REPORT ON THE U.S.S. 'TIMMERMAN'

BY

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During the past twenty years, the Navy's Bureau of Ships has from time to time undertaken to procure and evaluate ships having experimental machinery installations. These projects have been a part of a continuing research and development programme directed towards improved fuel economy and reduced machinery weights. Machinery plants installed in experimental ships utilize improved or advanced design components, improved systems or cycles, or a combination thereof. The most recent and far reaching of these undertakings was the design and development of the *U.S.S. Timmerman* (EDD-828). In this instance, several hull innovations were incorporated in a ship having a highly experimental propulsion plant.

World War II destroyer experience indicated the need for a ship having a greater cruising radius, increased speed, and improved seakeeping characteristics. Furthermore, the standardization of machinery designs during the war and the free exchange of this information with our allies had, to a large degree, resulted in the loss of our Navy's superiority in this field. With this background, the decision was made to build an advanced design destroyer whose main feature was a 100,000 s.h.p. machinery plant of equal or less weight and space than the 60,000 s.h.p. plant of the DD-692 Class—World War II—destroyer.

The *Timmerman* was one of the DD-692 Class destroyers which was partially complete at the Bath Iron Works Corporation when World War II ended. Construction was suspended, but was resumed in May 1946 when the Navy contracted with the Bath Iron Works to complete the ship as an advanced design destroyer. The contract stipulated that the shipbuilder would enter into an agreement with Gibbs & Cox Incorporated to act as the Design Agent.

The ship is now undergoing evaluation trials, which are at present inconclusive, and this paper constitutes an interim report based on the accomplishments to date. The subject matter deserves a more comprehensive report which will be possible at the conclusion of the trial and test programme.

DESIGN OBJECTIVES

In order to attain a 100,000 s.h.p. machinery installation which could replace a 60,000 s.h.p. plant, the following items were considered worthy of consideration :

(*a*) Reduction of design margins.

(*b*) Elimination of the pyramiding of design margins.

(*c*) Reduction in factors of safety. Each design was to be carefully analyzed to see that factors of safety were consistent.

(*d*) Use of higher rotative speeds.

(*e*) Use of higher voltage and frequency.

(*f*) Use of better materials, taking into consideration critical materials which present a bottleneck during emergencies.

The Circular of Machinery Design Requirements for the *Timmerman* was prepared, based on the following general concepts :

(*a*) Except for shockproofness, the technical portions of the General Specifications were not to be applicable.

(*b*) Machinery features were to be open to any new developments or designs leading to advancements in economy, space, or weight, commensurate with reliability.

(*c*) Guarantees were to be required only on workmanship and material. Failure to meet performance requirements were not to penalize the shipbuilder or any sub-contractor. All contractors and sub-contractors were expected to place their nameplates on their equipment. Each contractor and sub-contractor was charged with the responsibility of employing materials, stresses, design and methods of fabrication best suited, in his engineering judgment, to give satisfactory results in all parts of the plant subjected to high temperatures, or other unusual conditions.

(*d*) Machinery life expectancy was specified.

The contract set forth the following general characteristics of the machinery plant :

Full power : 100,000 shaft horsepower.

Number of shafts : 2.

Ship's speed : Not less than 40 knots.

Shaft revolutions per minute : About 350.

Steam drum pressure : Not less than 750 lb per sq in.

Steam temperature at outlets of superheaters : Not less than 1,025°F.

Steam pressure at superheater outlets : Not less than 700 lb per sq in.

Steam pressure at main turbine control valve : Not less than 650 lb per sq in

Steam temperature at main turbine control valve : Not less than 1,000°F.

Shaft horsepower astern : 20,000 (later modified to 8,000).

Ship's speed for best economy operating in units : 20 Knots.

With the foregoing guide lines established, there followed a period during which numerous design studies were made in order to form a basis for the selection of the most promising steam conditions, electrical plant characteristics and characteristics of components and systems to be employed. Leading manufacturers of boilers, propulsion machinery, electrical equipment and other auxiliaries were called upon to design, develop and furnish the machinery which met the requirements of the basic concept. In some instances, duplicate orders were placed with different manufacturers, with a view toward selecting those units for shipboard installation which showed the most promise, as designs were finalized and as units were factory or laboratory tested. In the case of electric motors, purchase orders were issued for the production of developmental units ; these orders ran until the manufacturers had acquired the necessary ' know how ', at which time orders were placed for the shipboard units. During the early phases of this period, there was created among the various subcontractors an acute sense of competition, and they were encouraged to break away from accepted practices and ' go out into the blue ' to obtain truly radical, advanced designs. This was a necessity if the Navy was to get a ship which was fully fifteen years ahead of her time. Throughout this period there existed a high degree of co-operation between the Bureau of Ships, the Design Agent, the cognizant Supervisor of Shipbuilding and the various subcontractors. The parties to the agreements regarding the finally accepted designs are deserving of special credit for their willingness to take calculated risks, for their far-sightedness, and for their perseverance in adhering to a concept which made them vulnerable to criticism if the end product failed to meet the usual standards of performance.

MACHINERY RÉSUMÉ

The ship which resulted from this bold venture included many untried features or variations from usual designs. The following summarizes these features.

Propulsion Plants

The starboard machinery installation utilizes two single-furnace, 875 lb per sq in 1,050°F boilers equipped with fully automatic combustion controls. These boilers supply steam to a main propulsion unit consisting of cruising, high pressure and low pressure turbines with a full power rating of 50,000 s.h.p. These turbines are connected through a single reduction gear to the high speed line shafting, through a planetary second reduction gear and low speed line shafting to the propeller shaft. This array is one of the most interesting features in the ship. The high speed shafting between the first and second reduction gears is 7¼ in in diameter, turns at 1,800 r.p.m. at full power, and is made up of four sections totalling approximately 72 ft. It is supported by seven trunnion roller bearings. The planetary gear is the first of its size to be used in Naval service. The outboard shafting is supported by sealed anti-friction bearings, lubricated through the struts. The port machinery combination consists of two single-furnace, 2,000 lb per sq in, 1,050°F controlled circulation boilers equipped with fully automatic combustion controls. These boilers furnish steam to a main propulsion unit consisting of cruising, high pressure and low pressure turbines rated at 50,000 s.h.p. at full power. The reduction gear for this plant is a double reduction unit. The shafting arrangement for the port plant is a conventional design.

Electrical Plant

The *Timmerman* electrical plant utilizes a 1,000 volt, 400 cycle, 3 phase system supplied by two 600 kW synchronous turbo generators. One unit is supplied by the 2,000 lb per sq. in, 1,050°F steam system and is a ' package unit ', direct coupled, turning at 24,000 r.p.m., having a static excitation system. The other unit is driven by an 815 lb per sq in, 1,045°F turbine of the ' packing unit ' design, direct coupled, turning at 12,000 r.p.m. and having a rotary exciter.

There are two 1,000 volt, 400 cycle, 3 phase emergency generators installed. The forward unit is driven by a gas turbine while the after unit is driven by a four cylinder 2 cycle radial Diesel engine. Both were originally rated at 250 kW but operational experience has indicated they are presently limited to between 175 and 200 kW.

All pumps and other auxiliary machinery, with the exception of feed pumps and main forced draft blowers, are driven by 950 volt 400 cycle motors. These high speed motors, utilizing silicone insulation, are substantially smaller than conventional shipboard motors, resulting in appreciable savings in weight. It was found possible to use newly developed, small diameter power cable for the 1,000 volt system, in spite of the fact that it had been designed for 440 volts, thus realizing additional savings in weight.

Alternate Components

As previously mentioned, components were purchased in excess of those required for shipboard installation. This was done with a view towards selecting those showing the most promise, as designs were finalized and laboratory tests proceeded, or to obtain components for laboratory evaluation. Among the units purchased, but not installed in the ship, were :

One 2,000 lb per sq in, 1,050 F steamotive boiler, being tested at the Naval Boiler and Turbine Laboratory.

One 2,000 lb per sq in, 1,040 F natural circulation boiler, being tested at the Naval Boiler and Turbine Laboratory.

One 875 lb per sq in, 1,050 F two-furnace, single uptake boiler, being tested at the Naval Boiler and Turbine Laboratory.

One 600 kW induction turbo generator, tested at the Naval Boiler and Turbine Laboratory.

Two 50,000 h.p. planetary type main reduction gears, tested at the Naval Boiler and Turbine Laboratory.

One 250 kW gas turbo-generator, which failed on test at the factory.

One 8,000 GPD vapour compression still, tested at the Engineering Experiment Station.

Machinery Weight Comparison—U.S.S. 'Timmerman' and DD-692 Class Destroyer

The following table is given to illustrate the advances made in the design and construction of the *Timmerman*. A 692-class long hull destroyer is used as a reference since the hull forms in each case are the same.

	DD-692—Long Hull	*Timmerman—EDD-828*
Standard Displacement (tons)	2,425	2,245
Total s.h.p.	60,000	100,000
Machinery Weight (tons) ..	939	835
Wt. s.h.p. (lb s.h.p.) ..	35	19
Wt. s.h.p. in per cent DD-692 Wt. s.h.p.	100	54
Wt. of Electrical Equipment (tons)	138	62
Wt. of Electrical Equipment in per cent DD-692 ..	100	45

HULL RÉSUMÉ

In order to improve sea keeping qualities in the *Timmerman*, the sheer line at the stem was raised two feet above that of the DD-692 Class and was faired into the DD-692 Class sheer at about frame 42. In addition, the forward 5 in/38 gun mount was moved aft seven feet, and light weight anchors in deck edge bolsters were installed.

The use of aluminium deckhouse construction, and the results of tests in connection therewith, yielded valuable information on the relative merits of welded, riveted and bolted aluminium construction. The fabrication of a welded aluminium 5 in/38 gun foundation, which was subsequently successfully tested at the Naval Proving Grounds, Dahlgren, demonstrated the feasibility of such construction, and valuable knowledge was acquired in welding, heat treating, and quenching large, thick section structures.

The ship is equipped with a new type steering gear which utilizes a ball bearing nut and screw with hydraulic drive, in lieu of the conventional hydraulic ram system. This unit weighs approximately one-fourth as much as a standard destroyer steering gear. There is also provided an automatic steering system.

The twin rudders are mounted in roller bearings and are fitted with seals. Provision was made for the installation of conventional sleeve bearings in case the roller bearings failed. One of the rudders has medium steel plating, while the other has plating of S.T.S. thus enabling a comparative evaluation of the effects of water flow, erosion, and corrosion.

Small, high speed fans are used throughout the ship for ventilation and air conditioning. Higher air velocities have resulted in smaller ductwork. Some of the smaller fans located in living spaces are encased in sound boxes and ductwork sound insulation is employed in an effort to reduce noise levels. Two central compressor plants supply air conditioning to living and berthing spaces as well as to ship control spaces.

OPERATIONAL EXPERIENCE TO DATE

A number of the components which are installed in the *Timmerman* were tested either at the Naval Engineering Experiment Station, Annapolis, or the Naval Boiler and Turbine Laboratory, Philadelphia. Throughout this phase of the programme it was found necessary to make modifications to certain components, in order to improve reliability or to correct design deficiencies. Some units failed on test or did not perform in a manner which warranted shipboard installation. In all but two of these instances, alternate EDD-828 units were used. In one case, which involved the main feed and booster pumps for 875 lb per sq in plant, spare pumps from another shipbuilding programme were diverted for use on the *Timmerman*. In the other case, there was no available substitute for the 2,000 lb per sq in auxiliary feed and booster pump which failed in the laboratory, and the ship was accepted without this unit, resulting in the necessity of using one of the main feed pumps for harbour use.

Delays in delivery of machinery components to the shipbuilder were reflected in the completion of the ship. These delays came about as a result of problems arising during the construction of the equipment, difficulties encountered during tests, and modifications necessitated by laboratory test results. There were also cases where the scope of the laboratory tests were curtailed in order to minimize delays in the ship's completion. During the period when the shipbuilder was activating and operating the ship's machinery plant, additional material failures occurred in some components, which necessitated further design modifications or repairs, causing additional delays in delivery. In many cases the solutions to these problems were not readily apparent, and most of the failures were occurring in units for which there was no 'back-up' component. However, the *Timmerman* completed builder's trials in September 1952, and was delivered to the Navy the same month. It was recognized that certain deficiencies existed at that time, but under the terms of the contract the shipbuilder was not accountable for failure of components to perform as anticipated except in the case of defective material and workmanship, and there was no evidence of this.

The *Timmerman* was commissioned and fitted out at the Boston Naval Shipyard following delivery, and some of the difficulties encountered by the shipbuilder continued during the fitting out period. The following is representative of the more significant operational difficulties or material failures which occurred during the shipbuilding period, the fitting out period, or in some cases, both.

Motors

The 950 volt 400 cycle motors are smaller, have less thermal capacity, and operate at higher speeds and temperatures than normally encountered. It is not surprising, therefore, that numerous failures, consisting of insulation breakdown, bearing failures, or both, have occurred. It is believed that a solution to these and other motor problems will be achieved as a result of carrying out the following programme now in progress :

(1) Using heat stabilized, silicone lubricated anti-friction bearings, which are good for temperatures up to 150 C.

(2) Paying particular attention to bearing fits and tolerances, alignment of motors, and bell fits, and alignment of motor with the driven unit. All of these are extremely critical.

(3) Replacing, in some instances, relatively flimsy end bells of stamped construction with more rigid end bells of cast construction.

(4) Exercising closer control over silicone insulation application when motors are re-wound.

Motor Controllers

There has been a high incidence of motor controller casualties due to failure of relays, control transformers and contractors. Flash-over has occurred in some instances when the circuits have been interrupted. Modifications to controller arc chutes and contact points are being made in an effort to eliminate this condition. A further modification to the thermal overload relay, to ensure more positive overload protection, is being laboratory evaluated.

Turbo-Generators

The electronic governor system on number one turbo generator has not given the desired speed and frequency control, and several failures of tubes, relays, and transformers in this circuit have occurred. The manufacturer has been requested to make recommendations regarding means whereby this system can be improved. The possibility of replacing this system with a mechanical governor is not being overlooked. Several failures of overspeed trip levers have resulted in a design and material change which now appears to have been successful. Experience with the high speed rotary exciter has led to the decision to replace it with a static excitation system which is at present under procurement. Extensive modifications to the number two turbo-generator were required soon after delivery of the ship, as a result of operational experience with this unit in the building yard. The capacity of the machine was found to be less than anticipated due to internal shorting in the field coils and arcing in the slip rings. Modifications included rewinding the rotor and increasing the field turns, installing new bearings and oil seals, resurfacing journals, installing new slip rings and brush holder assembly which accommodated additional brushes, thereby reducing current density. Additional rectifiers were provided in the excitation system and a cooling system provided for the separately mounted rectifiers. This unit is now generally satisfactory except for limited brush life and improved materials for this application are under investigation.

Emergency Generators

The high ambient temperature in the emergency gas turbo-generator compartment reduces the output of the machine. Rather extensive ventilation modifications are being made in order to correct this deficiency. The Diesel emergency generator is undergoing modifications providing for an oil lubricated bearing in the generator end which will replace a grease lubricated bearing. This is necessitated by repeated bearing failures after short periods of operation.

Internally Threaded Exhaust Valves

Due to the high exhaust temperature, exhaust valves fitted with internal threads were soon rendered inoperative and valves with an externally threaded yoke were used to replace them.

No. 1 Low Pressure Turbine

Leakage in the after bearing oil seals has occurred on numerous occasions and several modifications have been directed towards correcting this. The most recent modification has permitted operations up to about 30 knots before leakage occurred. Efforts to eliminate the leakage at higher speeds are continuing and the solution is believed to be in sight. In addition, there has been vibration in this turbine which cannot be accounted for, and will require close scrutiny during future operations in an effort to determine the cause and to take corrective action.

These are just a few of the numerous difficulties which have been encountered, and they are not surprising, in view of the many extremely radical and untried features resorted to in order to replace a 60,000 s.h.p. plant with one rated at 100,000 s.h.p. Some components have operated satisfactorily or were made to operate satisfactorily after minor modifications. The art of machinery design has certainly benefited by the failures as well as the successes.

In June 1953, after the fitting out period was completed, the ship got underway intermittently for a period of about six weeks and steamed nearly 2,500 miles. Valuable operating experience was gained during the period, even though it was punctuated with various types of failures to components. These operations were rather abruptly ended when a series of casualties in the electrical generating plant necessitated temporary repairs in Newport, R. I., to permit the ship's return to Boston Naval Shipyard. The causes of the electrical plant casualties were subsequently corrected, except for those in the case of the Diesel emergency generator which are still in process. For the past three months the ship has been operating in and out of Boston, carrying out part of the trial agenda, during which time work is continuing on improving the reliability of motors and other components.

To date, the maximum speed attained has been 31 knots, which corresponds to less than one-half of the full power rating of the ship. The deficiencies which have prevented going to higher powers are gradually being corrected and it is expected that in the near future full power trials will be possible. It is anticipated that speeds approaching forty knots will be reached during these trials.

TRIAL PROGRAMME

In order to evaluate the many unique features included in the design of the *Timmerman*, an extensive trial agenda has been prepared. The machinery trials have necessitated the installation of instrumentation which is far more extensive and complex than ever before attempted on a naval vessel, and includes the use of numerous thermo-couples, manometers, displacement meters, orifice meters and devices normally limited to laboratory use. There are approximately 3,000 such items. The trial programme is broken down into three major phases, the first of which is complete. There was a total of about twenty tests in this group and they consisted of evaluating individual pumps, valves, auxiliaries and minor systems.

The installation of instrumentation required for the second phase of the trial agenda is in progress. The trials and tests in this group include :

(1) Automatic Steering Control Tests : for the purpose of comparing the performance of hand electric steering with automatic steering.

(2) Vibration Trials : for the purpose of evaluating the suitability of the starboard machinery plant in regard to torsional, longitudinal and linear vibration, with particular attention directed towards determining the minimum stiffness required in the mountings for the high speed line shaft trunnion roller bearings to prevent possible whipping of the shaft.

(3) Noise Trials : which will include the measurement of underwater noise, airborne noise, ventilation and air conditioning noise.

(4) Observation and Photography of Cavitation : for the purpose of observing and photographing the inception and progress of cavitation on port rudder, sound dome, and port propeller at various speeds for correlation with model tests and noise trials. This will be accomplished through the use of underwater glass ports.

(5) Pressure Measurements: for the purpose of determining the instantaneous pressures on the hull in the vicinity of the port propeller for correlation with model tests.

(6) Boundary Layer Survey: to characterize the ship's boundary layer in the vicinity of the starboard inlet condenser scoop and overboard discharge, and to measure the velocity distribution in the throat of the inlet scoop. From this information, laboratory model experiments will be conducted for the purpose of improving the design of such cooling systems.

(7) Standardization Trials and Transient Thrust and Torque Determination.

(8) Tactical Trials.

(9) Astern Turbine Deceleration Performance Trials.

As can be seen from the foregoing summary of the phase two trials, many are being conducted for the purpose of correlating ship trials data with that obtained from model tests, which have been conducted at the Navy's David Taylor Model Basin at Carterock, Md. This correlation is often difficult to obtain because standard fleet type vessels cannot normally be spared for the long periods of time required for instrumentation and underway tests.

The final phase of the trial agenda will be conducted during the summer of 1954, and consists of main turbine water rate, fuel economy, and heat balance trials. All of these will be conducted for the purpose of correlating ship data with design predictions. During these trials, performance data will also be obtained on individual components such as boilers, main condensers and air ejectors, lubricating oil coolers, fuel oil heaters, and other units making up the main propulsion plant. The results of these trials will indicate the fuel economies which can be realized from going to higher steam pressures and temperatures and other advantages realized from the *Timmerman* designs. These results will form a basis for the selection of steam conditions and components to be employed in future designs of naval propulsion plants.

CONCLUSIONS

Even though the *Timmerman* trial programme is still in the early stages and underway operations have been limited, many technical achievements have already been realized. Some of these were acquired as a result of laboratory tests of the components which preceded shipboard installation, and additional information has been gained from shipboard operating experience and tests. In some instances, new ships already in service, and others under construction, reflect these advancements in the art of machinery design.

Some of the items falling into this category are the use of controlled circulation boilers, higher tooth loading in main reduction gears and four hundred cycle turbo generators.

It was not intended that the *Timmerman* should be a prototype, but rather a floating laboratory in which the maximum number of advanced design components could be service evaluated for possible future use. It is, therefore, not surprising to realize that some of the units acquired and tested under the *Timmerman* programme will not be used, at least in their present form, in the immediate future. The design and development of the *Timmerman* has already paid substantial dividends, and more will be realized when all of the scheduled tests are complete.