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INDEX NO. S-01-4

SHIP AND RELATED TARGETS

CHARACTERISTICS OF JAPANESE NAVAL VESSELS
ARTICLE 4
SURFACE WARSHIP MACHINERY DESIGN
(PLANS AND DOCUMENTS)

U.S. NAVAL TECHNICAL MISSION TO JAPAN

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

21 December 1945

RESTRICTED

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

Subject: Target Report - Characteristics of Japanese Naval Vessels, Article 4.

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

1. Subject report, covering the machinery design of Japanese surface warships as exemplified by plans and documents, 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 target report were accomplished by Capt. F.W. Slaven, USN, assisted by Lt.(jg) T.S. Montgomery, USNR, as interpreter and translator.

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Captain, USN

RESTRICTED S-01-4

CHARACTERISTICS OF JAPANESE NAVAL VESSELS
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"INTELLIGENCE TARGETS JAPAN" (DNI) OF 4 SEPT. 1945

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

DECEMBER 1945

U.S. NAVAL TECHNICAL MISSION TO JAPAN

SUMMARY

SHIP AND RELATED TARGETS

CHARACTERISTICS OF JAPANESE NAVAL VESSELS - ARTICLE 4
SURFACE WARSHIP MACHINERY DESIGN (PLANS AND DOCUMENTS)

Piping systems and the location of the machinery were the most interesting features of Japanese warship design. Documents concerning typical ships of each warship type were studied and generally indicated the following:

BB YAMATO: The firerooms were an outgrowth of NACHI class (CA). The main auxiliary steam and feed systems were, however, different.

CA MOGAMI: It is probable that the piping system of this class and that of the UNRYU class (CV) were much the same.

ATAGO class (CA): Ships of this class were much like that of NACHI class. This class moreover, indicates the gradual change that took place in Japanese cruiser machinery design.

CL OYODO: This ship, the latest Japanese CL, followed the general arrangement of six-boiler cruiser. Its main plant arrangement was very similar to AGANO class. It should be noted that OYODO had center line bulkheads in the forward boiler rooms and after enginerooms.

AGANO class (CL): The arrangements and system of this class were generally typical of other contemporary Japanese vessels. It differed but slightly from OYODO.

DD TERUTSUKI: She was typical of the latest DD design.

DD KAGERO: The machinery arrangements were very similar to TERUTSUKI class.

DD SHIMAKAZE: The machinery arrangements were much like that of TERUTSUKI class. It was an experimental type as far as the engineering plant was concerned.

MATSU class (DE): This class was the first and only class of warships to have a machinery arrangement of fireroom - engineroom - fireroom - engineroom. There was no cross connection between the high pressure sides of the main feed systems of the two boiler rooms, or the high pressure sides of the fuel oil systems so characteristic of other Japanese vessels. The float control tank on the condensate systems was also different. Cruising turbines and connected lines were removed after they were found to be impractical.

UNRYU class (CV): The main machinery plant was somewhat similar to OYODO, but of greater horsepower. The extensive firemain system in the machinery spaces was peculiar to carriers and more like the system of U. S. naval vessels insofar as the piping layout was concerned.

TABLE OF CONTENTS

REFERENCES

Location of Target:

Japanese Navy Technical Department.

Japanese Navy Yards.

Japanese Personnel Who Assisted in Gathering Documents:

Rear Adm. I. KONDO, IJN.

Rear Adm. AMARI, IJN.

Japanese Personnel Interviewed:

Rear Adm. I.KONDO, IJN.

Rear Adm. AMARI, IJN.

Capt. (Tech) YASUGI, IJN.

Comdr. (Tech) IDA, IJN.

LIST OF ENCLOSURES

(A) List of Documents Sent Directly to the Bureau of Ships

INTRODUCTION

The following report is based almost entirely on seized documents, which have been forwarded under separate cover to the Chief of the Bureau of Ships (See Enclosure A). It is believed that the piping diagrams, which in most cases are divided into two volumes, one for enginerooms and one for firerooms, will give a clear picture of the engineering layout. Pipe sizes shown on these diagrammatic sketches are in millimeters. Not all of the Japanese characters have been translated, because too much of the print would have been obliterated. However, it is considered that sufficient translation has been made for an understanding of the print.

A translation of the Machinery design specifications for at least one representative ship of each type (BB, CA, CL, DD, and DE) has been included in the text. These specifications, though brief, correspond most closely to U. S. Navy Specifications for Machinery.

In the case of a few ships, certain lists of machinery installed, with its characteristics, have been extracted from reports of machinery trials. Where available, summaries of these trials have been extracted.

In the case of at least one ship of each type, the column headings of the tabulated trial results have been translated for one run so that the data for that run may be studied if desired. Because of the shortage of translators, it was not considered justifiable at the time this report was prepared to translate all of the machinery trials. However, such records as were found have been forwarded to make them available for translation at a later date, if further detailed study of the plans is desired.

Attention is invited to the fact that all units in this report are metric. All temperatures are centigrade. The following conversion factors will be found convenient in reading the report. Some of these factors have been obtained directly from a handbook, while others were computed and are correct only within slide rule accuracy.

Pressure, 1 kg/sq. cm	14.223 lb/sq. in (roughly 15)
Length, 1 mm	.03937 in (roughly .04 in)
Vacuum, 760 mm	30" hg roughly
1 sq. meter	10.764 sq. ft
1 cu. meter	35.3 cu. ft
1 cu. meter/hr	4.4 gal/min

All of the documents are listed in Enclosure (A), but for the reader's convenience they will be referred to in the text by their NavTechJap Document Numbers and not by the conventional method, i. e. ref. (a), ref. (b), etc.

THE REPORT

Part I - YAMATO (BB)

YAMATO was the latest BB and therefore typical of the latest BB design. The main machinery, however, except for the boilers, appears to have been an outgrowth of NACHI class (CA) machinery plant. The firerooms were arranged and operated somewhat like two six-boiler cruisers side by side, with respect to cross connections of fuel, etc. The main and auxiliary steam and feed systems differed in that each group of three boilers in a fore and aft row constituted a unit with the engineroom directly aft.

The following translation of NavTechJap Document No. ND50-1026, "Machinery Design Requirements, YAMATO Class Battleship", has purposely not been edited to avoid the introduction of errors. All units are metric.

* * * * *

SPECIFICATIONS OF ENGINES FOR SHIP MODEL NO. 1 (BB YAMATO)
NAVY TECHNICAL DEPT., 1937

1. General arrangement of engines - see plans

2. Main engines

(a) General equipment

(1) The main engines consist of high pressure turbines and low pressure turbines connected by reduction gear equipment to a single shaft. Each of the four independent enginerooms has one shaft.

(2) An astern turbine is housed in each of the low pressure turbine casings.

(3) Cruising turbines are connected with each shaft's inboard high pressure turbine by means of cruising reduction gear equipment. The exhaust is connected to the first stage of the same high pressure turbine.

(b) Specified power of main engines

(1) Regarding the specified amount of the total power of the main engines in forward motion, the propeller makes 225 RPM, and under normal conditions, one shaft develops 37,500 hp and all four shafts develop 150,000 hp. The main engine must be able to bear an overload of 10%.

(2) Total specified power astern with the propeller making 150 RPM amounts to 11,000 hp for one shaft and 44,000 for all four shafts.

(3) The specified power of the cruising turbine and the specified revolutions of the main shaft are as follows:

Cruising power ..... 22,000 hp, 116 RPM
Total in excess of cruising power ..... 30,000 hp, 130 RPM
Maximum permitted cruising power ..... 42,000 hp, 146 RPM

(c) Amount of steam consumed by main engines

	Steam chest pressure kg/sq. cm	Temperature °C	Vacuum mm	Steam Consumption kg/shp/hr
Specified power	21	310	700	4.1 or less
Cruising power	21	310	725	5.0 or less

(d) Condenser equipment - The condensers are single-pass mounted under each low pressure turbine. The following auxiliary machinery is installed: Eight main condensate pumps - axial flow type connected to turbine speed reduction gear, sixteen main water intake pumps - centrifugal type connected to turbine speed reduction gear, eight air ejectors - two-step, triplex steam ejector type.

3. Shafts and propellers

(a) The shafting consists of thrust shaft, intermediate shafts, stern tube shaft and propeller shafts. The outboard shafts have three intermediate shafts and the inner shafts have five each. Aside from the thrust bearing, all bearings are self-lubricated.

(b) The propeller is made of manganese bronze and has a diameter of 5000 mm.

4. Boilers

(a) The boilers are Mark RO, Bureau Type, heavy oil burning boilers with superheaters and air preheaters. There are 12 in number, one boiler in each boiler room.

(b) The boiler rooms are open firerooms.

(c) The main specified characteristics of the boilers are as follows:

Specified pressure, steam drum ..... 27 kg/sq. cm
superheater outlet ..... 25 kg/sq. cm
Steam temperature ..... 325°C (combustion rate 4.44 kg/sq. meters)
Specified rate of combustion ..... 5.6 kg/sq. meters
Heating surface ..... about 1060 sq. meters

The boiler must be capable of being used safely at the rate of combustion of 8.0 kg/sq. meter.

(d) Oil injection equipment (for one boiler):

Cones ..... Bureau Type 15, Model 5; 9 per boiler
Atomizers ..... Bureau Type 16, Model 3; 7 per boiler
Bureau Type 16, Model 5; 2 per boiler

5. Uptakes and stacks

There is a single stack and it must be constructed so as to have sufficient strength to resist bomb attacks and the effects of bomb blast.

A drain elimination system is provided in the uptakes and stacks and a fixed rain cover is provided only where the rain cannot be taken care of by the drain elimination.

6. Pipes, valves, and various equipment

(a) Large type pipe guards

(b) Pipes are Grade A in thickness, but where pressures of 30 to 40 metric tons are usual, special provision will be made.

(c) Regarding various other equipment, it is planned to make four independent battle compartments by arranging three boilers to one shaft.

7. Auxiliary machines

(a) Auxiliary machinery in the engineroom:

Name	Type	Number
Lube oil pumps	Screw type turbo-red. gear	12
Oil cooler pump	Axial flow turbo-red. gear	4
F&B pump	Elect. centrifugal	5
Supply vent	Elect. axial flow	10
Exhaust vent	Axial flow turbo-red. gear	14
Exhaust vent	Elect. axial flow	10
Supply vent	Axial flow turbo-red. gear	4
Oil purifier	Elect. centrifugal	4
Feed heater	Vertical surface type	4
Evaporators	Spiral coil type	4
Evaporator pumps	Combination turbo-drive	2
Auxiliary evaps	----------	2
Oil cooler	Vertical; internal, water; external, oil	8
Fuel oil transfer pump	Electrically operated gear type	2

(b) Auxiliary machinery in the boiler rooms

Name	Type	Number
Main feed pumps	Centrifugal turbo-red. gear	12
Aux. feed pump	Weir reciprocating	12
Blowers	Axial flow, vertical, turbo-red. gear	24
FO service pump	Screw type, vertical, turbo-red. gear	12
Lube oil and lube oil cooler pump	Combination pump, turbo-drive	12
F&B pump	Elect. centrifugal	6
Ignition fuel oil pump	Elect. gear type	2
Feed heater	Vertical, surface type	12
Fuel oil heater	Vertical, bent tube type	12
Oil cooler	Vertical; internal, water; external, oil	12

(c) Auxiliary machinery outside of the engine room:

(1) Steering engine and equipment for same: each main rudder is equipped with an independent auxiliary rudder. The maximum amount of torque from flow of water which the rudder surface can stand in one complete turn from full rudder one way to full rudder the other way in 30 seconds is as follows:

Forward motion, main ..... 346 meter-tons
Astern, main ..... 235 meter-tons
auxiliary ..... 68.7 meter-tons

Further, the steering engines, both main and auxiliary, are electrically operated, hydraulic plunger type and besides, they are equipped with hand-operated oil pumps.

(2) Anchor windlass and equipment for same: the anchor windlass is an electrically operated type and has the power to raise a gross weight of 94 metric tons at a speed of nine meters per minute.

(3) Repair equipment: the repair equipment is standard.

(4) Fuel oil transfer pumps: the transfer of fuel oil outside of the machinery spaces is done by the following electric gear pumps:

20 pumps for emergency correction of list or trim
4 pumps for general use

(5) Hydraulic pumps: the turbines are directly connected to centrifugal pumps. There are a total of four pumps, three main and one reserve. The turbine has independent water condensing equipment. The capacity of each pump is as follows:

Specified capacity - 800 cu. m/hr with a pressure of 70kg/sq. cm
Overload capacity - 1100 cu. m/hr with a pressure of 60kg/sq. cm

Note: With regard to the reserve pump, depending on the circumstances, the intention is to use two pumps with a capacity of 400 cu meters/hr.

8. Gross weight of engines, official test conditions, metric tons:

Main engines	1028
Shafting and propellers	589
Auxiliary engines	480
Boilers	918
Uptakes and stacks	320
Piping, valves, cocks	640
Miscellaneous	388
Water	450
Hydraulic engines	230
Total	5043

9. Official test run

The official test run was carried out in accordance with the revised rules prescribed for ship construction and its details will be given separately.

* * * * *

The following are tables of machinery installed in the vessel as translated from the Machinery Trial Report (NavTechJap Document No. ND50-1046). The translation is rather literal, a centrifugal pump being referred to as a vortex pump, etc.

AUXILIARY ENGINES - YAMATO (BB)

	Name		Model / Type	Power Unit Type, #	Power Output M^3/hr.	Cylinder Turbine Diameters (mm)	Stroke (mm) or Stages	Pumps & Fan Diameters (mm)	Number of Pieces
Distiller Room	Aux. Air Ejector		2 Stage Double Steam Injection	----------	45 tons/hr	------	----	------	2
	Drain Cooler		?	----------	20	Cooling Area 33.4 sq. m			2
	Drain Cooler for Distiller		?	-------- -		Cooling Area 20.35 sq. m			2
	Fuel Oil Suction Pump		Side Gear Type	Direct Electricity	10	------	----	Diam x Width 65 x 35 x 2	2
	Fire Bilge Pump	Fire	Longitudinal Vortex Type	Direct Electricity	30	------	----	320	1
		Bilge			60	------	----	320	
Boiler Room	Main Feed Water Pump		Lateral Vortex Type	Reduction Gear Turbine	100	270	1	280	12
	Aux. Feed Water Pump		#D7 "Weir" Direct Drive Type	Piston Engine	90	420	550	300	12
	Feed Water Heater		?	----------	Heated Fluid 80	Heating Area 36 sq. m			12
	Fuel Oil Atomizer Pump		Longitudinal Screw Type	Reduction Gear Turbine	12	180	1	Main Drive Shaft Diam. (52) x Length (310)	12
	Fuel Oil Heater		Longitudinal Bent Tube Type	----------	Heated Fluid 8	Heating Area 4.04 sq. m			12
	Fuel Oil Ignition Pump		Side Gear Type	Direct Electricity	0.5	------	----	Diam. x Width 32 x 14	2
	Blower		Inverted Axial Flow Type	Reduction Gear Turbine	22 m^3/sec	270	1	895	24
	Lube Oil & Cooling Water Pump	Lube Oil	Side Gear Type	Reduction Gear Turbine	15	180	1	Diam x Width 45 x 55 x 2	12
		Cooling Water	Lateral Vortex Type		36			110	
	Oil Cooler		Longitudinal Inside Water Outside Oil Type	----------	Cooled Fluid 15	Cooling Area 13.98 sq. m			12
	Fire and Bilge Pump	Fire	Longitudinal Vortex Type	Direct Electricity	30	------	----	320	6
		Bilge			60	------	----	320	
	Control Room Blower		"Schlock" Type	Direct Electricity	0.5 m^3/sec	------	----	213	12
Others	Forward Anchor Engine		Gear Type	Direct Electricity	Main Anchor Wt. 12.5 tons	Test Load (tons) x Test Speed (m/min) 93.75 x 9			1 set
	Main Steering	Striker ? Head	Rapson Slide Type	Hydro Electric Striker Head Type	Rudder Torsion Lift Rate ?		1400.7	450	1 set
		Elec.Oil Press.Pump	"Junne" - K12		Full Advance Power 358.1 meter-tons Full Backing Power 235.8 meter-tons		47.232	54	
	Secondary Steering	Striker ? Head	Connecting Rod Type	Hydro Electric Strike Head Type	Rudder Torsion Lift Ratio ?		860.4	375	1 set
		Elec.Oil Press.Pump	"Junne" - K12		Full Advance Power 123.2 meter-tons		54.35	42	
		Manual Oil Press.Pump	2 Pump.Type		Full Backing Power 69.3 meter-tons		130	80	
	Fuel Oil Transfer Pump		Side Gear Type	Direct Electricity	100	------	----	Diam x Width 90 x 70 x 4	20
	Machine Shop Blower	Feed Air	Lateral Axial Flow	Direct Electricity	2 m^3/sec	------	----	395	1
		Exhaust	Lateral Axial Flow	Direct Electricity	3 m^3/sec	------	----	494	1
	Furnace Blower		Side Roots Type	Direct Electricity	3 m^3/min	------	----	Rotor Diam. x Width 200 x 130	3

AUXILIARY ENGINES - YAMATO (BB) (Cont'd)

	Name		Model Type	Power Unit Type and No.	Power Output M^3/hr.	Cylinder or Turbine Diameter (mm)	Stroke (mm) or Stages	Pump and Impeller Diameters (mm)	No. of Pieces of Equipment
Main Engineroom	Air Injector		2-Stage Triple, Steam Injection	-----	135 tons hr	----	-----	----	8
	Main Condensate Pump		Longitudinal Vortex Type	Turbine With Red. Gear	80	180	1	280	16
	Main Water Circulating Pump		Lateral Axial Flow Type	Turbine With Double Reduction Gear	6,000	270	1	656	8
	Lube Oil Pump		Longitudinal Gear Type	Turbine With Reduction Gear	100	180	1	?	12
	Cooling Water Pump		Longitudinal Axial Flow	Same as above	400	180	1	170	4
	Oil Cooler		Longitudinal Inside Air Outside Oil Type		Amount of Cooled Fluid 100	Cooling Area 59.6 sq. meters			8
	Oil Purifier		Hitachi #350	Direct Electricity	1300 ltrs hr	----	-----	----	4
	Engine Room Blower	Feed Air	Lateral Axial Flow Type	Direct Elect. Turbine With Red. Gear	13 m^3/sec	----	-----	895	8
						180	1	895	4
		Exhaust Air	Same as above	Direct Elect. Turbine With Red. Gear	16 m^3/sec	----	-----	945	8
						180	1	945	4
	Feed Water Heater		?		Amount Heated 260	Heating Area 43.8 sq. meters			4
	Control Room Air Blower (feed)		Shlock Type	Direct Electricity	0.5 m^3 sec	----	-----	213	5
	Fire and Bilge Pump	Fire	Longitudinal Vortex Type	Same	50	----	-----	380	4
		Bilge			100	----	-----	380	
	Intermediate Bearing Cooling Water Pump		Same as above	Same	30	----	-----	135	4
Distilling Plant Room	Distiller	Evaporator	Bu Ships Type	----	144 tons Daily	Heating Area 49.77 sq. m			4
		Distiller	?	----	288 tons Daily	Cooling Area 66.48 sq. m			4
		Distiller Air Ejector	1 Stage Single Steam Injection Type	----	20 tons hr	----	-----	----	2
		Feed Water Heater	?	----	Amount Heated 20	Heating Area 3.68 sq. m			2
		Auxiliary Pumps: Water Circulating	Lateral Vortex Type	Turbine With Reduction Gear	400			230	
		Auxiliary Pumps: Brine	Same as above		40	180	1	205	2
		Auxiliary Pumps: Fresh Water	Same as above		20			230	
	Blowers	Feed Air	Lateral Axial Flow	Direct Elect.	11 m^3/sec	----	-----	794	2
		Exhaust	Same as above	Same as above	13 m^3/sec	----	-----	895	2
	At Anchor Water Pump		Lateral Vortex Type	Direct Elect. With Accelerators	20	----	-----	166	2
	Auxiliary Condenser		?	----		Cooling Area 97.31 sq. m			2
	Auxiliary Water Circulating and Condensate Pump	Condensate	Lateral Vortex Type	Direct Electricity	25		-----	330	2
		Circulating	Same as above	Same	50		-----	215	

The following table of trial results has been translated from the Machinery Trial Report (NavTechJap Document No. ND50-1046).

TRIAL RESULTS - YAMATO (BB)

Trial Tests					Full Overload Power	Officially Tested Full Power	Greatest Curising Speed	Cruising Full Power	Standard Speed	Officially Tested Full Power (end)	
Dates & Places of Tests					22 June 1942 Sada Misaki Pylon		25 June 1942 Sada Misaki Pylon			24 June 1942 Sada Misaki Pylon	
				Specifications	Leaving Harbor	Entering Port	Leaving Port		Entering Port	Leaving Port	Entering Port
When Entering & Leaving Port	Draught	Forward	m		10.31	10.24	10.29		10.25	10.41	10.36
		Aft	m		10.76	10.72	10.72		10.69	10.78	10.72
		Average	m		10.54	10.48	10.51		10.47	10.60	10.54
		Amidships	m		10.63	10.55	10.58		10.56	10.67	10.61
	Displacement		Metric tons	69,935	70,602	70,132	70,379		70,174	70,811	70,467
At Time of Trial Run	Draught	Forward	m		10.26	10.28	10.28	10.28	10.28	10.38	
		Aft	m		10.74	10.75	10.71	10.71	10.72	10.76	
		Average	m		10.50	10.52	10.50	10.50	10.50	10.57	
	Displacement		Metric tons	69,935	70,358	70,433	70,302	70,328	70,342	70,638	
	Water Temperature		Degrees		18	18	18	18	19	22	
	Max. area cut across below water line		m^2		400.3	401.1	400.3	400.3	400.3	403.0	
Most recent date of leaving dry-dock & extent of fouling on bottom					9 June 1942, None					16 July 1942, None	
Full load of fuel			Metric tons		5,264.86						
Speed			Knots	27.0	28.05	27.61	21.69	19.36	16.16	27.62	
Shaft H.P.				150,000	167,310	154,470	44,560	30,341	17,527	153,930	
No. of Revolutions of screw shaft			Per Minute	225.0	230.0	224.9	156.4	139.1	115.9	224.3	
Wt. of steam consumed per hr. per. shaft H.P.	Main Engines		kg	4.1 or less	Not Calculated						
	Main & Aux. Engines Total		kg		Not Calculated						
Wt. of Fuel consumed per. hr. per. shaft H.P.			kg		0.354	0.359	0.399	0.432	0.455	0.355	
Fuel consumed per. hr. per. cm^2 heating surface			kg	4.5	4.66	4.36	2.80	3.09	1.85	4.29	
Amt. of water per 1,000 H.P. each 24 hrs.			Metric tons		Not Calculated						
Cruising	Each metric ton of fuel		Nautical Miles		0.473	0.498	1.22	1.48	2.03	0.506	
Distance	Full amt. of fuel		Nautical miles		2,366	2,493	6,095	7,392	10,141	2.530 (?)	

Part II - MOGAMI (CA)

Unfortunately, no machinery booklets for this class were located. It was verbally reported that piping arrangements were the same as UNRYU class (CV). However, an examination of NavTechJap Document No. ND50-1016 indicates that this could not be exactly true because of the arrangement of the main engines which is peculiar to this class. It is noted from the above document that the outboard engines were in the after enginerooms and the inboard engines in the forward enginerooms.

Aside from this rather unusual feature, it is very probable that the piping system of this class and UNRYU class carriers was much the same.

It was also reported, that TONE class had the same machinery plant as MOGAMI class. The first two ships of MOGAMI class were built with 10 boilers, which were cut to eight by improvements in boiler design.

A translation of the "Machinery Design Requirements", (NavTechJap Document No. ND50-1032) for SUZUYA and KUMANO (CA) follows. This is the only publication which approaches the U.S. Navy Special Specification for Machinery. The translation has been kept as literal as possible.

* * * * *

PLANS AND SPECIFICATIONS
NAVY TECHNICAL DEPARTMENT: TOP SECRET NO. 8-1

Approved 16 July 1935, Navy Technical Department, Top Secret No. 210

SUZUYA and KUMANO (CA)
Engine Plans and Specifications

CAUTION

i. This document must be handled with the utmost secrecy.

ii. This document must not be copied, summarized, or handed over to other persons. It must not be given over for inspection to those not concerned in the project.

iii. This document must be returned to the Navy Technical Dept. when it is no longer being used.

Table of Contents

14. Blower system
15. Steering system
16. Anchor windlass
17. Shop machinery
18. Overall weight of engines

1. General hull specifications

Under trial conditions the specifications are:

Length along water line	198.2 meters
Beam	18.0 meters
Draft	5.96 meters
Displacement	12,450 metric tons

2. Acceptance run

(a) The acceptance run shall be in accordance with Plan B as stipulated in Ship's Servicing Regulations No. 97 of 11 August 1931. Details will be prescribed by the Chief of the Navy Technical Department.

(b) Provision shall be made for the use of closed steam exhaust to heat the water supply during the various types of runs. When there is an excess of exhaust, it shall be used for the main turbines, in which case the exhaust still not useable shall be led off to the condensers.

(c) Water to be used for making steam for the acceptance run shall be distilled and its salt content shall be less than three parts per million.

(d) Water for the final test shall be supplied by the evaporators. Oil used for forced lubrication for this run shall be replaced by new oil if it is not purified completely.

3. Main engines

(a) General arrangement

The main engines shall consist of a four shaft system comprising high, intermedate and low pressure turbines, together with a speed reduction gear system. One set shall be installed in each of the four enginerooms. The astern turbines shall be enclosed within the low pressure turbine casings. The inner shaft main engines shall be installed in the after enginerooms. Two cruising turbines shall also be installed in the forward enginerooms. Each of these shall be coupled individually to the inner shaft intermediate pressure turbine shaft by means of the cruising reduction gear.

(b) Rated power and RPM

The rated power of the main engines during forward motion shall total 152,000 hp (metric units) or 38,000 hp for each shaft with propellers turning at 340 RPM and normal exhaust.

The rated power of the astern turbines with propellers turning at 220 RPM shall total 40,000 hp (metric units) or 10,000 hp for each shaft.

The rated power of the cruising turbines with propeller turning at 140 RPM shall total 7500 hp (metric units) or 3750 hp for each shaft. However, these turbines shall be capable, under overload power, with the propeller rate at 165 RPM, of total power of 11,500 hp (metric units) or 5750 hp for each shaft, and they shall be capable of being further stepped up to a top limit (DODANRAKU), with a propeller rate of 200 RPM and

a total of 20,000 hp or 10,000 per shaft.

(c) Steam pressure and comsumption

The steam used by the main engines when they are functioning under rated full power or cruising full power shall have a pressure of 17 kg per sq. cm (gage) and a temperature of 285°C in each steam compartment, while the vacuum on top of the condensers shall register 700 mm.

With full power while backing, the pressure and temperature shall amount respectively to 17 kg per sq. cm (gage) and 285°C in each steam compartment, while the vacuum tube in the top part of the condenser shall register 645 mm or above.

The steam consumption for the main turbines and cruising turbines shall not exceed the following:

SPECIFICATIONS FOR TURBINES - MOGAMI (CA)

	High Pressure Turbine	Intermediate Pressure Turbine	Low Pressure Turbine	Astern Turbine	Cruising Turbine
Type	Impulse type Kampon Model (TN - Navy Tech Dept) (single flow)	Same as at left (single flow)	Same as at left (compound flow)	Same as at left (single flow)	Same as at left (single flow)
RPM	2,613	2,613	2,291	1,481 (RPM of screw 220)	4,795 (full cruising power)
No. of Stages	4 (1 - bucket wheel with double row of buckets) (3 - bucket wheels with single row of buckets)	4 (4 - bucket wheels with single row of buckets)	4 (1 - two stage (?) bucket wheel with single row of buckets) (2 - bucket wheels with single row of buckets)	1 (1 - bucket wheel with three rows of buckets)	8 (1 - bucket wheel with two rows of blades) (1 - 7 stage (?) drumwheel (?) with single row of blades)
Pitch Circumference Diameter (Funhienkei) (millimeters)	1,050	1,300-1,220	1,470-1,480	1,300	640-404
Distance between bearings (TN: a pair) (millimeters)	1,440	1,440	2,885		1,010
Material used for the Blades	Non-rusting steel (OTSU)	Same as at left	Same as at left	Same as at left	Same as at left

SPECIFICATIONS FOR REDUCTION GEAR EQUIPMENT - MOGAMI (CA)

	Main Reduction Gear				Cruising Reduction Gear	
	Main Gear Wheel	High Pressure Pinion	Intermediate Pressure Pinion	Low Pressure Pinion	Main Gear Wheel	Pinion
RPM	340	2,613	2,613	2,291	1,076	4,795
Shaft Horsepower	38,000	12,410	12,340	13,250	2,770	2,770
Pitch Circumference Diameter of teeth (TN: Ha no Setsuenkei) (inches)	93.8381	12.2118	12.2118	13.9257	25.7349	5.7738
No. of Teeth	438	57	57	65	156	35
Overall Length of Teeth (millimeters)	1,280				620	
Helical Angle	29° 58' 51"				30° 0' 21.8"	
Reduction Ratio	1	7.684	7.684	6.738	1	4.457

(d) Turning gear of the main engines

For the purpose of turning the main engines an electric and a hand turning unit shall be installed at one end of the pinion shaft of the high pressure turbines. The electric motors shall be rated at 7 1/2 hp.

Condensers

(a) Main condensers

The condensers shall be of the single flow "UNIFLUX" type, all four of which shall be installed alongside the low pressure turbines. The specifications for a single unit are as follows:

Cooling surface ..... 1,275.91 sq. m
Length of tube sheet distance ..... 4,447 mm
Overall length of tubes ..... 4,500 mm
Outer diameter of tubes ..... 16 mm
No. of tubes 5,708

(b) Main condensate pumps

There shall be eight pumps in all, two being installed for every condenser. They shall be of the "TURBO" fan type with vertical reduction gear. The specifications for the pumps are as follows:

Capacity ..... 130 cu. m/hr
Total head of water ..... 30 m

(c) Steam ejectors

There shall be eight of these in all, two being installed for each condenser. The following are the specifications for the ejectors, which shall be the two-stage, three-nozzle model, steam jet (TN: JOKIFUNSHA) type, utilizing the condensed water to cool the units.

Vacuum - 710 mm, capacity of ejectors - 135 kg/hr.

(d) Circulating pumps

Propeller type pumps shall be installed, one for each main condenser, a total of four in all. They shall be turbo-driven through a double reduction gear. Capacity-11,000 cu meters per hour against a head of seven meters.

5. Shaft connections and propellers

(a) Shafting

	Outer (and inner) Diameter of Shafts (mm)		Length of Shaft (mm)	
	Outboard Shaft	Inboard Shaft	Outboard Shaft	Inboard Shaft
Thrust Shaft	460 (350)	460 (350)	5885	5095
1st Intermediate Shaft	460 (350)	460 (350)	5800	6600
2nd Intermediate Shaft		460 (350)		7200
3rd Intermediate Shaft		460 (350)		7500
4th Intermediate Shaft		460 (350)		7400
5th Intermediate Shaft		460 (350)		7300
Stern Shaft	472 (360)	472 (360)	10,600	10,900
Propeller Shaft	480 (360)	480 (360)	14,200 (to center of propeller)	14,200 (to center of propeller)

The claw brake which is installed at the junction of the intermediate shaft and the stern tube shaft must be able to hold the shaft at three quarters the specified full power torque.

(b) Propeller thrust bearings are of the Mitchel type and the thrust shall not exceed 20 kg per sq.cm on the white alloy pad.

(c) Propellers shall be made of manganese bronze. The main essentials are as follows:

Diameter ..... 3800 mm
Pitch ..... 4280 mm
Developed area ..... 8.0745 sq. m

6. Boilers

There shall be eight boilers of the Mark RO, Bureau Type equipped with superheaters and air preheaters. The boiler rooms shall be of the open type. Specifications for the boilers shall be as follows:

Pressure, steam drum	23 kg/sq.cm
superheater outlet	22 kg/sq.cm
Temperature	300°C
Heating surface, saturated plus superheater	1107 sq. m
Air heater area	207 sq. m
Temperature of preheated air	100°C
Volume, combustion space	42 cu. m
Pressure of air at burner entrance	300 mm of water
Atomizers	eight Type 20, Model 3
	two Type 20, Model 5
Rate of combustion	7.0 kg/sq. m
Cones	Type 20, Model 5
Steam drum, length	5230 mm
inside diameter	1420 mm
Water drum, length	5270 mm
inside diameter	640 mm
Superheater drum, length	2425 mm
inside diameter	450 mm
Arrangement of tubes and outside diameter,	
generating tubes, 2 rows	45 mm
3 rows	32 mm
3 rows	29 mm
superheater tubes, 6 rows	29 mm
saturated steam tubes, 11 rows	29 mm
preheater tubes, 7 rows	100 mm
Inner diameter and no. of downcomer tubes, forward	160 mm (2 tubes)
aft	180 mm (2 tubes)
Outer measurement of water drum	5200 mm
Distance between steam drum line equidistant from both water drums	3300 mm

7. Uptakes and stacks

There shall be two funnels, the forward one serves the forward boilers and the after one the after boilers. Each funnel shall be equipped with a tight rain cover. The specifications of the stacks and uptake areas for one boiler are as follows: Uptake area above main deck - 3.0 sq meters, area of stack 3.0 sq meters.

8. Lubricating equipment

The system shall consist of eight pumps, two to be installed in each engine compartment. The pumps shall be of the gear type, vertical, and driven by a turbine through a reduction gear. Capacity - 150 cu.m per hour, pressure - 3.5 kg/sq. cm.

The oil cooler pump system shall consist of four pumps, one for each engine room. The pumps shall be of the propeller type and turbo-reduction gear drive. They shall be vertical. Capacity - 400 cu.m/hr, pressure - 10 meters of water.

The oil coolers shall be four in number, one in each engine room. They shall be vertical and of the water-cooled type. Cooling surface - 120.87 sq meters.

Independent lubricating apparatus shall be installed for the inner shaft, the outer shaft and for the shaft bearings within the shaft compartments.

The combined lubricating oil pump and oil cooler pump for the fireroom will be vertical reduction gear type, one shall be installed in each fire-room, a total of eight. Oil capacity - 10 cu meters/hr, pressure - 2 kg/sq. cm, water - 24 cu. m/hr, pressure - 10 kg/sq. cm.

The oil purifiers shall be installed one in each engine room, a total of four.

9. Oil injection system (fuel oil service)

(a) Fuel oil pumps shall be of the vertical gear type driven by a turbine through a reduction gear. There shall be one in each fireroom, a total of eight. Capacity - 15 cu. m/hr, pressure - 16 kg/sq. cm.

(b) Heavy oil injection pumps for idling boilers

These pumps shall be used jointly for lighting off and while the ship is at anchor. There shall be two electrically operated pumps of the horizontal gear type, one in No. 1 fireroom and one in No. 2 fireroom. Capacity - 0.75 cu.m/hr, pressure - 14 kg/sq. cm.

(c) Fuel oil transfer pumps

Three electrically operated horizontal gear type pumps shall be installed, one in the port forward engineroom and the other two, one forward and one aft of the machinery spaces. Capacity - 30 cu meters per hr, pressure - 3.5 kg/sq. cm.

(d) Fuel oil heater

There shall be eight fuel oil heaters, one in each boiler room. Heating surface - 5.09 sq. m.

10. Boiler feed system (closed system)

(a) Main feed pumps

There shall be a total of eight, one in each boiler room. Type - centrifugal, directly connected to turbine. Capacity - 150 cu meters/hr, pressure - 29 kg/sq. cm.

(b) Auxiliary feed pumps

There shall be a total of eight, one in each boiler room. Type - reciprocating. Capacity - 85 cu. m/hr, pressure - 27 kg/sq. cm.

(c) Water feed heater

There shall be eight surface contact type feed heaters, one in each boiler compartment. There are also four additional feed heaters, one in each engineroom.

Feed water heater heating surface:

Heater in boiler rooms - 44.23 sq. m

Heater in enginerooms - 38.24 sq. m

11. Fire and bilge system

There are six electrically operated F&B pumps, one in each engine compartment, and one each in fireroom No. 1 and 2. Capacity - 30 cu.m/hr, pressure - 7 kg/sq. cm. These pumps are of the vertical centrifugal type.

12. Water purification system (evaporators)

There are two sets of evaporators, one in each of the two forward enginerooms. Each has a capacity of 144 tons per 24 hour operation. A combined pump serves the evaporator system and there is one in each space where the evaporator is located.

13. Ventilation system

(a) There are eight systems for supply and the same number for exhaust. Both supply and exhaust are of the horizontal, axial flow type, and half of each are turbo-driven through reduction gear, while the other half are electric. There are two supply and two exhaust for each engineroom, half of which are electric. Capacity - 650 cu.m/min, total head - 50 mm for supply; 800 cu.m/min and total head of 50 mm for exhaust.

(b) Control room ventilation

One appropriate electrically driven vent set is in the forward port side engine room for control room ventilation.

(c) Machine shop ventilation

One electrically operated vent set is provided for supply. Capacity - 1 cu.m/sec, hydrostatic head - 50 mm.

14. Blower system

(a) The apparatus consists of 16 vertical turbo propeller type driven through a reduction gear. Two are provided for each boiler. General performance: Capacity - 25 cu. m/sec, total head - 350 mm.

(b) Port use blowers

Two horizontal electrically operated blowers are provided in Firerooms No. 1 and 2 for use while at anchor. Capacity - 4 cu. m/sec, hydrostatic head - 50 mm.

15. Steering system

The steering system is an electrically operated hydraulic type, whose capacity will permit a turn from full right to full left, a 70 degree turn in 30 seconds against a maximum torque of 19 meter-tons on each rudder. The hydraulic cylinders are of the double striking head type. One set of these is installed for each rudder in the helm compartment. Two electrically operated hydraulic pumps are installed and each is capable of the above mentioned performance. One of these pumps is employed in a dual capacity being used on the "B" end of the windlass apparatus.

16. Anchor hoisting apparatus

The forward anchor hoisting apparatus is operated by electric motors with gear attachments and is capable of hoisting 31.8 metric tons at the rate of nine meters per minute. There are two motors of 100 hp (cheval vapeur) each operating at 850 RPM.

The after anchor apparatus is an electric hydraulic system which receives oil pressure from one of the steering hydraulic units as mentioned above. The apparatus is capable of hoisting 8.4 metric tons at the rate of nine meters per minute.

17. Machine shop equipment

There shall be one lathe, length of bed - 8 feet, swing - 30 inches.

Overall weight of engines in tons (metric)

1.	Main engines	580
2.	Shafting and propellers	280
3.	Auxiliary machinery	160
4.	Boilers and accessory equipment	520
5.	Stacks and flue installation	90
6.	Pipes valves etc.	387
7.	Miscellaneous	153
	Total	2170

The following tables of machinery data have been translated from Nav-TechJap Document No. ND50-1032.2, New Construction Machinery Trials of MOGAMI Class Heavy Cruiser.

MAIN CONDENSER, BOILERS, AND PROPELLERS - MOGAMI (CA)

Main Condenser	four
cooling area, one forward	1284.9 m^2
one aft	1285.4 m^2
total forward	2569.8 m^2
total aft	2570.8 m^2
Boilers	8 large, 2 small
type	FO single fired, Bureau RO
evap. heating tubes heating area, large	761 m^2
small	627 m^2
super-heat tubes heating area, large	156 m^2
small	130 m^2
one boiler total heating area, large	917 m^2
small	757 m^2
grand total heating area, large	7336 m^2
small	1514 m^2
fire box volume, large	37.0 m^3
small	30.4 m^3
designed steam pressure	23 tons
Propellers	four
diameter	3800 mm
pitch	4280 mm
developed area	9.285 m^2
projected area	8.075 m^2
no. of blades	three

MAIN ENGINES - MOGAMI (CA)

Name	Type and Number	Stages	Nozzles		No. or Rows of Blades		Average Diameter	RPM
			No.	Area (cm^2)	Moving	Stationary		
HP Turbine	Bureau, 4	1	60	219.8	2	1	1050	2613
		2	60	437.3	1		1050	
		3	60	502.3	1		1050	
		4	60	602.9	1		1050	
IP Turbine	Bureau, 4	1	76	673.7	1		1300	2613
		2	72	940.4	1		1280	
		3	70	1373	1		1250	
		4	68	1971	1		1220	
IP Turbine	Bureau Double Flow, 4	1	2x80	2x1511	1		1470	2291
		2	2x160	2x2276	1		1480	
		3	2x80	2x3650	1		1480	
		4	2x80	2x6265	1		1480	
Backing	4	1	36	174.4	3	2	1300	1469
Cruising Turbine	Bureau, 2	1	76	59.7	2	1	640	
		2 to 8	52 to 68	108.9 to 256.2	1			4796

REDUCTION GEAR - MOGAMI (CA)

Name	No. of Teeth	Average Diameter	Outside Diameter	Central Distance
Bull Gear	438	98.34"	94.21"	
HP Pinion	57	12.21"	12.58"	53.03"
IP Pinion	57	12.21"	12.58"	53.03"
LP Pinion	65	13.93"	14.30"	53.88"
Cruising Bull Gear	156	25.73"	26.02"	
Cruising Pinion	35	5.77"	6.06"	15.75"

AUXILIARY MACHINERY - MOGAMI (CA)

	Name	Model/Type	Kind	Power tons/hr	Cylinder or Turbine Pitch Diameter (mm)	Number of Stages or Strokes (mm)	Pump Fan Diameter	No.
Engineroom	Air Ejector	3-stage triple steam injection type		135				8
	Water Ejector Pump	Vertical, turbo-vortex type		120	27	1	280 mm	8
	Lubo Oil Pump	Vertical, turbo-geared type		100	28	1	80 mm	12
	Water Circulating Pump	Inclined, turbo-axial flow		1100	450	1	800 mm	4
	Cooling Water Pump	Vertical, turbo-axial flow		400	20	1	170 mm	4
	Engine Room Oil Cooler	Vertical; inside water, outside oil type		180	Cooling area 120.87 m²			4
	Oil Purifier	HITACHI 350		1300 liter				4
	Engine Room Blowers	Turbo-axial flow	Supply	650 m³/min	15		788 mm	4
		Electric axial flow	Supply	650 m³/min	15	K9	788 mm	4
		Turbo-axial flow	Exhaust	800 m³/min	20	1	808 mm	4
		Electric axial flow	Exhaust	800 m³/min	20	K13	868 mm	4
	Control Room Blower	Elect.Shlokk type		0.25 m³/sec	0.25	K1	180 mm	1
	Fire & Bilge Pumps	Vertical, turbo-vortex type	Fire	30	25	1	245 mm	4
			Bilge	30	25	1	245 mm	4
	Fuel Transfer Pump	Electric geared		30	7.5	K9	80 mm	1
	Water-making Plant	Int. press Weir type	Evaporator	144 tons/day	Heating area 29.10 sq. m			2
		?	Distiller	144 tons/day	Heating area 33/18 sq. m			2
		?	Drain water cooler	7.2	Cooling area 8.545 m²			2
		?	Exhaust air cooler	34 kg/hr	Cooling area 0.497 m²			2
		Steam injection	Exhaust air ejector	air 3 Exhaust 7 10				1
		Turbo-vortex type	Distiller pump	200			215 mm	
			Water extraction pump	20	30	1	200 mm	2
			Direct water pump	10			210 mm	
	Eng.Room Feed Water Htr.	?		185	Heating area 38.24 m²			4
	Main Feed Water Pump	Turbo-vortex	small	80	140	1	209 mm	2
Boiler Room	Main Feed Water Pump	Turbo-vortex	large	190	300	1	250 mm	4
	Aux. Feed Water Pump	Weir (D7)	large	85	420	550	300 mm	8
		Weir (D6)	small	70	400	500	280 mm	2
	Boiler Room Feed Water Heater	?	large	77	Heating area 38.86 m²			8
			small	65	Heating area 29.40 m²			2
	Fuel Oil Atomizer Pump	Turbo-geared type		12	22	1	65 mm	10
	Fuel Oil Heater	Upright, bent tube type	large	9.3	Heating area 5.09 m²			8
			small	7.6	Heating area 4.59 m²			2
	Aux. Fuel Atomizer Pump	Electric geared	-	0.75	1	K4	32 mm	2
	Aux. Blower	Shlokk type	-	4 m³/sec	10	K11	480 mm	2
	Blower	Turbo-axial flow	large	1300 m³/min	200	1	795 mm	16
			small	1150 m³/min	180	1	745 mm	4
	Lube Oil and Cooling Water Pump	Turbo-rotating type	large oil	10	8	1	45 mm	4
			large water	24	8	1	105 mm	4
			small oil	5	4	1	45 mm	6
			small water	12	4	1	100 mm	6
	Boiler Room Oil Cooler	Inside water, outside oil type	large	10	Cooling area 9.34 m²			4
			small	5	Cooling area 4.65 m²			6
	Fire & Bilge Pump	Turbo-vortex	-	30	25	1	245 mm	2
	Anchor Engine	Electric geared	-	Test load 31.8 tons				1
	Steering Engine & Mechanism	Hydro-electric Hele Shaw type	Hydro-pump, manual hydro pump	19 metric tons (advance)	35 metric tons (backing)			1
	Fuel Oil Transfer Pump	Electric geared type		30	7.5	1	80 mm	2
	Machine Shop Blower	Shlokk type		m³/sec	2	K4	320 mm	1

Part LXI - ATAGO Class (CA)

The last of these cruisers was completed in 1932. Translations of documents for this vessel are included mainly to show the gradual change in Japanese cruiser machinery design. The plant is very much like that of NACHI class which is illustrated by NavTechJap Documents No. ND50-1021.1 and ND50-1024.2.

Piping plans for ATAGO class are shown in NavTechJap Documents No. ND50-1036 and ND50-1036.1.

The following machinery design requirements for ATAGO class cruiser (MAYA) have been translated by Japanese and are included essentially as submitted by them. It is noted that the Japanese have expanded the title into one quite different from the literal translation.

The column headings have been translated for one run in the "New Construction Machinery Trial" (NavTechJap Document No. ND50-1036.2).

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PARTICULARS OF MAIN ENGINES, BOILERS, AUXILIARY MACHINERY, SHAFTING AND PROPELLERS TO BE FITTED ON THE 10,000 TON CRUISER MAYA (ATAGO CLASS CRUISER)

1. Main engines

Engine, type	4 pinioned, all geared
Turbine, type	single flow impulse
Gear type	rigid frame
S.H.P.	130,000
No. of shafts	four
S.H.P. per shaft	32,500
RPM of propeller	320
Steam pressure at normal full power	15.7 kg/sq. cm (abs.)
Steam quality	98% dry saturated
Vacuum at turbine exhaust	90% with barometer reading 760 mm
at top of condenser	92% with barometer reading 760 mm
Water rate	5.1 kg
Astern turbine (incorporated in LP turbines) .. total S. H. P.	36,000

Turbine details are as follows:

		Outer shafts		Inner shafts	
		Outer sets	Inner sets	Outer sets	Inner sets
HP	No. of stage	1-2 rows & 4-1 row	6-1 row	6-1 row	6-1 row
	P.C.D. (mm)	870 & 980	1020 & 980	1020 & 980	1020 & 980
	RPM	3017	2899	3017	2899
	Bucket speed, (m/s)	137.4 & 154.6	154.6 & 148.5	161 & 154.6	154.6 & 148.5
	Length between bearing centers (mm)	1,545			
	Height of nozzle (mm)	17 - 100 mm		20.5 - 100 mm	
	Estimated weight (tons)	10.0 tons		9.5 tons	
LP	No. of stage	6 - 1 row			
	P.C.D. mm	1,520			
	RPM	1998	2053	1988	2053
	Bucket speed,M/s	158.9	163.4	158.9	163.4
	Length between bearing centers (mm)	3,040			
	Height of nozzle (mm)	107 - 300			
	Estimated weight (tons)	18			
Material	Blading	Stainless steel			
	Wheel	Hard steel			

Pressure distribution in kg/sq. cm (abs) is as follows:

		Ordinary use (outer sets of forward engineroom)	Others
HP	Chest		15.7
	1st stage	7.03	9.15
	2nd stage	5.13	7.03
	3rd stage	3.73	5.13
	4th stage	2.71	3.73
	5th stage	1.93	2.71
	6th stage	----	1.93
LP	Chest	1.83	
	1st	1.23	
	2nd	0.809	
	3rd	0.52	
	4th	0.324	
	5th	0.19	
	6th	0.098	
Astern	Chest	17.25	
	Exhaust	0.155	

Gear particulars are as follows:

Gear wheel, S.H.P. 32,500
P.C.D. (in) 98.98
No. of teeth 462
Spiral angle ..... 30° approx.
Tooth speed, (ft/s) 138.4
Face length (total) ..... 920 mm
Press. in lbs/in run 892

		Outer sets	Inner sets	Outer sets	Inner sets
Pinion	S.H.P. (each)	8.125			
	P.C.D. (in)	10.5	10.93	15.85	15.43
	Load factor	275	270	224	227
	No. of teeth	49	51	74	72
	Gear ratio	9.43	9.06	6.24	6.42
	Estimated weight (tons)	40.0			

Cruising turbine particulars are as follows:

No. of sets	two
No. of stages	three - 1 row
Arrangement	coupled to H.P. (ordinary use) turbines
S.H.P. throughout turbine/set (18 kt)	7,050
RPM (18 kt)	5,439
Water rate at 3,750 S.H.P./set (14 kt)	6.3 kg
P.C.D.	650 mm
Bucket velocity, (18 kt)	185 m/s
Length between bearing centers	960 mm
Height of nozzle	20-33 mm
Estimated weight	3 tons
Material, blading	stainless steel
wheel	hard steel
Pressure distribution, chest	17.25 (98% dry) kg/sq. cm (abs)
1st	10.47 kg/sq. cm (abs)
2nd	6.19 kg/sq. cm (abs)
3rd	3.59 kg/sq. cm (abs)
Exhaust	to H.P. turbine 1st stage shell

Gear particulars:

S.H.P./set (18 kt)	3,100
P.C.D., gear wheel	20.353 in
pinion	6.000 in
Tooth speed, ft/s (18 kt)	142.3
Face length (total)	460 mm
Press. in lbs/in run (18 kt)	661
Load factor	270
Total face length/P.C.D.	3.02
Spiral angle (approx.)	30°
No. of teeth, gear wheel	95
pinion	28
Gear ratio, gear wheel	1
pinion	3.395
Estimated weight	2.3 tons

When the cruising turbines are in use, the inner turbines in the forward engineroom are discoupled and the sets in the after engineroom run freely or can be disconnected at the flange at the gear wheel if desired.

2. Main condensers

Type	single flow uniflux
No. of sets	eight
Position	four underneath and four aside
Cooling surface each	762 sq. m
Length between tube sheets	3,743 mm
Length of tubes	3,800 mm
Pitch of tubes	25x25
No. of tubes	4,070
C.S./S.H.P.	0.047 m^2

3. Main air pumps

Type	Weir dual type with steam ejectors
Bureau No.	IV
No. of sets	eight
Capacity	96,000 kg/hr.
Total swept vol. per kilogram of condensate	0.915 cu. m

4. Main circulating pumps

Type ..... two cylinder reciprocating
No. of sets ..... eight
Capacity ..... 5,650 tons/hr
Resistance head ..... 7.5 m
Diameter of steam cylinder ..... 210 mm
Stroke ..... 200 mm
Revolutions per minute 475
Diameter of suction pipe ..... 740 mm
Diameter of discharge pipe ..... 720 mm

5. Boilers

Type of boiler ..... Mk. RO, Bureau oil burning (without superheater)
No. of boilers 12
Working pressure of boiler ..... 20 kg/sq. cm
Heating surface, each ..... about 970 sq. m
Combustion volume, each ..... about 39.1 cu. m
H.S./C.V. 24.82
Oil burner capacity ..... eleven No. 2 i.e. 5,500 kg/hr
..... four No. 4 i.e. 1,200 kg/hr
Diameter of steam drum ..... 1,270 mm
Diameter of water drum ..... 740 mm
Length of steam drum ..... 4,670 mm
Length of water drum ..... 4,628 mm
Distance between water drum centers ..... 5,330 mm
Height between drum centers ..... 3,125 mm
Tube nest details ..... 2 rows of 1 3/4" x L.S.G. 9
..... 16 rows of 1 1/4" x L.S.G. 12
Downcomers ..... eight 3 3/4" x L.S.G.
Boiler room ..... open stokehold system

6. Forced lubrication pumps

Type ..... Weir
Bureau No. IV
No. of sets 12
Capacity, each ..... 39,000 liters/hr
Delivery pressure ..... 3.5 kg/sq. cm

7. Oil cooler pumps

Type ..... turbine driven by exhaust steam
No. of sets ..... four
Capacity ..... 300 tons/hr
RPM 2,000
P.C.D. of turbine ..... 400 mm

8. Oil coolers

Type ..... vertical, oil outside
No. of sets ..... four
Cooling surface ..... about 92 sq.m
Length between tube sheets ..... 2,000 mm

9. Feed pumps

Type, main ..... Brown Bovari
auxiliary ..... Weir
No. of sets, Bureau No. VII 9
large 2
medium 2
small 2

Capacity, each, Bureau No. VII 63
large 190
medium 135
small 65

10. Fuel oil pumps

Type ..... Weir
Bureau No. IV
No. of sets 12
Capacity, each ..... 10.5 tons/hr

11. Forced draft fans

Type ..... geared drive
Bureau no. ..... large No. 3
No. of sets 24
Capacity, each ..... 1,150 cu. m/min

12. Distilling system

Type of evaporator and distiller ..... Weir high pressure with connection to exhaust steam
No. of sets ..... two
Capacity ..... 133 tons/day
Type of pump ..... Weir
Bureau No. IV
No. of sets ..... two
Capacity, each ..... 133 tons/day

13. Fire and bilge pumps

Type ..... Weir
No. of sets in E.R. ..... two
corresponding Bureau No. III
capacity ..... 77.5 tons/hr
No. of sets in B.R. ..... two
corresponding Bureau No. II
capacity ..... 29.5 tons/hr

14. Fuel oil tank pumps

	E.R.	Pump Rooms
Type	Bureau No. 2	Rotary (motor driven)
No. of sets	one	two
Capacity, tons/hr	22	25 (each)

15. Ventilating fans in E.R.

	Suction		Exhaust
Type	Steam-driven Sirocco	Motor-driven Sirocco	Steam-driven Sirocco
No. of sets	four	four	eight
Dia. of fans	750 mm	not determined	1,000 mm
Capacity (head)	500 cu. m/min (40 mm)	500 cu. m/min (40 mm)	850 cu. m/min (40 mm)

16. Feed water heaters

Type	Surface heater each in B.R.	Ejector type
No. of sets	12	12

17. Oil heaters

Type ..... vertical, U-shape
No. of sets, large ..... three
small ..... six

18. Oil purifiers

Type ..... Sharples [illegible] 6
No. of sets ..... [illegible]our
Capacity, each ..... 760-950 liters/hr

19. Shafting

Intermediate shaft, outer diameter ..... 450 mm
inner diameter ..... 350 mm
Stern shafts, outer diameter ..... 465 mm
inner diameter ..... 350 mm
Propeller shaft, outer diameter ..... 470 mm
inner diameter ..... 350 mm
Total length of propeller shaft ..... 14,720 mm

20. Propellers

Diameter ..... 3850 mm
Pitch ..... 4200 mm
Pitch ratio 1.091
Projected area ..... 8.0 sq. m
Developed area ..... 9.15 sq. m
Weight, estimated ..... 10.33 tons each

21. Donkey boiler

Type ..... Mark RO, Bureau oil burning
No. ..... one
Working pressure ..... 14 kg/sq. cm
Heating surface ..... 61 sq. m
Combustion volume ..... 2.26 cu. m
H.S./C.V. 27.00
Oil burner capacity ..... 3x75 kg/hr
Auxiliary, feed and fuel pump ..... one
oil heater ..... one
feed and fuel tank pump ..... one

22. Weight distribution

Main engines ..... 681.0 tons
Shafting and propellers ..... 245.0 tons
Boilers ..... 592.0 tons
Funnels and uptakes ..... 96.0 tons
Auxiliary machinery (in machinery space) ..... 105.0 tons
Piping, valves, etc. ..... 326.0 tons
Miscellaneous ..... 126.0 tons
Steering gear ..... 25.5 tons
Forward capstan, etc. ..... 27.5 tons
Donkey boiler, etc. ..... 15.0 tons
Total ..... 2,248.0 tons (in metric tons)

Part IV - AGANO CLASS (CL)

The piping diagrams of this vessel are typical of the six-boiler cruisers. The arrangement differs slightly from OYODO, the latest Japanese six-boiler cruiser, in the main steam distribution and the lack of centerline bulkheads in the forward fireroom and the after engineroom. The cruising turbines on the outboard shafts only are to be noted. This arrangement is typical of all the late CAs, CLs and CVs. Aside from the inability to split completely the plant under full power conditions, the arrangements and systems are typical of those of other contemporary Japanese vessels.

No booklets of Machinery Design Requirements were recovered for this class. However, the following table of machinery installed, as well as a summary of the machinery trial results, has been translated from NavTechJap Document No. ND50-1037.1. Schematic diagrams of piping may be found in NavTechJap Documents Nos. ND50-1037 and ND50-1038.

Table of specifications for YAHAGI, an AGANO class cruiser, follow.

* * * * *

TRIAL TEST SUMMARY - YAHAGI (AGANO CLASS CL)

Item			Designed	Accept. Full Power measured standing out	Full Overload Power continuous standing in	Backing Power (continuous)	Accept. Full Power measured standing out	Accept. Full Power measured standing in
When standing out and in	Draft (m)	Fore	5.630	5.692	5.445		5.62	5.336
		Aft	5.630	5.672	5.679		5.641	5.637
		Average	5.630	5.684	5.562		5.553	5.487
		Center	5.630	5.679	5.541		5.559	5.470
	Displacement (tons)		7,710	7,840	7,628		7,641	7,508
At time of trial	Draft (m)	Fore		5.601	5.510	5.537	5.385	
		Aft		5.642	5.655	5.673	5.641	
		Center		5.622	5.583	5.605	5.513	
	Displacement (tons)		7,710	7,734	7,673	7,701	7,577	
	Sea water temp.			19	19	19	19	
	Max. cross section below water line, m^2		71.8	71.8	71.1	71.3	71.3	
Fuel consumption (tons)			1360.86	745.9			881.3	
Speed (knots)			35.0	35.17			35.08	
SHP (total)			100,000	101,100	105,800	26,570	100,600	
Shaft RPM			360	357.7	360.8	236.8	358.8	
(Steem consumed per shp per hour - not measured)								
Fuel consumed (kg/shp/hr)				0.36	0.37	0.92	0.36	
Fuel consumed per unit heating area per hour ($kg/cm^2/hr$)			7.73	6.84	7.37	4.59	6.88	
Cruising Distance	Per ton of fuel			0.96			0.96	
	Full load of fuel			1311			1307	

TURBINE DATA - YAHAGI (AGANO CLASS CL)

Name	Type No.	Stages	No.	Nozzles Area (cm^2)	No. of Rows of Blades: Moving	No. of Rows of Blades: Stat.	Average Diameter (mm)	RPM
HP Turbine	Impulse single flow, 4	1st	28	91.672	2	1	820	3644
		2nd	48	206.26	1		800	
		3rd	48	243.96	1		800	
IP Turbine	Impulse single flow, 4	1st	50	327.40	1		850	3395
		2nd	50	379.60	1		850	
		3rd	50	474.50	1		850	
		4th	50	592.55	1		850	
		5th	104	751.92	1		850	
		6th	116	947.836	1		850	
LP Turbine	Impulse single flow, 4	1st	78	672.204	1		1350	2334
		2nd	200	943.800	1		1352	
		3rd	164	1377.764	1		1370	
		4th	82	2111.254	1		1400	
		5th	132	3446.784	1		1400	
Backing Turbine	Impulse single flow, 4		36	outlet 208.116	3	2	1250	1498
				throat 63.360				
Cruising Turbine	Impulse single flow, 2	1st	16	outlet 36.100	2	1	530	6231
				throat 28.458				
		2nd	38	67.982	1		390	
		3rd	40	76.520	1		400	
		4th	40	90.168	1		410	
		5th	42	107.31	1		420	
		6th	42	132.3756	1		430	

CONDENSERS, BOILERS, AND PROPELLERS - YAHAGI (AGANO CLASS CL)

Condensers, number ..... four
cooling area, one ..... 862.737 m^2
total ..... 3450.948 m^2

Boilers, type ..... Bureau RO, oil fired
number ..... six
heating area, evaporating tubes ..... 737.0 m^2
superheater tubes ..... 152.0 m^2
one boiler total ..... 889.0 m^2
grand total ..... 5334.0 m^2
combustion chamber volume, one boiler ..... 36.2 m^3
total ..... 217.2 m^3
designed steam pressure ..... 30 kg/sq. cm (at superheater outlet)

Propellers, number ..... four
diameter ..... 3300 mm
pitch ..... 3850 mm
developed area ..... 6.8400 m^2
projected area ..... 5.9385 m^2
number of blades ..... three

REDUCTION GEAR - YAHAGI (AGANO CLASS CL)

Gear	No.of Teeth	Average Diameter (mm)	Outside Diameter (mm)	Center Distance (mm)	Reduction Ratio
Bull Gear	415	2396.01	2406.01		1
HP Pinion Gear	41	236.71	246.71	1316.36	10.12
IP Pinion Gear	44	254.03	264.03	1325.02	9.43
LP Pinion Gear	64	369.50	379.50	1382.755	6.48
Cruising Bull	141	569.85	576.85		1
Cruising Pinion	35	141.45	148.45	355.65	4.03

ENGINEROOM AUXILIARY MACHINERY - YAHAGI (AGANO CLASS CL)

Name		Type	Output m^3/hr	Cylinder or Turbine Pitch Diameter (mm)	Stages, Strokes (mm)	Pump Fan Diameter	No.
Condensate Pump		Turbo-geared with vertical reduction gear	100	180	1 (2 rows)	280 mm	8
Circulating Water Pump		Turbo-axial flow with horizontal reduction gear	8500	270	1 (2 rows)	786 mm	4
L.O. Pump		Turbo-geared with vertical reduction gear	100	180	1 (2 rows)	gear pitch dia 80 mm	7
Drain Cooler Pump		Electrical vortex type	60			175 mm	2
F&B Pump	Fire Bilge	Vertical electric Vortex type	30 60			164 mm	2
F.O. Transfer Pump		Vertical electric geared type	30			95 mm	1
Blow-ers	Supply	Turbo-axial flow with horizontal reduction gear	9 m^3/sec	180	1 (2 rows)	745 mm	2
			16 m^3/sec	180	1 (2 rows)	945 mm	1
		Horizontal electric	9 m^3/sec			745 mm	2
		Axial flow	16 m^3/sec			945 mm	1
	Exhaust	Turbo-axial flow with horizontal reduction gear	11 m^3/sec	180	1 (2 rows)	795 mm	2
			19 m^3/sec	180	1 (2 rows)	995 mm	1
		Horizontal electric	11 m^3/sec			795 mm	2
		Axial flow type	19 m^3/sec			995 mm	1

ENGINEROOM AUXILIARY MACHINERY - YAHAGI (AGANO CLASS CL) (CONT'D.)

Name			Type	Output m^3/hr	Cylinder or Turbine Pitch Diameter (mm)	Remarks	No.
Water-making Plant	Evaporator		Bureau	96 tons/day	Inside trunk diam 1450	Heating area (outside) 129.06 m^2	2
	Distiller		Vertical surface type	96 tons/day	same 470	Cooling area (outside) 122.31 m^2	2
	Drain Cooler		Vertical surface type	116 m^3/day	same 340		2
	Distiller Exhaust	ejector	Single nozzle steam injection, adiabatic compression type	7 kg/hr			1 each
	Ejector	cooler	Vertical surface type	24 kg/hr	same 150	Cooling area (outside) 0.455 m^2	2
	Circulating Water Brine Distilled Water		Tubro-vortex with horizontal reduction gear	140 14 7	120	1 stage (2 rows)	2
	Evaporator #1 Heat #2 Compressor		Single nozzle steam injection, adiabatic compression type			2 ejectors 2 ejectors	2 each 2 each
	Evaporator Feed Water Heater		Vertical surface	6.67	Inside trunk diam 340	Heating area 2.315 m^2	2
Air Ejector	Ejector	1st stage	Single nozzle steam injection, adiabatic compression type	75 kg/hr 30			3 each
		2nd stage		75 kg/hr 30			3 each
	Cooler	1st stage 2nd stage	Vertical surface type	900 kg/hr 900 kg/hr	Inside trunk diam 560	Cooling area 20.9 m^2 Cooling area 20.9 m^2	4
Control Room Blower			Horiz. elect. Shlokk type	0.5 m^3/sec			1
Oil Purifier			Hitachi Mk5 RO open type	1300 lit/hr			3
Drain Cooler			Vert. surf. type	15	same 460	Cooling area 20.8 m^2	2
Feed Heater			Vert. surf. type	130	same 510	Heating area 21.9 m^2	4
Oil Cooler			Vertical inside water, outside oil type	100	same 800	Cooling area 59.98 m^2	4
Gland Steam Cooler	Ejector		Single nozzle steam injection, adiabatic compression type	250 kg/hr			
	Cooler		Vertical surface type	330 kg/hr	same 320	Cooling area (outside) 6.57 m^2	4

AUXILIARY MACHINERY - YAHAGI (AGANO CLASS CL)

Space	Name	Type	Output	Cylinder or Turbine Pitch Diameter (mm)	Stages or Strokes (mm)	Pump Fan Diameter	No.
Boiler Rooms	Main Feed Pump	Turbo-vortex with horizontal reduction gear	100 m^3/hr	270	1 (2 rows)		6
	Auxiliary Feed Pump	Weir Direct Action (HD6)	70 m^3/hr	400	500		5
	F. O. Atomizer Pump	Turbo-screw with vertical reduction gear	12 m^3/hr	180	1 (2 rows)		6
	Auxiliary F. O. Atomizer Pump	Horizontal electric gear	1 m^3/hr				2
	L.O. with oil cooler pump L.O. oil cooler	Turbo with horizontal reduction gear (geared vortex)	15 m^3/hr 36 m^3/hr	120 120	1 (2 rows) 1 (2 rows)		6 6
	Blowers	Turbo with vertical reduction gear	19 m^3/sec	270	1 (2 rows)		12
	Auxiliary Blowers	Horizontal electric Shlokk type	5 m^3/sec				2
	F&B Pump Fire Bilge	Vertical electric Vortex type	30 m^3/hr 60 m^3/hr				2
	F. O. Heater	Vertical bent tube type	8 m^3/hr	Inside Trunk diameter 340	Heating area 4.04 m^2		6
	Feed Heater	Vertical surface type	80 m^3/hr	Same 640	Heating area 36 m^2		6
	Oil cooler	Vertical inside water, outside oil type	15 m^3/hr	Same 400	Cooling area 13.98 m^2		6
	Machine Shop Blowers	Horizontal electric axial flow type	1 m^3/sec			316	1
	Furnace Blowers	Horizontal electric Roots type	3 m^3/sec			Rotor Length and width 200 x 130 mm	2
Outside of Engine Rooms	Electric Motor Main Hydraulic Pump Manual Pump	Hydro-electric plunger	70/30 m^3/hr 15/60 m^3/hr			Plunger Diameter 42 mm	2
	Anchor Engine	Electric geared type	test speed 9 m/min	Maximum shaft diameter 320			1
	Cooler (refrigerator)						1
	Ice Making Machine	Compound carbonic acid type	15,000 gal/hr				1
	Turbo AC Generator	Completely closed self-ventilating type	KVA 400 V. 450 A. 513				3
	Diesel AC Generator	Completely closed self-ventilating type	KVA 270 V. 450 A. 347				2
	F. O. Transfer Pump	Vertical electric geared type	30 m^3/hr				1

Part V - OYODO (CL)

This vessel was the latest CL built by the Japanese and followed the general arrangement of six-boiler cruisers. The arrangement of the main plant was very similar to AGANO class CL except that there were six boiler rooms in OYODO compared to five in AGANO class, and four enginerooms compared to three in the AGANO class. This was due entirely to the centerline bulkheads provided in the forward boiler rooms and the after enginerooms. In this connection it is interesting to note that this vessel capsized. Further details concerning the damage to this vessel are contained in NavTechJap Report, "Reports of Damage to Japanese Warships, Article 1", Index No.S-06-1.

The piping for providing the standby lubricating oil pump with steam and exhaust from the adjacent space is shown very clearly in NavTechJap Document No. ND50-1040, "Engineroom piping systems, OYODO", plates 3 and 5. This arrangement of steam to lube oil pumps was typical of all Japanese naval surface vessels of cruisers and above. The boiler room piping is shown in NavTechJap Document No. ND50-1039.

No documents on machinery design requirements for this vessel were recovered. However, the following table translated from NavTechJap Document No. ND50-1039.1, "New Construction Machinery Trials, OYOKO", furnishes much of the information usually found in the design requirements. The proposed increase in fire pump capacity shown in the following table is to be noted.

The trial summary as well as one trial run contained in NavTechJap Document No. ND50-1039.1 have been translated in the document itself. Tables showing Principal Machinery Data for OYODO follow.

* * * * *

CONDENSERS, BOILERS, AND PROPELLERS - OYODO (CL)

Condensers,	number	four
	cooling area, one	0.1986 m^2
	total	966.19 m^2
Boilers,	type	Bureau RO, oil fired (air preheater attached)
	number	six
	heating area, evaporator tubes (on superheater side)	810 m^2
	(not on superheater side)	171 m^2
	one boiler total	981 m^2
	grand total	5886 m^2
	combustion chamber volume	39.8 m^3
	designed steam pressure	30.0 kg/cm^2 (superheater outlet)
Propellers,	number	four
	diameter	3600 mm
	pitch	3960 mm
	developed area	7.5600 m^2
	projected area	6.6008 m^2
	number of blades	three

TURBINE DATA - OYODO (CL)

Name	Type	Stages	Nozzles		No. of Rows of Blades		Average Diameter (mm)	Speed RPM
			No.	Area (cm^2)	Moving	Stat.		
HP Turbine	Bureau impulse single flow, 4	1st	28	102.34	2	1	820	
		2nd	48	206.26	1		800	3632
		3rd	48	243.96	1		800	
IP Turbine	Bureau impulse single flow, 4	1st	50	327.40	1		850	
		2nd	50	379.60	1		850	
		3rd	50	474.50	1		850	
		4th	50	592.55	1		850	3385
		5th	50	745.65	1		850	
		6th	Nozzle Blades 116	947.836	1		850	
LP Turbine	Bureau impulse double flow, 4	1st	78	627.204x2	1		1350	
		2nd	Nozzle Blades 200	943.8x2	1		1352	
		3rd	Nozzle Blades 164	1377.764x2	1		1370	2327
		4th	82	2111.254x2	1		1400	
		5th	Nozzle Blades 132	3446.784x2	1		1400	
Backing Turbine	Bureau impulse single flow, cruising two, and backing four.	1st	36	69.300	3	2	1250	1471
Cruising Turbine		1st	Round Type 7 4 6	throat 28.458 outlet 56.100	2	1	530	Cruising
		2nd	38	67.982	1		390	Full Speed
		3rd	40	76.520	1		400	7058 Cruising
		4th	40	90.168	1		410	Maximum
		5th	42	107.352	1		420	Speed
		6th	42	132.3756	1		430	7619

AUXILIARY MACHINERY - OYODO (CL)

Space	Name			Type	Output	Cylinder or Turbine Pitch Diameter (mm)	Number of Stages or Strokes (mm)	Pump Fan Diameter	No.
Engine Room	Main Condensate Pump			Turbo-vortex with vertical reduction gear	100 m^3/hr	180	1 (2 rows)		8
	Main Circulating Pump			Turbo-axial flow with horizontal reduction gear	8500 m^3/hr	270	1 (2 rows)		4
	L. O. Pump			Turbo-geared with vertical reduction gear	125 m^3/hr	180	1 (2 rows)		8
	Drain cooling Pump			Vertical electric vortex type	60 m^3/hr				2
	Lube Oil Purifier			Hitachi Mk. 5 D open type	1300 ltrs/hr				4
	Blowers	Supply	Turbine	Turbo-axial flow with horizontal reduction gear	9 m^3/sec	180	1 (2 rows)		4
			Electric	Horizontal Electric axial flow type	9 m^3/sec				4
		Exhaust	Turbine	Turbo-axial flow with horizontal reduction gear	11 m^3/sec	180	1 (2 rows)		4
			Electric	Horizontal electric axial flow type	11 m^3/sec				4
	Control Room Blower			Horizontal electric Shlokk type	0.5 m^3/sec				1
	F & B Pump		Fire Bilge	Vertical electric Vortex type	30 m^3/hr 60 m^3/hr				2
	F. O. Transfer Pump			Vertical electric geared type	30 m^3/hr				1
	Air Ejector	Ejector		2-stage, triple steam injection type	180 kg/hr				1
		Cooler	1st Stage	Vertical surface type	900 kg/hr	Inside Trunk diameter 560	Cooling area 20.9 m^2		4
			2nd Stage		900 kg/hr	Inside Trunk diameter 560	Cooling area 20.9 m^2		4
	Oil Cooler			Vertical, inside water, outside oil type	125 m^3/hr	Inside Trunk diameter 840	Cooling area 74.3 m^2		4
	Fesd Heater			Vertical surface type	130 m^3/hr	Inside Trunk diameter 510	Heating area 21.9 m^2		4
	Water Making Plant	Evaporator		Bureau type	96 tons/hr	Inside Trunk diameter 1450	Heating area (outside) 29.06 m^2		2
		Heat Compressor for Evaporator	Mark 1	Single nozzle steam injection, adiabatic compression type	990 kg/hr				4
			Mark 2		620 kg/hr				4
		Distiller		Vertical surface type	96 tons/day	Inside Trunk diameter 470	Cooling area (outside) 7.22 m^2		2

AUXILIARY MACHINERY - OYODO (CL) (CONT'D)

Space				Type	Output	Cylinder or Turbine Pitch Diameter (mm)	Number of Stages or Strokes (mm)	Pump Fan Diameter	No.
Engine Room	Water Making Plant	Air Ejector for Distiller	Ejector	Single nozzle steam injection adiabatic compression type	7 tons/day				2
			Cooler	Vertical surface type	24 kg/hr	Inside trunk diameter 160	Cooling area (outside) 0.454 m^2		2
		Feed Heater		Horizontal surface type	6.67 m^3/hr	Inside trunk diameter 340	Heating area 2.315 m^2		2
		Drain Cooler		Vertical surface type	116 m^3/day	Inside trunk diameter 340	Cooling area 7.22 m^2		2
		Aux. Pumps	Circulating water	Turbo-vortex with horizontal reduction gear	140 m^3/hr	120	1 (2 rows)	205 mm	2
			Brine		14 m^3/hr			215 mm	
			Fresh water		7 m^3/hr			200 mm	
	Drain Cooler			Vertical surface type	15 m^3/hr	Inside trunk diameter 460	Cooling area 20.8 m^2		2
	Gland Steam Cooler		Ejector	Single nozzle steam injection adiabatic compression type	250 kg/hr				4
			Cooler	Vertical surface type	330 kg/hr	Inside trunk diameter 320	Cooling area (outside) 6.57 m^2		4
Boiler Room	Main Feed Pump			Turbo-vortex with horizontal reduction gear	125 m^3/hr	270	1 (2 rows)	305 mm	6
	Auxiliary Feed Pump			Weir direct action type (HD7)	85 m^3/hr	420	550	300 mm	6
	F. O. Atomizer Pumps			Turbine-screw type with vertical reduction gear	16 m^3/hr	180	1 (2 rows)		6
	Blowers			Turbo-axial flow with vertical reduction gear	22 m^3/sec	270	1 (2 rows)	945 mm	12
	Auxiliary Blowers			Horizontal electric Shlokk type	7 m^3/sec			750 mm	2
	L.O and Cooling Water Pump		L.O.	Turbo-geared with horizontal reduction gear	15 m^3/hr	120	1 (2 rows)	Gear pitch diameter 45	6
			Cooling water	Turbo-vortex type with horizontal reduction gear	36 m^3/hr			110 mm	6
	Oil Cooler			Vertical, inside water, outside oil type	15 m^3/hr	Inside trunk diameter 400	Cooling area 13.98 m^2		6
	Feed Heater			Vertical surface type	100 m^3/hr	Inside trunk diameter 610	Heating area 43.7 m^2		6
	F. O. Heater			Vertical bent tube type	11 m^3/hr	Inside trunk diameter 360	Heating area 5.088 m^2		6
	F & B Pump		Fire Bilge	Vertical electric Vortex type	30 m^3/hr 60 m^3/hr			164 mm	2

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AUXILIARY MACHINERY - OYODO (CL) (CONT'D)

Space	Name		Type	Output	Cylinder or Turbine Pitch Diameter (mm)	Number of Stages or Strokes (mm)	Pump Fan Diameter	No.
Outside of Engine Room	Forward Anchor Engine and Installation		Electric geared type	Test load - 32.25 ton Test speed - 9 m/sec			Chain diameter 60	1 set
	Main Rudder Engine	Plunger	Hydro- Rapson electric slide	Torque (m-ton)	Turning speed		Plunger diameter 330	2
		Hydro-electric pump	Plunger Jonne type (12)-?	Forward-full power 74.5 Backing full power 117.89	70° 30 sec		Plunger diameter 42	2
	F. O. Transfer Pump	Forward	Vertical electric geared type	30 m^3/hr			Gear pitch diameter 75	1
		Aft		30 m^3/hr			Gear pitch diameter 75	1
	Machine Shop Blower		Horizontal electric axial flow type	1 m^3/sec			316 mm	1
	Furnace Blower		Horizontal electric Roots type	3 m^3/mm			Rotor diameter 200	2
	Planned additions and improvements after completion of the ship are as follows: (1) To install one condensate and exhaust (air) pump in each of the forward enginerooms, port and starboard, (2) to modify the number and type of fire and bilge pumps as follows: (a) to modify the type of one of those presently installed in the boiler room, (b) to put one more in each of the forward enginerooms, port and starboard; and (3) the principal data of this planned additional and improved machinery are as follows:							
Engine Room	Condensate and Exhaust Pump	Condensate	Vertical electric vortex	5 m^3/hr			224 mm	2
		Exhaust	Vertical electric Erumo type	15 kg/hr			190 mm	2
	F & B Pump	Fire Bilge	Turbo-vortex with vertical reduction gear	30 m^3/hr 60 m^3/hr	180	1 (2 rows)	320 mm	2
Boiler Room	F & B Pump	Fire Bilge	Turbo-vortex with vertical reduction gear	30 m^3/hr 60 m^3/hr	180	1 (2 rows)	320 mm	1

REDUCTION GEAR - OYODO (CL)

Name	No. of Teeth	Average Diameter (mm)	Outside Diameter (mm)	Center Distance (mm)	Reduction Ratio
Bull Gear	438	2528.80	2538.80		1
HP Pinion Gear	41	236.71	246.71	1342.79	10.68
IP Pinion Gear	44	254.03	264.03	1101.60	9.95
LP Pinion Gear	64	369.50	379.50	1048.82	6.84
Cruising Bull	141	569.85	576.85		1
Cruising Pinion	35	141.45	148.45	355.65	4.03

Part VI - TERUTSUKI (DD)

This vessel was typical of the latest Japanese destroyer design: two engine rooms and two fire rooms; three boilers, two in the forward boiler room and one in the after.

In general, the systems were typical of Japanese design except that a firemain ran throughout the machinery spaces instead of rising straight to the upper decks as in the case of cruisers and battleships. Moreover, the only drainage provided in the boiler rooms was by steam eductors.

The conventional open funnel type of fuel oil filling system was absent also. One system was used for suction and discharge. There was also provision for ballasting although all Japanese naval engineers denied using such a system.

Note, in this type of vessel too, the provision of standby steam and exhaust for the lubricating oil pumps in the engine rooms and the cross connection between the lubricating systems themselves in the boiler rooms.

The piping systems in the boiler and engine rooms are shown in NavTechJap Documents No. ND50-1041 and ND50-1042.

A copy of the "Machinery Design Requirements", NavTechJap Document No. ND50-1027, has been translated.

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TRANSLATION OF THE MACHINERY SPECIFICATIONS FOR ONE OF THE DESTROYERS OF THE TERUTSUKI CLASS

Navy Technical Department, "Military Very Secret"
Class 360 Ship Engine Specifications
Initiated October 1941. General specifications follow those of Class 104.

The difference in detail are as follows:

1. General - greater use has been made of substitute materials.

2. Main engines - modification has been made in the fittings, such as nuts and bolts.

3. Boilers -

   a. Emergency (T.N.-not clear) are employed except for twin tubing and the superheater tubing.

   b. Superheater steam tubes do not pass through the steam drums.

4. Auxiliary engines

   a. Main water pumps are of the auxiliary thrust bearing type.

   b. The heating coils in the evaporators have been modified.

5. Valve cocks on piping

   a. Substitute materials are employed as far as possible. For the low pressure, welded steel plate valves have been adopted.

b. Standard valves are used as far as permitted by the change in specification of couplings.

c. Pistons of bulkhead stop valves have been remodeled to permit ease of opening for inspection.

Table of Contents

1. General

Under forward test conditions this engine develops 52000shp (cheval vapeur), at a displacement of 3470 tons. At normal speed (18 knots) the fuel consumption comes to within 0.46 kg per hour per shp. In other respects, too, it responds well to war demands.

2. Engine layout

The main engines have two shafts, each geared to its own main turbine. Each main turbine is further geared to a cruising turbine. The port shaft runs to the forward engineroom and the starboard shaft to the after engineroom. There are three boilers, two in the forward boiler room, one in the after boiler room.

3. Main engines

a. General arrangement - the main engines consist of high pressure, intermediate pressure and low pressure turbines geared to a single shaft. The astern turbine is in the low pressure turbine casing. In each case the high pressure, low pressure, and intermediate pressure turbines are connected to the reduction gear. The two cruising turbines are coupled to the intermediate pressure turbine through the cruising turbine reduction gear and a claw coupling. The exhaust steam of the cruising turbines is led directly to the steam chamber of the low pressure turbine.

b. Power and RPM of the main engines: When moving forward under ordinary steam the main engines turn the screw at 340 RPM, each shaft developing 26,000 shp (cheval vapeur), totalling 52,000 hp.

The cruising turbine, when turning the shafts 163 RPM, develops 2700 hp in each shaft, totalling 5400 hp. However, when overloaded, they will give 185 RPM and develop 3900 hp in each shaft, totalling 7800 shp; when used in conjunction with the main engines, they will achieve 26 knots, that is up to 244 RPM, 9250 on each shaft, a total of 18,500 hp.

The total power of the astern turbine is 5000 hp for each shaft, totaling 10,000 hp. Below is given a table showing the RPM and S.H.P. developed under the various applications of power:

Power Used	S.H.P.	RPM	Notes
Specified full power	52,000	340	fuel/hr/shp-0.36 kg or less
Overload full power	54,600	347	
Full cruising power	5,400	163	fuel/hr/shp-0.46 kg or less
Overload cruising power	7,800	185	
Permissible cruising power	18,500	244	
Full power astern	10,000	198	

c. Steam temperature, pressure and steam consumption of the main engines:

Power Used	Steam Chest Pressure (kg/sq. cm)	Steam Temp (°C)	Vacuum (mm Hg)	Steam Consumption (kg/shp/hr)
Specified full power	26	335	700 or more	3.75 or less
Full power astern	21	330	645 or more	9.0 or less
Full cruising power	26	285	725 or more	4.5 or less

4. Condensers

Single pass surface type are mounted one for each shaft.

5. Shafting and propellers

a. Shaft systems are made up of the first intermediate shaft, the thrust shaft, the second intermediate shaft (port side only), the stern tube shaft, and the propeller shaft. The claw type rotary brake mounted on top of the joint of the connection between the stern tube shaft and the intermediate shaft is able to hold the shaft at half the full power torque.

b. Thrust bearings - Mitchel type bearings are used and the pressure exerted against each square centimeter of the white alloy thrust bearing collar must not exceed 20 kg. This complete thrust system will be mounted on the first ship of this type.

c. Propellers - the propellers will be made of manganese bronze. The general spacifications are as follows: diameter - 3650 mm, pitch - 3860 mm, developed area - 7.270 sq. m, weight - 8500 kg.

6. Boilers

The ship has three Type RO heavy oil fired boilers, which are equipped with superheaters and air preheaters. Two boilers are mounted in the forward fireroom and one in the after fireroom. Boiler rooms are of the open type. The general specifications for a single boiler are as follows:

Steam pressure, steam drum	32 kg/sq. cm
superheater	30 kg/sq. cm
Steam temperature	350 °C
Rate of combustion, specified full power	6.7 kg/sq. m
Heating surface, generating and superheating	955.0 sq. m
air preheater	427.2 sq. m
Combustion chamber volume	38 cu. m
Blowers, Bureau Type 16	Model 9
	Model 2
Burners, Bureau Type 15	Model 5

7. Stacks and uptakes

There shall be one funnel to which the smoke outlets from each boiler shall be connected. However, the interior of the funnel shall be divided into separate divisions for each boiler.

8. Miscellaneous equipment

The water feed apparatus shall be a closed feed system.

9. Auxiliary machinery in the engineering spaces

The engineroom auxiliary machinery will be of the following type and quantity:

Name	Type	Quantity
Circulating pump	Axial flow, turbo-reduction gear drive	2
Condensate pump	Vertical, centrifugal, turbo-reduction gear drive	4
Air ejector	Dual bank, triplex, injection type	2
Lubricating oil pump	Vertical, gear pump, turbo-reduction gear drive	4
Supply vent	Axial flow, turbo-reduction gear drive, horizontal	2
Exhaust vent	Axial flow, electric, horizontal	
Fire and Bilge Pump	Vertical, electric, centrifugal	2
Cruising feed pump	Centrifugal, turbo-reduction gear drive	1
Portable heavy oil pump	Horizontal, gear, electric driven	1
Evaporator	Bureau Type	1
Evaporator pump	Combine pump	1

Boiler water	Horizontal, electric drive gear pump	1
Oil purifier	Electric centrifugal	2
Oil cooler	Vertical, internal oil, external water	2
Feed water heater	Vertical surface type	2

Equipment for boiler room:

Name	Type	Quantity
Main feed pump	Horizontal, centrifugal, turbo-reduction gear drive	3
Auxiliary feed pump	Weir reciprocating	2
Blower	Vertical, reduction gear, turbo-drive, axial flow	6
Fuel oil service pump	Vertical, screw type, turbo-reduction gear drive	3
Ignition pump	Electric gear type	
Lube oil and lube oil cooler pump	Turbo-reduction gear, combine pump; oil-gear, water-centrifugal	3
Feed water neater	Vertical surface	3
Oil cooler	Vertical; internal water, external oil	3

The spring bearings on the shafting are self-lubricating.

10. Auxiliary machinery outside the engineering spaces

a. Rudder mechanism - the steering engine is an electrically driven hydraulic plunger type and it is capable of turning the rudder from hard port to hard starboard (or the opposite); that is, the rudder angle can be changed 70 degrees, in 30 seconds against a maximum torque of 45.6 meter-tons when going full speed astern.

The hydraulic cylinder is the four-plunger type and it is equipped with two electrically driven hydraulic pumps having the capacity required for the above.

In addition, it is equipped with a small model manual hydraulic pump which can operate the rudder at speeds up to 30 knots when the electric pump is inoperative.

b. Anchor windlass - the windlass is driven by a two-cylinder reciprocating steam engine. It is capable of hoisting 19.5 tons at the rate of nine meters per minute.

11. Repair facilities

In the after engineroom there is a universal machine used as a lathe, milling machine and drill press. There is also an electric-drill. On the upper deck there is a set of welding tools, and, in addition, within the ship there are the same repair facilities as on a standard first class destroyer.

12. Official trial trips

a. Method and type of trip - the official trial trips complied with the rules established for the servicing of ships and the Chief of the Navy Technical Department handled the details.

b. Method of using auxiliary exhaust steam - it was standard procedure on all types of trips to use the auxiliary exhaust steam to heat the feed water. It was led off to the main water condenser when under full power and full cruising power, since there was an excess, and used in the main turbine under other circumstances.

c. During the official trial trips and the various other tests, distilled water with a salt content of three parts per million or less was used as feed water. At standard speed, whenever it is possible from the standpoint of safety, economy or fuel should be attempted.

13. Estimated weight of engines

The estimated weight of engines (in metric tons) under official test conditions is as follows:

Main engines	215
Shafts and propellers	92.5
Auxiliary machinery	55.5
Boilers	195.5
Smoke stack and flues	13
Pipes, valves and cocks	97
Miscellaneous	56
Water	78
Oil	5.5
Total	724.5 without water and oil
	808.0 with water and oil

End of Specifications

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The following tables of machinery installed, with certain pertinent characteristics, are furnished for general information. These tables were translated from NavTechJap Document No. ND50-1041.1.

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TURBINE DATA - TERUTSUKI (DD)

Name	Type	Stages	Nozzles		No. of Rows of Blades		Average Diameter (mm)	RPM
			No.	Area (cm^2)	Moving	Stat.		
HP Turbine	Impulse single flow, 2	1st	28	95,788	2	1	800	3,618
		2nd	46	213,348	1		780	
		3rd	46	243,846	1		780	
Intermediate Pressure Turbine	Impulse single flow, 2	1st	56	298,032	1		980	3,003
		2nd	56	375,256	1		980	
		3rd	56	485,632	1		980	
		4th	56	655,760	1		980	
		5th	56	873,040	1		980	
Low Pressure Turbine	Double flow impulse (single flow backing impulse), 2	1st fore and aft	74	658,230	1 each		1300 each	2,613
		2nd fore and aft	156	1,017,900	1 each		1300 each	
		3rd fore and aft	74	1,767,860	1 each		1300 each	
		4th fore and aft	138	3,116,454	1 each		1300 each	
		Backing	36	throat 51,192 outlet 164,556	3	2		1,522
Cruising High Pressure Turbine	Impulse single flow, 2	1st	8	throat 13,760 outlet 16,408	2	1	400 each	7,746
		2nd	22	36,542	1		345	
		3rd	22	42,262	1		350	
		4th	24	49,920	1		360	
		5th	24	59,904	1		370	
Cruising Low Pressure Turbine	Impulse single flow, 2	1st	34	78,642	1		570	
		2nd	34	102,068	1		570	
		3rd	34	138,856	1		570	
		4th	34	211,378	1		570	
		5th	34	318,104	1		570	
		6th	84 each fans nozzle	500,304 each fans nozzle	1		570	

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		5th	34	318,104	1		570	
		6th	84 each fans nozzle	500,304 each fans nozzle	1		570	

REDUCTION GEAR - TERUTSUKI (DD)

Name	No. of Teeth	Average Diameter (mm)	Outside Diameter (mm)	Center Distance (mm)	Reduction Ratio (mm)
Bull Gear	415	(2395.21) 2396.01	(2405.21) 2406.01		1
HP Pinion Gear	39	225.17	235.17	Vertical 280 Horizontal (1279.921) 1280.33	10.641
IP Pinion Gear	47	271.35	281.35	Vertical 550 Horizontal (1102.332) 1103.816	8.830
LP Pinion Gear	54	311.77	321.77	Vertical 920 Horizontal (992.741) 993.287	7.685
Cruising Bull	147	594.10	601.10		8.830
Cruising HP Pinion	31	125.29	132.29	359.7	41.872
Cruising LP Pinion	44	177.82	184.82	385.96	29.501

CONDENSERS, BOILERS, AND PROPELLERS - TERUTSUKI (DD)

Condensers, number ..... two
cooling area, one, condensate water ..... (728.08) m^2
..... 727.39 m^2
air ..... (157.28) m^2
..... 156.93 m^2
total ..... (885.36) m^2
..... 884.32 m^2
grand total ..... 1769.68 m^2

Boilers, type ..... Mark 3B Model 17 RO
number ..... two
heating area, evaporator tubes ..... 787 m^2
superheater tubes ..... 166 m^2
one boiler total ..... 953 m^2
grand total ..... 2859 m^2
fire box volume, one boiler ..... 37.8 m^3
total ..... 113.4 m^3

Propellers, (equal pitch), number ..... two
diameter ..... 3.650 mm
pitch ..... 3.720 mm
developed area ..... 7.6275 m^2
projected area ..... 6.7200 m^2
number of blades ..... three

AUXILIARY MACHINERY - TERUTSUKI (DD)

Space	Name			Type	Output	Cylinder or Turbine Pitch Diameter (mm)	Number of Stages or Strokes (mm)	Pump Fan Diameter	No.
Engine Room	Condensate Pump			Turbo-vortex with vertical reduction gear	100 m^3/hr	180	1 (2 rows)	280 mm	4
	Water Circulating Pump			Turbo-axial flow with horizontal reduction gear	8,500 m^3/hr	270	1 (2 rows)	736 mm	2
	Lube oil Pump			Turbo-Gear with vertical reduction gear	125 m^3/hr	180	1 (2 rows)	Gear pitch diameter 80	4
	Cruising Feed Pump			Turbo-vortex with horizontal reduction gear	50 m^3/hr	270	1 (2 rows)	250 mm	1
	Fire and Bilge Pump			Vertical electric Vortex type	Fire 30 m^3/hr Bilge 60 m^3/hr			164 mm	2
	Fuel Oil Transfer Pump			Vertical electric gear type	30 m^3/hr			Gear pitch diameter 75	1
	Oil Purifier			Hitachi Mark 5D open type	1300 m^3/sec				2
	Blowers		Supply	Turbo-axial flow with reduction gear	16 m^3/sec	180	1 (2 rows)	945 mm	2
			Exhaust	Horizontal electric axial flow	19 m^3/sec			995 mm	2
	Water Making Plant		Evaporator	Bureau	96 tons/day	Inside trunk diameter 14.50	Heating (outside) area 29.06 m^2		1
			Heat Compresser for evaporator	Single nozzle steam injection, adiabatic compression type	Mark 1 940 m^3/hr Mark II 59[illegible] m^3/hr				Mk. I 2 Mk. II 2
			Feed Heater for evaporator	Horizontal surface type	6.67 m^3/hr	Heating area 2.315			1
			Distiller	Vertical surface type	96 tons/day	Inside trunk diameter 470	Cooling area (outside) 22.31		1
		Air Ejector on distiller	Ejector	Single Nozzle, steam injection, adiabatic compression type	7 tons/hr				1
			Cooler	Vertical surface type	24 tons/hr		Cooling area (outside) 0.454 m^2		1
			Drain Cooler	Vertical surface type	116 m^3/day	Inside trunk diameter 340	Cooling area (outside) 7.22 m^2		1
			Auxiliary Pumps	Turbo-vortex with vertical reduction gear	Circulating 140 m^3/hr Brine 14 m^3/hr Fresh water 7 m^3/hr	120	1 (2 rows)	Circulating 205; Brine 215 Fresh water 200	1
		Air Ejector	Ejector	Parallel 2-stage triple steam injection type	180 tons/hr				2
			Cooler	Vertical surface type	900 tons/hr		Cooling area (outside) 1 stage 20.9 m^2 2 stage 20.9 m^2		2
	Oil Cooler			Vertical, inside water, outside oil type	125 m^3/hr	Inside trunk diameter 840	Cooling area (outside) 74.3 m^2		2
	Feed Heater			Vertical surface type	130 m^3/hr	Inside trunk diameter 510	Heating area (inside) 21.9 m^2		2

AUXILIARY MACHINERY - TERUTSUKI (DD) (CONT'D)

Space					Output	Cylinder or Turbine Pitch Diameter (mm)	Number of Stages or Strokes (mm)	Pump Fan Diameter	No.
Boiler Room	Main Feed Pump		Turbo-vortex with horizontal reduction gear		125 m^3/hr	270	1 (2 rows)	305 mm	3
	Auxiliary Feed Pump		Weir (HD6)		84 m^3/hr	400	500	280 mm	2
	Blower		Turbo-axial flow with vertical reduction gear		22 m^3/sec	270	1 (2 rows)	945 mm	6
	Fuel Oil Injection Pump		Turbo-screw with vertical reduction gear		16 m^3/hr	180	1 (2 rows)		3
	Lube Oil Cooling Water Pump		Turbo-geared vortex type with horizontal reduction gear		Lube oil 15 m^3/hr Cooling water 36 m^3/hr	120	1 (2 rows)	LO gear pitch diameter 45 water, 110	3
	Fuel Oil Ignition Pump		Horizontal electric geared		0.5 m^3/hr			Gear pitch diameter 32	1
	Boiler Flooding Pump		Horizontal electric geared		10 m^3/hr			Gear pitch diameter 65	1
	Boiler Room Feed Water Heater		Vertical surface type		80 m^3/hr	Inside trunk diameter 600	Heating area (inside) 37.2 m^2		3
	Fuel Oil Heater		Vertical bent tube type		11 m^3/hr	Inside trunk diameter 360	Heating area (inside) 5.088 m^2		3
	Oil Cooler		Vertical, inside water, outside oil type		15 m^3/hr	Inside trunk diameter 400	Cooling area (outside) 13.98 m^2		3
Anchor Engine	Anchor Engine and Installation		Vertical 2-piston type		Test load 19.5 tons Winding speed 9.0 m/sec				1
Rudder Engine Room	Rudder Engine and Installation	Plunger	Hydro-electric plunger type	Aonne	Rudder turning speed 70°/30 sec	Plunger diameter 250	Plunger stroke 840.24		4
		Main Hyd.Pump		Model 6	70°/30 sec	Rudder torque 70 m	Plunger stroke volume 218.8 liter/sec	Plunger diameter 34	2
Personnel Room		Manual Hyd. Pump		Vertical 2-cylinder			120	Plunger diameter 60	1

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The following summaries of trial runs have been translated from Nav-TechJap Document No. ND50-1041.1, and are furnished for information without discussion.

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TRIAL TEST SUMMARY - AKITSUKI - (TERUTSUKI CLASS DD) - PART I

							Full Trial Power			Overload Full Power		
							Time of Test					
			Leaving Port	During Test	Returning	Leaving Port	8/10	Measured	1 hr run	Measured	3 hr run	Entering Port
Leaving Port	Draft (m)	Fore	4.18		4.12	4.18						3.95
		Aft	4.12		4.12	4.12						4.11
		Average	4.15		4.12	4.15						4.03
		Center	4.17		4.12	4.19						4.03
	Displacement (tons)		3,494		3,457	3,501						3,375
Time of Acceptance run	Draft (m)	Fore		4.15			4.17	4.15	4.15	4.11	4.09	
		Aft		4.13			4.14	4.14	4.14	4.14	4.13	
		Average		4.14			4.16	4.15	4.15	4.13	4.11	
	Displacement (tons)			3,469			3,487	3,472	3,474	3,452	3,440	
	Sea Water Temperature			13 °C		14 °C						
	Maximum Cross Section Below Waterline (m^2)		42.48	42.25		42.53						
Fuel Carried (tons)				1091.42								
Speed (knots)				17.5			31.85	33.39		33.77		
Actual Horsepower				10,172			41,690	52,193	51,670	54,763	54,315	
Shaft revolutions per minute				200.5			315.3	343.00	339.8	348.2	346.4	
Fuel consumed (kg/shp/hr)				0.905			0.364	0.352	0.352	0.359	0.358	
Fuel consumed per unit heating surface per hour ($kg/cm^2/hr$)				3.22			5.33	6.43	6.35	6.86	6.82	
Cruising Distance	por ton of fuel			1.90			2.10	1.81		1.72		
	por total load of fuel			1,970			2,177	1,877		1,783		

TRIAL TEST SUMMARY - AKITSUKI - (TERUTSUKI CLASS DD) - PART II

										Full Power	Standard Speed					
			Leaving Port	Time of Test				Entering Port	Leaving Port	Time of Test			12 knot Speed	Entering Port	Leaving Port
Leaving Port	Draft (m)	Fore	4.17					4.05	4.16					4.13	4.08
		Aft	4.13					4.12	4.11					4.11	4.18
		Average	4.15					4.09	4.14					4.12	4.13
		Center	4.15					4.09	4.05					4.12	4.13
	Displacement (tons)		3,475					3,414	3,473					3.451	3,467
Time of Trial run	Draft (m)	Fore		4.15	4.13	4.12	4.10			4.16	4.16	4.16	4.15		
		Aft		4.13	4.13	4.13	41.3			4.12	4.12	4.12	4.12		
		Average		4.14	4.13	4.13	4.12			4.14	4.14	4.14	4.14		
	Displacement (tons)			3,466	3,456	3,450	3,442			3,467	3,464	3,464	3,460		
	Sea Water Temp.(°C)					14					14			13	17
	Maximum Cross Section below water line (m^2)		42.30	42.2	42.1	42.06	41.98	41.71	42.28	42.22	42.22	42.19	42.15	42.03	42.22
Speed (knots)				26.71	30.04	27.81	26.11			20.99	18.26		12.27		
Actual Horsepower				17.995	31,595	21,845	19,120			7,704	4,839	4,732	1,460		
Shaft RPM				243.7	288.2	258.4	280.0			187.9	161.2	159.5	106.3		
Fuel Consumed (kg/shp/hr)				0.392	0.374	0.394	0.377			0.402	0.430	0.425	0.745		
Fuel Consumed per unit Heating Surface per hour ($kg/cm^2/hr$)				3.70	4.13	4.52	3.79			3.24	2.18	2.11	1.14		
Cruising Distance (naut. m.)	Per ton of Fuel			3.78	2.55	3.23	3.61			6.77	8.74		11.2		
	Per Total Load of fuel			3,919	2,644	3,349	3,743			7,019	9,062		11,610		

Part VII - KAGERO Class (DD)

The machinery in this vessel was very similar to that in TERUTSUKI class. However, the arrangement differed in that there were three boiler rooms with only one engineroom and an auxiliary machinery space abaft the engineroom.

Even though both engines were in the same space, the piping systems provided for complete segregation of the two plants except when all three boilers were in use and it was necessary to split the load of boiler No. 3. It was intended that each group of engineroom auxiliaries would obtain its auxiliary steam from its own main steam line.

A copy of "New Construction Trials", NavTechJap Document No. ND50-1043.1 has not been translated because of the similarity between the machinery plants of TERUTSUKI and KAGERO classes.

The following is a translation of the machinery design requirements for KAGERO class.

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SUMMARY OF THE ENGINEERING SPECIFICATIONS FOR THE TYPE 112 NAVAL VESSEL

Navy Technical Department, Very Secret, No. 15-5.

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c. When finished using this document, it must be handed in immediately to the Chief of the Navy Technical Department.

HISTORY

Proposed September 1939 - However, the type of windlass, make, the weight of the engines and the engine terminology were revised.

Table of Contents

1. Hull dimensions

At the time of the official trial, the hull dimensions were:

Length at waterline	116.20 m
Beam	10.80 m
Draft	3.755 m
Displacement	2500 metric tons

2. Operating tests

Plans and types of operation - operating tests shall be in accordance with the regulations for the construction and repair of naval vessels, the details to be indicated by the Chief of the Navy Technical Department.

a. Methods of using auxiliary exhaust steam - all types of operation make provision for the use of the auxiliary exhaust steam in the feed water heaters, the remainder to pass to the main condenser when on official trial, or to be utilized in the main turbines.

b. The water supply necessary for getting up steam for operating and other tests shall be distilled water with a salt content of three parts or less per million.

c. The operation of the engines at standard speed shall allow for the following conditions:

(1) Main engines - use the cruising turbine.

(2) Boilers - use one boiler.

(3) The main engines and the auxiliaries connected with the boilers shall be kept at the minimum necessary for power required consistent with the number of main engines in use, utilizing one feed pump and one blower per shaft.

(4) Previous allowance shall be made for not using auxiliary machinery not connected with navigation, except those referred to in the preceding paragraph and except for the use of the minimum number of generators and blowers.

(5) One internal combustion generator will be used for generating power. When there is insufficient power, diesel generators and turbines shall be operated simultaneously.

d. In the final tests, the supply of feed water shall be obtained by means of the evaporators. Lubricating oil which was used for pressure feeding prior to operation shall be replaced by new oil in order to carry out completely accurate tests.

3. General layout

The main engine is made up of HP, IP and LP turbines coupled to the shafts by reduction gears, two shafts being mounted in each vessel.

The astern turbine shall be attached to the front part of the housing of the low pressure turbine. The reduction gear and clutch mechanisms of the two cruising turbines shall be coupled to the intermediate pressure turbine. The exhaust steam of the cruising turbines shall be transmitted directly to the steam chamber of the low pressure turbine.

4. Main engines

The specified power of the main engines for propulsion shall be 26,000 hp for each shaft, a total of 52,000 for both shafts, when operating at 380 RPM.

The specified power of the cruising turbines shall be 2050 hp per shaft or a total of 4100, the propellers operating at 165 RPM. However, with overload power, these turbines shall produce 3500 hp per shaft, or a total of 7000 hp, and when used together with the main engines, they will achieve up to 228 RPM (about 5500 hp per shaft or a total of 11,000).

The specified power of the astern turbines shall be 5000 per shaft, or a total of 10,000 hp with the propellers operating at 220 RPM.

Steam pressure, temperature, and consumption:

Power Used	Steam Chest Pressure (kg/cm^2)	Steam Temp (^oC)	Vacuum (mm hg)	Steam Consumption (kg/shp/hr)
Specified full power	26	335	700	3.75 or less
Total astern power	21	330	645	9.0 or less
Total ahead power	26	335	725	4.3 or less

5. Main condensers

The main condensers shall be of the single-pass type, one being attached to each low pressure turbine.

6. Shafting and propellers

The shafting consists of the first intermediate shaft, the thrust shaft, the second intermediate, the stern tube shaft, and the propeller shaft. The claw type brake placed over the joint of the intermediate shaft and the stern tube shaft will hold the shaft at one half the normal torque of specified full power.

The thrust bearings are of the Mitchel type. The pressure on each sq. cm of the thrust face shall not exceed 20 kg. The first ship of the class shall have a thrust indicator installed.

The propellers are made of manganese bronze.

7. Boilers

The boilers have superheaters and air preheaters. RO type boilers are installed, a total of three, one in each fireroom. Important particulars concerning the boilers are listed below:

Steam pressure, steam drum ..... 32 kg/sq. cm
superheater outlet ..... 30 kg/sq. cm
Steam temperature ..... 350 ^oC
Rate of combustion, specified power ..... 7.7 kg/sq. cm
actual test ..... 6.7 kg/sq. cm
Heating surface, generating and superheating ..... 953 sq. m
air preheater ..... 427.2 sq. m
Combustion chamber volume ..... 38 cu. m
Blowers ..... Bureau type 1-6
Atomizers ..... Models 3-9 and 5-9
Air cone ..... Bureau type 15

8. Stacks and uptakes

The two forward boilers are attached to the forward funnel and the after boiler to the after funnel.

9. Feed water system

The feed system is a closed system.

10. Auxiliary machinery in the engineering spaces

The following are the numbers and types of the auxiliaries in the engineering spaces:

Name	Type	Quantity
Main circulator	Axial flow, turbo-reduction gear drive	2
Air ejector	Dual bank, triple-flow, steam ejector	2
Lube oil pumps	Gear type, vertical, turbo-reduction gear	3
Blower supply	Axial flow, turbo-reduction gear	2
Exhaust vent	Axial flow, electric	3
Fire and bilge pump	Vertical, electric, centrifugal	1
Fuel oil distributing pump	Vertical, electric gear	1
Evaporators	Bureau	1
Evaporator pump	Combine pump, turbine-drive	1
Oil purifier	Electric centrifugal	2
Oil cooler	Vertical, oil inside, water outside	2
Feed heater	Vertical surface, Boiler room auxiliaries	3
Main feed pump	Centrifugal, turbo-reduction gear	3
Auxiliary feed pump	Reciprocating	6
Blower (FD)	Axial flow, vertical, turbo-reduction gear	3
F. O. service pump	Vertical, gear type, turbo-reduction gear	3
Lube oil and lube oil cooler pump	Combine pump, turbine-drive	1
Boiler filling pump	Latest electric gear	

Fuel oil heater	Vertical, coiled-tube
Feed heater	Vertical, surface
Oil cooler	Vertical, oil inside, water outside

11. Steering mechanism

The steering mechanism shall be of the electric hydraulic type. It is capable of turning the rudder from hard port to hard starboard, an angle of 70 degrees, in 30 seconds against a torque of 30.04 metric tons when going full speed ahead, and a maximum torque of 16.99 metric tons going full speed astern.

It shall be equipped with two electric powered hydraulic pumps of the power indicated above.

In addition, it shall be equipped with one small sized hand-operated hydraulic pump capable of being used for steering in case of breakdown of the electric-powered hydraulic pumps.

12. Windlass mechanism

The windlass machinery shall operate through a gear mechanism powered by an upright dual-pistoned steam engine, capable of hoisting 12.6 tons at a speed of nine meters per minute.

13. Repair facilities

In addition to the universal machine tool (capable of being used as a lathe, miller, and boring mill) and an electric drill in the engine room, there shall be a gas welding set topside.

14. Weight of engines

The specified weight of the main engines in tons (metric) shall be as follows:

Main engines	194.2
Drive shaft and propellers	78.0
Auxiliaries	51.5
Boilers	196.0
Stacks and uptakes	12.0
Pipes, valves, and cocks	82.8
Miscellaneous	52.5
Water	7.7
Oil	5.0
Total, not including water and oil	667
including water	744
including water and oil	749

End of Specifications

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Part VIII - SHIMAKAZE (DD)

This vessel was an experimental type as far as the engineering plant was concerned. It was the first Japanese combatant vessel to have a steam plant with pressures as high as 560 lb/sq. in. Economizers were provided in the boilers. The machinery arrangements, as far as could be determined, were very much like TERUTSUKI class except that there were three firerooms instead of two. A copy of the machinery design requirements was obtained and a translation is furnished.

An automatic firing control, whereby a variation in steam pressure actuated a pilot valve in a hydraulic system to increase or decrease the oil to the burners in use and thus restore the steam pressure to a predetermined figure was installed in the firerooms of this vessel. The system was reported to have been not too satisfactory and also to have given considerable trouble from smoking. No plans for this system were obtained.

In spite of the high steam pressure, the same type of feed system found on lower pressure plants was used.

The ship was relatively fast, 39 knots, but too short-lived to determine how well the machinery stood up under war conditions.

The following translation of the "Machinery Design Requirements", NavTechJap Document No. ND50-1030, is furnished. It is to be noted that it contains no reference to the automatic firing device.

Plans for engineroom piping systems were not located. The boiler room piping plans are contained in NavTechJap Document No. ND50-1044.

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TRANSLATION OF ENGINE SPECIFICATIONS OF SHIP NO. 215 SHIMAKAZE (DD)

HISTORY

Drafted 1 June 1940.

Concluded 1 February 1941.

Approved 10 February 1942; 59 of No. 5.

Second approval 3 December 1942; 524 of No. 5. Classified "Secret" by Navy Technical Department.

Following the success of the second test plan, the following improvements were made in the original:

a. Survey of propulsion equipment.

b. Type and horsepower or the blowers.

c. Type and horsepower of the heavy oil ignition pump.

d. Type of anchor windlass.

Table of Contents

1. Summary of the plans

In the preconmissioning trial run (gross weight of engine 1012 tons, displacement 2920 tons) the entire 75,000 hp of the plant was developed. The amount of fuel consumption at standard speed (18 knots) leveled off at an average of 0.38 kg/hp/hr. It was able to meet the various wartime demands.

2. Disposition of the engines

There are two shafts and each is connected with one main turbine and respective reduction gear. To each main turbine are connected two cruising turbines and respective reduction gears. In the forward engineroom they are located on the port shaft, and in the after engineroom on the starboard shaft. There are three boilers, one to a boiler room.

3. Main engines

a. General disposition of main engines - on every shaft there are geared high pressure, No. 1 medium pressure, No. 2 medium pressure, and low pressure turbines (including the reversing turbine), every pinion mated with a single parent gear. The two cruising turbines connect through a reduction gear to the No. 2 intermediate turbine. The exhaust of the cruising turbine leads to the No. 2 medium pressure turbine steam chest.

b. Specified power and RPM of the main engines - the specified power ahead of the main engines is reckoned at 370 RPM of the shaft. With ordinary exhaust, one shaft is rated at 37,500 hp, a total of 75,000 for both shafts.

The specified power of the cruising turbine (total cruising power) is reckoned at 172 RPM of the shaft. The horsepower of one shaft is 3750, giving a total of 7500 for both shafts. It is possible to use these without disengaging to the maximum of 218 RPM of the shaft, i. e., 26 knots (approximately 16,000 hp total for two shafts). At standard speed it will be 146 RPM of the shaft, approximately 2400 hp per shaft, or a total of 4800 hp.

The specified power for the reversing turbine is 214 RPM of the propeller shaft, or 7000 hp per shaft (grand total 14,000 hp). The relation between the S.H.P. and RPM at various speed is shown in the following table.

Power Used	S.H.P.	RPM	Notes
Specified full power	75,000	370	Approximately 0.33 kg/hp/hr (fuel consumption)
Overload full power	79,000	378	
Standard speed	4,800	136	0.38 kg/hp/hr (fuel consumption)
Cruising full speed	7,500	173	
Maximum cruising power	18,000	218	
Astern	14,000	214	

Main engine steam pressure, temperature, and rate of steam consumption for the above conditions are as follows:

Power Used	Steam Pressure (kg/sq. cm)	Steam Temp (°C)	Vacuum (mm hg)	Steam Consumption (kg/hp/hr)
Specified full power	35	385	700 or more	3.45 or less
Full power astern	24	375	700 or more	8.5 or less
Full power cruising	35	345	728 or more	4.1 or less
Standard speed	35	330	728 or more	4.3 or less

4. Condensers

There is one condenser on each shaft, of the single-pass surface type, a total of two main condensers.

5. Shafting and propellers

a. Shafting - the shafting consists of a thrust shaft, intermediate shafts (two on the port side and one on the starboard), the stern tube shaft and the propeller shaft. The claw type brake between the stern tube shaft and the intermediate shaft can stand a torque of one-half the torque which occurs at specified full power.

b. Thrust-bearings - the Mitchel type is used. The thrust block is made of white metal and shall withstand a pressure of 20 kg/sq. cm. In addition, it is equipped with a thrust gage.

c. Propellers - the propellers are of uniform pitch and are made out of manganese bronze. General specifications are as follows:

Diameter ..... 3550 mm
Pitch ..... 4300 mm
Developed area ..... 8.43 m
Weight ..... about 9000 kg

(TN: All of the above figures, except the weight of the propellers, have been scratched out, indicating that some change was made. However, the new figures were not added.)

6. Boilers

There are three Bureau, RO type boilers fitted with a superheater and an air preheater. There is one boiler in each boiler room. The boiler rooms are of the open type. Specifications for one boiler are as follows:

Steam pressure,	steam drum	43 kg/sq. cm
	superheater outlet	40 kg/sq. cm
Steam temperature,	at specified rate of combustion	400 °C
	at fuel comb. rate of 2.0 kg/sq. m	325 °C
Combustion rate,	planned	7.0 kg/sq. m
	effective use limit rate	7.7 kg/sq. m
	maximum possible	8.75 kg/sq. m
Efficiency ratio,	specified	75%
	at 2.0 kg rate	86%
Heating surface,	economizer	1150 sq. m
	generating	1150 sq. m
	superheating	1150 sq. m
	air preheater	440 sq. m
Volume of combustion chamber		45 cu. m
Burners, Bureau Type 22,	Model 3	seven
	Model 5	22
Cones		Bureau Type 20, Model 5

Note - each boiler room is equipped with an injector which is controlled by oil pressure.

7. Auxiliary machinery in the engineering spaces

Name	Capacity	Type	Quantity
Feed heater	200 cu. m/hr	Vertical surface	2
Packing leadage steam cooler			2
Main feed pump	150 cu. m/hr 52 kg/sq. cm	Centrifugal, turbo-reduction gear	3
Auxiliary feed pump	80 cu. m/hr 50 kg/sq. cm	Weir reciprocating	3
Blower	22 cu. m/hr 27 cu. m/hr (450 mm, 600 mm)	Axial flow, vertical turbo-reduction gear	6
Fuel oil service	20 cu. m/hr 20.5 kg/sq. cm	Screw, vertical, turbo-reduction gear	3
Lube oil cooling pump		Combination water and oil, turbo-drive	3
Oil pump	10 cu. m/hr 10.5 kg/sq. cm	Turbo-reduction gear, vertical	3
Oil heater	15.0 cu. m/hr	Bent tube	3
Water heater	1200 cu.m/hr	Vertical, surface	3
Oil cooler	15.0 cu.m/hr	Vertical	3

(TN: Blower capacity figures have been crossed out in the original.)

8. Auxiliary machinery outside of the engineering spaces

a. Steering gear - the steering mechanism is of the electrically operated, oil pressure plunger type. The rudder has the capacity of withstanding a maximum torque of 28 meter-tons at full speed ahead and 52.7 meter-tons at full speed astern, when the rudder is turned from full rudder one way to full rudder the other, that is a turn of 70 degrees, in 30 seconds.

The rudder moving mechanism is of the four-cylinder, Rapson type. In order to have sufficient power, the rudder mechanism is equipped with two electric oil pressure pumps. In case of a breakdown of the electric pumps, the rudder may be moved by the use of a manually operated pump, which maintains steering control for speeds up to thirty knots.

b. Anchor hoist - the anchor hoist mechanism.....
(TN: Both "steam" and "electric" were written in and then both crossed out.)

9. Repair facilities

In the forward engineroom there is the universal repair equipment (lathe, milling machine and drill press) and an electric drill; on the upper decks there is a gas welding outfit. In addition, the engineering department has all the allowances of a first class destroyer.

10. Trial run

a. Methods and types of trial - the official tests were carried out according to shipbuilding specifications. Detailed results may be obtained by referring to the Chief, Navy Technical Department.

b. Methods of utilizing auxiliary exhaust steam - the standard procedure in each of these trials has been to utilize the auxiliary exhaust in the feed water heaters, then, if there is any surplus, it is diverted to the main condensers.

c. In the official trial and all other tests, the water used in making steam was distilled water with a salt content of less than three parts per million.

d. At normal speed fuel economy could be expected as long as there was no hindrance to smooth operation of the engines.

11. Weight of engines

The specified weight of the engines and auxiliary machinery in tons follow:

Main engines	274
Shafting and propellers	112
Auxiliary machinery	72
Boilers	251
Stacks and uptakes	14
Tubes, valves, and cocks	124
Miscellaneous	68
Water and oil	97
Total, without water and oil	915
with water and oil	1012

End of Specifications

* * * * *

Tables of machinery installed, with the corresponding characteristics, have been translated in NavTechJap Document No. ND50-1045.1. One run of the trial plus the summary of results have also been translated in this document.

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Part IX - MATSU Class (DE)

Cruising turbines and connecting lines were removed after they were found impractical for this vessel.

These were the first and only vessels noted to have had a machinery arrangement of fireroom - engineroom - fireroom - engineroom. There were no cross connections between the main steam lines of the two plants.

The auxiliary steam lines ran down the starboard side of the ship as was the case for destroyers. The same characteristic of cross connections between lubricating oil pumps existed. The tendency to supply steam for the emergency bilge eductors from the other plant is to be noted.

The fresh water transfer system is on the same diagram as the main feed and condensate system. The fresh water drains were similar, in general, to those of other vessels. The feed and fuel oil heater drains could be led to either main condenser. As on other vessels, no open funnel drains passed through athwartship bulkheads.

There was no cross connection between the high pressure sides of the main feed systems of the two boiler rooms, or the high pressure sides of the fuel oil system so characteristic of other Japanese vessels.

The float control tank in the condensate system of this vessel differed. A movement of the float, actuated by the level in the condenser, moved a pilot valve. This pilot valve controlled the movements of two oil pistons which in turn were connected to two fresh water valves which caused water either to leave the system via the surge tank, or enter the system via the condenser. Oil pressure for this system was supplied by the main lubricating system.

A copy of the "Machinery Design Requirements", NavTechJap Document No. ND50-1028, was translated. The translation has not been edited or paraphrased any more than was found necessary to make it intelligible.

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TRANSLATION OF MACHINERY SPECIFICATIONS FOR JAPANESE DE MATSU CLASS

Instructions for handling this volume:

a. This volume is classified "Military Very Secret" and shall be handled accordingly.

b. Reproducing or tracing any part of this document which does not bear a direct relationship to the work is strictly prohibited.

c. Immediately upon termination of the need for this document, it should be returned to the Chief, Navy Technical Department.

HISTORY

20 January 1943 - Proposed

5 May 1943 - Approved

No. 196 of No. 5 Classified "Top Secret" by Navy Technical Department.

Table of Contents

1. Outline of general hull specifications

Hull conditions for the official tests follow:

Length at waterline	98.00 m
Beam at waterline	9.350 m
Depth	5.700 m
Mean draft	3.300 m
Displacement	1053 metric tons
Speed	27.8 knots
Fuel capacity	360 metric tons

2. General arrangement of machinery

The main steam engine and main engineroom arrangement are as set forth in the engineering plan, the same as Model 2021, which calls for a No. 1 boiler room and a forward engineroom, a No. 2 boiler room and an after engineroom. Each space is arranged in the following manner:

Fireroom No. 1
One boiler with auxiliary machinery

Forward engineroom
Port main engine and its auxiliaries
Cruising turbine - one
Condensing apparatus - one
Exhaust and supply blower - one each
Turbine driven fire and bilge pump - one
Portable fuel oil pump
..... pump (not clear)
YU Type air compressor
Turbo-generator

Fireroom No. 2
One boiler and its auxiliaries

After engineroom
Starboard main engine and its auxiliaries
Supply and exhaust blower - one each
Electric fire and bilge pump
Diesel generator - two
YU type air compressor

3. Main engines

a. General arrangement of the main engines - the main turbine is a No. 3c, Model 5481. It is composed of high, medium, and low pressure turbines and joins with the main shaft by a No. 1c, Model 5481, reduction gear. The port main engine is located in the forward engineroom and the starboard main engine in the after engineroom. The high pressure turbine joins the front of the low pressure turbine, and the astern turbine is housed in the low pressure turbine inner casing.

The cruising turbine is a No. 3a, Model 5481 cruising turbine and drives through the No. 1a, Model 5481, cruising reduction gear. It joins the extremity of the port medium pressure turbine. Its exhaust passes to the high pressure turbine in the after engineroom, and from there follows the course of steam that normally enters the starboard engine through the ahead throttle.

b. Capacity of the main engines - the capacity of the main engines ahead is such that at 400 RPM of the propeller, 9500 hp (Cheval Vapeur) is produced on one shaft and a total of 19,000 hp on both shafts.

The rated cpacity of the cruising turbine (cruising full power) 3000 hp for two shafts; furthermore, using all the main turbines at the same time, they can be used without disengaging the cruising turbine up to the maximum cruising speed (about 21.5 knots), that is to say, propeller RPM of 280 (one shaft - 3000, both shafts - 6000 hp).

The rated capacity of the astern turbines at 247 RPM is 2000 hp on one shaft, with a total of 4000 hp for both shafts (note: hp is Cheval Vapeur).

Relation of the S.H.P. and the RPM for each power unit is as follows:

Power Used	S.H.P. (Cheval Vapeur)	RPM Shaft
Specified full power	19,000	400
Overload full power	20,000	407
Cruising	3,000	218 port* 238 Stbd
Standard speed	3,200	231
Maximum cruising speed	6,000	280
Astern	4,000	247

*As for the starboard shaft, the exhaust of the cruising turbine provides only 1600 shp with regards to the port shaft, using the main turbines at the time as the cruising turbines, produces 1600 shp on the port shaft. (as translated).

c. Main engine steam pressure, vacuum and steam consumption rate

Power Used	Steam Chest Pressure (kg/sq. cm)	Steam Temp (°C)	Vacuum (mm hg)	Steam Consumption (kg/shp/hr)
Specified	26.0	335	700 or more	3.85 or less
Standard	26.0	310	720 or more	4.8 or less
Total cruising	26.0	310	720 or more	4.8 or less
Astern	21.0	320	665 or more	915 or less

d. Main condenser - the main condensers are of the single-flow surface type and are suspended under the low pressure turbines.

4. Drive shaft and propellers

a. Shafting - the port shaft is composed of 7 lengths: the thrust shaft, No. 1, 2, 3, and 4 sections of line shaft, the stern tube shaft, and the propeller shaft. The starboard shaft is composed of four sections: the thrust shaft, one section of line shafting, the stern tube shaft and the propeller shaft. The claw type rotor brake which is located above the coupling between the line shaft and the stern shaft can lock the shaft up to one half the full power torque. All of the intermediate bearings on the shafting are self-lubricating.

The thrust bearing is the Mitchel type: the pressure against each square centimeter of the thrust bearing pillow must not exceed 20 g.

b. Propeller - the propeller has a diameter of about 2.650 meters, gross weight of about 3.300 metric tons and is made of manganese bronze.

5. Boilers

There are two No. 3-B, Model 5481, RO class, oil burning boilers. One is placed in each of the boiler rooms. The boiler rooms are of the open type. In general, essential data for the boilers are as follows:

Steam pressure, steam drum ..... 32 kg/sq. cm
superheater outlet ..... 30 kg/sq. cm
Steam temperature, at fuel rate of 3.0 kg/sq. cm/hr ..... 350 °C
Fuel rate, specified full power ..... 7.3 kg/sq. m
burners full use ..... 8.0 kg/sq. m
overload ..... 9.1 kg/sq. m
Heating surface, saturated ..... 416 sq. m
superheater ..... 82 sq. m
air preheater ..... 130 sq. m
F. D. blower, Ship type 13, Model 13, Style 5.5 ..... two
Burners ..... Ship Type 11 cone, Model 5

6. Uptakes and stacks

There are two stacks, No. 1 stack takes care of boiler No. 1 and No. 2 stack takes care of boiler No. 2

7. Miscellaneous equipment

The various fittings are made extremely simple for speed of contruction and ease of operation.

a. The arrangement is such as to have a telephone room which does not place the control room in the engineroom or the boiler room.

b. The engine control equipment is made as simple as possible.

c. The following articles are not provided:

(1) Engineroom electric thermometer, absolute pressure gages.

(2) Boiler room oil purifying fittings.

(3) One internal and one external mineral oil tank. (Seed oil, Colza oil).

8. Auxiliary machinery in the engineering spaces

Equipment in the forward fireroom:

Name	Capacity	Type	Quantity
Main feed pump	50 lit/hr	Centrifugal, turbo-reduction gear	2
Auxiliary feed pump	50 lit/hr	Reciprocating	2
Blower (FD)	20 lit/sec	Vertical, axial flow turbo-reduction gear	2
F. O. service pump	10 cu. m/hr	Vertical, turbo-reduction gear, screw	2
Oil ignition pump	0.5 cu. m/hr	Electric gear	1
Oil ignition pump	.25 cu. m/hr	Hand	1
Lube oil and lube oil cooler	oil 5 cu. m/hr water 12 cu. m/hr	Horizontal turbo	2
Feed heater	50 cu. m/hr	Vertical surface	2
Oil heater	5 cu. m/hr	Vertical, coil	2
Oil cooler	5 cu. m/hr	Vertical, inside water, outside oil	2

Equipment in the forward engineroom:

Main circulator	4000 cu. m/hr	Turbo-propeller	1
Condensate pump	50 cu. m/hr	Centrifugal, vertical, turbo-reduction gear	2
Air ejector	60 kg/hr	Two-stage, jet	
Oil pump (lube)	50 cu. m/hr	Vertical, turbo-reduction gear	2

Supply vent	10 cu. m/sec	Horizontal, electric, axial flow	1
Exhaust vent	12 cu. m/sec	Horizontal, turbo-reduction, axial flow	1
Fire and bilge pump	Fire 30 cu. m/hr Bilge 60 cu. m/hr	Vertical, turbo-reduction, centrifugal	1
Oil transfer pump	20 cu. m/hr	Electric gear	1
Equipment in after fireroom:			
Boiler water pump	10 cu. m/hr	Horizontal, electric gear	1
Oil purifier	750 lit/hr	Electric, centrifugal	1
Oil cooler	50 cu. m/hr	Vertical, water outside, oil inside	1
Feed heater	50 cu. m/hr	Vertical, surface	1
Evaporators	72 tons/day Water circulating 100 cu. m/hr; brine 10 cu. m/hr; fresh water 5 cu. m/hr	Horizontal, combine	1
Equipment in after engineroom:			
Main circulator	4000 cu. m/hr	Turbo-propeller	1
Main condensate pump	50 cu. m/hr	Centrifugal, vertical, turbo-reduction gear	1
Air ejector	60 kg/hr	Two-stage, jet	1
Lube oil pump	50 cu. m/hr	Vertical, turbo-reduction gear	2
Supply vent	10 cu. m/hr	Horizontal, electric, axial flow	1
Exhaust vent	12 cu. m/hr	Horizontal, axial flow, turbo-reduction gear	1
Fire and bilge pump	Fire 30 cu. m/hr Bilge 60 cu. m/hr	Vertical, centrifugal, electric	1
Oil purifier	750 lit/hr	Centrifugal, electric	1
Oil cooler	50 cu. m/hr	Vertical, water inside, oil outside	1
Feed heater	50 cu. m/hr	Vertical, surface	1

9. Auxiliary machinery outside the engineering spaces

a. Steering mechanism - the steering mechanism is an electric oil pressure plunger type. It has the capacity to turn from full rudder one way to full rudder the other, that is to turn 70 degrees, in 15 seconds when the maximum torque from the water from full speed is 7.4 meter-tons and full astern is 13.1 meter-tons.

On the starboard side there is an electric oil pressure pump of requisite capacity, and on the other side there is a manual oil pressure pump which, in the event of a breakdown of the electrical equipment, has sufficient power to steer the ship.

b. The anchor hoist machine is a piston type and can raise a weight of 9.8 tons at the rate of nine meters per minute.

10. Repair facilities

The standard repair equipment of these vessels is based on that of second class destroyers and in the engine room one small lathe and one large electric drill are installed. In a suitable place in the ship there is a blacksmith shop with one small portable forge.

11. Official trial run

a. The official trial run is carried out in conformity with the stipulations of the rules of ship construction and repair, and its details are laid down by the Chief of the Navy Technical Department.

b. In official trial runs as well as in other tests, the water supply used when necessary to get steam up in boilers will be distilled water with a saline content of no more than three parts per million.

c. Throughout all kinds of runs, the auxiliary exhaust steam will always be utilized for heating the water supply, and any excess steam will be diverted to the main water condenser.

d. The method of employing the engines at normal speed is standardized as follows:

(1) The main turbines and cruising turbine, and one boiler are used.

(2) The main engines, as well as the auxiliary machinery relating to the boilers, are generally limited to the minimum strength and number required and they use one oil pump and one blower for each shaft.

(3) One internal combustion generator is normally employed, and in the event of a lack of power, a turbine generator is used to supplement it.

(4) It is desirable not to use auxiliary equipment which is not directly related to navigation or cruising.

12. Specified weight of engines

The weight of machinery for official trial conditions shall be:

Main engines	91.0 tons
Propeller and shafting	50.0 tons
Auxiliary engines	34.0 tons
Boilers	73.0 tons

Stacks and uptakes	46.0 tons
Pipes, valves, and cocks	43.0 tons
Miscellaneous	28.0 tons
Water	32.0 tons
Oil	6.0 tons
Total, without water and oil	325.0 tons
with water and oil	363.0 tons

End of Specifications

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Piping plans for MATSU class destroyer escorts are contained in Nav-TechJap Document No. ND50-1046.

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Part X - UNRYU Class CV

This vessel was one of the group of carriers of which there was the largest number and several of which were partially completed by the end of the war. The main machinery plant is somewhat similar to OYODO but of more horsepower. The eight boilers divided well for split plant operation. The rather extensive firemain system in the machinery spaces was peculiar to the carriers and more like the system installed in U.S. vessels in so far as the piping layout was concerned. One vessel of this class was equipped with destroyer main engines, indicating a shortage of main machinery.

Piping diagrams have been assigned NavTechJap Document Nos. ND50-1024 and ND50-1025. One trial run and the summary of results have been translated in NavTechJap Document No. ND50-1025.1, "New Construction Machinery Trials". A copy of the "Machinery Design Requirements", (NavTechJap Document No. ND50-1031) was obtained and translated.

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TRANSLATION OF MACHINERY SPECIFICATIONS FOR UNRYU CLASS AIRCRAFT CARRIER

25 November 1942
Navy Technical Department "Top Secret" Classification 5

Navy Technical Department No. 77 of 17.

Outline of Engine Specifications

Ship No. 302

Ship Class No. 5001

Ship Class No. 5007

Table of Contents

1. General notes on ship's hull

As given in the official table of specifications, hull data are as follows:

Length at waterline ..... 223 meters
Beam at waterline ..... 22 meters

Depth	20.5 meters
Draft, bow	7.490 meters
stern	7.990 meters
mean	7.740 meters
Displacement	20,100 tons
Speed	34 knots
Cruising radius at 18 knots	8000 miles
Fuel oil capacity	3750 metric tons

2. Engine layout in general

The main engines consist of four shafts with each shaft connected to one main turbine by a reduction gear. The enginerooms are made up of four compartments and one main engine is placed in each compartment. In the forward rooms are the outer shafts and in the after rooms are the inner shafts. The cruising turbine and its reduction gear are connected to the forward engineroom high pressure turbine pinion gear shaft. The exhaust from the cruising turbine goes to the after engineroom high pressure turbine. There are eight boilers and they are distributed one in each of the eight boiler rooms.

a. Turbines and reduction gear (No. 1-C, Model 300, main turbine and No. 1-C, Model 300, main reduction gear) - the turbines and reduction gears are as follows:

(1) There are high pressure, intermediate pressure, and low pressure turbines attached to each shaft and each turbine connects to pinion gears through its respective coupling joints. Each pinion gear meshes with a large gear wheel which is connected to the main shaft.

(2) The astern turbine mechanism is contained in the low pressure turbine housing.

(3) No. 1-A, Model 300, cruising turbine and No. 1-A, Model 300 reduction gear are installed in both forward enginerooms and are connected to each forward engine high pressure turbine pinion gear shaft through adjustable mechanisms.

b. Rated power:

Power	Shaft Horsepower		RPM
	One shaft	Total	
Total rated power	38,000	152,000	333
Total power astern	10,000	40,000	220
Standard speed		14,000 (about)	150 (about)
Cruising full power		17,000	165
Maximum cruising speed		56,000 (about)	175 outer shaft 275 inner shaft

Each main unit can stand an overload of 5% of its 38,000 hp.

Permitted cruising RPM - 200.

Under maximum cruising speed, conditions are such as to introduce steam into the inner shaft main turbine while using a number of nozzles in the cruising turbine and the first pressure reduction stage for full cruising power, thus allowing the inner shaft to attain full power.

c. Steam consumption of main engines:

Power Used	Steam Chest Pressure (kg/sq. cm)	Steam Temp.(°C)	Vacuum (mm Hg)	Steam Consumption (kg/shp/hr)	No. of Boilers
Total rated	17	285	over 700	under 4.3	8
Total rated astern	17	250	over 665	under 10.0	8
Cruising full power	17	270	over 720	under 5.2	2
Standard	17	260	over 725	under 5.25	2

d. For rotating each main engine there is attached to each low pressure turbine pinion gear an electrically operated and manually operated rotating mechanism

e. Main condensers are single-pass surface type and there is one for each main engine, or a total of four. Those in the forward engineroom are inboard and those in the after engineroom are outboard of the low pressure turbine.

4. Drive shaft and propeller

a. Drive shaft

(1) Shafting consists of inner and outer shafts each having a thrust shaft, No. 1 intermediate shaft, No. 2 intermediate shaft, No. 3 intermediate shaft, the stern tube shaft, and the propeller shaft.

(2) The thrust bearing is of the Mitchel type. Pressure on the thrust block made of white metal alloy should not exceed 20 kg/sq. cm.

(3) The outer No. 3 intermediate shaft is equipped with two intermediate shaft bearings and the other intermediate shafts have one each. All of the shafts bearings are self-lubricating.

b. Propeller - the diameter of the propeller is 3900 mm.

5. Boilers

There are eight No. 1-B, Model 300 Mark "RO" (B) boilers and the boiler rooms are of the open type. Principal data for one boiler are as follows:

Steam pressure, steam drum, total rated power ..... 22 kg/sq. cm
full overload ..... 23 kg/sq. cm
superheater outlet, total rated power ..... 20 kg/sq. cm
full overload ..... 20 kg/sq. cm
Steam temperature, total rated power ..... 300 °C
full overload ..... 308 °C

Heating surface, evaporating and superheating	1130 sq. m
air preheater	43 sq. m
Burners, Model 3	eight
Model 5	one
Cones	Model 6
Smoke making apparatus, number	one
capacity	2000 kg/hr

Note: Boilers No. 1 and No. 2 have an auxiliary burner.

6. Uptakes and stacks

There are two stacks, and the No. 1 stack takes care of the uptakes for boilers No. 1, 2, 3, and 4, while the No. 2 stack takes care of the uptakes for boilers No. 5, 6, 7, and 8.

7. Water supply system

The main feed system shall be a closed system.

8. Auxiliary machinery

The type and number of auxiliaries are as follows:

a. Those installed in the enginerooms:

Name	Type	Quantity
Main circulator	Axial flow, turbo-reduction gear drive	4
Main condensate pump	Centrifugal, vertical, turbo-reduction gear	8
Air ejector	Two-stage, triplex, steam ejection	4
Lube oil pump	Vertical, gear, turbo-reduction gear	8
Lube oil cooling pump	Axial flow, vertical, turbo-reduction gear	4
Supply vent	Horizontal, axial flow, turbo-reduction gear	4
Exhaust vent	Electric, axial flow, horizontal	4
Fire and bilge pump	Centrifugal, vertical, turbo-reduction gear	2
Fire and bilge pump	Electric, vertical, centrifugal	2
Fuel oil distributing pump	Electrical, gear, vertical	2
Lube oil purifier	Electric, centrifugal	4
Evaporators	Spiral tube	2
Drain cooler	Vertical	2
Feed water heater	Vertical, surface	4

Oil cooler	Vertical, internal water, external oil	4
Drain cooling pump	Electric, centrifugal	1
Combination cendensing and air pump	Electric	2
Control room vent	Electric	5
b. Auxiliaries installed in the boiler rooms:		
Main feed pump	Centrifugal, horizontal, turbo-reduction gear	8
Auxiliary feed pump	Reciprocating	8
F. D. blower	Vertical, axial flow, turbo-reduction gear	16
F. O. service pump	Screw, vertical, turbo-reduction gear	8
Port use fuel oil pump	Electric, gear	2
Auxiliary blower	Electric	2
Lube oil and lube oil cooling pump	Horizontal, turbo-reduction gear, oil-gear, water-centrifugal	8
Oil cooler	Vertical, internal water, external oil	8
Feed heater	Vertical, surface	8
Fuel oil heater	Vertical, bent tube	8
Fire and bilge pump	Vertical, turbo-reduction gear, centrifugal	4
Fire and bilge pump	Electric, centrifugal	4
Control room vent	Horizontal, electric	8
c. Auxiliaries outside of the machinery spaces:		
Fuel oil distributing pump	Horizontal, electric gear	2

9. Steering mechanism

The steering mechanism is the electric oil pressure plunger type. It has the capacity to turn the rudder from full over one way to full over the other, a 70 degree turn, in 30 seconds when the maximum torque from the flow of water at full speed ahead is 29.8 meter-tons (on each rudder) and when the maximum at full astern is 51.2 meter-tons (on each rudder). The steering mechanism is made up of two units, the capacity of each being described above. The oil pressure cylinder is the two-plunger type and there is one for each rudder, a total of two. They are located in the helm housing. In addition, there is one manually operated pump.

10. Anchor hoist

a. The forward anchor hoist is electrically driven through a double reduction gear and a screw. Its capacity is such that it can lift 45 tons at the rate of nine meters per minute.

b. The stern anchor hoist is a single action electric motor type and its capacity is such that it can lift 15.6 metric tons at a rate of nine meters per minute.

11. Cooling system

It is equipped with two horizontal electrically operated two-stage centrifugal type water cooling pumps with a capacity of 400 cubic meters per hour (outlet pressure of 10 kg/sq.cm).

12. Repair equipment

The repair equipment includes one gas welding machine (gas generating capacity 0.2 cu. m/hr) beyond the standard table of allowances (for aircraft carriers with a registered displacement of 30,000 or less). Furthermore, there is provided one axial type horizontal, electrically operated blower.

13. Engine weight

Machinery weights in metric tons are:

Main engines, Ship No. 302,	Ship Model 5001	608
	Ship Model 5007	608
Drive shaft and propellers,	Ship Model 5001	313
	Ship Model 5007	313
Boilers, Ship Model	5001	544
	5007	563
Auxiliary engines, Ship Model	5001	247
	5007	244
Uptakes and stacks, Ship Model	5001	116
	5007	116
Valves, cocks, and pipes, Ship Model	5001	370
	5007	370
Misceallenous, Ship Model	5001	197
	5007	197
Water and oil, Ship Model	5001	288
	5007	288
Total, without water and oil, Ship Model	5001	2395
	5007	2411
with water and oil	5001	2683
	5007	2699

14. Official trials

Official trials are carried out according to the regulations governing construction of ships, and the summary of their results is published by the Chief, Navy Technical Department.

Auxiliary exhaust - according to each type of test, it is prearranged so that the auxiliary exhaust is usually utilized in the feed heater, and if there is any left, in the case of trial full and cruising speeds, it is piped to the main condenser. In other trials it is utilized in the low pressure turbine, and again, if there is any left, it is piped to the main condenser. In the various tests which accompany the runs and official trial runs, the source of water should be distilled water with a salt content of less than three parts per million.

End of Specifications

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Part XI - NAGATO (BB) - MYOKO (CA NACHI Class)

Piping plans of these vessels, which were relatively old, (NAGATO 1920, MYOKO 1930), were forwarded only as a matter of secondary interest. No specifications or test data were recovered. Note in NAGATO the auxiliary turbines for driving the center shafts at synchronous speed when cruising on wing shafts.

Piping plans have been assigned document numbers as follows:

NavTechJap Document No.	Ship	Space
ND50-1047	NAGATO	Engineroom
ND50-1048	NAGATO	Boiler room
ND50-1024.1	NACHI Class (CA)	Engineroom
ND50-1024.2	NACHI Class (CA)	Boiler room

ENCLOSURE (A)

LIST OF DOCUMENTS SENT DIRECTLY TO THE BUREAU OF SHIPS

NavTechJap No.	Title
ND50-1024	Engineroom piping plans, UNRYU class carrier.
ND50-1024.1	Engineroom piping plans, NACHI class heavy cruiser.
ND50-1024.2	Boiler room piping plans, NACHI class heavy cruiser.
ND50-1025	Boiler room piping plans, UNRYU class carrier.
ND50-1025.1	New construction machinery trials, UNRYU class carrier.
ND50-1026	Machinery design requirements, YAMATO class battleship.
ND50-1027	Machinery design requirements, TERUTSUKI class destroyer.
ND50-1028	Machinery design requirements, MATSU class destroyer escort.
ND50-1029	Machinery design requirements, KAGERO class destroyer.
ND50-1030	Machinery design requirements, SHIMAKAZE (Single ship class DD).
ND50-1031	Machinery design requirements, UNRYU class carrier.
ND50-1032	Machinery design requirements, MOGAMI class heavy cruiser.
ND50-1032.1	New construction trials, Vol. I, MOGAMI class heavy cruiser.
ND50-1032.2	New construction trials, Vol. II, MOGAMI class heavy cruiser.
ND50-1032.3 ND50-1032.4 ND50-1032.5	Arrangement plans, engineroom and fireroom, MOGAMI class heavy cruiser.
ND50-1033	Piping plans, outside of machinery spaces, YAMATO class battleship.
ND50-1034	Piping plans, boiler rooms, YAMATO class battleship.
ND50-1035	Piping plans, enginerooms, YAMATO class battleship.
ND50-1036	Piping plans, enginerooms, ATAGO class heavy cruiser.

ENCLOSURE (A), continued

NavTechJap No.	Title
ND50-1036.1	Piping plans, boiler rooms, ATAGO class heavy cruiser.
ND50-1036.2	New construction machinery trials, ATAGO class heavy cruiser.
ND50-1037	Piping plans, boiler rooms, AGANO class light cruiser.
ND50-1037.1	New construction machinery trials, AGANO class light cruiser, Vol. I.
ND50-1037.2	New construction machinery trials, AGANO class light cruiser, Vol. II.
ND50-1038	Piping plans, enginerooms, AGANO class light cruiser.
ND50-1039	Piping plans, boiler rooms, OYODO, light cruiser (Single ship class).
ND50-1039.1	New construction machinery trials, OYODO, light cruiser (Single ship class).
ND50-1040	Piping plans, engineroom, OYODO, light cruiser (Single ship class).
ND50-1041	Piping plans, TERUTSUKI class destroyer.
ND50-1041.1	New construction macninery trials, TERUTSUKI. class destroyer.
ND50-1042	Piping plans, engineroom, TERUTSUKI class destroyer.
ND50-1043	Piping plans, KAGERO class destroyer.
ND50-1043.1	New construction machinery trials, KAGERO class destroyers.
ND50-1044	Piping plans, boiler rooms, SHIMAKAZE, (Single ship class DD).
ND50-1044.1	New construction machinery trials, SHIMAKAZE, (Single ship class DD).
ND50-1045	Piping plans, MATSU class destroyer escort.
ND50-1045.1	New construction machinery trials, MATSU class destroyer escort.
ND50-1046	New construction machinery trials, YAMATO class battleship.
ND50-1047	Piping plans, engineroom, NAGATO class battleship.
ND50-1048	Piping plans, engineroom, NAGATO class battleship.