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

Subject: Target Report - Lead-Acid Storage Batteries Used by the Japanese Navy.

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

1. Subject report, covering Target S-92(N) of Fascicle S-1 of reference (a) with special emphasis on submarine batteries, is submitted herewith.

2. The investigation of the target and the target report were accomplished by Mr. J.L. Rupp, civilian technician attached to this Mission.

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30682

RESTRICTED S-92(N)

LEAD-ACID STORAGE BATTERIES USED BY THE JAPANESE NAVY

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

FASCICLE S-1, TARGET S-92(N)

DECEMBER 1945

U.S. NAVAL TECHNICAL MISSION TO JAPAN

SUMMARY

SHIP AND RELATED TARGETS

LEAD-ACID STORAGE BATTERIES
USED BY THE JAPANESE NAVY

The high-underwater-speed submarine's storage battery was a two-cell glorified automobile type with multiple thin plates. It was deficient in electrolyte, separation, and sediment space. A multitude of parallel circuits were used. It was entirely undependable and was so recognized by the Japanese.

The special Mark I Type 33 designed to replace it was of the same design except that four plates were welded together and a large container was used. The apparent higher capacity was obtained by dropping the allowable end voltage on the new type from 1.72 volts to 1.50 volts per cell.

Other types of submarine batteries offered nothing of interest, being ordinary pasted-plate batteries with glass mats. They were of the thin-plate type and resembled German batteries in some respects.

The electric torpedo battery was of similar design to the small submarine battery and was deficient in the same respects.

Other types of lead-acid batteries had no distinguishing features and were of conventional design.

In design, specification, and inspection the Japanese were weak. Much of the design was copied and little experimental work was done. Basic points were missed in copying. Specifications, when set up, were not closely followed. Little materiel inspection and product testing were done.

A comparison of Japanese and American batteries can best be made on a watt hour cycle basis. Comparing the Japanese optimistic ratings and statement of life cycles against our own proven minimums of the same, the batteries for the I-Class submarines would deliver 677.6 watt hour cycles per pound of battery weight, whereas the American battery will deliver 4122 watt hour cycle per pound of battery weight. There is, therefore, a six-to-one ratio in favor of the American battery.

The unfavorable position of the Japanese battery in these comparisons is owing largely to the short life of 80 cycles versus 600 minimum for American batteries. Assumption is made that they will meet this claim, although it has been pointed out that with the construction used such life is hardly possible; furthermore, the low volume of electrolyte makes it obvious that the capacity ratings cannot be met. If these factors are taken into consideration along with average rather than minimum performance of American batteries, the ratio in favor of the latter would rise to the neighborhood of 20 to 1.

Japanese battery practice resembles American practice of 25 years ago, when it was more of an art than a science. Research work has been notably absent. The methods used have been copied.

All casting is done by hand by ladle pouring, even though the use of small grids lends itself naturally to machine casting. No new technique for producing large castings was developed, although lack of such technique is a definite handicap in submarine battery manufacture.

continued

In the United States, the Schmadsu oxide process, once extensively used, has been largely abandoned, but not before control of the product had been obtained. The Japanese did not secure much control, and the deficiency makes a paste-control specification impossible and leads to a lack of uniformity in the finished plate.

The expander as used by the Japanese was American practice thirty years ago. Americans have since made great improvements in expanders.

The Japanese arrangement for the formation of positives and negatives in separate tanks displays a lack of knowledge of forming process control - a waste of electrical current and labor.

Japanese battery practice shows nothing novel and largely represents processes which have been abandoned in the United States.

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REFERENCES

A. Location of Target:

Japanese Submarine Fleet, SASEBO.

B. Japanese Personnel Interviewed:

Rear Admiral MURAKAMI - Military Supervisory Inspector.

Captain YAMAGI - MURAKAMI's immediate subordinate.

Commander IWANO - Head of Submarine Electrical Section of the Technical Department.

C. Other Reports Referred to:

1. NavTechJap Report - "Characteristics of Japanese Naval Vessels, Article 6" - Index No. S-01-6. This report is a compilation of:

   a. "Preliminary Intelligence Reports on the Japanese Submarine Forces as Observed at the Yokosuka Naval Base" by Submarine Squadron 20.

   b. "Japanese Subs and Sub Material, Western Japan", by Submarine Squadron 13.

2. NavTechJap Report - "Characteristics of Japanese Naval Vessels, Article 1" - Index No. S-01-1.

LIST OF ENCLOSURES

(A) List of Japanese Documents and Equipment Shipped to the United States.

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INTRODUCTION

Because of information to the effect that the Japanese had developed a high-underwater-speed submarine, and because such a submarine would require a special storage battery, the prime purpose of the investigation was to study the battery for this submarine.

Of secondary importance was a general investigation of any other types of submarine batteries or electric-torpedo batteries the Japanese may have had.

Of third importance was an interrogation of available submarine design engineers to learn details of design and manufacturing methods that might prove useful.

The method was to: (1) review reports already prepared which were pertinent to the subject; (2) go aboard the various submarines available, inspect battery installations, and interview the crews; (3) select available samples for dismantling and examination on location; (4) select for return to the Navy Department data for detailed study; (5) select for return to the Navy Department sample cells for laboratory analysis and tests; (6) interrogate Japanese design engineers.

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THE REPORT

Part I
SPECIAL TYPE-D STORAGE BATTERY USED IN HIGH-UNDERWATER-SPEED I-200 SUBMARINES

The I-201, 202, and 203, built in 1945, are reputed to deliver 5,000 horsepower submerged and to have a speed of 16.3 knots for 50 minutes. The battery weighs 417,600 pounds and is rated by the Japanese at 4,176 kilowatt hours at the one-hour rate. There are a total of 4,176 cells per ship. Each hard rubber container encloses two cells, so there are 2088 containers. There are 36 parallel lines with 116 cells per line, making a total voltage of 232 volts.

The capacity per cell is variously stated at from 500 to 540 ampere-hours at the one-hour rate. In view of the low electrolytic volume it is questionable whether 500 ampere-hours would be obtainable, although according to American ratings this amount of plate volume (with sufficient electrolyte) should deliver 600 ampere-hours.

The two-cell unit appears to be identical to those taken from the midget submarine captured at Pearl Harbor. The Bureau of Ships already has complete reports from various manufacturers and the Naval Research Laboratory on these units and a re-examination of them will be of assistance in reading this report.

Description of the Battery:

1. Container. The container is of moulded hard rubber, 13 inches long, 11½ inches wide and 10¼ inches high. Because of the extension on one end for the filler cap and vent stack, and the extension of the intercell connection on the other end, the total overall length is 16 inches. The container walls are one-half inch thick except for occasional 1/16 inch high ribbing for strength. There are no element support bridges in the container.

2. Covers. Two hard-rubber covers run longitudinally, one on each side of a parallel center partition in the container. The covers are provided with a 5/8 inch sealing well of conventional design and contour. The underside of each cover is equipped with a baffle running half way down the cell length to avoid sloppage in case of undue tilting. A standpipe is threaded into the cover at one end for venting. A hard-rubber filler plug, threaded, is located immediately adjacent to the standpipe.

3. Sealing Compound. The sealing compound used obviously has a low melting point and is brittle at room temperatures. While its adhesive qualities are good it is similar to American "Chatterton" compound, which was abandoned years ago.

4. Intercell Connection and Terminals. Connection and terminals are of copper. The lead plating is thin and poorly applied.

5. Element Plate Connector Bars. These bars running the length of the cells are tapered, increasing in cross section as they approach the terminal. They are made up of tapered copper bars, surrounded with lead. The lead has been cast around the copper and the cohesion is good. The lead is of such thickness on one side as to permit the welding of the individual plate lugs to that section. The workmanship is good.

Connector bar posts are also of copper covered with lead, the lead again being cast around the copper. The posts pass up through the cover, through lead inserts moulded in the cover. The whole assembly including the intercell connector is welded into a single unit.

The element suspension is arranged by means of notches on the inside ends of the case into which fit projections on the ends of the connector bars. Although the connector bar is 12 inches long it has sufficient rigidity to support the plates because of the copper insert.

6. Plates. Both positive and negative plates are .055 inches thick. They are identical in design, having been cast in a surface cut mould, so that both vertical and horizontal conductors run from surface to surface of the finished plate. This is not considered good practice but is passable in plates as thin as these. Plates are five inches wide and 7½ inches high, with conductor lugs on the extreme corner. The antimonial content is approximately 8% in both plates. No attempt has been made to eliminate or reduce antimony contamination on the negative; the hydrogen emission of the cell on discharge is undoubtedly high.

7. Active Material. The battery examined is quite new and the active material in both positive and negative is in good condition. The positive material is porous and of low gram weight per unit volume. The negative active material, while spongy and of fair texture, exhibited but little expansion tendency and may be deficient in expander. Both plates had been pressed with cloth after fastening, giving a good external appearance.

Although the battery is new the horizontal positive grid bars are nearly peroxidized away and the vertical conductors have been attacked to a considerable extent. Only the outside grid frames showed appreciable bright metal when broken.

8. Plates per Cell. There are 68 positive and 70 negative plates per cell. The even number is due to a rubber spacer in the center of each cell acting as a brace and a support for the connector bar. A total of 69 plates (positive and negative) are on each side of the rubber spacer. The spacer has holes one inch in diameter in it to permit circulation of the electrolyte from one side to the other.

9. Active Material Retainer. Glass mats are applied to both sides of the positive plates. These mats are .04 inch thick, thicker than necessary for a positive only .055 inches thick (.02 inches is enough). The mats are made of spun-glass fiber. The fiber diameter is of a size used in the Gould battery (much larger than the Owens-Corning glass fiber). The mats are indefinite strata and an insoluble binder has been used. There was no active material saturation of the mat (the battery was new).

10. Separation. Separators consisted only of a piece of flat wood veneer .013 inches thick. (The glass mat is considered a retainer of active material only, not a separator). The wood is cedar and, because of its thinness, very fragile. The use of an .02 inch mat would have permitted a heavier, grooved wood separator, allowing not only a separator life consistant with the plate life but a much needed increase in electrolyte volume.

11. Sediment Space. A 1/16 inch sediment space is provided. Although the battery was new, short circuits were already occuring. The sediment space is entirely inadequate (half-an-inch should have been provided) and the fit of the plates on the sides in the container is too close, as short circuits were in evidence there also. Glass mats tend to aggravate this condition on the sides unless properly bound in place.

12. Specific Gravity. A fully charged specific gravity of 1.280 was intended, but in the I-200 it has so far been impossible to bring the cells uniformly up to this. In some cases the specific gravity has risen to 1.290, but numbers of cells will not rise above 1.140.

Short circuits no doubt already exist in many cells of this comparatively new battery. The method of parallel-charging 36 lines of cells makes uniform charge per bank impossible. Examination of connections shows that even with the greatest of care varying resistance between parallel lines will occur.

13. Ventilation. Cells are allowed to vent directly into the battery compartment through the 3½-inch stacks previously described. Hydrogen detectors are used but the submarine was operated with a hydrogen content as high as 6%.

14. Operating Instructions. Log books could not be obtained. If there were any, they had been destroyed. Questioning of officers and crew members leads to the conclusion that instructions were very general and probably verbal.

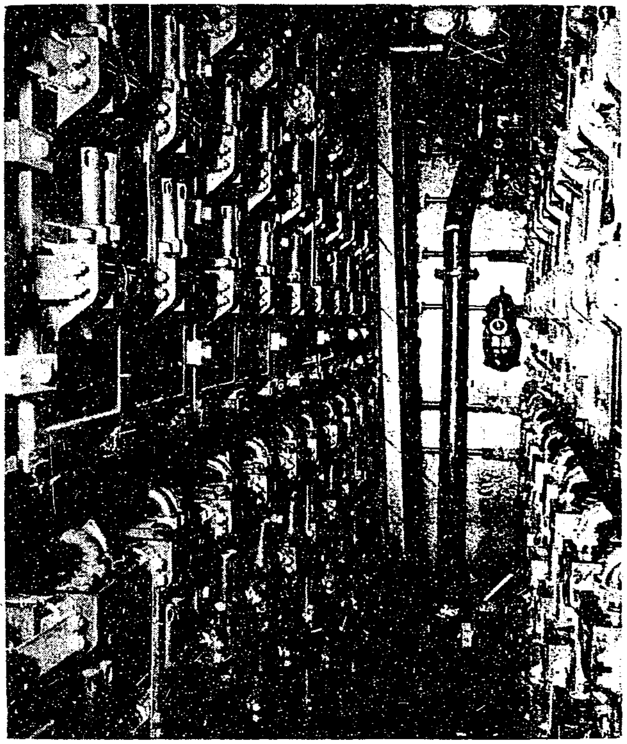

Figure 1
BATTERY INSTALLATION ON THE I-200

The two-cell units are mounted back-to-back with two similar units adjacent to each other. Thus a group of four units are in immediate contact with each other without wedging. They are held together with thru belts and clips. Under the clips, blocks of sponge rubber are placed. The first group of four units rests on blocks of similar rubber on top of steel shelves supported by channel irons. There are a total of four groups of units as described above, piled one top of the other on each shelf. If there were any considerable roll of the ship it is doubtful whether these tiers of units would remain in place. A sharp roll could readily allow acid sloppage from the vent stack.

15. End Voltages. An attempt to learn what voltages were used for termination of discharge produced the following questionable information:

Ampere Hours

540 voltage at 1 hr (low voltage limit) 1.72
580 voltage at 2 hr (low voltage limit) 1.76
620 voltage at 4 hr (low voltage limit) 1.80
640 voltage at 8 hr (low voltage limit) 1.84
660 voltage at 20 hr (low voltage limit) 1.84

For the longer discharges these voltages are within reason, but for the shorter ones, especially the one hour, these voltages are very high. A thin-plate battery at the one-hour rate may conceivably have an end voltage as high as this, but only if the materials in the battery are in proper balance. With such an obvious shortage of electrolyte only a laboratory test on samples being returned can determine what the end voltage actually is.

16. Computations and Comparisons. Plates are 5 inches by 7.5 inches or 37.5 square inches. There are 68 positives per cell, giving a total positive plate area (one side) per cell of 2550 square inches. According to American practice for plates of this thickness, .237 amperes per square inch at the one-hour rate should be produced. This would give an ampere-hour capacity of 604. From best measurements obtained each cell contains only 1.45 gallons of electrolyte at 1.280 specific gravity. Again, according to American practice, a minimum of 2.00 gallons should have been available. Therefore the cell contains only 71% of the electrolyte it requires. On the basis of plates for 604 ampere-hours, but with only 71% of the required electrolyte, 428 ampere-hours is all that may be expected from this cell, even if no internal short circuits occur.

The weight of the cell unit complete with electrolyte is 200 pounds. There are a total of 2088 units, making a total battery weight of 417,600 pounds. There are 36 parallel rows of cells with 116 cells per row, or 232 volts; 232 volts at 500 ampere-hours is 116,000 watt-hours per row. However, the cell cannot deliver more than 428 ampere-hours per cell, or 98,296 watt-hours per row. With 36 parallel rows a capacity of 3,538 kilowatt-hours is indicated. The battery should deliver 8.47 watt-hours per pound of weight.

The life of the battery is reported by the Japanese to be 80 cycles, but observation shows that it is far short of this.

Good American design produces 5,720 ampere-hours at the one-hour rate for 1,660 pounds of weight and a life of 600 cycles at 1.280 specific gravity. Therefore, two 126-cell, 2-volt American batteries would have an output of approximately 2882.8 kilowatt-hours.

$$\left(\frac{126 \times 2 \times 5720}{1000} \times 2 = 2882.8\right)$$

The total battery weight is 418,320 pounds; therefore the battery delivers 6.87 watt-hours per pound.

The Japanese battery should deliver 847 watt-hours for 80 cycles, or 677.6 watt-hour cycles, for one pound of weight.

The American battery will deliver 6.87 watt-hours for 600 cycles, or 4122 watt-hour cycles for one pound of weight.

The ratio in favor of the American battery compared to the Japanese is therefore six-to-one.

It is further pointed out that a life of 80 cycles is extremely doubtful for the Japanese battery, and that 600 cycles for the American is a minimum.

17. Conclusions. To attempt to obtain large capacity with a multitude of small units is moving in the wrong direction. The container, covers, and connections, both inside and outside of the cell, represent a larger proportion of the total cell weight as the size becomes smaller. The proportion of inactive grid metal to active working material also increases with the small units.

The use of multiple thin plates is proper design procedure for high capacity batteries, but when rates no higher than 30 minutes are contemplated, it is useless to go below a positive plate thickness of .080 inches, with .093 to be preferred. Negatives may be made thinner by a special grid design, with some saving in weight.

The insulation between plates, the electrolytic volume, and the sediment space were entirely inadequate; these deficiencies lead to lower than rated capacity, short life, and unreliability. A battery with fewer and thicker plates, with less glass mat, with a grooved wood separator (since microporous was not available), and with a greater sediment space would have been much more desirable.

Part II
THE SPECIAL MARK I TYPE 33 BATTERY

Realizing the deficiencies of the special D-type battery, the Japanese produced a Mark I Type 33 battery to replace it. Apparently unable to cast large grids successfully, they placed four grids edge to edge and burned them together. The plate lugs of a given polarity were left extending out on one side. To these was burned or welded a vertical riser. In some cases a copper insert was cast into this riser to assist in current conduction. The result was a plate 20 inches high by 7½ inches wide. Twenty-five positives and twenty-six negatives were used. The container shape was changed, of course, but the general construction as to separator, glass mats, and other parts remained the same. Thus it was possible to place 100 of the new type positive plates in a cell versus the 68 plates in the D-type.

This new battery was rated at 1060 ampere-hours at the one-hour rate, compared to 540 ampere-hours for the D-type. Proportionally, the new battery should have been rated at 800 ampere-hours.

It was found upon investigation that the end voltage of the new battery was given as 1.5 volts per cell compared to 1.72 volts per cell for the D-type.

It may be concluded, therefore, that the Japanese moved in the right direction in making large plates, thus obtaining a larger proportion of working material weight to total weight.

The extra grid metal used in welding small units together was a definite loss. A properly designed single casting would have been much better.

The defects of insufficient electrolyte, poor separation, and probability of short circuits were not remedied.

Most serious error was dropping the end voltage from 1.72 to 1.50. An end voltage of 1.72 volts falls on the discharge curve well before the knee of the curve is reached, but 1.50 volts is well below the knee.

It is estimated, without test data, that the old D-type, if in good condition, could be rated 30% higher, with an end voltage of 1.50 instead of 1.72.

It should be remembered that the Mark I Type 33 was to be a substitute for the D-type in the I-200 submarine. Obviously, if they were designed to operate at a minimum cell voltage of 1.72 they would not do well at 1.50. Therefore, all that was gained was a slightly better use of material by putting more plates in a single container. Other deficiencies remained.

Part III
BATTERIES USED IN VARIOUS OTHER JAPANESE SUBMARINES

1. Mark I Model 12. This model battery was used on the Ra-type submarine. It contains 120 cells, 27 positive and 28 negative plates per cell. Positive plate thickness is .092; negative plate thickness is .082 inches. Fully charged specific gravity at 80° F. is 1.280. Its capacities are as follows:

Ampere Hours	Discharge Rate
2750	1 hour
3500	2 hours
4300	4 hours
5000	8 hours
5600	20 hours

2. Mark I Model 2. This battery used on the Ro-type submarine; it contains 184 cells - two groups in parallel - giving a voltage of 184 volts. There are 13 positives and 14 negatives per cell. Positive plate thickness is .092 inches; negative plate thickness is .083 inches. Fully charged specific gravity at 80° F. is 1.280. Capacities are as follows:

Ampere Hours	Discharge Rate
2400	1 hour
3180	2 hours
3860	4 hours
4600	8 hours
5400	20 hours

3. Mark I Model 14. This battery contains 118 cells in series, giving a voltage of 236 volts; there are 30 positive and 31 negative plates per cell. Positive plates are .092 inches thick; negative plates are .082 inches thick. Specific gravity fully charged is 1.280 at 80° F. This battery was used on the medium-sized I-class patrol submarine. Capacities are as follows:

Ampere Hours	Discharge Rate
4500	1 hour
5900	2 hours
7200	4 hours
8400	8 hours
9500	20 hours

4. Mark I Model 13. This battery, used in the I-400 special large-class submarine, contains 360 cells divided into three 120-cell batteries connected in parallel; each cell contains 54 positive and 56 negative plates. Positive plate thickness is .092 inches; negative plate thickness is .082 inches. Specific gravity fully charged is 1.280 at 80° F. The rubber jar has a divider in the center; the size and general construction are similar to the older German cells. Capacities are as follows:

Ampere Hours	Discharge Rate
5500	1 hour
7000	2 hours
8600	4 hours
10000	8 hours
11200	20 hours

5. Mark I Model 15. This battery was used on the Ha-201 class submarines, which were trainers similar to British "L" boats. There are 120 cells per boat divided into two 60-cell groups of 120 volts each. Positive plate thick-

ness is .092 inches; negative plate thickness is .082 inches. Specific gravity fully charged is 1.280 at 80° F. Capacities are as follows:

Ampere Hours	Discharge Rate
3160	1 hour
4000	2 hours
4900	4 hours
5680	8 hours
6400	20 hours

Pasted plates were used throughout. Glass mats and wood veneer separators were used. Microporous separators were preferred but were unobtainable. Glass baffles were general practice for some control of acid spray.

Four hundred and fifty cycles of life were expected with microporous separators but batteries apparently fell short of this and, when wood came into general use, the life dropped to such an extent that batteries were usually removed after 250 cycles.

Intercell connections were lead-plated copper of ample cross-section. The lead plating was thin and not well applied. Battery terminals were of the stud type used by the Russians and Germans. A washer was applied under the stud head.

Sealing compound has a low melting point and is brittle at room temperatures. It is of a kind long ago abandoned by American manufacturers.

Jars and covers were of hard rubber, quite hard and brittle. The jars were solid hard rubber with no provision to retain electrolyte in case of breakage.

There is no evidence that plastic jars were ever used.

Battery compartments were lined with paraffin-impregnated wood. The cells themselves sat on pads of sponge rubber 3/4 inches wide running the length of the jar. Strips of the same material were placed between the cells for side wedging. No distortion of the jars was noticed, supporting the belief that the jars had a low elongation and perhaps a high tensile strength.

Some attempt was made to use ventilating ducts, but in general the gas was free to escape into the battery compartment.

All ships inspected were equipped with hydrogen detectors of apparently good design. They were marked with a danger point at 3% but since no steps were taken in the battery design and construction to keep hydrogen emission low, the ships were kept submerged with the hydrogen content as high as 6%. The detectors were of much better appearance and workmanship than the German, and a study of them may be worth while. A hydrogen detector has been forwarded to BuShips as listed in Enclosure (A).

Electrolytic type ampere-hour meters of clever design were universally used. They were shock-proof mounted and in appearance far superior to those observed on German submarines. An ampere-hour meter has been forwarded to BuShips as listed in Enclosure (A).

<u>Conclusions</u>. Except for the hydrogen detectors and ampere-hour meters, there was nothing in these five types of submarine batteries to warrant further American interest, unless the laboratory tests of returned samples discloses some unexpected advantage. This might be in the form of higher average voltage on discharge, but there is no strong reason to expect it.

Part IV
JAPANESE ELECTRIC TORPEDO BATTERIES

These batteries are of the lead-acid type. There are two rows of 56 cells, making a total of 112 cells per battery. Each cell is encased in a hard rubber container 3/32 inches thick with strengthening bosses of 1/16 inch height. The containers appear quite brittle. The hard rubber cover is of conventional design with a 5/8 inch sealing well. The sealing compound is the usual low-melting-point material, brittle at room temperatures. The cells are loosely enclosed in a rectangular alloy box, allowing a double row of 56 cells each. This is in contrast to American design, in which the cells are compounded into the container. This arrangement was intended to permit ready removal of individual cells should they become dead. Terminals are of the bolted type with copper inserts moulded into the posts. These copper inserts are threaded and the intercell connector is held in place with nuts.

The filler cap and vent plug are of the tube type, formerly used on American aircraft batteries. It is unique, however, in that instead of the tube extending down into the cell electrolyte chamber, the entire assembly is removable for filling, and the reservoir for collecting the electrolyte upon inversion is above the cell proper. Figure 2 describes the non-spill device.

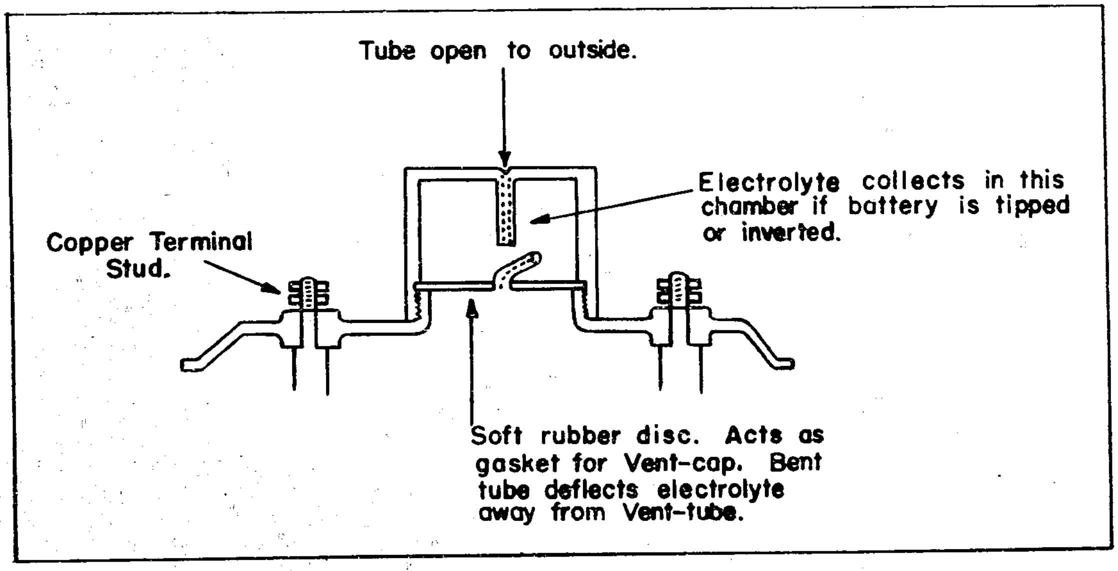

Figure 2
DETAIL OF TORPEDO BATTERY VENT-CAP

Plates are of the pasted type. There are 14 positives and 15 negatives per cell. Both positives and negatives are .055 inches thick, the same as the plates in the I-200 submarine batteries. The height is six inches and the width 4½ inches.

Grids are of about 8% antimonial content and on surface type moulds, so the grid bars and vertical conductors run from plate surface to surface. Both grids are alike.

Separators are of .01 inch wood veneer, paper thin and very fragile. The element is tightly "packed" in the container. With only 7/8" between the tops of the plates and the cover, the electrolyte space is very small. A fully charged specific gravity of 1.280 was used.

There was no sediment space and no feet on the bottoms; plates and veneer separators rested directly on the bottom of the container.

Battery was rated at 150 amperes capacity. Since there are 378 square inches of positive plate surface (one side), on the basis of .237 amperes per square inch (American practice for this plate thickness) the capacity would be 90 ampere-hours. This battery exhibited the extreme in the Japanese tendency to provide inadequate electrolyte, and it is certain that the capacity would fall far short of 90 amperes.

One must conclude that the dependability of this battery would be poor. Perhaps this realization led the Japanese to make the individual cells so easily removable. They were carried aboard ship in a charged and wet condition and, as shorted cells were sure to be frequent, only good cells were placed in the trays before use. Fewer plates per cell, grooved separators, additional space for electrolyte, and some sediment space would have added to the battery's performance and immeasurably to its reliability.

Part V
JAPANESE LEAD-ACID STORAGE BATTERIES, GENERAL

During the course of the special submarine storage battery investigation, lead acid storage batteries of other types were observed and investigated wherever possible.

These included automobile, truck, radio "A", radio "B", and aircraft batteries. In not a single instance was anything novel or of interest to the Navy and American manufacturers disclosed. The usual pasted plates with wood separators were always used. Occasionally glass mats were applied, but whenever this was done, grooving on the wood was eliminated, resulting in an electrolyte shortage. Monobloc containers and covers of conventional design were used.

On aircraft batteries the non-spill vent device was of the tube type developed by the United States during World War I. It has some merit but was abandoned by the U.S. ten years ago.

Part VI
JAPANESE STORAGE BATTERY DESIGN AND SPECIFICATION

The impression gained is that the Japanese had only elementary knowledge of some fundamentals in storage battery design. They were alert to copy, but often missed the basic point, and owing either to lack of laboratory facilities or to lack of proper reasoning on the part of their engineers, they did not correct deficiencies. They were not exactly ethical in some of the steps taken to make a good showing and were weak on manufacturing technique. Although they had available, at least early in the war, ample quantities of crude rubber, their jars and covers remained hard and brittle. Except for mounting them on soft rubber pads, no attempt was made to make them more rugged.

Jars were made by the Mitasuchi Rubber Company and the Dai Nihon (Greater Japan) Manufacturing Company in large quantities, but examination of old and new parts showed no change or improvement.

Microporous separators using latex were made by the Meiji Rubber Company. Their superiority was recognized, but in all batteries examined Japanese cypress was used. If rubber did become scarce, it must not have had high priority for submarine use. The wood separator was one of the weakest parts of

Japanese batteries. The Japanese assumed that glass mats used as a retainer would also serve as a separator and medium for holding electrolyte, but they packed the element so tightly that there was inadequate electrolyte.

It is interesting to note that whereas American manufacturers secured all the available Kobe agar in the country for glass mat binders, the Japanese used a bone gellatin.

The Japanese claim to have used in grids four to five percent antimony and from .2% to .3% arsenic, thus greatly prolonging the grid life. Tests on returned samples will check this claim. They used flat-faced moulds for casting grids .055 inches thick, but for greater thicknesses used interlocking moulds. This latter practice is questionable when glass mats are used.

The Japanese could not develop the technique for casting large grids. They offered all sorts of reasons as to why they did not wish to, such as mass production on small sizes, but the fact is that they did not know how. They lost much of the advantage of thin plates because of the excessive grid metal per cell owing to these small sizes.

For mould coating carbon black was mostly used, but some experimenting was done with magnesium carbonate. All grids were hand cast.

In all of their designs there was a shortage of electrolyte and inadequate sediment space. They state that they were only trying to build a high-capacity, short-life battery, but additional electrolyte and sediment space would have improved both quality and life, lessened weight, and would have added immeasurably to the reliability of the battery. For positive active material oxide they used sub-oxide manufactured by the Schmadsu process, patented in the United States under that name. An acid mix was used, and since the amount varied with the quality of the oxide, a lack of control in its manufacture is indicated.

Some litharge was used with Schmadsu oxide in the negative. The expander was precipitated barium sulphate in percentage of from .5 to 1.3 percent, varying with the quality of the oxide and the barium sulphate. Some experimentation was done with barium carbonate.

Sulfuric acid was purchased simply as battery acid with an iron content not to exceed .012% at 1.280 specific gravity.

Positives and negatives were formed in separate forming tanks against dummies. Antimony grids were used as dummies, but occasional reference to pure lead indicates that they may have believed it desirable in some cases. They seem to have made little or no check on the raw materials going into the batteries.

Once a manufacturer was placed on the Navy approved list his product was checked only once each year, provided his processes had remained unchanged.

In the yearly tests on submarine batteries, samples were selected and sent to the Naval laboratory for test.

Discharges were first conducted at the 20, 8, 4, 2 and 1-hour rates; then the cells were placed on cycle at the 2-hour discharge rate, followed by a 125% charge. After each 50 cycles a capacity test was made at the 8-hour rate. No tensile strength or elongation tests were conducted on the hard rubber. The manufacturer's reliability was depended upon for a good product. Some shock tests were conducted on the completed cells, consisting of a series of increasing vertical drops until breakage occurred. On older types, elevations as high as 30 inches were obtained; on newer types they reached as high as 76 inches. Further questioning disclosed that on the newer types the tests were conducted with the cell protected with shock absorbing rubber. The inspection and testing of batteries were quite inadequate.

Japanese batteries. The Japanese assumed that glass mats used as a retainer would also serve as a separator and medium for holding electrolyte, but they packed the element so tightly that there was inadequate electrolyte.

It is interesting to note that whereas American manufacturers secured all the available Kobe agar in the country for glass mat binders, the Japanese used a bone gellatin.

The Japanese claim to have used in grids four to five percent antimony and from .2% to .3% arsenic, thus greatly prolonging the grid life. Tests on returned samples will check this claim. They used flat-faced moulds for casting grids .055 inches thick, but for greater thicknesses used interlocking moulds. This latter practice is questionable when glass mats are used.

The Japanese could not develop the technique for casting large grids. They offered all sorts of reasons as to why they did not wish to, such as mass production on small sizes, but the fact is that they did not know how. They lost much of the advantage of thin plates because of the excessive grid metal per cell owing to these small sizes.

For mould coating carbon black was mostly used, but some experimenting was done with magnesium carbonate. All grids were hand cast.

In all of their designs there was a shortage of electrolyte and inadequate sediment space. They state that they were only trying to build a high-capacity, short-life battery, but additional electrolyte and sediment space would have improved both quality and life, lessened weight, and would have added immeasurably to the reliability of the battery. For positive active material oxide they used sub-oxide manufactured by the Schmadsu process, patented in the United States under that name. An acid mix was used, and since the amount varied with the quality of the oxide, a lack of control in its manufacture is indicated.

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ENCLOSURE (A)

LIST OF SEIZED DOCUMENTS AND EQUIPMENT
SHIPPED TO THE UNITED STATES

I. Documents Shipped to the Washington Document Center by U.S.S. EURALYE
NavTechJap Document NO. ND50-1140 Atis No. 3146

GROUP 1
Blueprints, Plans, and Miscellaneous Publications

Number	Description
1.	Method of Suspending Batteries While Installing in Submarines.
2.	Performance Data MK 3 Model 3 & MK 3 Model 4 Batteries.
3.	Battery Suspension Device.
6.	Arm Used for Battery Suspension With Fitting.
7.	Print, Metal Part Sulphuric Acid Pump.
8.	22cm Cut Out Valve for Exhausting Battery Gas.
9.	28cm Cut Out Valve for Exhausting Battery Gas.
10.	Regulations for Section in Charge of Battery Charging and Maintenance.
11.	Characteristics & Handling of Storage Batteries, Dated 1939.
12.	Ordering Paint & Acid Proof Paint for Submarine Batteries.
13.	Large Model Submarine Storage Batteries (Rough Notes Indicating Information Regarding These - Recovered From Battery Shop, SASEBO).
14.	General Information Book on Storage Batteries, SASEBO.
17.	Blueprints of Parts for Model 3 Water Purifier.
20.	Blueprints of Welding Tools for MK 3 Model 4 Batteries, SASEBO.
23.	Blueprint of Use of Ebonite Distilled Water Tank, SASEBO.
24.	Storage Battery Exhaust Gas Ducts.
26.	Terminal Connections for MK 3 Model 3 Storage Battery, SASEBO.
27.	Blueprint of Separators (Possibly Wood) for MK 3 Storage Battery.
28.	Water Filling Connections for Storage Batteries.
29.	Method of Wedging Submarine Batteries.
30.	Blueprint Notes on Improvement in Battery Installation Methods, Dated 1943.
31.	Method of Installation of Storage Batteries (Group 2).
32.	Plans for Container for Charging Batteries of Type 92 electric torpedoes.
35.	Specification for Battery Water Distiller.
36.	Assembly and Plans for MK 5 Model 8 Storage Batteries.
37.	HA-126 Initial Battery Charge & Discharge.
43.	Formula for Making Ebonite Pipes for Discharge of Battery Gas.
45.	Specifications for Phenol-Resin (Bakelite), SASEBO.

GROUP 3
Hydrogen Detectors

Number	Description
1.	Four (4) Pamphlets on Hydrogen Detector (Wheatstone Bridge Type) Used on Japanese Submarines.
3.	Blueprints for Hydrogen Detector.
4.	Six (6) Copies of Hydrogen Gas Detector Connectors.
6.	Hempel Type Hydrogen Detector.
7.	Diagram of Model 1, Hydrogen Detector.

ENCLOSURE (A), continued

GROUP 7
Submarines - General

Number	Description
3.	Log of Submarine HA-216.
4.	Characteristic Data of all Types of Japanese Submarines Obtained From Japanese Naval Engineers at SASEBO.

II. Equipment Delivered to ComSubPac by USS EURALYE for Forwarding to Bureau of Ships

1. Batteries for Torpedo Exercise Warheads

Type 2	76 batteries
Type 3	37 batteries

2. Submarine Batteries.

Type	Number
2	1
12	1
13	1
14	1
15	1
5	1 (not assembled)

3. Accessories

Hydrogen tester	- 1
Battery water cleaner	- 1