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

29 November 1945

RESTRICTED

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

Subject: Target Report - Characteristics of Japanese Naval Vessels, Article 3.

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

1. Subject report, covering the procedure and methods employed by the Japanese in the design of surface warships as outlined by Targets S-01 and S-05 of Fascicle S-1 of reference (a), is submitted herewith.

2. The investigation of the target and the report were accomplished by Commander R.L. Evans, USN. U.S. Navy personnel who assisted materially in providing information from which this report was compiled were: Capt. F.W. Slaven, USN, who supplied information regarding the machinery installations of the ships discussed; Commander E.C. Holzworth, USN, who supplied information regarding damage to the ships discussed and the manner in which those ships withstood such damage as was inflicted on them; and Lt.(jg) S.B. Levine, USNR, and Lt.(jg) T.S. Montgomery, USNR, who acted as interpreters and translators.

C. G. GRIMES
Captain, USN

RESTRICTED S-01-3

CHARACTERISTICS OF JAPANESE NAVAL VESSELS
ARTICLE 3
SURFACE WARSHIP HULL DESIGN

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

FASCICLE S-1, TARGETS S-01 AND S-05

NOVEMBER 1945

U.S. NAVAL TECHNICAL MISSION TO JAPAN

SUMMARY

SHIP AND RELATED TARGETS

CHARACTERISTICS OF JAPANESE NAVAL VESSELS - ARTICLE 3
SURFACE WARSHIP HULL DESIGN

This report discusses the procedure and methods employed in the design of Japanese warships. Specifically, Part I of the report describes the procedure used to change the requirements of the Japanese General Staff into a firm ship design. For a proper understanding of this procedure, the organization of the Navy Ministry and the Navy Technical Department is given.

Part II discusses the detailed elements of design and the methods used by the Japanese to design these elements to withstand the service to which their warships were submitted.

Part III gives the characteristics of the latest design classes of the following types of vessels: battleships, aircraft carriers, cruisers, destroyers, escort vessels, and a Japanese version of a landing craft which, in size, was midway between an LST and LSM.

TABLE OF CONTENTS

LIST OF ENCLOSURES

REFERENCES

Japanese Personnel Interrogated:

Rear Admiral A. KATAYAMA - In charge of Fundamental Design, and nominal head of Detailed Design, Fourth Section, Navy Technical Department.
Captain MAKINO - In charge of Detailed Design, Fourth Section, Navy Technical Department.
Vice Admiral FUKUDA - Retired head of the Fourth Section, Navy Technical Department. In charge of the design of YAMATO class BB's.
Vice Admiral EZAKI - Successor of Vice Admiral FUKUDA.
Rear Admiral YAGASAKI - In charge of the design of aircraft carriers, both fundamental and detailed design, Fourth Section, Navy Technical Department.
Captain INAGAWA - Assistant to Rear Admiral YAGASAKI.
Captain OZONO - In charge of the design of heavy and light cruisers, both fundamental and detailed design. In charge of the design of OYODO. His background on other cruiser designs was good.
Captain MAKINO - In charge of destroyer design. Had prepared the fundamental and detailed designs for ASASHIO and KAGERO classes.
Commander TOYAMA - Assistant to Captain MAKINO. Had prepared the fundamental design of TERATSUKI. In charge of the fundamental and detailed design of escort vessels.
Lt. Commander HANITA - Assistant to Commander TOYAMA. In charge of the fundamental and detailed design of SB type landing craft, and in addition, was present incumbent of underwater protection desk in Fourth Section, Navy Technical Department.
Captain DATE - In charge of the design of turret revolving structures; attached to the First Section, Navy Technical Department.
Rear Admiral SASAGAWA - Japanese Navy's expert on armor and steel and head of the Material Section, Navy Technical Department.
Dr. David IINO - Professor of English at the Japanese Naval Academy at KURE at the time of the Japanese surrender; of great assistance in interpreting, translating and in providing connections with the Japanese on field trips to MAIZURU and KURE.

U.S. Naval Personnel Who Assisted in Collecting Documents:

Commander N. Sonenshein, USN (YOKOSUKA)
Commander V. R. Hayes, USN (KURE)
Commander R. H. Hedgecock, USN (SASEBO)

Additional information was obtained from inspections of operational and damaged ships in various ports in Japan.

INTRODUCTION

This report is intended to cover Japanese naval design procedures and methods that have been used in the design of surface warships. As the first step in the design of a warship requires coordination between the various units of a navy department, the organization of the Japanese Navy Ministry and the Naval General Staff, as well as the line of command for these units, is outlined to provide a better understanding of the preliminary steps employed in the process of design.

This report is not a report on the characteristics of all Japanese naval vessels, but rather a discussion of design procedures used by the Japanese naval designers. As design procedure changes with a knowledge of the art, the methods and ships chosen for discussion are those that will provide an insight into the latest Japanese design methods, and a discussion of those methods as they affect the latest designs produced by the Japanese. No attempt has been made to investigate earlier designs as all improvements are believed to have been included in the latest ships. In this regard, it may be stated that except in a few instances, the latest ships of a type were logical extensions of previous designs. The influence of previous design classes was strong in Japanese vessels.

The information contained in this report has been obtained by interrogation of the personnel actually charged with the prosecution of the various designs; that is, the technical personnel of the Navy Technical Department, a study of such plans, data, etc. as were available, and inspections of the remaining ships of the various classes. Documentation of data given from memory by the technical personnel is not complete. However, where a check was possible, such data have proved surprisingly accurate. Documentation of all data was made difficult because of the following three reasons:

1. The inherent Japanese secrecy with the resulting limited dissemination of design data.

2. The destruction caused by Allied bombings. (The Navy Technical Department was burned, along with its mass of data, in the fire raids on TOKYO.)

3. The burning of many Japanese documents that was ordered when it became evident that the home islands would be invaded.

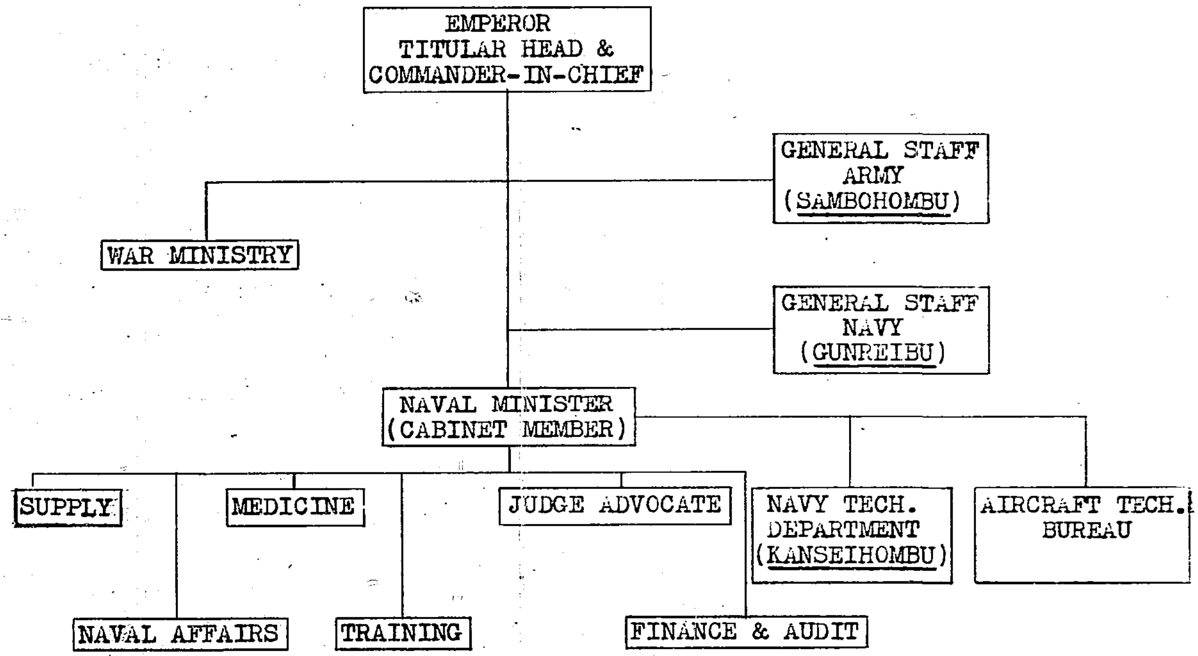
In spite of these difficulties, the documentation that has been possible is sufficient to provide assurance that the unsupported information given is reasonably correct.

THE REPORT

PART I
DESIGN PROCEDURE

A. Organization of the Japanese Navy Ministry

1. The organization of the line of command of the Japanese Navy Ministry was as indicated below:



The functions of the different divisions of the Navy Ministry were:

a. General Staff (Navy)

To dictate military characteristics of ships, and to decide the strategic policies which govern the naval establishment.

b. Naval Affairs

In essence, a liaison between the General Staff and the remaining divisions of the Navy Ministry, with subsidiary functions similar to those of the General Staff.

c. Supply

To fill the logistic requirements of the fleet.

d. Medicine

To fill medical needs of the fleet.

e. Training

To care for the training of personnel to man the naval establishment and the administration of such personnel.

f. Judge Advocate

Administration of naval law.

g. Finance and Audit

To administer the expenditures of the naval establishment.

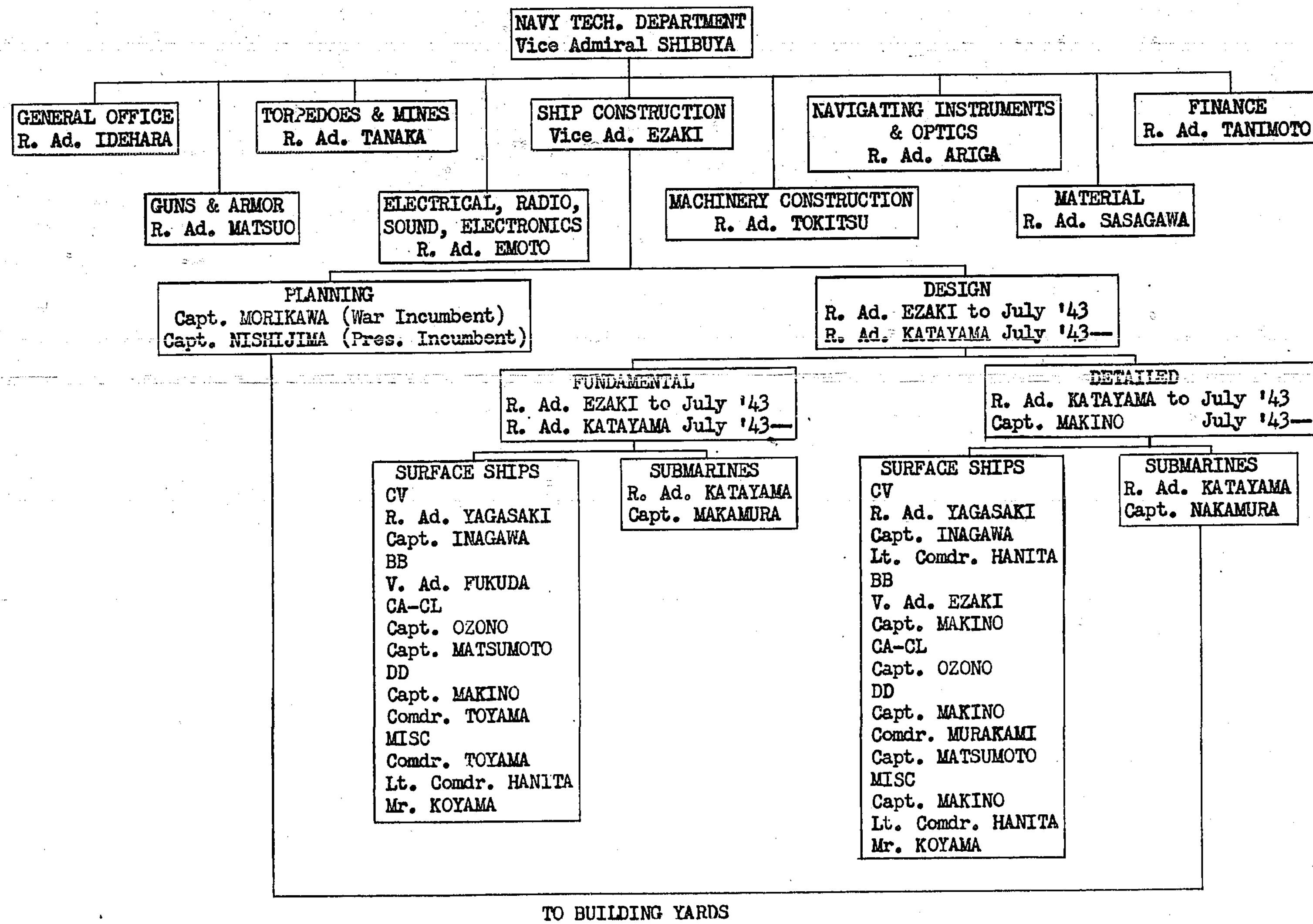
h. Navy Technical Department

To control the design, building, and maintenance of all naval vessels.

i. Aircraft Technical Bureau

To control the design, building, and maintenance of all naval aircraft.

2. From this organization it is apparent that the organization of the Navy Technical Department is of primary importance in understanding Japanese methods of warship design. It was organized as indicated on the following page:


NAVY TECH. DEPARTMENT
Vice Admiral SHIBUYA
GENERAL OFFICE
R. Ad. IDEHARA
GUNS & ARMOR
R. Ad. MATSUO
TORPEDOES & MINES
R. Ad. TANAKA
ELECTRICAL, RADIO, SOUND, ELECTRONICS
R. Ad. EMOTO
SHIP CONSTRUCTION
Vice Ad. EZAKI
MACHINERY CONSTRUCTION
R. Ad. TOKITSU
NAVIGATING INSTRUMENTS & OPTICS
R. Ad. ARIGA
MATERIAL
R. Ad. SASAGAWA
FINANCE
R. Ad. TANIMOTO
PLANNING
Capt. MORIKAWA (War Incumbent)
Capt. NISHIJIMA (Pres. Incumbent)
DESIGN
R. Ad. EZAKI to July '43
R. Ad. KATAYAMA July '43—
FUNDAMENTAL
R. Ad. EZAKI to July '43
R. Ad. KATAYAMA July '43—
DETAILED
R. Ad. KATAYAMA to July '43
Capt. MAKINO July '43—
SURFACE SHIPS
CV
R. Ad. YAGASAKI
Capt. INAGAWA
BB
V. Ad. FUKUDA
CA-CL
Capt. OZONO
Capt. MATSUMOTO
DD
Capt. MAKINO
Comdr. TOYAMA
MISC
Comdr. TOYAMA
Lt. Comdr. HANITA
Mr. KOYAMA
SUBMARINES
R. Ad. KATAYAMA
Capt. MAKAMURA
SURFACE SHIPS
CV
R. Ad. YAGASAKI
Capt. INAGAWA
Lt. Comdr. HANITA
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CA-CL
Capt. OZONO
DD
Capt. MAKINO
Comdr. MURAKAMI
Capt. MATSUMOTO
MISC
Capt. MAKINO
Lt. Comdr. HANITA
Mr. KOYAMA
SUBMARINES
R. Ad. KATAYAMA
Capt. NAKAMURA
TO BUILDING YARDS

With this organization, all the elements comprising a ship were under the control of one head. The sections controlling these elements were given numbers from one to six. The fourth section, ship construction, was charged with the design of the hull form, arrangements, structure, stability, etc., and so had a controlling interest in shaping a design. For this reason, the breakdown of this division has been included in the organization chart of the Navy Technical Department.

3. The organization as to ship types was vertical, both in the fundamental and detailed design stages. A certain amount of leavening of ideas from one type to another was accomplished through the heads of these two design sections, and also by an overlapping of personnel from one type and one section to another. The drafting rooms, however, were distinct entities, and so the practice from type to type varied somewhat due to the personalities of the drafting forces employed. In regard to the organization of types within the two design sections, the vertical organization approximated that employed by the British Admiralty, and the U.S. Navy Bureau of Ships, after the contract plans, from which the working plans are developed, were completed. There was no counterpart for the technical sections included in the organization of the U.S. Navy Bureau of Ships in the Fourth Section of the Japanese Navy Technical Department, but some of the other sections of that department performed a horizontal function of providing similar design principles in the different types of ships for similar systems and units.

B. Fundamental (Preliminary) Design Procedure

1. To start a new design, of an existing type, or of a type not previously built, the characteristics that determine the size of the ship were established by the General Staff (Gunreibu). These characteristics, such as armament, speed, protection, and cruising radius, were transmitted to the Navy Ministry, Naval Affairs Division, to determine the general features of the ship, such as her dimensions, displacement, and general arrangement. The Naval Affairs Division referred the matter to the Navy Technical Department. The Fourth Section of that Department made a preliminary study to determine the range of dimensions, general arrangement, and displacement of the ship. This information was sent back through the same channels to the General Staff.

2. At this point, the technical answers to such questions as size, building period, desirable changes, etc. were discussed between members of the Naval Affairs Division and the Second Division of the General Staff. Changes that were desired were resubmitted by the General Staff to the Navy Ministry and the whole process was repeated.

3. When a firm design had finally been developed, the Vice Chief of the General Staff met with the Vice Minister of the Navy, at which time they reviewed the design, either to approve it or to request further minor changes.

4. The final step was the meeting of the Navy Minister and the Chief of the General Staff. At these meetings the design was approved. Upon approval of the design, the Navy Minister issued an order to the Navy Technical Department to build a certain number of ships to the design chosen, specific building periods were established and the building process started.

5. At this point, the development of the design was transferred from the fundamental design section to the detailed design section, and plans prepared and forwarded to the building yards for the preparation of working plans. The detailed design section controlled the design through the commandants of navy yards or inspectors at shipyards owned by private concerns.

6. From this point on the design proceeded to its completion, any major changes being handled by the Navy Technical Department in conjunction with the Naval Affairs Division of the Navy Ministry.

7. The General Staff had for its assistance in preparing ship characteristics an advanced technical council. This council was composed of the following members:

Vice Chief of the General Staff

Vice Minister of the Navy

Chief of the First Division of the General Staff

Chief of the Second Division of the General Staff

Chief of the Naval Affairs Division of the Navy Ministry

Chief of the Training Division of the Navy Ministry

Chief of the Navy Technical Department of the Navy Ministry

Head of the Fourth Section of the Navy Technical Department

President of the Naval Staff College in TOKYO

One or two naval constructors of wide experience

A few other members of lesser importance.

This council provided assistance to the General Staff in studies dealing with ships' characteristics and overall strategy. The council was consulted as desired by the Chief of the General Staff.

PART II
GENERAL DESIGN PRACTICES

A. General

1. The Japanese design methods and practices were generally similar to those employed by other maritime nations. They followed the outline of theoretical naval architecture much as it is taught in Great Britain and France, since it was in these countries that the Japanese naval architects received their advanced training. There were few instances of startling originality. The various classes and types of vessels were largely logical steps from similar ships previously built.

2. The lack of attention to fundamental details of design, or rather the lack of a search for the proper manner of accomplishing seemingly small details left "holidays" that may have invited trouble from war damage, and undoubtedly contributed to the sinking of some of the major Japanese ships. The Japanese did not develop sufficient test data to analyze properly such puzzling detail problems.

3. On the other hand, the audacity with which the Japanese attacked problems such as the run of uptakes in aircraft carriers, the employment of sloping armor and the use of armor in torpedo protection systems indicates no lack of originality.

4. The Japanese were hampered by some seemingly small problems such as the choice of a system of units. In the 1930's, they used a combination of English and metric units. The final practice was to employ metric units entirely, but they finished their longitudinal strength calcula-

tions with the anomaly of converting a stress in kilograms per square centimeter into tons per square inch!

5. There was a great paucity of basic design information that could not be built up without years of research and background of experience. The Japanese must have felt the need for such information keenly, for much of their design data was culled from foreign publications.

6. Enclosure (284), a two volume text book, was written for the use of students of the Tokyo Imperial University who aspired to the vocation of naval architect. It is included in this report, as it provides an insight into the methods taught the young Japanese designers, and reflects the latest design methods that were in use in the Japanese Navy shortly before and during the war.

B. Materials

1. The steel used in Japanese ship construction for structural as well as protective purposes had the following chemical and physical properties:

STRUCTURAL STEEL - CHEMICAL PROPERTIES
(Quantities are in percentages)

	C	P	S	Si	Cr	Cu	Ni	Mn
MS	0.25	<0.05	<0.05	<0.2	trace as impurity	0.2*		0.3-0.6
DS	0.25-0.30	<0.05	<0.05	<0.2	trace to 0.02 as impurity	0.2*	0-0.2	1.2-1.6
HTS	0.35	<0.05	<0.05	<0.2	trace as impurity	trace as impurity	0-0.2 as impurity	0.8-1.2
HHTS	0.40	<0.05	<0.05	<0.2	trace as impurity	trace as impurity	0-0.2 as impurity	0.8-1.2

* This copper content resulted from a copper in the scrap used and was not intentionally added to the steel.

STRUCTURAL STEEL - PHYSICAL PROPERITES

	Tensile Strength Psi	Yield Point Psi	Elongation in 8"
MS	58,000-71,000	Abt. 39,800	18%
DS	85,200-94,000	Abt. 57,000	Under ½"-20% Over ½"-18%
HTS	79,000-83,000	Abt, 53,000	18%

2. Structural steel was made by the basic open hearth process. Poor scrap accounts for some of the copper content of these steels. An additional reason for the copper content of the finished steel was the copper contained in the Chinese iron ore that was used in steel manufacturing.

3. Steel used for protective plating had the following chemical and physical properties:

PROTECTIVE PLATING CHEMICAL PROPERTIES

	C	P	S	Cu	Mo	Ni	Cr	Mn	Si
MNC	0.3- 0.38	<0.035	<0.4	0.25 as impurity	0.25-0.40	3.3-3.8	3.3-3.8	0.3-0.45	<0.35
CNC	0.38-0.46	<0.035	<0.03	0.9-1.3	0	2.5-3.0	0.8-1.3	0.3-0.45	0.05-0.25
CNC_1	0.36-0.44	<0.035	<0.045*	0.6-1.0	0.1 -0.25	1.8-2.3	1.4-1.8	0.3-0.45	<0.35
CNC_2	0.36-0.44	<0.035	<0.045*	0.6-1.0	0.1- 0.25	1.3-1.8	1.4-1.8	0.3-0.45	<0.35

* The high sulphur content of this steel was due to bad scrap.

PROTECTIVE PLATING - PHYSICAL PROPERTIES

		Tensile Strength Psi	Elastic Limit Psi	Elongation in 50 mm	% Reduction in Area	Ft. Lbs. Izod
MN	Over 7"1	103,000±10%	>57,000	>28%	>40%	35 min 40 mean
	Under 7"1	120,000 ±6%	>71,000	>20%	>40%	30 min 35 mean
CNC		120,000 ±6%	>85,000	>19%	>40%	30 min 35 mean
CNC_1		114,000-128,000	>85,000	>19%	>40%	30
CNC_2		114,000-128,000	>85,000	>19%	>40%	30

4. The protective plating described above was used in the following thickness:

MNC.................. 180-75mm(7"1-2"95)
CNC.................. 75-50mm(2"95-1"97)
CNC_1................ 50-25mm(1"97-0"97)
CNC_2............ Under 25mm(under 0"97)

5. These protective plating steels were substitutes developed by the Japanese to replace homogeneous armor formerly made to a Vickers formula but changed in copper, chromium and nickel content for material conservation. Copper replaced the nickel in the MNC steel, and chromium as well in the CNC series.

6. Ballistic tests at KAMEGAKUBI were said to have proved the superiority of MNC over homogeneous Vickers steel, the superiority being of the order of 10-15%. The degree of protection desired in the CNC series was obtained primarily by varying the chrominum and nickel content, reducing it for the thinner plating.

7. This plating was all tested at rather high angles of obliquity, the range of obliquity being 55° to 65°.

8. Thin homogeneous armor was attached to Japanese vessels by riveting. Heavy armor was attached by armor bolts, or quilting bolts depending on whether the armor was horizontal or vertical. Armor bolts were provided for each two square feet of armor area.

9. Heavy vertical and horizontal armor was made to work as a unit in protecting the ship by a tongue and groove system of connections. The center of the tongue and groove was located in the geometric center of thickness of the armor plate. Portland cement and wood were used for

armor backing. Cement has been used for crusiers, while wood was used for YAMATO.

10. Armor tolerances were apparently not specified except in the detailed instructions given in the case of each class of ship built requiring armor. Rear Admiral SASAGAWA stated that the thickness tolerances were +0 and -1% by weight. Allowances in curvature for curved armor were not stated explicitly, but were said to be large.

C. Production Methods

1. The Japanese employed riveting as their essential method of ship fabrication. All longitudinal strength members were riveted - longitudinals in inner bottom, shell plating, connections of frames and bulkheads to shell, strength deck plating, side stringers, etc. The rivet spacings and diameters were much the same as used by the U.S. Navy, and they changed from MS rivets in MS plating to DS rivets in DS plating. The joint efficiencies were carefully calculated and a specific plan was prepared for each class of vessels to insure that the proper riveting standards were maintained. Enclosure (249) is such a plan for the cruiser SAKAWA. Tests of riveted joints are described in Enclosure (248).

2. Welding was never extensively used in the fabrication of large Japanese warships. Where welding has been used, it has been applied to MS principally and to a limited extent to a special steel poorly described in Enclosure (250) as ST52; a steel of slightly higher strength than MS. A proper DS or HTS welding rod had not been developed in Japan.

3. The most daring step taken by the Japanese in regard to the extension of welding was the use of an all welded pressure hull for submarines of the I-201 class.

4. As long ago as 1933 the Japanese constructed a minelayer, YAEYAMA, fabricated completely by welding. The ship was apparently successful. However, the next extension of the technique to the fabrication of part of the hull structure of MOGAMI, near her stern, was not successful. Cracks appeared on her trials in the welded area, and the technique was abandoned for large warships.

5. When the need for many escort vessels became pressing during the war, the Japanese reverted to welding in the fabrication of their KAIBOKANs (Escort type). These ships were largely built by the sub-assembly method, small "blocks" being fabricated in the shops and erected on the building ways; then connected together by a complete riveted girth butt. This method of manufacture produced a number of ships rapidly, and they had been operating successfully until the end of the war.

6. The chart in Enclosure (250) indicates that welding in warships was slowly increasing in quantity, which is reasonable to expect as the knowledge of the technique increased.

7. Rules for welding inspectors are given in Enclosure (251). The rules were rigid enough so that, if properly carried out, good welding should have resulted. It is interesting to note that X-ray inspection methods were required for certain welds in the highly stressed portions of the ship.

8. Additional information on the welding technique as it was developed in Japan is given in Enclosures (252) through (254).

9. Lack of experience and welding rods capable of more universal application than those that were available retarded advancement of the welding technique in the shipbuilding industry in Japan.

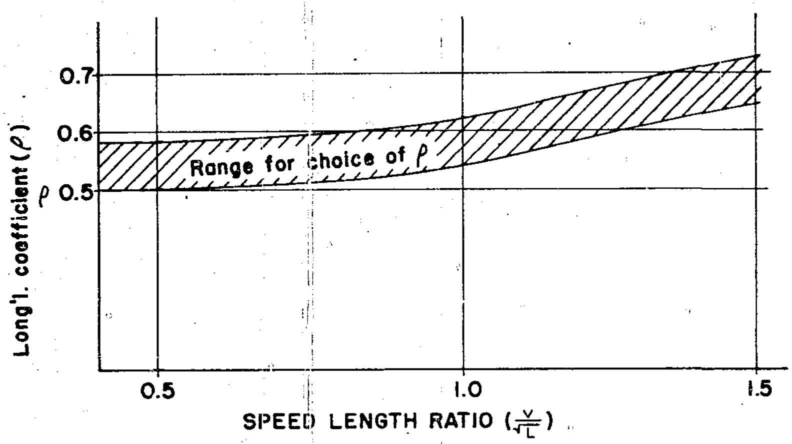
D. Hull Form

1. One outstanding characteristic of Japanese warships was their high length to beam ratio. This ratio varied between 10.3 to 11.6 for most vessels, the exceptions among the new ships being the CV's TAIHO, with a L/B ratio of 9.4 and SHINANO, whose L/B ratio was 7.86. The principal reason for the lavish use of length appears to have been to gain speed and still maintain reasonable powers for propelling plants.

2. Along with the exceptional lengths used by the Japanese, another outstanding characteristic was the low midship section coefficient used. The shape of the maximum section (usually aft of amidships) may be characterized by describing it as one with an extremely slack bilge. The Japanese used a large bilge radius in conjunction with a large deadrise, and consequently the midship section coefficient had a low value compared to that used for U.S. Navy ship designs. Captain MAKINO of the Navy Technical Department stated that in their designs, the Japanese strove to attain a midship section coefficient of 0.785, as research at their model basin had indicated such a value to be the optimum. This value was never achieved in their designs because of practical considerations; however, the tendency of the Japanese was toward low midship section coefficients.

3. Because of the slack midship sections used by the Japanese, their beam-draft ratios appear to have been rather small. For their older ships, such as ATAGO, and their larger ships, such as YAMATO and SHINANO, the beam-draft ratio was greater than 3, but for their other recent ships the value varied between 2.68 and 2.9.

4. The Japanese used a curve for their original choice of the prismatic or longitudinal coefficient for a new design. The curve has the general shape indicated below:



The longitudinal coefficients used by the Japanese were generally low for the speed-length ratio of their ships at designed speed.

5. The waterline coefficients used for Japanese ships were very close to 0.75, varying a little either side of this value.

6. Japanese designers have stated that for high speed ships, and most of their combatant ships were vessels of this type, they preferred to locate the center of buoyancy about 5% of the length of the ship aft of amidships. If this was their aim, they did not achieve it, for the location of the CB varied from 1 to 4.4% of the length of their ships aft of amidships. In their favor, it should be stated that their later ships

tended toward the larger figure, though none but CV KATSURAGI actually reached this value. For most vessels, the value varied between 3.1 and 3.8% of the length of the ship aft of amidships.

7. Of all the peculiarities of Japanese vessels the most noticeable one is the sheer line adopted. When questioned as to the reason for adopting such a peculiar sheer line, the answer was certainly utilitarian. The freeboard at the bow was determined by consideration of seaworthiness. Freeboard amidships was determined by consideration of the range of stability. Freeboard at the stern was made as little as appeared possible. The gun positions required a certain depth of ship. After all these points had been determined, they were connected with straight or slightly curved lines, such methods resulting in the sharply rising fore-castle deck, the straight run between extreme gun positions and the downward slope of the main deck from the after gun position to the stern. An additional reason for the downward slope of the main deck aft was given as being to save structural hull weight without actually notching the ship's girder by dropping the main deck one level to the freeboard thought required at the stern.

8. Another peculiarity of Japanese warship hull form was the manner in which the forefoot was cut away. Recent vessels, for example, TERUTSUKI, employed a straight, slightly raked stem, with only the lowermost corner, at the intersection of the base line and stem, removed. Older ships, ATAGO for example, have the forefoot largely cut away, thus tending toward what is sometimes known as a Maierform.

9. The Japanese, in their later designs have made use of the decrease in EHP that can be effected by the use of a bulbous bow. A bulbous ram bow was used in YAMATO's design, and was stated to have decreased the ship's resistance about 5 to 6%. The use of a bulbous bow had not become uniform as later ships were built with the forefoot cut away.

10. The deadwood aft was cut away to assist in turning, but primarily to obtain better propulsion. The length from the after perpendicular to the after keel knuckle, the point at which the stern cut up begins, was determined by practical factors, such as docking, and this length varied between the different classes of ships from 10 to 15%.

11. The Japanese used transom sterns in their cruiser and destroyer designs, but it was not a true transom stern as known to the U.S. Navy. The water line aft was rounded, and there was no distinct knuckle between the stern transom plating and the side plating. The shape of this part of the vessel made little difference to propulsion as treated by the Japanese for they designed their ships with no transom immersion in the trial condition. Such practice must have caused trouble at displacements greater than the trial displacement, for under heavier loadings the transom would be immersed, and probably caused increased resistance because of the above water shape of the stern.

12. The Japanese used Taylor's method of calculating EHP. They did not use his standard series hull form in developing their own hull forms, however, having developed parent forms of their own. From these forms, new ship lines were developed.

13. After the ship's lines drawings were completed, they were sent to the model basin located at Meguro-ku, TOKYO to check the EHP calculations by model tests.

E. Weight and Weight Classification

1. The weight classification used by the Japanese in recording the weights of their warships is given in Enclosure (256). An interesting book that was used by the Japanese for rapidly estimating weight in the

early fundamental design stage is included as Enclosure (257). With the information contained in it, it was possible to make a rapid and reasonable estimate that would indicate the displacement range that might be expected for a new design. Enclosure ($257\frac{1}{2}$) shows a comparison of calculated versus actual wights for several destroyers.

2. The Japanese designed their ships to make their required speed at trial displacement. Trial displacement was defined as full load displacement less 1/3 of the full load fuel oil, water (both potable and reserve feed) and provisions.

3. The calculation of standard displacement in accordance with the terms of the Washington Treaty, although not completely discontinued, was not religiously carried out for some time before the war. Standard displacements were frequently calculated but were not considered essential after the abrogation of the Washington Treaty. It is interesting to note that the design of YAMATO, whose standard displacement was in excess of 60,000 tons, was begun as far back as 1934.

4. Weights of many of the classes of ships discussed in Part III are included among the enclosures under ships' titles.

5. The Japanese laid considerable emphasis on weight saving but were never able to achieve the weight saving that accrues to welded construction because of a lack of knowledge of the art.

F. Stability Considerations

1. The stability of Japanese warships was determined from a consideration of the following factors:

a. Metacentric height (GM)

b. Range of stability

c. Distance of the center of gravity above the waterline (OG)

d. Maximum righting lever (GZ)

e. Dynamical stability

f. Period of roll.

The beam of the vessel, the controlling form factor in determining the initial stability (GM) of the vessel, and the freeboard, which controls the range of stability, were the principal variables that were changed until acceptable stability characteristics for a new design were obtained. The distance of the center of gravity above the waterline, the maximum righting arm, and the dynamical stability are derivatives of the primary variables and although they were considered, they did not control the choice of beam. Tabulated below are stability characteristics that were considered acceptable, and those actually achieved by the Japanese in their later vessels:

	GM		GZ		Range		Period of Roll	
	Accept. Meter	Actual Meter	Accept. Meter	Actual Meter	Accept. Degree	Actual Degree	Accept. Seconds	Actual Seconds
BB	2.7		1.2		70		16-18	16
CVB	2.7	2.5	1.2		70	90+	16-18	16.6
CV	2	2.06	.9	3.5	80	90+	13-15	15.3
CVL	1.7	1.78	.8	2.0	80	90+	13-15	13
CA	1.4	1.6	.7	1.48	80	90+	14-15	11.7
CL	1.2	1.37	.7	1.07	80	90+	13-14	11.3
DD	1.0	1.07	.5	0.67	80	92.6	10 secs MIN.	8.9

2. All these values are for the trial condition, which was the condition on which the design of Japanese vessels was based. The trial condition is defined in Part II, section E, paragraph 2. GM's were generally higher than the acceptable limit. The Japanese had an additional requirement for DD's; that the range of stability be greater than 70° in the light condition. This requirement grew out of the investigation following the loss at sea, by capsizing, of DD TOMOZURU in 1934.

3. In general, all of the design requirements were met in Japanese designs except that for period of roll. It is difficult to believe that they ever achieved a period of roll as high as ten seconds in any of their destroyers, yet their designers stated this period was considered a minimum for the type.

4. The slack midship sections employed in most Japanese ships tended toward a higher GM, by virtue of raising the center of buoyancy, and in consequence, the transverse metacenter. Of course, a slack bilge radius tends to raise the ship's center of gravity, but in spite of this fact, the ratio of the height of the center of gravity above the base to the depth of the ship for Japanese vessels was relatively small, being on the order of 0.52 to 0.62. The only logical explanation for the low value of this ratio appears to lie in the type of hull construction adopted by the Japanese. Heavy bottom construction, in conjunction with an essentially transversely framed ship, seems to indicate that this is the reason for such low values of this ratio; however, a more exhaustive study than has yet been given this subject is necessary to prove definitely that this is the case.

5. The acceptable and actual values of GM were slightly higher than the values employed in the design of some of our vessels. This may be accounted for because the centerline bulkheads installed in the machinery spaces of all vessels of CL types and larger required considerable initial stability in order to limit the angle of heel after damage when a machinery space on one side of the ship was flooded. Extensive flooding calculations were carried out to ensure that a particular design would have acceptable stability.

6. Some of these calculations are listed below:

a. Large heavily armored vessels (BB's, CV's):
(1) With all the unprotected spaces in the ship flooded, the volume of the armored box above the damaged waterline should still be from 20-25% of the total volume of the armored box. Under this condition of flooding, the ship must have positive GM.

(2) With all the torpedo protection spaces on one side of the ship flooded, as well as the unprotected ends of the ship, she should have positive GM and not capsize.

b. Lightly armored vessels, without torpedo protection (CA's, CL's DD's):

(1) For crusiers, the GM must be sufficient to permit two machinery spaces on the same side of the centerline machinery space bulkheads to flood without capsizing.

(2) For destroyers, exemplified by the latest design class, TERUTSUKI, the GM was just sufficient to permit flooding the

two largest machinery spaces clear across the ship (in destroyers no centerline bulkheads were installed) and still maintain positive stability.

Many more flooding calculations were carried out during the design stage as indicated by the plans of the vessels discussed in Part III, but those outlined above were the primary determinants of acceptable stability in the damaged condition.

7. An additional consideration used in determining acceptable initial stability was the angle of heel during high speed turns. The desired relationship between GM, KG and the remaining elements affecting the angle of heel during a turn was to have been adjusted so that GM was suficient to limit the angle of heel to no more than 9° during radical maneuvers, which, of course, included high speed turns.

8. The range of stability for Japanese warships was high, particularly so for their aircraft carriers. In the case of CV's, the range of stability was determined by considering the hanger side plating as watertight in the calculation of the cross curves of stability. The fact that water could enter the uptake and boiler air intake openings, should the vessel heel to starboard, was ignored. The typically Japanese aircraft carrier uptakes, that is, uptakes that curved downward after piercing the skin of the ship close under the flight deck, were changed between the design of UNRYU class and TAIHO. One reason for changing was to eliminate the possibility of flooding the machinery spaces through the uptakes after damage. The large ranges achieved by the Japanese were partially due to the parts of their ships considered watertight when making the calculations for cross curves of stability. Insofar as the assumptions made were realistic, the range figures were accurate, but the assumptions must be more rigidly checked than has yet been possible before the accuracy of the ranges shown can be definitely established.

G. Structure

1. Longitudinal Bending Calculations

a. Acceptable stresses for design purposes allowed by the Japanese in their vessels were based primarily on the use of the relatively high strength DS steel. Because of the extensive use of this material, higher stresses were allowed than would have been the case had MS been used. Acceptable design stresses, as well as those calculated for the full load condition of Japanese warships, are tabulated below:

LONGITUDINAL BENDING STRESSES

	Hogging Condition				Sagging Condition			
	Acceptable		Actual		Acceptable		Actual	
	DT	KC	DT	KC	DC	KT	DC	KT
BB*	10 tpsi	8 tpsi	10 tpsi	8 tpsi	8 tpsi	9 tpsi	7.75 tpsi	8.5 tpsi
CV*	10 tpsi	8 tpsi	8 tpsi	7 tpsi	8 tpsi	9 tpsi	7 tpsi	8 tpsi
CA*	10 tpsi	8 tpsi	9.47 tpsi	7.74 tpsi	8 tpsi	9 tpsi	7.11 tpsi	7.49 tpsi
CL*	10 tpsi	8 tpsi	8.5 tpsi	7.56 tpsi	8 tpsi	9 tpsi	7.36 tpsi	8.53 tpsi
DD**	8.5 tpsi	7 tpsi	8.2 tpsi	6.95 tpsi	6.5 tpsi	8 tpsi	5.84 tpsi	6.62 tpsi

Longitudinal strength data for several warships are given in Enclosure (261).

* For ships over 200 meters long.
** For ships under 200 meters long.

To determine acceptable values had MS been used, the values tabulated above would have been decreased by 20%. When questioned as to the relatively small effect which the increased tensile strength of DS had on the critical compressive strength of plating, which value would be the same for either MS or DS, the Japanese justified their use of higher stresses, when using DS steel, by stating that in this case, plating panel sizes were made smaller to accommodate the higher compressive stresses. The weight saving that should accrue to the higher stresses was not known. It was probably not great because of the panel stiffening that was added to decrease plating panel sizes.

b. Tensile stresses were increased by a factor of 1/6 to account for the loss in area due to rivet holes.

c. Longitudinal stress calculations were carried out in the classical manner, by plotting weight and buoyancy curves, from these deriving a load curve, and integrating the load curve twice, first to determine the sheer curve, and second to determine the bending moment curve. An integraph was used for the integration, and no graphical integration methods were employed.

d. The wave used in obtaining a bouyancy curve was the standard L/20 trochoidal wave. Small destroyers were also placed on a wave whose height was 1/10 of its length. In addition to making a longitudinal strength calculation for the ship in the upright position, one was also made for all ships heeled over to a 30° angle. Besides these two calculations, a calculation was made for destroyers only, heeled over to 90°. Because of these extensive calculations no strength studies were made under special loading conditions.

e. Three longitudinal strength calculations were made, one as soon as weight and form data were available in the early fundamental design stage, a first approximation of the final result. In this calculation, weight was distributed over the length of the ship using parabolae and trapezoids to represent the ship's weight. A second calculation was made near the finish of the fundamental design, and a third when the vessel had reached the detailed design stage. In the last calculation, estimated weights were available from which the ship's weight curve could be developed in as great a detail as was considered necessary. When it was asked what interval of length along the ship was used for distributing weight, the answer was the distance between bulkheads. Easily located weights, such as bulkheads, turrets or gun mounts, were definitely located without any general distribution.

f. In calculating the inertia of the various sections of the ship the longitudinal material considered effective was that connected to shell plating, deck plating, or other longitudinal material, and which extended at least 12 meters in a longitudinal direction. The material not considered effective in the vicinity of large shell or strength deck openings was that material inside a line making an angle of 30° with the longitudinal centerline of the vessel and tangent to the edge of the opening. Stress concentration factors as determined by the Japanese and what was considered the most practicable way of applying reinforcing doublers are shown in Enclosure (248). The part of the ship for which compensation for hull openings is required is shown on Enclosure (262). It should be noted, in this instance, that the flight deck is not a strength deck in KATSURAGI design. As stated previously, the Japanese did not weld to the longitudinal strength members of their ships. Enclosure (267) indicates where welding was and was not acceptable for Japanese warships.

2. Framing Systems

a. Japanese warships were all essentially transversely framed. They used longitudinal members, however, in the inner bottom, under decks, and on shell plating above the inner bottom. The Japanese stated that the side stringers applied to shell plating were used as "panel breakers" to reduce the size of the shell plating panels. Their side stringers were much too large for this purpose and had the definite appearance and continuity of longitudinal strength members. The use of both a transverse and longitudinal system of framing appears to be a lavish use of hull weight.

b. Frame spacing was varied in different parts of Japanese warships. Forward and aft, in some cases of the machinery spaces, and in others of the armored box, the frame spacing was smaller than that used amidships.

3. Shell Plating

a. The thickness of the shell plating of Japanese warships was determined by the requirements of longitudinal strength. The thickness and panel size necessary to support the hydrostatic head to which the bottom plating was subjected, was checked, but was usually found to be satisfactory.

b. Almost all large Japanese warships had their flat keel fitted in two strakes. In KATSURAGI, the bottom out to Longitudinal Number 4 was doubled 25mm DS plating. This thickness of plating is large for a vessel of the displacement of KATSURAGI.

c. The midship section of ATAGO, a relatively old cruiser, shows no plating behind the side armor, thus requiring that the armor be used in the longitudinal strength of the vessel. During her modernization, a blister was fitted, and some plating was carried outside of the armor. There were no serious complaints of structural strength of ships of this class; however, the connection to make armor plate effective in longitudinal strength was a difficult one. The design of this connection is described in Part II, section L, paragraph C of this report.

d. The calculation of critical compressive strength of plating panels in the shell plating, inner bottom plating and for longitudinals was done according to the theory developed by Timoshenko. Discussion with the Japanese did not bring the method of calculation nor the factor of safety against buckling, clearly to an issue, and for this reason, it is doubted that much attention was paid to buckling stresses. Answers were evasive, and simple statements that shell plating and longitudinals were checked for buckling were made. There appeared to be no definite policy that determined what factor of safety a member should have in compression so long as that factor was at least one.

4. Inner Bottom Plating

a. The thickness of the inner bottom plating was determined by considerations of longitudinal strength in the same manner as the thickness of the shell plating was determined. Test heads required for tanks located in the inner bottom were stated never to have been a controlling factor in the choice of thickness for this plating.

5. Longitudinal and Transverse Framing

a. The longitudinal framing provided in the inner bottom, and as side stringers and deck girders were not considered by the Japanese to provide a longitudinally framed vessel. The longitudinals have the appearance of those used in the construction of ships of the U.S. Navy about 1920. The use of riveting entirely for the construction of such members forded the Japanese to a necessarily heavy system of angles to connect the longitudinals to the shell and inner bottom plating and floors.

b. Late in 1936 the Japanese had an experience similar to the U.S.S. PITTSBURGH (CA 72) incident, except that in their case the type of ship was a destroyer. One of FUBUKI class lost her bow back to about the bridge structure in a typhoon, but did not founder. As a result, the Japanese were subsequently careful to marry the system of transverse and longitudinal framing in the forward part of the ship to make sure there were no large discontinuities in longitudinal strength.

c. The scantlings of transverse frames were determined by known loads and the beam theory and by comparison with previous successful ships, or by judgement and experience. Transverse strength calculations were not generally made, although infrequently such calculations were conducted. They were not satisfactory, however, for the determination of scantlings, for stresses beyond the yield point of the material used were obtained.

d. Transverse frames were fitted on every frame. They were usually two bars, although in some instances, requiring special consideration, such as the transverses in way of turrets, under the forward superstructure, etc., they were built up sections, made by riveting.

e. It is interesting to note in the midship sections of the various warships the arched transverses between longitudinals. Ostensibly, the reason for using such a transverse was first to fix its ends, and second to provide the necessary plating to accommodate the required rivets.

f. The Japanese have used little, if any, theory in the calculation of their bow and stern framing. It was developed by judgement, and the experience of previous successful ships. The framing in way of the stern keel knuckle, although known to absorb severe docking stresses on occasion, was not calculated for this condition. The record of previous successful ships was used in the determination of this framing also.

6. <u>Deck Plating</u>

a. A search of the ship construction activities in Japan unearthed but few deck plating plans. Those that were available showed such small portions of the decks, and were in such detail that they were considered useless for general study. Interrogations of Japanese designers did, however, uncover the following facts concerning their methods of designing deck plating and its supporting structure.

b. The Japanese had no specified local deck loads which a particular deck might be called upon to support. For example, the main deck amidships was not required to withstand any local loads in addition to the stress imposed upon it by longitudinal bending. Forward, on the weather deck, it was realized that a rather severe waterhead might be imposed, but instead of attempting to set up a reasonable standard, the Japanese designed such structure by comparison with other ships.

c. The calculation of the strength of decks that might be subiected to gun blast pressure was done by using gun blast pressure data taken from curves developed by the Japanese naval proving ground. There were several pressures measured, and contour curves drawn, and from these deck loads could be estimated.

d. Storeroom deck loadings were not standardized, and in case there was doubt about the ability of a deck to withstand the load to which it might be subjected, a calculation was made based on the assumed stores that would be stowed in the storeroom. Likewise, stanchion loads were calculated in the same manner, making the best estimate of the proable load and designing the stanchion for that load.

e. The Japanese considered that the deck under the weather deck amidships should be built with heavy enough scantlings to provide some measure of assistance to the remaining structure, in case of damage to the main strength deck, to prevent the possibility of the ship breaking up when retiring from an action. How much actual consideration this feature was given could not be ascertained, but it is noted that the deck under the weather deck amidships was the strength deck in both ATAGO and TONE designs.

f. The method used by the Japanese to compensate for large openings cut in hull strength members is shown on Enclosure (268). In this case, which is an example of a difficult problem, the Japanese used a conglomeration of doubling, and even tripling, of the plating around the uptake openings in conjunction with riveted coaming bars. It is questionable that so much material so disposed could properly have done the job that was asked of it.

7. Bulkheads

a. Bulkheads installed in the later ships designed by the Japanese were of welded construction. In general, they were shop fabricated, but riveted to the hull of the ship. The designed heads for main transverse watertight bulkheads that were installed in TERUTSUKI class DD's were:

(1) From and including the forward collision bulkhead to the bow: 3 meters above the waterline.

(2) From the forward collision bulkhead to the after magazine bulkhead: 2.4 meters above the waterline.

(3) From the after magazine bulkhead to the stern: 2.6 meters above the waterline. The waterline here referred to is the trial waterline, the Japanese design waterline.

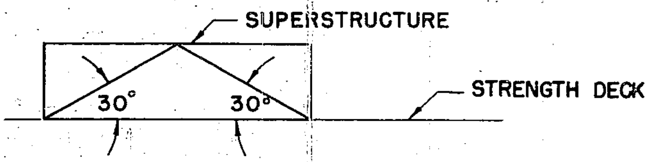
b. Watertight bulkheads were generally designed with a vertical stiffener system. Horizontal stiffeners were used in some cases, in addition to vertical stiffeners. The plating of the bulkheads was light, and in the case of the light cruiser SAKAWA, did not appear to be designed to resist a hydrostatic head between the second and main decks. In this instance the plating was thin and stiffeners were flat bars instead of "I" beams or tees.

c. Typical bulkhead plans will be found in the plans for KATSURAGI. A plan showing measured deflections for a destroyer bulkhead, as well as the test head applied, is contained in Enclosure (269).

8. Superstructures

a. There was no set standard in the Japanese Navy for calculating the scantlings of a warship's superstructure framing and plating. Of all the parties interrogated, Captain OZONO, in charge of cruiser design, was the only one who indicated that such things as wind and rolling forces were important. On such flimsy evidence, it must be assumed that superstructures of Japanese warships were designed primarily on the basis of past experience.

b. There were no expansion joints fitted in the superstructure of Japanese warships, except in the rare instances where the flight decks of aircraft carriers were not designed as the strength decks. The Japanese considered that any superstructure which was less than 1/4 the length of the ship would not cause structural difficulty because of ship's girder stresses and consequently would not require an expansion joint. Another criterion that was stated to have been used to determine the length of superstructure was as indicated below:



As long as the length indicated in this sketch was not exceeded, (with a fixed superstructure deck height) the superstructure was considered to be satisfactory without the use of expansion joints.

c. It is interesting to note that in the design of cruisers of both ATAGO and TONE classes, the weather deck amidships was constructed as a superstructure deck, lightly scantlinged, and still did not result in any structural difficulties during the service of these ships.

d. Light metals were not used in the design of the superstructures of recent Japanese warships. Aluminum was used 20 years ago in order to save weight, but corrosion difficulties with this material caused its use to be discontinued.

9. Masts

Masts were designed on the same premise as were superstructures, that is, judgement and experience. No definite criteria of wind loading or roll were used in the determination of the strength of masts.

10. Bilge Keels

a. All Japanese warships were fitted with bilge keels. These keels were large in comparison with U.S. standards, being wider than in U.S. practice. Although Japanese designers stated that the length of bilge keel usually installed in their vessels was between 40 and 50% of the length of the vessel, perusal of available plans indicates this value is closer to 30% of the length of the ship than the figures given. The width of Japanese bilge keels varied from 1.8m for large ships to 0.84m for destroyers.

b. Bilge keels were assumed effective in the longitudinal bending calculation and were included as effective material in the calculation of the moment of inertia of the various sections affected.

c. Bilge keels were located on the bilge diagonal, although on interrogation, the Japanese stated that bilge keels were located in positions to provide the least resistance to propulsion at top speed. Because of the bilge keel's width, they would have interfered with hauling dry dock blocks during docking operations, but as the Japanese did not use hauling blocks, this interference was of no consequence to them.

d. The shell connection of the bilge keels was a riveted one, but no calculations were made to determine the number of rivets necessary to withstand the forces applied to the bilge keel during rolling. Experience was relied upon for the design of this connection. Bulkheads were fitted at intervals along the length of the bilge keel, the number of bulkheads depending on the length of the keel. The bulkhead spacing approximated 100 feet.

e. No filling material was fitted in bilge keels to exclude water in the event of leakage. The interiors were stated to have been painted with something similar to bitumastic paint.

f. Calculations of the damping effect of the bilge keels on rolling were never carried out for a specific design. Experiments with models with varying sizes of bilge keels and their damping effect, as well as the published literature on the subject, formed the background for the Japanese method of designing bilge keels.

g. A typical bilge keel is shown on Enclosure (270).

11. <u>Shaft Struts</u>

a. For the design of shaft struts, the Japanese used the theory developed by Mr. Johns and published some time ago in the Proceedings of the Institute of Naval Architects. They calculated their struts to withstand the forces imposed on them when one propeller blade had been lost from the propeller. Under these conditions, the stress in the strut arms was not to exceed 4 to 5 tons per square inch for cast steel struts (with which most Japanese ships were equipped) or 5 to 5.5 tons per square inch for forged steel struts. (It is interesting to note the Japanese acceptance of English units in this case, one in which a foreign design standard was being used).

b. The Japanese had no standard strut section. They used a streamlined form for the strut section as soon as it was possible to change from the more or less rectangular section with triangular ends added, which was used near the intersection of the strut arm and the shell plating. For the streamlined form there was no distinct specification for the maximum width of a strut arm section. In interrogations, the Japanese stated that the maximum width of the strut section was 1/5 of its length. The width of the strut arm shown on Enclosure (271) was 0.184 of the length, or somewhat thinner than that stated by the Japanese to have been their design standard.

c. The Japanese apparently made little effort to place the long dimension of their strut arm sections in lines of flow. They recognized that this condition was a desirable one, but the longitudinal axis of the strut section shown on Enclosure (271) was specified to be parallel to the centerline of the ship. It was stated, however, that the whole strut arm, for some classes, had been given a twist to put it in the lines of flow, but the twist given the strut arms was a uniform one, each section being parallel to all other strut arm sections.

d. The increased resistance due to the struts was estimated by the Japanese to be 10% of the bare hull resistance. This figure is quite high, and particularly so when it is realized that the Japanese seldom used intermediate struts. They did use small bossings around the after end of their stern tubes, and as fitted on HARUTSUKI, a TERUTSUKI class destroyer, the unfairness of the bossings would appear to have added more resistance to propulsion than an intermediate strut.

12. Ruddeirs

a. Rudder area for Japanese ships was determined by taking from 1.8 to 2.2% of the area defined by the product of trial waterline length and trial draft. The lower range was used to determine the rudder area for large ships while the upper range of values was used for smaller vessels, such as destroyers.

b. Rudder forces were calculated by the classical Joessel method, the forces so calculated being used to determine rudder scantlings and the center of pressure and force to determine rudder torque. The Japanese knew that Joessel's formula was not accurate, but were forced to use this method for lack of a better one. The worst condition, full astern, was used as the criterion for calculating scantlings of the rudder, rudder stock, tiller, etc., while the ahead torque was used to determine the power required for the steering engines. The specification requirement for steering engine power was that the rudder be capable of being moved from hard over to hard over in 30 seconds while the ship was going ahead full speed. Ordinarily no time requirement was specified for rudder movement with the ship going full astern.

c. The rudder balance used by the Japanese was 33% of the total area of the rudder. This large balance was used to reduce the total rudder torque applied, and hence to reduce the power required from the steering engines. A balance of 33% was calculated to give a negative rudder torque out to a 25° rudder angle at which point the torque became positive. By this means, it was hoped that the maximum positive torque could be reduced. The Japanese found, however, on full scale trials, that the point at which the torque changed from negative to positive was closer to 30° than 25°, so they were continually faced with high negative torques and higher power than were calculated from their steering engines.

d. Because of the full scale test results that indicated high negative torques were being encountered, the Japanese design tendency was toward a reduction in the amount of rudder balance provided.

e. No change in balance was made for a rudder placed directly behind a screw from one located on the ship's centerline not in the propeller slip stream.

f. No standard rudder sections were developed by the Japanese. The rudder was simply of streamlined shape. The shape and scantlings of the rudders used for KATSURAGI are shown on Enclosure (272) and (273). The maximum width of the rudder was determined by the diameter of the rudder stock.

g. Spade rudders were used because the Japanese thought it was a lighter installation than what they termed a semi-balanced rudder, or a rudder with a partial skeg before it.

h. All major Japanese warships, that is, all vessels included between the battleship and destroyer types, were equipped with electro-hydraulic steering gears. There were two power plants for each steering unit, whether that unit comprised two rudders and four rams, or one rudder and two rams. One exception to this statement was the steering gear arrangement provided for YAMATO and TAIHO. In this instance, the twin rudders were located on the longitudinal centerline, the after one being twice the area of the forward one. Both rudders were equipped with complete steering engines, the longitudinal separation being provided to prevent loss of steering control in the event one or the other of the rudders was shot away.

i. The power plants provided were composed of electric motors driving radial piston hydraulic pumps (Hele-Shaw pumps were usually used) the hydraulic pumps being connected to hydraulic rams. In the ships inspected there were four rams per unit. The tiller was located between the two sets of rams, in some cases being connected to the rams by sliding blocks, and in others by a piston rod fitted in the ram piston.

j. Transmission of wheel movement from the bridge to the hydraulic pump was by telemotor. The telemotor control was connected to the hydraulic pump control through a floating lever, to which the follow-up gear from the tiller was also attached, throwing the pump off stroke when the desired rudder angle was reached.

k. High pressure by-passes were fitted on the rams to function if the ram pressures became too high.

l. Emergency control of the rudders was furnished by a small hand oil pump. Operating personnel did not consider this means of control satisfactory.

m. In addition to the emergency hydraulic control, lugs were welded to the tiller to provide a purchase for screw jacks; these provided a supplemental emergency means of rudder control.

n. The diagrammatic arrangement of a typical steering gear is shown on Enclosure (281).

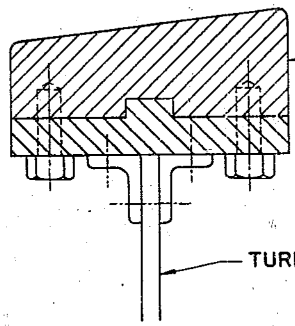
13. Turret Structure, Fixed and Rotating

a. The nomenclature used by the Japanese for parts of their turrets was the same as that used in the U.S. Naval vessels except in the following particulars:

USN DESIGNATION	IJN DESIGNATION
Shelf plate	Bed plate of gun house
Pan plate	Deck of working chamber
Turret stool	Ring support
Center column	Central trunk
Base casting	Central pivot
Gun girder	Trunnion girder

b. The rotating turret structure for Japanese turrets was poorly calculated by our standards. Most of the calculations made were in the form of comparisons with existing successful turrets; i.e., turrets or gun mounts that had not failed in service. For example, the turret structure for the 45cm guns of YAMATO was designed by scaling up the turret structure used in NAGATO and previous battleship gun mountings for 14 inch guns. Some few calculations may have been made for gun girders, for in answer to the question whether stresses or deflections were the governing factor in gun girder design, the answer was that deflections governed. Inspection of ships indicated generally heavy construction of the structure of the gun girders, pan plate and shelf plate of the turret, although the gun shields on smaller ships such as CL's and DD's were of very light, riveted construction. The turret stools were calculated in much the same manner as the rotating turret structure, mostly by judgement and comparison with previous ships.

c. No calculations were made for the torsional stresses induced in the lower roller path by the turret roller flanges when the guns were fired. The detail of the connection of the lower roller path to the turret stool does not appear to be a very rigid one. The elements of this connection are shown below:



d. The lower roller path was made from Ni-Cr steel and had a hardness measured on the Schore scale of 45. During the war, because of a scarcity of materials, the hardness was dropped to a value of 40. No large turrets were made after the outbreak of the war, but there were no complaints of indented roller paths in smaller turrets, even though the hardness was reduced.

e. The specification for parallelism of the plane of the various roller paths with which a ship was provided was not explicitly stated. Parallelism of from two to three minutes between the roller paths of the guns installed and their controlling directors was required on inspection, however. The Japanese stated they had encountered trouble in meeting this requirement because of temperature differentials throughout the ship.

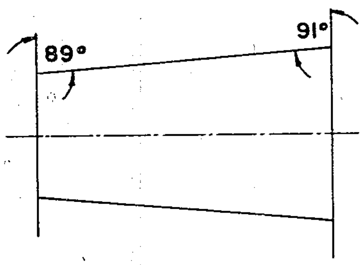
f. The allowed tolerance for roundness of roller paths was stated to be about 2 to 3mm difference between the major and minor axes for 20.3cm guns. There appeared to be few general specification requirements for such measurements; they were developed for each design as the design developed.

g. There was no specification requirement for planeness of the roller path. The weight of the rotating parts and the elasticity of the supporting structure were supposed to take care of such "out of planeness" as might occur.

h. Turret rollers used by the Japanese were much the same as those used in the U.S. Navy. The rollers were spaced by a cage, were conical, and were flanged to take the reaction of firing the guns. The rollers were made from Ni-Cr steel, and were heat-treated as a unit, no effort being made to surface harden either the barrel of the rollers or the flanges. After heat treatment the hardness of the roller was 45 on the Schore scale.

i. The rollers were evenly spaced in the roller retaining ring, but there were no complaints from the operating forces regarding the indentation of roller paths except from small caliber, high-angle guns, 12.7cm and below. The damage in these cases was considered to have been caused by the heavy downward forces exerted by the guns on the roller paths when the guns were firing at high angles of elevation.

j. The roller clearance, flange to track, was stated to have been 0.5mm for a 20.3cm gun. This clearance was proportionately increased for a 45cm gun. The diameter tolerance for turret rollers was 0 to -0.05mm. The roller flanges were eased off about 1° as indicated in the sketch below:



k. Although interrogation did not reveal that the Japanese had ever had any trouble with galling of turret roller flanges or tracks, easing off of the roller flanges may have been required by such a casualty. On the other hand, the turret train rates were so slow that it is questionable whether such galling would occur.

l. There was no specification requirement that a certain number of rollers should be in contact with the upper and lower roller path simultaneously. Apparently no trouble had been encountered on this score, for the question of number of rollers in contact was a matter of inspection, and as long as a majority of the rollers were in contact, the job was considered satisfactory.

m. The Japanese used two training pinions in most of their turrets. These pinions were located forward of the athwartship diameter of the turret. The turret training rack and pinion teeth were of involute shape, designed with a 14° involute angle. The contact ratio between the pinion and rack apparently meant little to the Japanese designers, for they had not calculated it. They stated that 2.5 pinion teeth were always in contact with the rack. Such a condition was supposed to be a design condition, but trouble was encountered in some cruisers of ATAGO and TONE classes with slivers being cut off the pinion teeth during the "run in" period before the guns were fired.

n. The speed of train provided for Japanese turrets was relatively low; some values of training speeds:

YAMATO:

45 cm gun turrets - 2° per second
20.3cm gun turrets - 4° per second

TONE:

20.3cm gun turrets - 4° per second
12.7cm gun mounts - 16° per second

TERUTSUKI:

10 cm gun mounts - 12° per second

o. Positive stops in the form of turret buffers were provided in the design of gun mounts and turrets. Those provided for destroyer (12.7cm and 10cm) mounts were located on the deck outside the mount. Although the mount train rates were relatively low, the flimsy support provided for such buffers raises a question of their adequacy. The buffers were never tested during the building period, and so the adequacy of their design was never checked. The buffers were designed to work at the low operating pressure of 3500 pounds per square inch.

p. Flame seals between the turret rotating structure and the handling rooms below were not fitted. Rotating powder scuttles provided a flame seal between the lower turret handling room and the powder magazines. An overlap of 1mm and a clearance of 1mm was stated by the Japanese to provide what they considered an adequate flame seal. The powder and shell hoists in the Japanese turrets were provided with flame-tight doors both at the upper and lower ends, so it would have been difficult, short of leaving access hatches open, for flame to travel from the gun chamber to the lower handling room.

q. Holding-down clips for the large turrets installed in Japanese ships were located as follows:

YAMATO:

4 clips in the forward sector
2 clips, one at each side
2 clips in the after sector

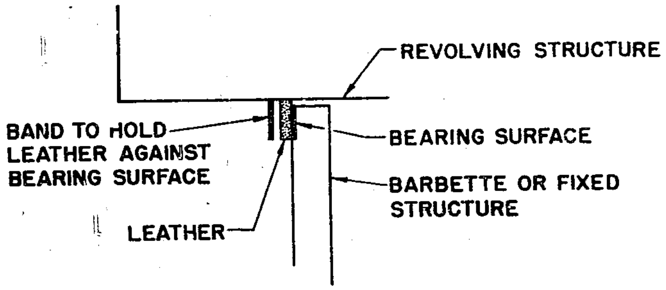
NAGATO:

3 clips in the forward sector
4 clips, two at each side
2 clips in the after sector

TONE:

4 clips in the forward sector
2 clips, one at each side
2 clips in the after sector

r. The weather seal provided for Japanese turrets and gun mounts was a relatively simple one. The elements of it are sketched on the next page:



A turnbuckle arrangement was provided to hold the leather washer tightly against the bearing surface. Grease was used to keep the leather pliable.

H. Arrangements

1. The arrangement of the interior of Japanese warships followed necessarily the conventions of other navies, because such an arrangement is dictated by the battery and machinery locations within the ship. The height allowed between decks, however, was low. The designers' criterion for an adequate deck height was stated to be between 1.9 and 2.3 meters, or plating to plating deck heights of from 6.21 feet to 7.4 feet. The higher value of these two figures might have provided adequate clear head room, but even this is questionable, for ventilation ducts seldom pierced the structure provided under the decks. Head room of five feet or slightly less was not uncommon in passageways.

2. The Japanese nomenclature for decks differed from that in the U.S. Navy as indicated below:

USN DESIGNATION	IJN DESIGNATION
Main deck	Upper or uppermost deck
Second deck	Upper or middle deck
Third deck	Middle or lower deck
1st platform deck	1st stores deck
2nd platform deck	2nd stores deck
For CV's	
Gallery deck	AA machine gun deck

The reason for two designations opposite each of the USN decks is that in a ship containing three continous decks, the deck corresponding to the USN main deck would have been called the upper deck, and in a ship containing four continuous decks, the deck corresponding to the USN main deck would have been called the upermost deck. In older designs the Japanese had no compunction about maintaining continuous decks at any given figure above the base line of the ship. The height of decks was varied to suit the particular problem involved. This change in deck height to suit convenience can be noted in the arrangement plans for both ATAGO and SAKAWA.

3. Earlier Japanese cruisers were marked by the peculiar shape of their smoke pipes. This shape was partially caused by the location of the bridge with respect to the boiler rooms. The machinery spaces for later

Japanese cruisers required from 33.5 to 35.4% of the length of the ship to accommodate the machinery. These cruisers were designed with the preponderance of their main battery forward, a factor that caused the bridge structure to be located over the forward boiler rooms. To get the boiler stack gases out of the ship, the Japanese ran their uptakes into the base of the mast structure. From here, the forward uptakes swept up and aft, joining the uptakes from the after boiler rooms in one large stack, with an additional smoke pipe aft of the large one in the case of ATAGO.

4. Access in Japanese vessels was poor. Hatches were small, ladders were narrow and steep, and no apparent system of access could be determined during the inspection of Japanese vessels. Doors in watertight bulkheads were not located with a view to easy and rapid access to any part of the vessel.

5. The hatches were "D" shaped, and were generally made as small as practicable. There were, of course, exceptions to this general type of access, showing in some instances that rapid access must have been considered. Where the "D" shaped hatches were used the ladder from the deck below was attached to the straight edge of the "D". The radius at the corners formed by the intersection of the straight vertical part of the "D" and its sides was small. Thus, if the reason for using such shaped hatches was to eliminate the stress concentrations associated with small radius hatch corners, the aim was not achieved.

6. Hatches in the deck next above the waterline were provided with very high coamings. In KATSURAGI these coamings were approximately 40 inches high. Such high coamings made access through these hatches difficult.

7. The ladders in the main access hatches were generally quite steep. These ladders had various angles of slope, as there was apparently no specification requirement covering the slope of ladders, convenience of location being the controlling factor. Ladders were constructed of steel, using corrugated steel plates for the treads.

8. Watertight bulkhead doors were nearly rectangular, with only a small corner radius being used. The doors were of light construction and were secured with small dogs. The general appearance of the watertight doors was one of light construction, so light that their adequacy to keep the bulkhead tight appeared at issue. The doors must have been reasonably satisfactory, however, for Japanese ships stood up well in many cases after severe battle damage.

9. There were no quick-acting doors provided for closing the ship rapidly on the lowest deck provided with fore and aft passage. Quick-acting scuttles, or rather scuttles equipped with gang operated dogs, were profided for some of the main access hatches.

10. No doors were provided in main transverse watertight bulkheads below the level of the deck next above the waterline.

11. Because of the poor access provided in Japanese ships, it must have been difficult to secure them properly in a short interval of time when going to general quarters. No good answer was given to questions as to the length of time necessary to place a large Japanese warship in a USN general quarters condition, answers varying from five minutes to fifteen minutes, with some question as to the truthfulness of these answers, due primarily to a lack of proper understanding of what the USN general quarters condition signifies.

12. Crews of Japanese warships were generally berthed and messed in the same compartment. Hooks were provided for swinging hammocks, and bunks were provided in some cases; for example, for the enlisted pilots quarter-

ed on board aircraft carriers. Crews berthing compartments, unless they were located on or above the lowest deck, provided with fore and aft access, were equipped with a false wood deck about six inches above the steel deck. On this deck mess tables and mats were placed to provide living accommodations for the crew.

13. Galleys were located on the main or second decks, and were poorly equipped by USN standards. Large vats were used to cook rice and fish, but no facilities were provided for baking. The galleys were coal or oil fired, and had a very dirty appearance.

14. The poor appearance of Japanese ships was accentuated by the type of fireproof interior paint that was used. The vehicle of the paint was waterglass, or sodium silicate, and the pigment consisted partly of chalk. Surfaces painted with this mixture received little protection. The paint could be rubbed off in large flakes and the surface underneath the paint was corroded or rusty.

15. The sanitary facilities in most cases were stripped to essentials. WC's in adequate numbers were provided, but washing and bathing facilities were primitive. On the cruiser SAKAWA, a trough at the deck edge, on the weather deck, was installed in which the crew bathed with salt water. Showers were not provided, although a few bath tubs were installed in washrooms.

16. The foremast pagodas, another peculiar feature of Japanese warships, were developed to satisfy the requirements of the many control stations that were required by the Japanese. Living quarters, such as the commanding officer's cabin, executive officer's cabin, and navigator's stateroom, as well as radio, radar and coding rooms, were located in the base of the foremast pagoda. The damage control station was also located in this general neighborhood, usually about one deck level below the bridge. Except on the older ships, and destroyers of TERUTSUKI type, the bridge was without steering control, the wheel being located one level below the bridge, in a small station provided with reasonably good view. Above the bridge or conning station were located control stations for the various batteries with which the ships were equipped. In a few instances, a second conning station was provided above the first or lower station, adding one more level to the foremast in that case. No open bridges, providing overhead vision, were employed.

17. The bridges inspected were crowded with equipment, particularly on small ships. Compasses, lookout stations provided with large binoculars, target designators, and in the case of destroyers, torpedo directors, so used the space available that with the bridge fully manned, access would have been difficult at best.

18. Ammunition handling facilities provided Japanese vessels were, in general, of the type that utilized manpower more than machinery. For large caliber guns, where it was patently impossible to handle the large weights involved, mechanical means were provided, but for guns approximating six inches and below, ammunition handling in a horizontal plane was done by hand.

19. The powder and shell handling arrangements on NAGATO were interesting. They formed the basis for the method of ammunition handling provided for YAMATO, and so will be discussed here. Specific plans of handling arrangements on YAMATO are not available but the principal difference in the ammunition handling arrangement for the two classes, was that about one half the projectiles were stowed on the rotating turret structure of YAMATO, and none were so stowed in the case of NAGATO.

20. For NAGATO, shells were stowed in bins forward or aft of the turret they served. They were located directly over the powder magazines. Shells were hoisted from their stowage bins by a small mechanical hoist mounted on a transverse beam over the shell bins. There were as many transverse tracks as there were transverse rows of shells. From its stowage position, then, the shell was transferred athwartships to a fore and aft track.

21. There were two fore and aft tracks provided for each shell magazine, one port and one starboard. These tracks each supplied one gun in the turret. The shell carriers on these tracks were driven by a piston carrying a movable sheave at its end. The sheave was rove five or six times with a steel cable so that a small movement of the piston would provide a large movement for the shell carrier on the fore and aft track. The shell was transported, then, from the transverse track to the fore and aft track, then along the fore and aft track to a fixed tray in the shell handling room near the rotating turret structure. A movable tray, mounted on a circular track, could match with the fixed tray on which the shell had been placed. The shell was then transferred to this movable tray, and moved by a screw mechanism operated by a hand wheel to the loading tray of the turret ammunition hoist. Powder was handled by hand, one level lower, to a similar tray arrangement, being transferred from the fixed to the movable tray, and thence to the hoist loading tray.

22. Powder and shell were hoisted in the same car. At the deck of the gun chamber they were transferred to another car, the tracks for which were a sector of a circle with its center of curvature at the trunnion center, and attached to the inboard side of the gun chamber bulkhead. Thus, powder and shell, after being transferred to the last car, could be hoisted until the car matched the position of the gun breech, and then loaded into the gun, without requiring the gun to return to a predetermined loading angle.

23. No elaborate system of ammunition handling such as was provided for NAGATO was installed in light cruisers. A description of the installation provided for SAKAWA, an AGANO class cruiser, follows:

24. SAKAWA was equipped with gun mounts, and not turrets. Her magazines were in the general vicinity of the mounts, but the magazine for Mount number one was located approximately under Mount number two. Powder and shell were hoisted by the same hoist and delivered to the level of the upper handling room by Mount number one or two. A hoist was provided for each mount. From here the ammunition was carried by hand to the upper handling room, from which place the shell was hoisted to the gun chamber and the powder passed up by hand. The loading operation in the gun chamber was manual.

25. The guns installed in OYODO were mounted in turrets with a lower handling room located at the magazine level under the turret. No ammunition handling plans are available for these guns, but the profile indicates a hoist going from the lower handling room into the turret. The route the ammunition followed was, therefore, more direct than in SAKAWA. These ammunition handling arrangements were undoubtedly superior to those provided SAKAWA.

26. Ammunition handling arrangements for TERUTSUKI were essentially similar to those provided SAKAWA. The hoists from the magazines to the level of the upper handling rooms were of the pusher type, however, while in SAKAWA, the hoists were of the horizontal dredger type.

I. Ventilation

1. The most striking feature of ventilation systems provided for Japa-

nese warships was their vertical character, a system being contained between two main transverse watertight bulkheads below a level of one deck height above the trial waterline. Below this level, ventilation ducts were not allowed to pierce transverse watertight bulkheads. Ventilation diagrams for SAKAWA, KATSURAGI, ATAGO, and TERUTSUKI, show this arrangement of ventilation system clearly.

2. Ventilation, although provided for the comfort of the crew of Japanese ships, was not based on the volume of air required to maintain a particular compartment at a specified temperature above the temperature of the outside air. The volume of air required was based on a number of changes of air per minute, the exact value depending on the type of compartment for which the ventilation was being designed.

3. Ventilation alone was apparently not adequate for the comfort of the crews of Japanese ships, for in recent designs the use of air cooling was extended. From an original installation of magazine and plotting room air cooling, its use was extended to such spaces as officers' quarters, crews' living quarters over machinery spaces, and for aircraft carriers, the operations room and the pilots' ready rooms. The highest temperature permitted in powder magazines within the ships for the Japanese Navy was 27°C or 80.5°F.

4. Centrifugal type fans were generally used to provide ventilation air for Japanese warships. Axial flow fans were used, it was stated, in MOGAMI class cruisers, but in spite of the greater efficiency of this type of fan, its noise level was considered so objectionable that the designers reverted to centrifugal type fans. KATSURAGI had axial flow fans installed to exhaust the ventilation air from the voids built around the gasoline tanks. These fans were not the same type of axial flow fans as are used in the U.S. Navy, for the fan motor was located outside of the ventilation duct, an elbow fitting being provided to permit the motor and fan to be mounted on the same straight shaft. It is not surprising that trouble was encountered with this type of fan for the change in direction of the ventilation air so close to the fan introduced unnecessary pressure drops in the system, and invited the turbulence associated with high noise levels.

5. Air velocities used in ventilation ducts varied from 150 to 700 meters per minute. The ventilation air velocities, pressure losses for various ventilation duct fittings, and fan pressures and deliveries are tabulated in Enclosure (277).

6. The Japanese employed a great number of ventilation duct closures. These closures were gate or flapper valve types. All weather deck ventilation openings were guarded with a closure. Closures were also fitted where ventilation ducts penetrated armored decks in armored ships, or the unprotected deck next above the waterline in unarmored or lightly armored ships. This rule did not apply to destroyers. The closures fitted at the armored decks were located under the armor and were capable of remote operation from above the armored deck. The location and type of closures provided can be seen on the ventilation diagram of the specific ships included in this report.

7. The weather deck closures installed for all Japanese warships were provided for gastight as well as watertight integrity. The ventilation systems of their warships were designed with a view to minimizing the dangers incident to gas attacks, although no quick means was provided for securing all the weather ventilation closures.

8. Armor gratings of the flat bar type were installed in most Japanese warships. A modification of the flat bar grating was provided for KATSURAGI. These gratings are shown in Enclosure (279). The effective-

ness of such gratings is open to question even in such lightly armored ship as KATSURAGI. YAMATO was provided with a full fledged armor grating similar to those now used in the U.S. Navy. A brief description of this grating with a few pertinent facts is given in Enclosure (275).

9. Before the sinking of the aircraft carrier TAIHO, the Japanese provided ventilation for the cofferdams surrounding the gasoline tanks installed in aircraft carriers. Both supply and exhaust ventilation were installed, the system serving the cofferdam serving no other spaces except the gasoline system pump room. After the loss of TAIHO, from a gasoline explosion eight hours after torpedoing, the voids around the gasoline tanks installed in aircraft carriers were filled with concrete to provide more protection. With the installation of concrete, the ventilation for these spaces, of course, was removed. A typical arrangement of the gasoline tank cofferdam ventilation is shown in Enclosure (55).

10. Heat insulation was provided for all Japanese warships for the decks and sides exposed to the weather. Under weather decks covered with wood, insulation was not installed, the wood being accepted as sufficient insulation. Weather decks covered with linoleum, or decks left bare, were insulated with one inch rock wool bats, covered with a cloth facing. Of the ships inspected there were none with the insulation completely intact, the cloth facing apparently being inadequate to hold the insulation in place properly.

11. Heat insulation that was provided for air-cooled spaces consisted of cork board of varying thicknesses sheathed with wood. The wood sheathing was painted in some installations, and in others it was not. The later installations were generally unpainted. The reason extended for not painting the wood sheathing in the later ships was to reduce the fire hazard!

12. Several of the air-cooled spaces such as the radio receiving room, damage control station, and coding room were located topside. In spite of the exposed location of these stations there was little complaint from operating forces regarding the fire hazard introduced during of enemy action.

13. Calculations for ventilation air quantities for some typical spaces in CV SHOKAKU are shown in Enclosure (280).

J. <u>Fire Main and Drainage System</u>

1. The fire mains installed in Japanese vessels were single line mains for small unprotected ships, and more complicated loop mains for larger ships. For battleships a horizontal loop was provided below armor, and for lightly protected ships such as KATSURAGI, a partial vertical loop, the loop extending through the machinery spaces, was installed. The upper leg of the loop was not below protection while the lower leg was. Forward and aft of the machinery spaces the fire main was a single pipe line.

2. The Japanese had no criterion by which the pumping capacity of a ship's fire system was calculated. The only rule that was used in the design of such systems was that the pumping capacity was determined by the size of the ship. The differences in pumping capacity provided for the various types can be seen by a perusal of the plans included of the fire system of the various types of vessels.

3. As was the case with ventilation systems, the fire mains developed by the Japanese guarded the integrity of watertight bulkheads as much as possible. Below the level of the single line mains, run as high as pos-

sible within the ship, the ship was subdivided into transverse sections, and no fire main piping penetrated the bulkhead boundaries of these sections except that of the lower (in the case of vertical loops syste) fire main loop itself. A few exceptions to this rule may be noted; however, the general scheme was that outlined above.

4. Powder magazines were both sprinkled and flooded. Shell magazines were flooded only. The flooding connections were arranged to provide a large enough capacity to flood a powder magazine in 15 minutes and a shell magazine in 20 minutes. The volume of water introduced in the powder magazine by the sprinkling piping was not considered in the calculation of flooding time. It was interesting to note that there have been cases of inadvertent flooding of magazines in the Japanese Navy. MOGAMI and MUSASHI both reported flooding of magazines through inadvertence. Such incidents should not be surprising in view of the maze of remote control shafting and the peculiar manner in which some fire pump sections are located in some ships. For example, in KATSURAGI, a fire and bilge pump took suction from an inner bottom tank. The magazine flood sea chests were located in this same tank, which was a sort of drain tank, and the sea chests were provided with two remotely operated valves. Between the valves was a pipe connection that permitted flooding the tank, and the second valve in the magazine flood line prevented the magazine from flooding. With the sea chest valve open, the inner bottom tank could be flooded to provide a suction for the fire pump. With such a set up, it would be easy to open the wrong valve and consequently flood the magazines inadvertently.

5. Segregation and isolation valves were provided in the fire main piping, but by U.S. Navy standards the number would have been insufficient. The express purpose of these valves, according to the Japanese designers, was to keep the system in operation, after damage, rather than to permit segregation of the various parts before battle.

6. The fire pumps used for the fire main system were generally centrifugal pumps. Some of the pumps located in the machinery spaces were steam-driven as well as electric, while those pumps located outside of the machinery spaces were either electric or diesel-driven pumps.

7. The material used for the fire main piping was galvanized steel seamless tubing.

8. The hose sizes used for fighting fires varied with the type of ship; 50mm diameter hose was used for destroyers while cruisers used 65mm and the larger ships 75mm diameter hose. The connection of the hose to the fire plug was by a bayonet joint that required less than a half turn to secure. Connections between sections of hose lines and hose nozzles were of the same type.

9. The Japanese had no special types of nozzles such as the U.S. Navy all-purpose nozzle. The nozzles used were of a straight venturi type.

10. For emergency use small gasoline "handy billy" pumps were provided. Apparently the Japanese had difficulty with the overboard suction of these pumps, for on all ships inspected a steel suction pipe, which could be swung over the side, was installed so that it could be used for the pump suction in emergencies. Operating personnel stated that the pipe had provided a satisfactory suction at speeds as high as 18 knots.

11. The drainage systems installed in Japanese vessels were essentially gravity drain systems. WC's and WR's were located high enough above the waterline to assure drainage without the use of drain tanks or drain pumps. Spaces within the ships, so low that they could not be drained overboard, were drained to inner bottom tanks or bilges and the drainage

water picked up at this point by fire and bilge pumps or steam ejectors.

12. Steam ejectors were used extensively by the Japanese for drainage purposes.

13. The drainage system followed the transverse subdivisions established by the fire main subdivision, and by so doing, saved many bulkhead penetrations by drain piping.

14. Steering gear drainage for large ships was provided by installing a small pump above the steering gear armored box. The capacity of this pump was ten tons per hour, or about 40 gallons per minute. For smaller ships, that is, light cruisers and destroyers, no drainage was provided for steering gear compartments.

15. Fire main and drainage diagrams for various ships are included in the enclosures of ship plans.

16. A foam system, closely allied to the water fire system, although not directly a part of it, was installed in Japanese aircraft carriers. Prior to 1941 the Japanese had used CO_2 systems for fire protection in aircraft carrier hangars, but about this time, a foam fire fighting system was developed. It was simple in its application, as is shown in Enclosure (50).

17. The system consisted essentially of pumps located below the armored deck, provided with a sea suction and a foam liquid tank located in the pump room. The foam liquid was injected into the system by leading a line from the foam tank to the pump suction. From the pump discharge the salt water mixed with the proper proportion of foaming agent, was led to what the U.S. Navy terms "conflagration stations," two stations being provided for each hangar bay. Either station could start the operation of the foam system in its own bay, but not in the adjacent one.

18. From the conflagration station the foam piping main was led around the hangar decks, protected by a guard plate as well as being located as closely as possible to the intersection of the hangar deck and hangar side plating. The nozzles, mounted in a vertical position, with their ends so arranged as to throw a horizontal sheet of foam out over parked planes in the hangar, were attached to this pipe.

19. The nozzles were aspirated nozzles, the air being entrained in the foam liquid and salt water mixture near the base of the nozzle.

20. The foaming agent used was stated to have been "Foamite," but it was manufactured by Japanese concerns, and consequently might not have been the same as the material manufactured in the United States under the trade name of "Foamite."

K. <u>Aircraft Carrier Gasoline Systems</u>

1. The gasoline systems installed in Japanese aircraft carriers were very simple ones. They were direct suction systems, no water displacement systems being used because of the fear of contaminating the aviation gasoline with water. The diagrammatic arrangement of sych a system is shown in Enclosure (48) and (49).

2. The system consists essentially of a screw pump, driven by electric motors located outside and above the pump room, that took suction from the bottom of the gasoline tanks. The gasoline was discharged to a main, run inside the ship, that serviced both the upper and lower hangar decks as well as the flight deck. The tanks were fitted with vents as well as a connection to a bilge pump.

3. An airplane degassing system had not been designed for Japanese aircraft carriers, although the need for such a system was recognized. What amounted to a jury-rigged system had been installed, however, which consisted of degassing the planes by draining the gasoline out of the planes' tanks into buckets, and then pouring the gasoline from the buckets into funnels connected to the gasoline main. The gasoline drained back to the tanks by gravity, and no means of securing the system with inert gas was provided.

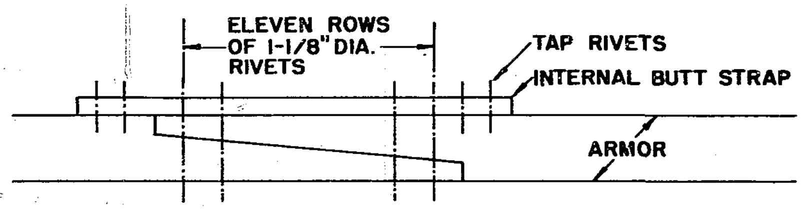
L. Protective Arrangements

1. Above Water Protection

a. In the larger Japanese warships, such as battleships and large aircraft carriers, armor protection against bombs and shell fire followed conventional modern methods, with sloping side armor being introduced in YAMATO and MOGAMI classes. YAMATO, the latest Japanese design of a heavily armored ship, introduced a novel feature of protecting the deck under the magazines with armor, thus forming a completely protected box for the ammunition, with the exception of the end of this box adjacent to the machinery spaces.

b. One striking characteristic of Japanese above water protection was the extensive use of internal armor. This type of protection was most extensively used in cruisers, and was first introduced in the design of MOGAMI class cruisers. ATAGO was provided with a suit of conventional exterior armor, whereas MOGAMI's, similar to TONE's, armor was completely internal. For light cruisers of AGANO and OYODO classes, a combination of internal and external armor was used. The use of a system of external and internal armor creates a number of weak spots in the armor suit, at the point of shifting from internal to external armor, and the design of such spots, in Japanese warships, was not exceptionally good. Angle bars, through riveted or tap riveted, depending on the thickness of the armor, were used with rabbets in the edges of the armor to provide better support against ballistic impact. These rabbets were often omitted.

c. As previously stated, the side armor on ATAGO, four inch and five inch in thickness, was worked in the longitudinal strength of the vessel. Typical calculations for such armor joints are shown in Enclosure (278). The joint actually used for ATAGO was that sketched below.



The joint efficiency of this connection was stated to have been calculated to be 60%. The use of this type of joint was not perpetuated in subsequent designs.

d. The internal armor fitted on TONE presented difficult problems of erection and fabrication of the shell plating and armor of the ship. The working space available between the sloping vertical armor and its intersection with the shell plating was extremely small and presented difficult problems of workmanship.

e. The barbette protection on all Japanese cruiser classes was weak compared with U.S. Navy standards. The shadow of adjacent turrets was used to reduce the thickness of barbettes in a 30° sector either side of the longitudinal centerline on ATAGO. The barbette armor provided TONE was only about one inch in thickness, and because of the meager protection afforded, this armor was not reduced in thickness in the shadow of adjacent barbettes.

2. Underwater Protection

a. A striking feature of Japanese heavy cruiser design was the amount of underwater protection that was provided these ships. Although no heavy cruiser protection system was adequate to resist the contact explosion of a modern torpedo, the protection would have been effective against close "near misses." The system built into ATAGO was designed to resist a 200 kg charge of Japanese explosive, but was stated to have been unsuccessful.

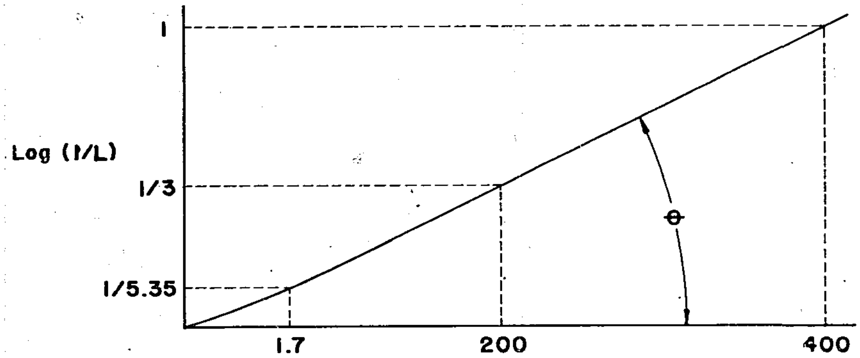
b. YAMATO's underwater protection was designed by exterpolating a series of tests that had been conducted for the modernization of NAGATO. Small-scale models, as well as full-scale caissons were used in this work. No models smaller than 1/5.35 scale counterpart were used, but a number of 1/3 scale models were tested before going to full scale caissons. The reason smaller models than 1/5.35 scale were not used was because of difficulty encountered in representing the full scale joints in model size.

c. YAMATO's underwater protection system was designed to withstand a charge of 400 kgs. The following relationship was used to determine the model charge weights that would correspond to the full scale desideratum:

$$\frac{1}{L} = \left(\frac{\overline{W}}{\overline{W}o}\right)^n$$

where
$\overline{W}o$ is the actual charge weight
$\overline{W}$ is the model charge weight
L is the model scale
n is 1/2.85 (approximately)

The value of "n" can be found by determining the tangent of the line shown as follows (the following values should be plotted on logarithmic paper):



CHARGE WEIGHT IN kg.
TAN θ IS EQUIVALENT TO n.

d. The Japanese preferred to use voids for their underwater protection layers, primarily because it eliminated piping to the outboard tanks, and thus reduced the chance of progressive flooding through broken piping after damage. In any event, the Japanese had conducted tests that indicated to them that air-backed shell plating was as effective in preventing damage from underwater attack as liquid-backed plating. Unfortunately, the records of all underwater tests were stated to have been burned during the fire bombing attacks on TOKYO.

e. The Japanese had developed a formula that supposedly gave the thickness of the bulkheads in an underwater protection system that would withstand penetration by any assumed weight of explosive. The formula is as follows:

$$\Sigma t = k \times \bar{w}^{m} \times d^{-1/3}$$

where
- Σt is the total thickness of underwater protection bulkheads in the system
- $\bar{w}$ is the assumed charge weight
- m an exponent whose value is 0.669 approximately
- d is the distance of the holding bulkhead from the center of the explosion
- k is an experimental constant.

Metric units are used in this equation. The Japanese stated that they used this formula in determining the thickness of underwater protection system bulkheads, but stated that it was incomplete because a volume factor was omitted in its formulation. Different values of "k" were assumed to cover this point adequately as well as to care for the different destructive powers of different explosives.

f. The construction of underwater protection systems was no different from the remaining ships' structure. No special care was taken to eliminate hard spots that might cause "punching" under explosive loadings. Curved transverse bulkheads were not used in these systems. Riveting alone was used, principally because most of the steel employed in the underwater protection system was DS for which no acceptable welding technique had been developed.

PART III
CHARACTERISTICS OF THE LATEST DESIGN CLASSES

Note: In the following tabulations all displacements and shaft horsepowers are given in metric units. The metric ton is equivalent to 0.985 English long tons, and the metric horsepower is equivalent to about 0.98 English horsepower. All conversions shown below from meters to feet have been done with a six-inch slide rule, so their accuracy must be judged accordingly.

A. <u>Battleships</u>: YAMATO class

1. The characteristics of YAMATO class battleships, of which two units were built, YAMATO and MUSASHI, have been chosen as representing the culmination of Japanese design experience in the battleship type. The principal characteristics of these ships as they were built are tabulated below. Aside from verbal information given by the Japanese, the characteristics are substantiated by Enclosure (1) to (9) and (255).

YAMATO CHARACTERISTICS

Displacement, Trial	69,935
Displacement, Full	72,200
Displacement, Standard	62-63,000
LOA	259m (850')
LTWL	256m (838')
B-TWL	36m (117'5)
B-EXT	39m (127')
H-TWL	10.4m (34')
Depth	19m (62'3)
Longitudinal or Prismatic Coefficient	0.60 (?)*
Midship Section Coefficient	0.97 (?)*
$\frac{V}{\sqrt{L}}$	1.1
$\frac{\Delta}{(\frac{L}{100})^3}$	116
V DES	27 Kts
V Trial	27.7 Kts
SHP	150,000
Cruising Radius/Speed(DES)	7200mi/16 Kts
Stability (Trial Cond.)	
GM	10'-11'
GZ	7'
Range	Abt 70°
Strength	
Hogging	
Deck Tens.	10 tons psi
Keel Comp.	8 tons psi
Sagging	
Deck Comp.	7.75 tons psi
Keel Tens.	8.5 tons psi
Battery	
Main	
Bore/Caliber	45cm (17"7)/45 Cal. in Length
Type of Mount	Triple
Angle of Elevation	40°
No. of Guns	9

*These coefficients do not check with the displacements and dimensions given above. The midship section coefficient should be greater than one, but the prismatic or longitudinal coefficient should not be much lower.

Secondary
Bore/Caliber ... 15.5cm (6".1)/50 Cal. in Length
Type of Mount .... Triple
Angle of Elevation .... 70°
No. of Guns 12

AA Guns
Bore/Caliber .... 12.7cm (5")/40 Cal. in Length
Type of Mounts .... Twin
Angle of Elevation .... 75°
No. of Guns 12

AA MG
Caliber .... 25mm (0".988)
Type of Mount .... Triples
No. of Mounts .... 36 bbls (DES)
(AA MG Battery was doubled after completion of Ship)

Protection
Machinery Spaces
Main .... 41cm (16".05) at 20° slope, VC
Lower ..... 200mm (7".9), tapered to 75mm (2".95) .... at 20° slope, CNC

Magazines
Main .... 41cm (16".05) at 20° slope, VC
Lower ... 270mm (10".45), tapered to 175mm (6".9) .... at 20° slope, VC
Bottom ...... 80mm (3".15) and 50mm (1".965), CNC

Decks
Machinery Spaces - Magazines ..... Originally designed at 20.3cms but reduced to 19cm(7".5) ..... as the result of ballistic tests, NVNC

Armored Bulkheads .... 14" tapered to 10", VC
Turrets .... 45cm (17".7)
Face PL .... 20" VC
Top PL .... 9" VC
Rear PL (for counter balance) .... 18" VC
Barbettes .... 20" VC
Turrets .... 15.5cm (6".1)
Face PL .... 3" CNC
Top PL .... 1" CNC
Side PL .... 1" CNC
Barbettes .... 3" CNC

C.T.
Sides .... 20" VC
Top .... 8" VC

Steering Gear -
(10% thinner than corresponding thickness of .... main armor box)
Sides - (Calculated) .... 14".5
Top .... 6".75
Ends .... 9"

2. The design of YAMATO began in 1934. Her design period was exceptionally long, for her construction was not started until 1937. YAMATO was built at the KURE Navy Yard, and MUSASHI at NAGASAKI. Both were completed in 1941, shortly before the outbreak of the war.

3. This class of battleships was the largest in size, the most heavily gunned, and the most heavily protected class of its type in the world. The fact that the ships were poorly handled, both strategically and tactically, should be no discredit to their designers.

4. There are few points requiring further discussion for these ships; the table and the enclosures describe them quite fully. There were some

deficiencies in their design, however; one was the lack of depth of their underwater protection system and another was the connection between the upper and lower side belt armor. The details of these points are shown clearly in Enclosures (8) and (255).

5. Enclosures (3) to (9) were reproduced by the Japanese from detailed plans found at the KURE Navy Yard.

B. Aircraft Carriers: UNRYU (KATSURAGI), TAIHO, SHINANO classes.

1. The three classes of aircraft carriers chosen for discussion were the latest warships of this type designed by the Japanese. UNRYU class approximates U.S. Navy CVL's in displacement, although their dimensions were greater than these CVL's. TAIHO approximates very closely U.S. Navy CV's of ESSEX class both as to hull dimensions and displacement, while SHINANO could be compared with U.S. Navy CVB's of the MIDWAY class. The characteristics given below can be substantiated from the information shown on Enclosures (10) to (58) for KATSURAGI, (59) to (67) for TAIHO. and (68) to (78) for SHINANO.

Enclosures (64) to (67) for TAIHO and (72) to (78) were prepared by the Japanese from detailed plans found at YOKOSUKA and SASEBO.

2. One of the outstanding features of Japanese aircraft carriers was the smoke pipe arangement. Downsweeping smoke pipes below the flight deck were used through the design of UNRYU class of carriers. The reason for the use of this type of smoke pipe arrangement is obvious, namely, to keep boiler flue gases from interfering with flight operations. The method, so typically Japanese, of sweeping the smoke pipes downward was abandoned in TAIHO and SHINANO, and stacks integral with the island were used.

3. No wood was ordinarily used as deck covering for the flight decks of Japanese aircraft carriers. Wood was used on the converted carriers of the HAYATAKA class, however. The flight deck covering used for the three classes chosen for discussion was a non-skid paint.

4. The strength of the flight decks of Japanese aircraft carriers was based on a plane landing load of twice the weight of the airplane. The deck was supported by transverse bents, located on every frame of the vessel. Every other bent was a heavy one; the heavy ones, however, being only about 18 inches in depth. Longitudinals were run across the transverses to assist in the support of the flight deck, but they were relatively widely spaced. With the transverse method used by the Japanese for flight deck support, there was no necessity for deep transverse girders and consequently no gallery deck was installed in their carriers.

5. The flight decks of TAIHO and SHINANO were armored, and these decks were also designed as the strength decks of the vessels. Under these design condidtions, airplane landing loads were not the determining factor in the flight deck design.

6. Experience and judgment were used as a basis for the design of the flight deck supporting structure. So far as could be determined, the Japanese had no established criterion for roll, pitch, wind and snow loads that were used in designing this structure.

7. The hangars of Japanese aircraft carriers were closed hangars. The clear deck heights required were:

KATSURAGI	Upper hangar 4.6m Lower hangar 4.2m
TAIHO	Upper and lower hangar 5m
SHINANO	Upper and lower hangar 5m

AIRCRAFT CARRIER CHARACTERISTICS

	KATSURAGI	TAIHO	SHINANO
Displacement — Trial	20,898.870	34,600	64,000
Displacement — Full	22,534.440	37,270	66,500
Displacement — Light	16,745.072	28,287	
LOA	227.350m (743')	260.5m(852')	260m(850')
LTWL	223m (730')	253m (828')	250m(818')
BTWL	22m (72')	27.7m (90'8)	33m(108')
B-EXT	26.8m (87'5)	33.6m (109'8)	
H-TWL	7.93m (25'9)	9.67m (31'5)	10m(32'7)
Depth	15.7m (51'5)	16.8m (54'9)	22m(72')
Depth to Flight Deck	20.4m (66'7)	22m (72')	40m(130.5)
B-Flight Deck	27m (88'1)	Abt 28m(91'5)	
L-Flight Deck	214.5m (700')	256m (839')	
Longitudinal or Prismatic Coefficient	0.60	0.60	0.60
Midship Section Coefficient	0.86	0.85	0.97
$\frac{V}{\sqrt{L}}$	1.4	1.23	0.99
$\frac{\Delta}{(\frac{L}{100})^3}$	53.8	55.8	105
V Trial	32.709 Kts	33.34 Kts	26-28 Kts
SHP	104,000*	180,000	150,000
Cruising Radius/Speed	8000/18 Kts	8000/18 Kts.	
Oil Capacity	3,671.396 Tons		
Stability (Trial Cond.) — GM	1.78m (5'82)	2.06m (6'75)	2.5m (8'2)
Stability (Trial Cond.) — GZ	2.0m (6'55)	3.5m (11'4)	
Stability (Trial Cond.) — Range	90°	90°	90°
Strength — Hogging — Deck Tens.	8 tons psi	8 tons psi	8 tons psi
Strength — Hogging — Keel Comp.	7 tons psi	7 tons psi	7 tons psi
Strength — Sagging — Deck Comp.	7 tons psi	7 tons psi	7 tons psi
Strength — Sagging — Keel Tens.	8 tons psi	8 tons psi	8 tons psi
Battery — Main — Size	12.7cm (5")	12.7cm (5")	12.7cm (5")
Battery — Main — Type of Mount	Twin	Twin	Twin
Battery — Main — No. of Guns	12	16	16
Battery — AA MG — Caliber	25mm(0"988)	25mm(0"988)	25mm(0"988)
Battery — AA MG — Type of Mount	Triple and Twins	Triple and Twins	Triple and Twins
Battery — AA MG — No. of Guns	Increased during war after battle experience		
Battery — Plane Capacity — Planes	48	60	60
Battery — Plane Capacity — Gasoline Capacity	182 tons (53,500 gal)	600 tons (176,000 gal)	600 tons (176,000 gal)
Battery — Plane Capacity — Catapults	None	None	None
Battery — Plane Capacity — Barriers	3	2 {110m(360') 112m(367')	From Aft End of Flight Deck
Battery — Plane Capacity — Arresting Wires	9	9	9
Battery — Plane Capacity — Elevators	2	2	2
Battery — Plane Capacity — Elevators — Fwd.	14m(45'9)x 14m(45'9)	14m(45'9)x	14m(45'9)x
Battery — Plane Capacity — Elevators — Aft.	14m(45'9)x 13m(42'5)	14m(45'9)	14m(45'9)
Protection — Side Belt — Machinery Spaces	46m(1"81) DS	55mm(2"17) DS	200mm(7"9) VC
Protection — Side Belt — Magazines	140-150mm (3"5-5"9)VC	153mm(6"06)VC	350mm(13"8)VC
Protection — Decks — Armored Deck — Mach'y / Mag's	Mach'y: 25mm (0"988)CNC; Mag's: 55mm (2"17) CNP	100mm(3"93) NVNC on 25mm (0"988) DS	200mm(7"9) NVNC on 20mm (0"79)DS
Protection — Decks — Flight Deck	None	80mm(3"15) NVNC on 20mm (0"79)to 25mm (0.988)DS	Same as TAIHO
Protection — Torpedo Protection	Partial	Depth 3m (3'27) Holding bhd 40mm (1"57)DS	Same as YAMATO
Built at:	KURE	KOBE	YOKOSUKA
Completed:	October 1944	March 1943	November 1944

*Katsuragi only.

8. The elevator dimensions for Japanese aircraft carriers are given on page 45. The hoisting system used for these elevators was very simple. The elevator platform was counter-weighted, and the hoisting wires, two at each corner of the elevator platform, were connected to winches mounted on the same shaft and driven by an electric motor located in the elevator pit. The speed of the elevator was controlled by a Ward-Leonard control system. The maximum velocity of the elevator was 50 meters per minute. Its time for a cycle consisting of going from the lower hangar level to the flight deck level was 15 seconds. Plans of the elevators are in Enclosures (56) to (58).

9. The locks used to hold the elevator platform at the flight deck were large brackets mounted on hinges. These brackets were swung under the elevator platform manually when it was desired to secure the elevators in the up position.

10. The ammunition handling arrangements provided for aircraft carriers were simple. Two bomb and torpedo elevators were installed, one to serve the forward magazines and one the after magazines. These elevators hoisted bombs or torpedoes to the lower hangar level, and further hoisting was done by the airplane elevators themselves.

C. <u>Cruisers</u>: ATAGO (CA), TONE (CA), IBUKI (CA); AGANO (CL), OYODO (CL).

1. Few plans were found for MOGAMI class cruisers, but the Japanese stated that MOGAMI and TONE were essentially the same except for the difference in armament. MOGAMI was equipped with the same battery as ATAGO, but the arrangement of the forward battery was different between the two classes. In ATAGO, Mount No. 1 was low, No. 2 high, and No. 3 low. In MOGAMI, Nos. 1 and 2 were low and No. 3 high. IBUKI, for which some particulars are available, was to have been a repeat of MOGAMI, before her construction was changed to an aircraft carrier. The characteristics of both heavy and light cruisers are tabulated on pages 47 and 48. These characteristics can be substantiated by Enclosures (79) through (196).

2. Recent designs of Japanese cruisers, all of which were started either before the war or during the early phases of it, emphasized the use of aircraft. The principal change in characteristics between MOGAMI and TONE classes was the increase in aircraft facilities provided for TONE. As stated above, by the end of the war, the use of so much valuable space that could have been devoted to armament was considered a mistake, hence the reversion of the original IBUKI design to MOGAMI instead of TONE class when construction was started.

3. This emphasis on the employment of scouting aircraft from cruisers is even more apparent in the change between the design of AGANO and OYODO classes. Again, in OYODO as in TONE, an after turret or mount was sacrificed, leaving the after gun arcs of the ship completely blind, so that six large scout planes might be carried on her after deck. As originally conceived, OYODO was to have worked with fleet submarines, her large shipborne aircraft spotting the targets, which the submarines were then to intercept and sink. The irony of the fate of OYODO was that even after her completion, no planes of the type she was designed to carry were ever built, and so she never was used as she was originally intended. Instead, her large after catapult was removed, a smaller one substituted in its place, and the hangar space converted into living quarters. After this conversion she was used as a fleet flagship and saw little real service.

4. The Japanese emphasized speed in their cruisers. ATAGO, finished in the early thirties, was designed for the high speed of 34.25 knots. To achieve this speed, sacrifices were made in protection, for all Japanese cruisers were lightly armored by U.S. Navy standards. The high speed achieved was obtained by using long hulls and large powers.

HEAVY CRUISER CHARACTERISTICS

			ATAGO	TONE	IBUKI*
Displacement,	Trial		14,670	14,000	13,890
	Full		15,751	15,200	14,828
	Light		11,960		11,440
LOA			668'5	201.6m(659')	200.6m(656')
LTWL			650'	198 (648')	198.3m(650')
B-TWL			64'	18.5m (60'7)	19.12m(62'4)
B-EXT			68'	19.4m (63'5)	20.2m(65'9)
HTWL			6.41m(21'03)	6.48m (21'2)	6.043m(19'7)
Depth			36'0	11.25m(36'8)	10.433m(34'4)
Longitudinal or Prismatic Coefficient			0.62	0.61	
Midship Section Coefficient			0.89	0.94	
Δ			1.33	1.38	
$\frac{\Delta}{(L/100)^3}$			51	51	
V DES			34.25 Kts	35.2 Kts	33 Kts
V trial					
SHP			133,000	152,000 (340 RPM)	152,000
Cruising Radius/Speed			8-9000mi/18 Kts	9.000mi/18 kts	8,150mi/14 Kts
Oil Capacity				3,000(2950)	2,163
Stability (Trial Cond.)	GM		1.51m(4'95)	1.6m(5'23)	1.48m(4'83)
	GZ		1.294m(4'22)	1.48m(4'83)	1.43m(4'68)
	Range		88.3°	Over 90°	85.8°
Strength	Hogging	Deck Tens.	9.36 tons psi	9.47 tons psi	
		Keel Comp.	7.79 tons psi	7.74 tons psi	
	Sagging	Deck Comp.	6.87 tons psi	7.11 tons psi	
		Keel Tens.	7.26 tons psi	7.49 tons psi	
Battery	Main	Bore/Caliber	20.3cm(8")/?	20.3cm(8")/?	20cm(7".87)/50 Cal.
		Type of Mount	Twin	Twin	Twin
		Angle of Elevation	53°	53°	
		No. of Guns	10	8	10
	Secondary	Bore/Caliber	12.7cm(5")/?	12.7cm(5")/?	12.7cm(5")/40 Cal.
		Type of mount	Twin	Twin	Twin
		Angle of Elevation			
		No. of Guns	12	8	8
	AA MG	Caliber	25mm	25mm	13.2mm 25mm
		Type of Mount	Singles Twins Triples	Singles Twins Triples	Twins
		No. of Guns	50-60	Abt 60	25mm 8 13.2mm 4
	Torpedo Tubes	Dia	61cm(24")	61cm(24")	61cm(24")
		Type of Mount	Quadruplets	Quadruplets	Quadruplets
		No. of Tubes	16	16	16
	Catapults		2	2	2
	No. of Planes		3-4	8	3
Protection	Main Belt	Machinery Spaces	4" NVNC	100mm(3".93)	100mm(3".93)NVNC-30mm(L".18)CNC
		Magazines	5" NVNC	145mm(5".72) Tapered to 55mm(2".17)	140mm(.".50)NVNC-30mm(1".18)CNC
	Decks	Machinery Spaces	1 3/8"	31mm(1".22)	35mm(1".38)CNC
		Magazines	1 7/8"	56mm(2".2)	40mm(1".57)CNC
	Barbettes		3" Sides 1½" ℄	25mm(0".987)	
	CT		5/8"	90mm(3".55) sides 40mm(1".57)top	
	Steering Gear		2" Sides 1" Top 1½" Ends	31mm(1".22)top 35mm(1".38) ends 100mm(3".93) sides	50mm(1".96)CNC-100mm (3".93)NVNC sides 30mm(1".18)CNC top
	Director Tubes		Abt. 3/4"	None	

*Design Particulars

LIGHT CRUISER CHARACTERISTICS

			AGANO	OYODO
Displacement		Trial	7,895	10,417
		Full	8,534	11,433
		Light	6,288	8,002
LOA			174.5m(571')	192m(630')
LTWL			172m (563')	189m(618')
BTWL			15.2m (49'8)	16.60m(54'3)
B-EXT			15.2m (49'8)	16.60m(54'3)
H-TWL			5.70m (18'6)	6.10m (19'9)
Depth			10.17m(33'2)	10.6m (34'7)
Longitudinal or Prismatic Coefficient			0.61	0.624
Midship Section Coefficient			0.84	0.849
$\frac{V}{\sqrt{L}}$			1.48	1.42
$\frac{\Delta}{(\frac{L}{100})^3}$			58	41
V DES			35.35	35.3
V Trial			35.45	35.2
SHP			100,170(355 RPM)	110,430(340.3 RPM)
Cruising Radius/Speed			6,178mi/18.44 Kts	10,619mi/18 Kts
Oil Capacity			1,405.404 tons	2,360 tons
Catapults			1	1
No. of Planes			2	6
Stability (Trial Cond.)		GM	1.01m(3'31)	1.39m(4'49)
		GZ	0.92m(3'03)	1.07m(3'49)
		Range	Over 90°	Over 90°
Strength	Hogging	Deck Tens.	7.53 tons psi	8.5 tons psi
		Keel Comp.	7.06 tons psi	7.56 tons psi
	Sagging	Deck Comp.	7.03 tons psi	7.36 tons psi
		Keel Tens.	8.51 tons psi	8.53 tons psi
Battery	Main	Bore/Caliber	15cm(5"9)/50 cal.	15.5cm(6"1)/?
		Type of Mount	Twin	Twin
		Angle of Elevation		
		No. of Guns	6	6
	Secondary	Bore/Caliber	8cm(3"15)/?	10cm(3"9)/?
		Type of Mount	Twin	Twin
		Angle of Elevation		
		No. of Guns	4	8
	AA MG	Caliber	25mm	25mm
		Type of Mount	Singles (18 mounts) Twins Triples (10 mounts)	Singles, Twins, Triples
		No. of Guns	About 40	About 50
	Torpedo Tubes	Diameter	61cm(24")	
		Type of Mount	Triple - changed to quads	
		No. of Tubes	6 - changed to 8	
Protection	Main Belt	Machinery	60mm(2"32)CNC	60mm(2"32)CNC
		Magazines	55mm(2"16)CNC	50mm(1"97)CNC
			(Interior armor)	(Interior armor)
	Decks	Machinery	20mm(0"79)CNC	25mm(0"98)CNC
		Magazines	20mm(0"79)CNC	50mm(1"97)CNC
	Mounts		Abt. 25mm(0"98) splinter protection	60-70mm(2"32-2"76)CNC & 30mm(1"18)CNC
	Barbettes		25mm(0"98)DS	25mm(0"98)DS
	C.T. (Steering Station)		40mm(1"58)CNC 20-25mm(0"79-0"98)CNC	40mm(1"58)CNC 20-25mm(0"79-0"98)CNC
	Steering Gear		20mm(0"79)CNC top 30mm(1"18)CNC sides 16mm(0"63)DS ends	40mm(1"58)DS 20mm(0"79)DS
	Director Tubes		8mm(0"315)DS	25mm(0"98)DS
Built at:			SASEBO	KURE
Completed:			1942	February 1943

*Protection of Oyodo unsubstantiated.

D. Destroyers: TERUTSUKI, ASASHIO, KAGERO classes.

1. The three classes of destroyers listed above represented the three latest destroyer design classes produced by the Japanese. Their destroyers, before TERUTSUKI class, were equipped with a heavy torpedo battery, and carried one reload per tube. The gun battery was concentrated aft, in both ASASHIO and KAGERO classes because there was not sufficient space to install two mounts forward, comfortably, without crowding the bridge structure into the smoke pipes. It is interesting to note that no helm control is provided on the bridge for either ASAHIO or KAGERO, steering control being located one deck below the bridge. Steering control was installed on the bridge, however, in TERUTSUKI class.

2. TERUTSUKI class of destroyers was a special design, with emphasis placed on anti-aircraft fire or gun fire against ships of a similar type rather than torpedo fire. A new gun mount was designed for this class, a high angle, high muzzle velocity and small bore (the diameter of the tube was only 10 cm.), with the primary function of shooting down aircraft.

3. Designed speeds of Japanese destroyers were not unreasonably high, in fact, considering the speeds with which their heavy and light cruisers were provided, it is surprising that they were not designed and built as faster ships.

4. The Characteristics of these three classes are tabulated on page 50. They were taken from Enclosures (197) through (225) and (282) through (283). The latter two enclosures also contain information on a few selected cruisers.

E. Escort Vessels: MATSU, MIKURA (UKU), SHIMUSHU, KAIBOKAN #1 and 2 classes.

1. There are few outstanding features incorporated in these vessels that require comment. MATSU was the forerunner of the later escort vessels, and in her original design was conceived as a shipshaped vessel built to conventional lines. When it became apparent to the Japanese that great numbers of escort vessels would be required to meet the menace of our submarine warfare, simplified lines were developed for MATSU, and the remainder of the escort program was started. The simplification of the lines to permit more rapid construction consisted primarily of developing lines that required flat plates and plates with curvature in only one direction. The ships were built in sub-assemblies as much as possible and erected on the building ways in blocks. The blocks were riveted together to form the ship.

2. The propelling plants with which these ships were equipped were as follows:

MATSU .... Steam turbines
MIKURA .... Two diesel engines
SHIMUSHU .... Two diesel engines
KAIBOKAN #1 .... Two diesel engines
KAIBOKAN #2 .... Steam turbine

3. The characteristics of the escort vessels are tabulated on pages 51 and 52:

DESTROYER CHARACTERISTICS

			TERUTSUKI	KAGERO	ASASHIO
Displacement		Trial	3,478	2,524	2,450
		Full	3,894	2,700	2,646
		Light	2,433		1,815
LOA			134.2m(440')	Abt. 117m(383')	Abt. 117m(383')
LTWL			132m (432')	116.2m(380')	115m(376')
BTWL			11.6m (38')	10.8m(35!8)	10.35m(34!3)
B-EXT			11.6m (38')	10.8m(35!8)	10.35m(34!3)
H-TWL			4.15m(13!5)	3.76m(12!3)	3.79m(12!35)
Depth			7.05m (23!0)	6.46m(21')	6.3m (20!6)
Longitudinal or Prismatic Coefficient			0.60	0.64	0.64
Midship Section Coefficient			0.87	0.82	0.80
$\frac{V}{\sqrt{L}}$			1.58	1.80	1.75
$\frac{\Delta}{(\frac{L}{100})^3}$			40.5	47.8	44.2
V DES			33 Kts.	35 Kts.	34 Kts.
V Trial			33.52 Kts.	35.2 Kts.	33.8/34.3 Kts.
Cruising Radius/Speed			8,381mi/18	5,000mi/18	4,500mi/18
Oil Capacity			1,072.16 tons	600 (594)	570 (563)
Stability		GM	1.07m(3!5)	1-0.95 m(3!27-3!10)	0.96m(3!13)
		GZ	0.672m(2!2)		0.587 m (1!91)
		Range	92.6°	85°-87°	95.6°
Strength	Hogging	Deck Tens.	8.2 tons psi	8.46 tons psi	8.54 tons psi
		Keel Comp.	6.95 tons psi	6.88 tons psi	6.52 tons psi
	Sagging	Deck Comp.	5.84 tons psi	6.53 tons psi	6.10 tons psi
		Keel Tens.	6.62 tons psi	6.99 tons psi	6.27 tons psi
Battery	Main	Bore/Caliber	10cm(3"94)/60 Cal.	12.7cm(5")/50 Cal.	12.7cm(5")/50 Cal.
		Type of Mount	Twin	Twin	Twin
		Angle of Elevation	90°	75°	75°
		No. of Guns	8	6	6
	AA MG	Caliber	25mm & 73mm	25mm	25mm
		Type of Mount — Designed:	Single & Triple	Twin	Twin
		Type of Mount — Altered:	Singles, Twins, Triples	Singles, Twins, Triples	Singles, Twins, Triples
		No. of Guns — Designed:	29	4	4
		No. of Guns — Altered:	About 30	About 25	About 25
	Torpedo Tubes	Diameter	61cm(24")	61cm(24")	61cm(24")
		Type of Mount	Quadruplet	Quadruplet	Quadruplet
		Mounts	1	2	2
		Reloads	One reload/tube	One reload/tube	One reload/tube
	Depth Charges	Number — DES	36	18	18
		Number — WAR	52	52	52
		Weight	200 Kg(440)	200 Kg(440)	200 Kg(440)

ESCORT VESSEL CHARACTERISTICS

			MATSU	MIKURA	SHIMUSHU
Displacement		Trial	1530	973.6	999.3
		Full	1690	1,052.2	1,096
		Light	1320	741.4	760
LOA			100m(327')	78.77m	77.7m
LTWL			98m (320')	76.5m	76.2m
B-TWL			9.35m(30!5)	9.1m(29!8)	9.1m(29!8)
H-TWL			3.4m(11!1)	2.948m	2.99m
Depth			6m (19!6)	5.354m	5.3m(17!3)
V DES			27.8	19.7	19.93
V trial			28.3	19.37	20.31
SHP			19,000	4,288	4,214
Longitudinal or Prismatic Coefficient			0.63	0.582	0.582
Midship Section Coefficient			0.80	0.796	0.807
		$\frac{V}{\sqrt{L}}$	1.55		1.24
		$\frac{\Delta}{(\frac{L}{100})^3}$	46.2	62.7	66.2
Cruising Radius/Speed			3500/18	2,040/19.37	7000/14
Oil Capacity			353 tons	133.85 tons	210.581 tons
Stability (Trial Cond.)		GM	0.95m(3!10)	0.827m	0.92m(3!02)
		GZ	0.45m(1!47)	0.25m(0!82)*	0.25m(0!82)
		Range	87°-88°	110°	110°
Strength	Hogging	Deck Tens.	6.4 tons psi	4.5 tons psi	4.5 tons psi
		Keel Comp.	5.5 tons psi	3.8 tons psi	3.8 tons psi
	Sagging	Deck Comp.	5.0 tons psi	3.5 tons psi	3.5 tons psi
		Keel Tens.	5.6 tons psi	4.2 tons psi	4.2 tons psi
Battery	Main	Bore/Caliber	12.7m(5")/ 40-45	12.0cm/45	12.0cm/45
		Type of Mount	1 Single, 1 Twin } HA	1 Single, 1 Twin } HA	1 Single (Surface Gun)
		No. of Guns	3	3	3
	AA MG	Caliber	25mm	25mm	25mm
		Type of Mount DES	Triple	Triple	Twin
		Type of Mount ALT	Single	Triple	Triple
		No. of Guns DES	12	15	2
		No. of Guns ALT	?	3	3
	Torpedo Tubes	Diameter	61cm(24")	None	N[illegible]
		Type of Mounts	Quad.	None	N[illegible]
		No. of Mounts	1	None	None
		Reloads	None	None	None
	Depth Charges	Number	36	120	36
		Weight	200kg(440#)	200kg(440#)	200kg(440#)
	No. of Throwers		1"Y"Gun	16-18 Singles	7"Y"Guns

*Light conditions.

ESCORT VESSEL CHARACTERISTICS (cont.)

	KAIBOKAN #1	KAIBOKAN #2
Displacement – Trial	810	900
Displacement – Full	850	1,000
Displacement – Light	740	740
LOA	67-68m (219'-222')	69-70m (226'-228')
LTWL	66(215')	66(215')
B-TWL	8.4m(27'4)	8.6m(28'2)
H-TWL	2.9m(9'5)	3.05m(10')
Depth	5.0m(16'3)	5.2m (16'9)
V DES	16.5	17.5
V Trial	16.8	18.0
SHP	1900	2500
Longitudinal or Prismatic Coefficient	0.56	0.56
Midship Section Coefficient	0.88	0.88
$\frac{V}{\sqrt{L}}$	1.24	1.16
$\frac{\Delta}{(\frac{L}{100})^3}$	80	79.5
Cruising Radius/Speed	6500/14	4500/14
Oil Capacity	100 Tons	240 Tons
Stability (Trial Condt.) – GM	0.77m(2'52)	0.82m(2'68)
Stability (Trial Condt.) – GZ	0.350m(1'14)	0.4m (1'31)
Stability (Trial Condt.) – Range	110°	100°
Strength – Hogging – Deck Tens.	4.0 tons psi	4.0 tons psi
Strength – Hogging – Keel Comp.	3.0 tons psi	3.0 tons psi
Strength – Sagging – Deck Comp.	2.8 tons psi	2.8 tons psi
Strength – Sagging – Keel Tens.	3.6 tons psi	3.6 tons psi
Battery – Main – Bore/Caliber	12.0cm/45	12.0cm/45
Battery – Main – Type of Mount	Single-HA	Single-HA
Battery – Main – No. of Guns	2	2
Battery – AA MG – Caliber	25mm	25mm
Battery – AA MG – Type of Mount – DES	Triple	Triple
Battery – AA MG – Type of Mount – ALT	Single	Single
Battery – AA MG – No. of Guns – DES	3	3
Battery – AA MG – No. of Guns – ALT	?	?
Battery – Torpedo Tubes	No Tubes Provided	No Tubes Provided
Battery – Depth Charges – Number	120	120
Battery – Depth Charges – Weight	200kg(440#)	200kg(440#)
Battery – No. of Throwers	12 Singles	12 Singles

F. Landing Craft - SB Type

1. Of the variety of landing craft the Japanese developed, their SB type falls between the U.S. Navy LSM and LST. It is smaller than the LST, but has a decked over tank compartment similar to it.

2. The craft was designed to land on a beach slope of 5°. The beaching characteristics were achieved by cutting up the bottom of the ship forward and fitting two runners or keels to the ship's bottom at the bow, the angle between the runners and the base line of the vessel being 5°. These ships were not built with a drag as were LST and LSM.

3. The tank capacity for the size of the ship was small. The tanks were discharged from the tank deck and upper deck in much the same manner as was used in later LST's. Enclosures (243) through (246) show the SB type landing craft.

4. The characteristics of this landing craft were as follows:

LARGE LANDING CRAFT, SB TYPE CHARACTERISTICS

Displacement, Trial	1020 tons
Displacement, Full	1100 tons
Displacement, Landing	1020 tons (includes water ballast)
LOA	80.5m (263')
LTWL	75m (245')
B-TWL	9.1m (29'7)
H-TWL	
Forward	2.67m
Aft	3.21m
Mean	2.94m(9'61)
Depth	5.6m (18'3)
V DES	16 Knots
SHP	2500
Longitudinal or Prismatic Coefficient	0.55
Midship Section Coefficient	0.91
$\frac{V}{\sqrt{L}}$	1.02
$\frac{\Delta}{(\frac{L}{100})^3}$	69.5
Cruising Radius - at 16 knots	1300mi
at 14 knots	1700mi
Oil Capacity	208 tons
GM	0.7m(2'28) (designed GM - 0.9m)
Range	Over 90°
Armament	
8cm(3"15) HA gun	1
25mm	15 - 2 twin, 11 single mounts
Tanks	
30 ton	5 - 3 in hold, 2 on upper deck
18 ton	7 - 4 in hold, 3 on upper deck
8 ton	9 - 5 in hold, 4 on upper deck

ENCLOSURE (A)

LIST OF DOCUMENTS FORWARDED TO BUREAU OF SHIPS

(The documents listed below are considered enclosures to this report for purposes of reference.)

Enclosure No.	NavTechJap No.		Contents
1	ND50-1000.1	YAMATO:	Weight tables
2.	.2		Center of gravity tests
3	.3		General arrangement
4	.4		General arrangement
5	.5		General arrangement
6	.6		General arrangement
7	.7		Stability curves
8	.8		Structural midship section
9	.9		Protection arrangement
9A	.10		Lines
10	ND50-1001.1	KATSURAGI:	Particulars
11	.2		Center of gravity test
12	.3		Stability
13	.4		Flooding calculations
14	.5		Stability tests
15	.6		Offsets
16	.7		Forward hull lines
17	.8		Lines drawing
18	.9		Forward body plan
19	.10		Aft body plan
20	.11		Displacement & other curves
21	.12		Displacement curves
22	.13		Height of decks and frame spacing
23	.14		Water & oil tight compartment
24	.15		Water & oil tight compartment
25	.16		Water & oil tight compartment
26	.17		Deck plans
27	.18		Deck plans
28	.19		Deck plans
29	.20		Deck plans
30	.21		Deck plans
31	.22		Water & oil tight compartment
32	.23		Structural midship section
33	.24		Shell expansion forward below lower deck
34	.25		Aft shell expansion under lower deck
35	.26		Shell expansion lower to uppermost deck
36	.27		Aft shell expansion between lower and uppermost deck
37	.28		Lower deck armor amidships
38	.29		Inner bottom plating
39	.30		Forward gasoline tank construction
40	.31		Transverse bulkheads 89,72,55
41	.32		Transverse bulkhead 8° below lowermost deck
42	.33		Transverse bulkheads 13,21,33, 55 above lower deck
43	.34		Armor arrangement

ENCLOSURE (A), continued

Enclosure No.	NavTechJap No.		Contents
44	ND50-1001.35	KATSURAGI:	Side armor construction amidships
45	.36		Fire main pipe, and drain pipe diagram
46	.37		Drainage pipe system
47	.38		Bilge pipe diagram
48	.39		Diagrammatic arrangement of gas system
49	.40		Diagrammatic arrangement of gas system
50	.41		Foam system
51	.42		Hangar foam sprinkling system
52	.43		Sprinkler system
53	.44		Aft ventilation diagram
54	.45		Forward ventilation diagram
55	.46		Ventilation of aft compartment surrounding gas tanks
56	.47		Elevator arrangement section
57	.48		Arrangement forward elevator side elevation
58	.49		Arrangement forward elevator plan view
59	ND50-1002.1	TAIHO:	Stability tests
60	.2		Stability data
61	.3		Lines drawing
62	.4		Body plan
63	.5		Displacement curves
64	.6		General arrangement
65	.7		Protection arrangement
66	.8		Structural midship section
67	.9		General description
67A	.10		Lines
67B	.11		Curves of stability
68	ND50-1003.1	SHINANO:	Explanation of stability
69	.2		Result of inclining experiment
70	.3		Forward structural section
71	.4		Aft structural section
72-1,-2,-3,-4	.5		General arrangement
73	.6		Armor arrangement
74	.7		Lines
78	.11		Structural midship section
79	ND50-1004.1	ATAGO:	Stability data
80	.2		Data on flooding
81	.3		Stability improvement tests
82	.4		Stability data
83	.5		Offsets
84	.6		Aft hull form
85	.7		Lines drawing
86	.8		Lines, hull form
87	.9		Stern profile
88	.10		Body plan
89	.11		Bow profile
90	.12		Displacement & other curves
91	.13		Displacement data
92	.14		Displacement tests at anchor
93	.15		Outboard profile

ENCLOSURE (A), continued

Enclosure No.	NavTechJap No.		Contents
94	ND50-1004.16	ATAGO:	Inboard profile
95	.17		Water & oil tight compartments
96	.18		Water & oil tight compartments
97	.19		Plan view of flight deck, AA gun deck & bridges
98	.20		Plan view of superstructure
99	.21		Plan view of upper deck
100	.22		Plan view of middle deck
101	.23		Plan view of lower deck
102	.24		Plan view of hold deck
103	.25		Plan view of hold
104	.26		Structural midship section
105	.27		Structural midship section
106	.28		Various transverse sections
107	.29		Protection arrangement
108	.30		Protection arrangement
109	.31		Fire main pipe & other diagrams
110	.32		Fire prevention sprinkler system for AA guns & bridge decks
111	.33		Fire prevention piping for middle & upper deck
112	.34		Fire control sprinkler system for holds, lower and middle decks
113	.35		Fire prevention piping for ships hold & lower deck
114	.36		Fire prevention piping for ship's hold & bottom
115	.37		Profile of drainage control system
116	.38		Plan view of drainage control system
117	.39		Forward drain pipe system
118	.40		Midship drain pipe system
119	.41		Aft drain pipe system
120	.42		Ventilation diagram
121	.43		Bridge ventilation system
122	.44		Ventilation system for upper & AA gun decks
123	.45		Ventilation system for lower & middle decks
124	.46		Ventilation system for hold & hold deck
125	ND50-1005.1	TONE:	Stability test results
126	.2		Stability data
127	.3		Flooding data
128	.4		Flooding data
129	.5		Offsets
130	.6		Lines drawing
131	.7		Displacement curves
132	.8		General arrangement, outboard profile & superstructure plan
133	.9		Water-tight compartments, etc.
134	.10		Water- & oil-tight compartments
135	.11		Structural midship section

ENCLOSURE (A), continued

Enclosure No.	NavTechJap No.		Contents
136	ND50-1005.12	TONE:	Structural forward section
137	.13		Structural aft section
138	.14		Profile
139	.15		Forward profile
140	.16		Forward shell plating arrangement
141	.17		Aft shell plating arrangement
142	.18		Midship shell plating arrangement
143	.19		Armor arrangement
144	ND50-1006.1	IBUKI:	Designed particulars
145	.2		Designed weight & C.G.
146	.3		Lines
147	.4		Body plan
148	.5		Fire main & drain pipe diagram
149	.6		Drain pipe diagram
150	.7		Forward ventilation diagram
151	.8		Aft ventilation diagram
152	ND50-1007.1	SAKAWA:	Particulars
153	.2		Weight & C.G. tests
154	.3		Stability
155	.4		Lines
156	.5		Body plans
157	.6		Displacement & other curves
158	ND50-1007.7	YAHAGI:	General arrangement profile, Upper plan & bridge plan
159	.8		General arrangement, profile & upper deck
160	.9		General arrangement, sections
161	.10		General arrangement: Main deck, lower deck & hold deck
162	.11		General arrangement: Hold & double bottom
163	ND50-1007.12	SAKAWA:	Water & air tests for water, oil & air-tight compartments
164	.13	NOSHIRO:	Structural section, forward & aft
165	.14	YAHAGI:	Structural section, forward & aft
166	.15	SAKAWA:	Transverse bulkheads below middle deck
167	.18		Gasoline tanks
168	.19		Armor arrangement
169	.20	YAHAGI:	Fire main pipe diagram
170	.21	SAKAWA:	Partial drainage diagram
171	.22		Ventilation diagram forward
172	.23		Ventilation diagram, aft
173	.24	NOSHIRO:	Structural midship section
174	ND50-1008.1	OYODO:	Particulars
175	.2		Test results of C. of G.
176	.3		Designed weights & C.G.'s
177	.4		C.G. test results
178	.5		Trim curves for various speeds
179	.6		Flooding data
180	.7		Stability notes

ENCLOSURE (A), continued

Enclosure No.	NavTechJap No.		Contents
181	ND50-1008.8	OYODO:	Lines drawing
182	.9		Offsets
183	.10		Body plan
184	.11		Displacement curves
185	.12		Outboard profile
186	.13		Inboard profile
187	.14		Inboard profile
188	.15		Inboard profile
189	.16		Inner bottom plating & longitudinal butts
190	.17		General arrangement, upper decks
191	.18		Upper deck structure, forward
192	.19		Midship section
193	.20		Structural midship section
194	.21		Profile of construction
195	.22		Rudder head, support of
196	.23		Emergency rudder
197	ND50-1009.1	HARUTSUKI:	Particulars
198	.2		Results of C.G. tests
199	.3		Stability
200	.4		Characteristic curves
201	.5	TERUTSUKI:	Lines
202	.6		Body plan
203	.7	HATSUZUKI:	Outboard profile & superstructure plan
204	.8		Inboard profile, main deck & bridges
205	.9		Sections & double bottom plan
206	.10		Deck & hold plan
207	.11	TERUTSUKI:	General arrangement after alteration
208	.12		General arrangement after alteration
209	.13	NATSUZUKI:	Structural forward & aft sections
210	.14	HATSUZUKI:	Shell plating
211	.15		Forward transverse compartments
212	.16		Forward compartments
213	.17	HARUTSUKI:	Diagrammatic piping arrangement
214	.18	NATSUZUKI:	Ventilation diagram
215	ND50-1010.1	KAGERO:	Midship section
216	.2		General arrangement
217	ND50-1011.1	MICHISHIO:	C. of G. tests after alteration
218	.2		Light condition calculation
219	.3		Stability
220	.4		Displacement & other curves
221	.5		Midship section
222	.6	OYASHIO:	Piping diagram
223	.7	ASASHIO:	Piping diagram
224	.8		Ventilation diagram
225	.9	OYASHIO:	Ventilation diagram
226	ND50-1012.1	UKU:	Particulars
227	.2	UKU, KUGA:	Offsets
228	.3	UKU:	Outboard profile, main deck & bridges

ENCLOSURE (A), continued

Enclosure No.	NavTechJap No.	Contents	
229	ND50-1012.4	UKU:	Inboard profile, main deck arrangement
230	.5		Arrangement sections
231	.6		Lower deck & hold plan
232	ND50-1013.1	ETOROFU:	Particulars
233	.2		C. of G. tests
234	.3		Wt. & stability curves
235	.4		Flooding
236	.5		Lines
237	.6		Displacement & other curves
238	.7		Outboard profile main deck & bridges
239	.8		Inboard profile & bridges
240	.9		Arrangement sections
241	.10		Various deck plans
242	.11		Structural midship section
243	ND50-1014.1	LSM:	Bow door construction
244	.2		Arrangement of bow & deck ramp operating gear
245	.3		Arrangement of shell plating
246	.4		General arrangement
247	ND50-1015.1	Armor plate	
248	.2	Experiment on riveted joints	
249	.3	Riveting instructions for cruiser SAKAWA	
250	.4	Historical development of the application of electric arc welding on hull of Japanese warship	
251	.5	Rules for inspection of welding on hull construction	
252	.6	Welding symbols & types of connections	
253	.7	Practical application of welding to naval surface vessels	
254	.8	Results of testing welding on armor plate	
255	.9	Records of methods of erection of BB YAMATO: four blueprint leaflets	
256	.10	Weight classification pamphlets	
257	.11	Comparison of weights of various ships for weight estimating	
257½	.11A	Comparison of calculated & actual weights for various destroyers	
258	.12	Stability tables of various ships	
259	.13	Warship construction and equipment, two volumes	
260	.14	Data for the structural design of our ships (recent cruisers & destroyers)	
261	.15	Longitudinal stress data for miscellaneous ships	
262	.16	Limits of plating requiring compensation for holes cut in strength deck or shell plating CV KATSURAGI	
263	.17	Comparative midship sections, battleships	
264	.18	Comparative midship sections, aircraft carriers	
265	.19	Comparative midship sections, cruisers	

ENCLOSURE (A), continued

Enclosure No.	NavTechJap No.	Contents
266	ND50-1015.20	Comparative midship sections, torpedo boat destroyers
267	.21	Specifications for welding of small fillings on warships
268	.22	Reinforcing in way of uptakes on uppermost deck, KATSURAGI
269	.23	Deflection of main bulkhead of TBD by water pressure
270	.24	Typical bilge keel
271	.25	Shaft structure of TBD ODORO (FUBUKI Class)
272	.26	Rudder framing & scantling plan, KATSURAGI
273	.27	Rudder framing & scantling plan, KATSURAGI
274	.28	Principal items of ships, SAKAWA & UKIKAZE
275	.29	Ventilation research by Mr. ETO
276	.30	Specifications for piping, KAIBOKAN Type D
277	.31	Tables for ventilating equipment, ordinary warships
278	.32	Armor joint calculations
279	.33	Armor gratings, KATSURAGI
280	.34	Ventilation calculations, SHOKAKU
281	.35	Graphical explanation of steering apparatus by oil pressure
282	.36	General arrangement of miscellaneous warships
283	.37	General arrangement of TBD's

No protection arrangement plan was prepared for SHINANO, as her protection system was essentially the same as YAMATO.