

MOST Project -4

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PROJECT ARTEMIS .

**THE INSTALLATION OF A BOW THRUSTER
IN THE USNS MISSION CAPISTRANO (T-AG 162) .**

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Sound Division

Final report

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ABSTRACT

A 500 shaft horsepower, controllable pitch screw propeller has been installed in a transverse tunnel through the forefoot of the USNS MISSION CAPISTRANO (T-AG 162), a naval research vessel. The propeller, commonly referred to as a bow thruster, has delivered 11,250 pounds of thrust during dock trials. It is for the single purpose of controlling the vessel's heading when lying to in the open ocean. Under these conditions, it is reported capable of swinging the ship to any given bearing and maintaining it to within one degree of yaw in sea conditions of 15 knot winds and five foot waves upon six foot swells.

PROBLEM AUTHORIZATION

ONR RF 001-03-03
NRL Problem 55S02-11

PROBLEM STATUS

This is a final report on this phase of Project ARTEMIS. Work is continuing on other phases.

INTRODUCTION

The USNS MISSION CAPISTRANO (T-AG 162) is a former T2-SE-A2 tanker which has been converted for use as a project ship. The vessel, shown in figure 1, has characteristics as follows:

Length overall	523 feet
Length between perpendiculars	503 feet
Beam (molded)	68 feet
Draft, maximum	26 feet
Tonnage	10,500 gross tons (before conversion)
Propulsion	Steam turbine electric drive, 10,000 shaft horsepower, single screw

During the ship's operations it is necessary to maintain bearing while lying to in the open ocean. At the outset of the project, tug assistance was relied on for this but proved unsatisfactory. The predominant reason was that to afford proper control the tug would have had to keep her bow against the ship's side. This was not practicable because of the usually prevalent ocean waves and swells. Instead a towing hawser was utilized, bent to a Liverpool bridle on the MISSION CAPISTRANO. It frequently proved impossible to use one tug or even two opposing tugs to maintain the vessel's heading to within twenty degrees.

After several weeks of intermittent operations, it was decided to install in the vessel a propulsion device which could exert transverse thrust so as to afford heading control within a few degrees of yaw. There existed in this country and more notably in Europe much precedent for this so that no engineering development appeared necessary. The British luxury liner ORIANA, the World War II German cruiser GRAF ZEPPELIN, the German buoy tender WALTER KÖRTE and the Great Lakes bulk carrier J. R. SENSIBAR are prime examples.

There are several types of maneuvering devices which are commercially utilized for auxiliary propulsion. These include vertical axis propellers, right angle drive units, active rudders and ducted propellers.^{1,2}

1. H. E. Saunders, Hydrodynamics in Ship Design, Society of Naval Architects and Marine Engineers, 1957

2. Robert Taggart, Special Purpose Marine Propulsion Systems, American Society of Naval Engineers, Journal, 1959

Briefly, vertical axis propellers consist of four to six equally-spaced airfoil-shaped paddles which extend vertically downward from the circumference of a horizontal turntable affixed to a vessel's bottom. As the turntable rotates, the paddles revolve about the common center and in addition change pitch by rotating about their individual axes in the same manner as a helicopter rotor. Thrust direction and control is therefore a matter of regulating the blade pitch. The most modern version of the vertical axis propeller, the Voith-Schneider propeller, is one in which the blades describe a cycloid as they revolve and rotate. Hence, these propellers are sometimes referred to as cycloidal propellers. Vertical axis propellers are usually located aft and may be either of single or twin screw configuration.

Right angle drive units are simply overgrown outboard motor installations in which the propulsion engine, unlike the usual pleasure outboard, is affixed to the deck of the vessel just forward of the vertical drive shaft. The propeller shaft can be rotated from one side to the other to establish the desired direction of thrust. Engine speed determines the degree of thrust.

Active rudders are rudders in which a motorized propeller is installed on the trailing edge. The motor is mounted in line with the screw in the body of the rudder. By turning the rudder, the direction of thrust is oriented.

The ducted propeller consists of a tunnel usually containing a screw propeller of the fixed or controllable pitch type and of single or contra-rotating blading. Since the tunnel is fixed, thrust can be delivered only along the axis of the tunnel unless exit guide vanes are installed. This method of auxiliary propulsion is generally installed in the forefoot of a vessel and is sometimes supplemented with an active rudder in cases where heading control response is most critical.

In larger vessels most auxiliary propulsion is for directional control at low speeds where rudder action is sluggish and ineffectual. It is not relied upon for use as a take-home device should the main plant fail. In such cases the simplest, most effective installations have proven to be ducted propellers because they need not be retracted in shoal water or when not in service. In addition, unlike active rudders, they are suitable in high power sizes, and, unlike right angle drives, are very simply installed in a ship's forefoot. Vertical axis propellers could be installed in a tunnel but are not usually utilized unless relied upon for main as well as auxiliary propulsion. Their

configuration lends best to an especially designed vessel with a flat run aft. Too, these propellers would not be hydrodynamically as efficient in a tunnel as the axial screw and are considerably more expensive. Experience with them in this country has mostly been of an experimental nature.

All of the aforementioned devices have been installed for such purposes as docking a ship, navigating a canal, or tending a buoy. However, no application has been noted where precise bearing keeping at sea is necessary. Because of this, no suitable test data as to the necessary thrust was found available.

There was not sufficient time for model tests nor would the vessel's schedule permit bollard pull measurements at sea. However, calculations of drag were made for swinging the vessel in smooth water and twist-ship performance data was obtained from the J. R. SENSIBAR, a comparable existing installation.

This vessel utilizes a 500 shaft horsepower, ducted, controllable pitch screw propeller of the Swedish Ka Me Wa design, manufactured by the Bird-Johnson Company of South Walpole, Massachusetts. The propeller assembly is located in the vessel's forefoot. Hence, this application has become known as a bow thruster.

As reported from the Columbia Transportation Division of the Oglebay Norton Company who operate the J. R. SENSIBAR, thrust data is as follows:

Length overall	614 feet
Beam (molded)	56 feet
Draft (full load)	21 feet, 6 inches
Static thrust of bow thruster	13,600 pounds
Twist rate at bow thruster full power (sea conditions unknown)	12 degrees per minute

The MISSION CAPISTRANO's requirements were that a maneuvering device would have to twist the ship's head to a particular bearing and hold it to within a few degrees of yaw in weather up to moderate, i.e., Beaufort 4. To meet these requirements, it was determined that such a device would have to exert 10,000 pounds of static thrust

against either end of the ship. Slow speed applications such as this where propellers are properly designed to operate at high slip prove only one-third to one-half as efficient as properly designed free-running propellers. Because of the kinetic energy lost from slip, experience shows that only about twenty to thirty pounds of thrust can be realized per shaft horsepower. Therefore, about 500 shaft horsepower would be required to deliver the necessary 10,000 pounds of thrust.

For the application of the MISSION CAPISTRANO it was determined that the simplest yet most precise thrust control would result from the installation of a controllable pitch propeller in an athwartship tunnel through the vessel's forefoot. Such an installation is commercially proven and available in this country without abnormal delay. In addition, the comparatively high efficiency of this propulsion method would keep to a minimum the size and cost of the drive motor and associated electrical equipment.

On the matter of the location of the unit, it would not have been feasible to install such a tunnel aft because of the main propeller line shafting, engines and the general shape of the underwater body. In addition, from a hydrodynamic viewpoint, the entrances of the tunnel would significantly interfere with the smooth flow of water into the MISSION CAPISTRANO's propulsion screw whenever she would be underway.

A 500 shaft horsepower Ka Me Wa controllable pitch bow thruster was selected for installation. This unit is rated by the manufacturer, the Bird-Johnson Company of South Walpole, Massachusetts, to deliver 13,200 pounds of static thrust.

DESCRIPTION

Bow Thruster Unit

The thruster unit (figure 2) consists of a controllable, reversible-pitch propeller having four blades of symmetrical cross section.

The propeller is located in the vessel's forefoot in the center of a transverse tunnel (figure 3) midway between port and starboard support struts. Through the starboard strut passes a vertical drive

shaft which turns the propeller through a five and one-half to one right angle bevel gear. It should be noted that the gear diameter and not the pitch control mechanism in the hub controls the minimum diameter of the propeller hub design, a factor which is of great concern in propeller hydrodynamics. The port strut assembly houses both the tubing for hydraulic pitch control and the mechanical follow-up cable, later described herein.

Power Supply

Various means for powering the propeller were looked into. Electrical power was selected since it was already available aboard the vessel and because it would be lowest in first cost, and operation and maintenance costs. There was not sufficient power available from the ship service generators but, since the main screw would not be used during thruster operation, it was decided to utilize the main propulsion generator for the thruster power. Three single-phase 3500/450 volt transformers step down the generator voltage to 440 volts for the 1800 rpm, 500 horsepower alternating current propulsion motor.

Control System

the thruster machinery room (figure 4), a hydraulic power and control unit receives pneumatic signals from a remote control station and hydraulically positions a pitch setting servo and crosshead assembly which in turn regulates the propeller pitch. A mechanical follow-up linkage provides pitch position feedback. Maximum blade pitch for full rated thrust is regulated by positioning mechanical stops in the hydraulic pitch control unit.

INSTALLATION

To gain a maximum twisting moment, the thruster was installed in the forward peak tank (figure 5) as low down and as far forward as practicable. Since the forepeak is used for water ballast and because of the close proximity and size of the ammunition flat just above, it was decided to use the latter for the thruster machinery space.

In order to best fit the MISSION CAPISTRANO's operations, two yard availabilities were utilized for the installation. During the first, a

complete port-to-starboard tunnel and vertical drive shaft and pitch control trunks were built into the ship. These trunks connect the thruster and machinery spaces. During the second availability, the thruster in its own short shrouding or tunnel was slid into the outer concentric tunnel, positioned on mounting rings and bolted in place. A conical shaped fairwater was installed between the two tunnels to smooth out the water flow. However, it is expected that this type of tunnel construction is hydrodynamically less efficient than if the tunnel had been constructed of constant diameter throughout. This latter method is the usual way in which these thruster units are installed; i. e., the propeller shrouding is extended outboard to the vessel's hull plating.

The thruster is installed with the drive shaft in the vertical position, directly below the vertically mounted drive motor in the machinery space. The two are connected by means of an extension shaft with flexible couplings at each end.

The three 3500/450 volt transformers are located on the port side of the machinery space; power for them runs forward from the vessel's engine room along main deck just below the catwalk and down to the thruster machinery space.

TEST RESULTS AND OPERATING EXPERIENCE

Both static and dynamic performance tests of short duration were conducted on the installation. The static tests were run at dockside, the vessel being moored to a pier by a total of four nearly perpendicular and horizontal lines located port and starboard, fore and aft. The standard mooring lines were slacked and the gangplank lifted. 11,250 pounds of static thrust were measured at normal rated power.

In a mild sea condition the vessel was able to twist at a constant rate of 18 degrees per minute. The mean draft at the time was twenty feet, six inches, several feet less than the full load draft. From the maximum swing rate in one direction to the maximum in the other, an elapsed period of three minutes was required. On another occasion at about the same draft, with 15 knot winds, five foot waves and six foot swells, the vessel reported ability to twist to any given heading and maintain it within one degree of yaw. On the matter of helmsmanship, it is reported that no special training is required to utilize the device for bearing keeping to within one degree of yaw.



Figure 1 - USNS MISSION CAPISTRANO (T-AG 162)

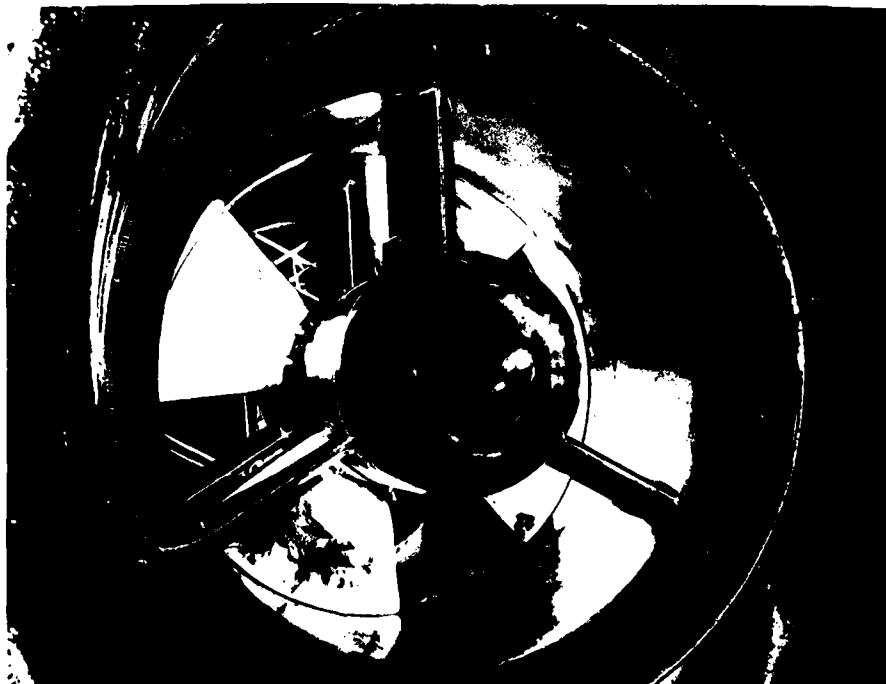


Figure 2 - Propeller assembly installed in
USNS MISSION CAPISTRANO

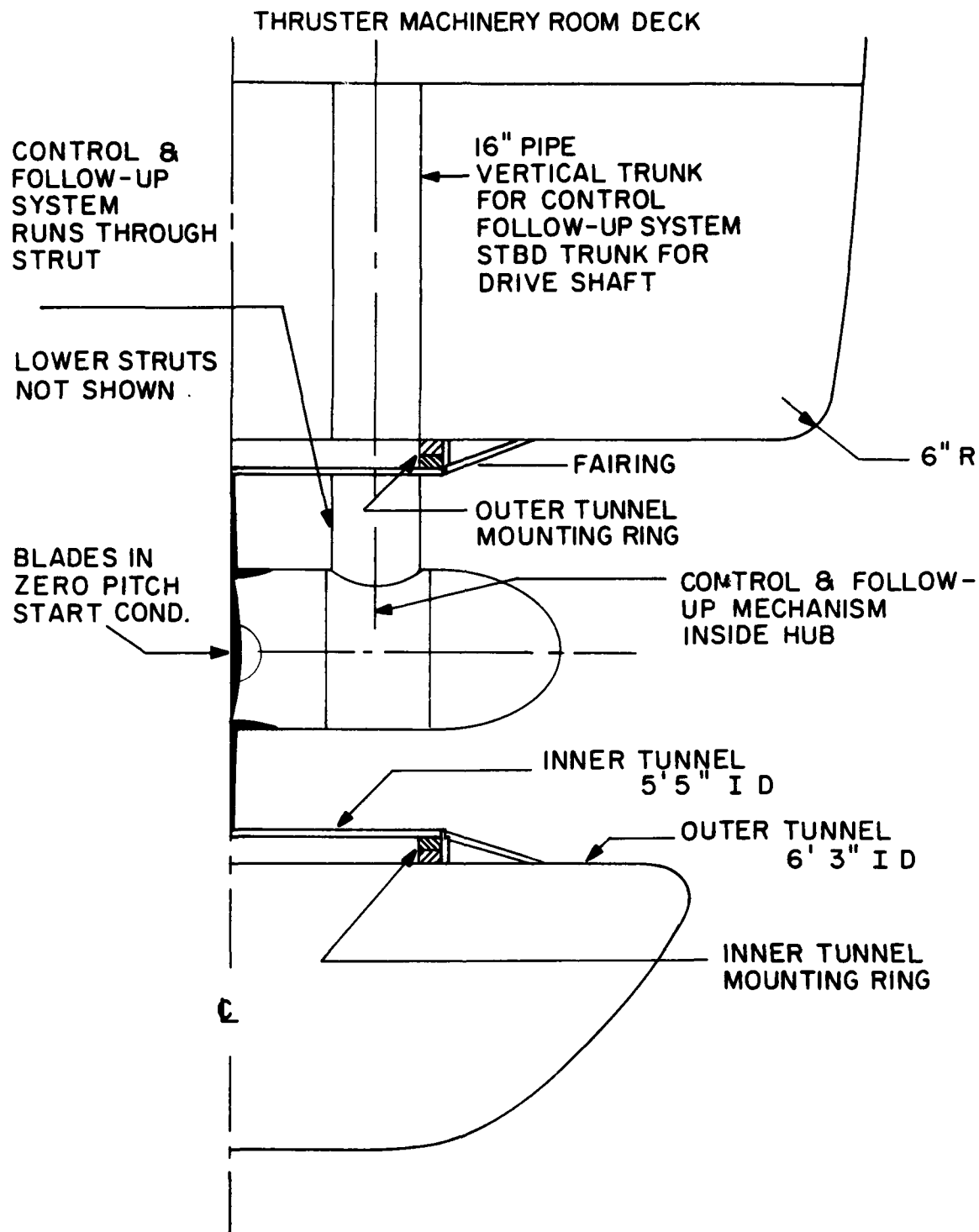


Figure 3 - Thruster tunnel configuration looking aft (starboard side symmetrical)

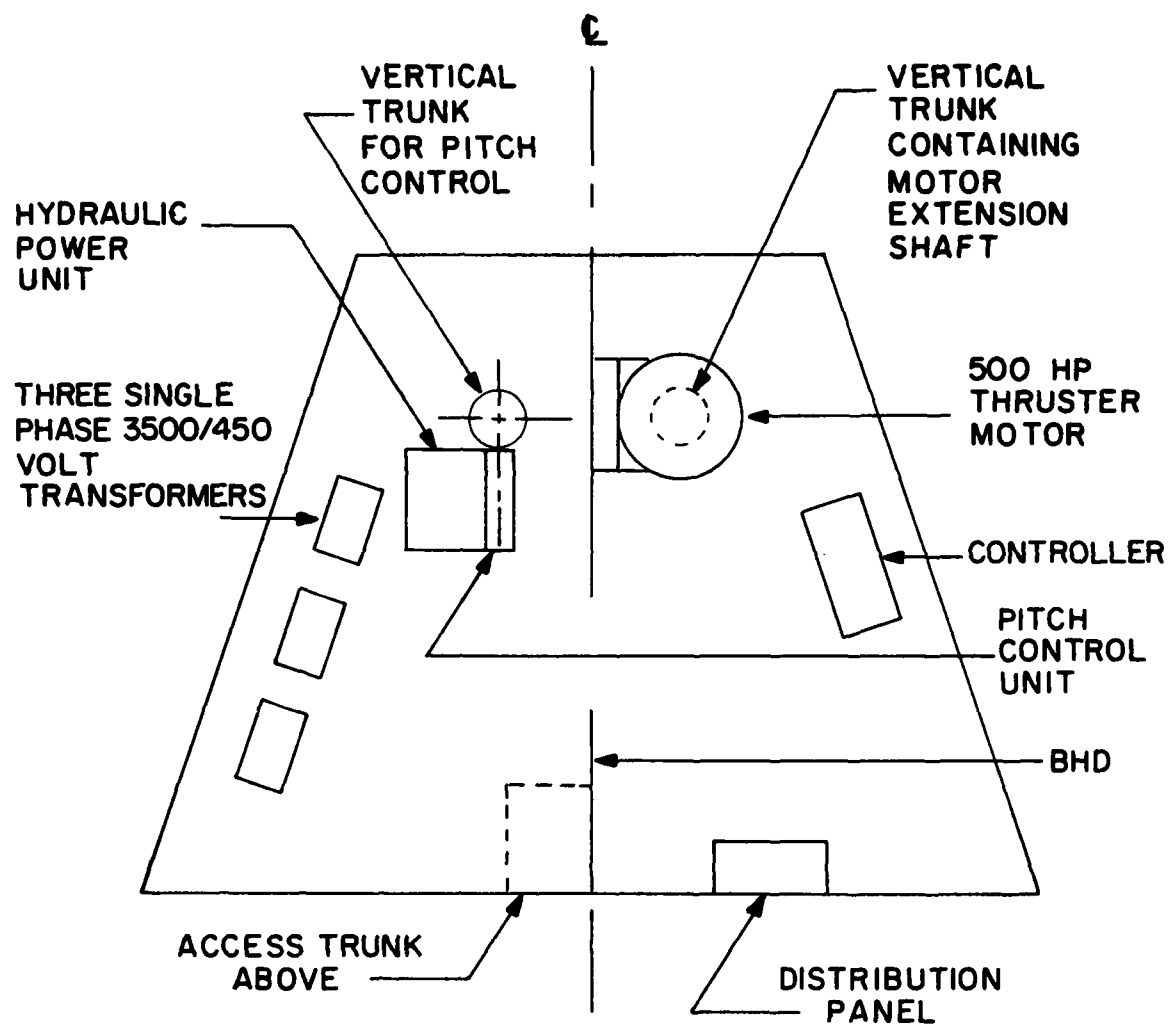


Figure 4 - Plan view of thruster machinery room showing propulsion and control machinery

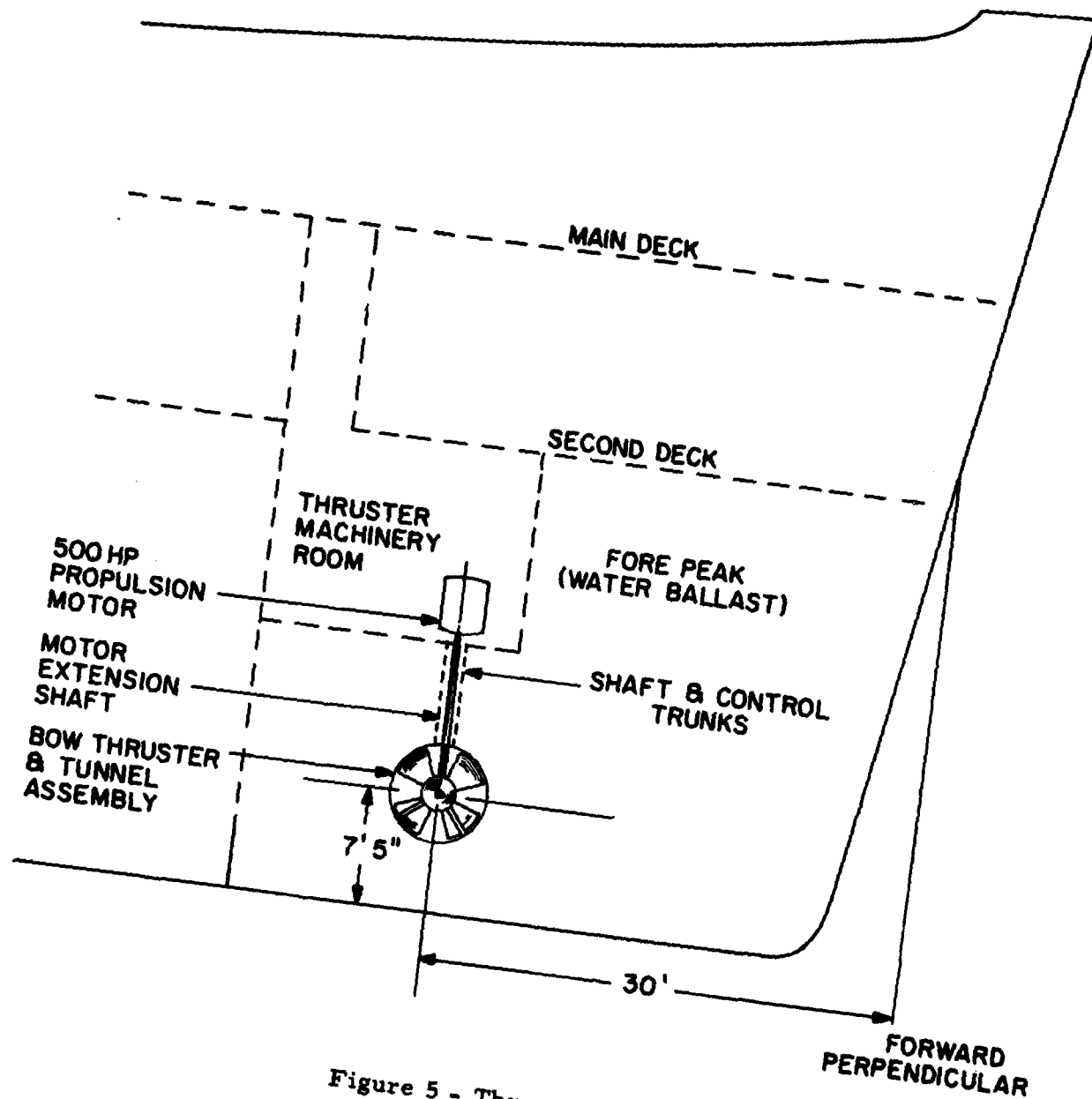


Figure 5 - Thruster layout