	4248	Experiments on pressure measurement.
ND50-3446	4219	Relation between temperature and compression of copper crusher gauges. 1931.
ND50-3457	4249	Copper gauges for measuring powder pressures. 1934.
ND50-3447	4217	Experimental results on copper crusher gauges. 1934.
ND50-3459	4251	Measuring powder pressures with copper cylinder gauges. 1936.
ND21-3413	4235	Vibration pressures. 1942.

ENCLOSURE (A), continued

NavTechJap No.	ATIS No.	Title (Contents) and Date
PRESSURE (Cont.)		
ND50-3416.1-2	4267	Inspection tests of laboratory-made copper pressure gauges. 1943.
ND50-3483	4574	Calibration sheet for copper cylinder gauge.
POWDER TEMPERATURE		
ND50-3437	4231	Temperature coefficients of bore pressure and muzzle velocity for various powders. 1933.
FLASH		
ND50-3468	4356	Research on gun flashes. 1936.
ND50-3462	4289	Research on flash hiding. 1938.
ND50-3413	4264	Flash characteristics of halogen and alkali salts. 1939.
ND21-3424	4223	Theory of flash hiding. 1940.
ND21-3418	4226	Duration of muzzle blast. 1940.
ND21-3419	4225	Muzzle flash in 25mm automatic cannon. 1940.
ND50-3441	4227	A flash reducing agent (ethyl dinitro benzene). 1941.
ND50-3440	4228	Flash preventing compounds. 1942.
ND21-3420	4224	Muzzle flash. 1943.
FLAREBACK		
ND50-3476	4362	Determining temperature and gas composition at muzzle for various guns. 1936.
ND50-3439	4229	Back flash (prevention). 1939.
BLAST		
ND21-3423	4239	Blast-measuring gear.

ENCLOSURE (A), continued

NavTechJap No.	ATIS No.	Title (Contents) and Date
BLAST (Cont.)		
ND50-3403	4255	Standard blast curves. 1936.
ND50-3470	4358	Explanation of handling lead plate-type blast gauge. 1937.
ND50-3414	4265	Report of research on gun-blast measuring devices. 1938.
ND50-3482	4573	MS plans of ships.
EROSION AND GUN LIFE		
ND50-3402	4254	Erosion of guns and their standard span of life. 1939.
DECOPPERING		
ND21-3417	4237	Chemical decoppering of bore deposits. 1943.
CHROME PLATING		
ND50-3445	4220	Research on chrome-plating gun barrels.