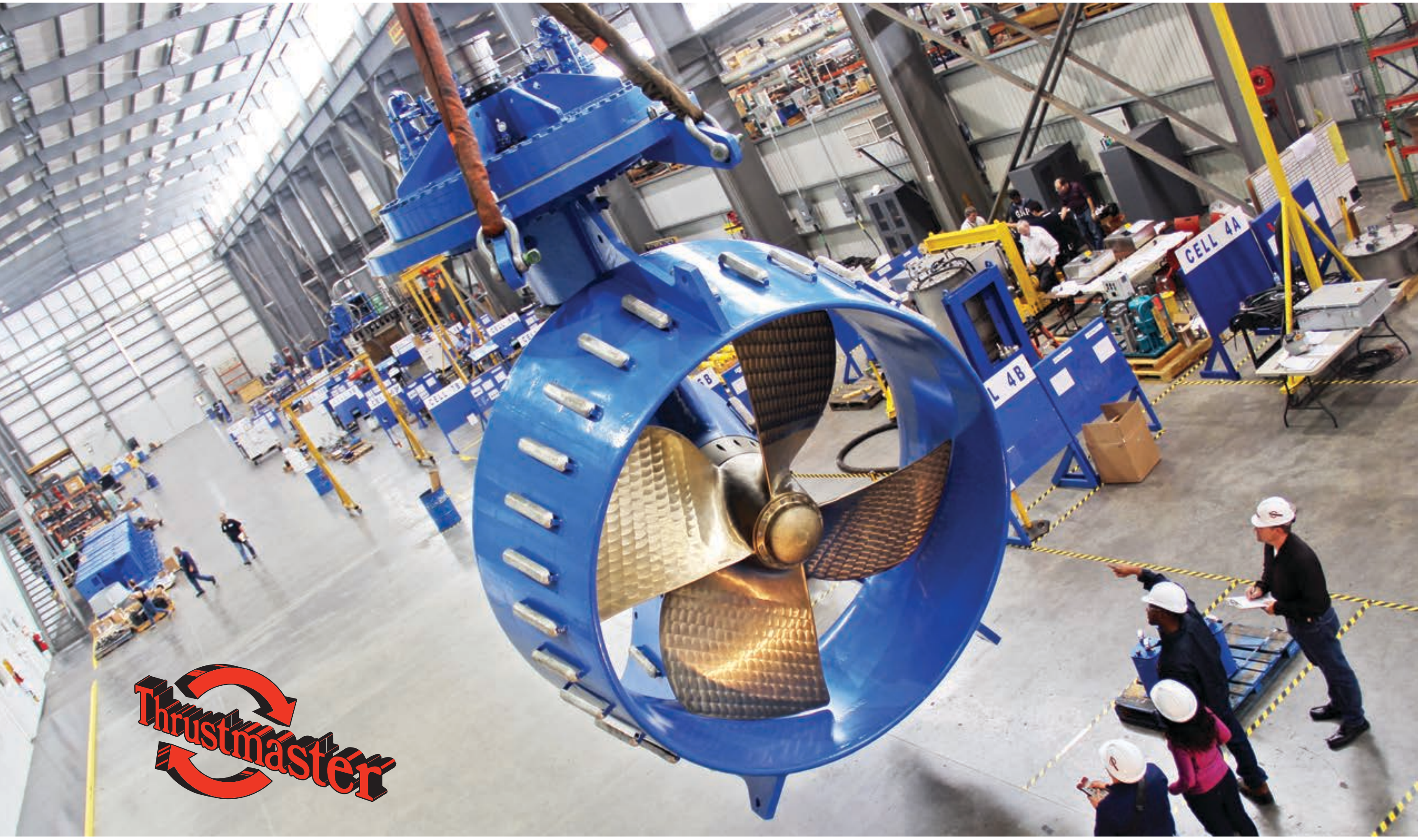


Fig. 1 - The TH5000ML underwater mountable azimuth thruster shown inside Thrustmaster's Houston, TX based factory.

Thrustmaster's Underwater Mount Azimuth Thrusters

Efficient Thruster Design Optimized for Drillships and Semi-submersibles for Ease of Installation.

Thrustmaster's underwater mount azimuth thrusters provide 360° pinpoint precision thrust and seamless integration with offshore drilling and dynamic positioning applications. The steerable propulsion system's ability to be replaced without interrupting drilling operations is a key benefit, along with unmatched performance, operational efficiency and field tested reliability. Thrustmaster's large engineering staff developed a series of azimuth thrusters up to 10,750HP (8MW) that are optimized for underwater installation in drillships, semi-submersible drilling rigs and construction vessels.

Thrustmaster's headquarters in Houston Texas consist of the largest thruster manufacturing facility in the world, with complete fabrication, machining, assembly and testing carried out under one roof. Thrustmaster gives the highest attention to quality, safety, environmental and operational efficiency.

Features:

- 1. Reduced Maintenance Downtime
- 2. Pinpoint Station Keeping
- 3. Exceptional Reliability
- 4. Economical Operation
- 5. Optimum Efficiency

Fig. 2 - The TH5000ML with a 7° titled propeller shaft and nozzle.

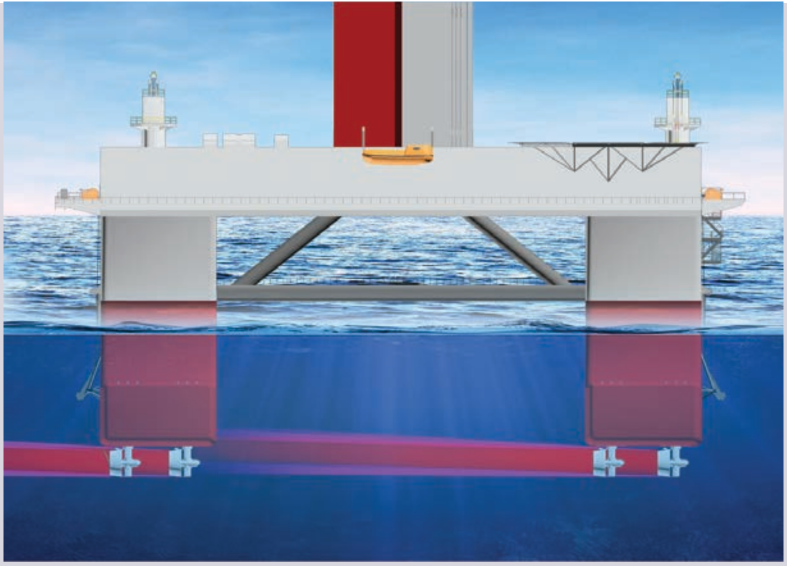


Fig. 2 - Traditional thrusters propels a wake adhering to the hull bottom, creating flow deflection known as the Coanda Effect.

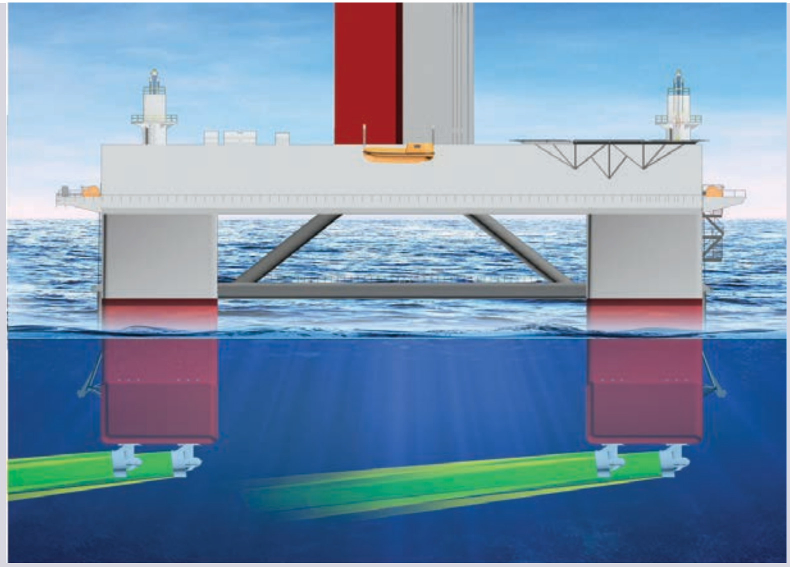


Fig. 3 - For semi-submersible & drilling rigs, Thrustmaster thrusters with a 7° down angle are significantly more efficient than any other thrusters.

The Coanda effect is the phenomenon in which a jet flow attaches itself to a nearby surface and remains attached even when the surface curves away from the initial jet direction. The phenomenon derives its name from a Romanian born aeronautical engineer – Henri Coanda. In free surroundings, a jet of fluid entrains and mixes with its surroundings as it flows away from a nozzle. When a surface is brought close to the jet, it restricts the entrainment in that region. As flow accelerates to try to balance the momentum transfer, a pressure difference across the jet results and the jet is deflected closer to the surface – eventually attaching to it.

Even if the surface is curved away from the initial direction, the jet tends to remain attached. This effect can be used to change the jet direction. In doing so, the rate at which the jet mixes is often significantly increased compared with that of an equivalent free jet. The jet stream exiting the nozzle of a thruster is affected by the Coanda effect, since the bottom of the hull is an adjacent flat surface. When a conventional azimuth thruster on a semi-submersible vessel is thrusting in the athwart ship direction, toward the opposing pontoon, the jet stream will first attach itself to the bottom of the pontoon where the thruster is installed. It will then follow the radius at the edge of the pontoon, turning the jet stream in an upward direction. It will then cross the distance toward the opposing pontoon where it hits the side of that pontoon.

This results in two significant thrust losses:

- 1. Friction of the jet stream where it flows along the bottom plating of the pontoon at high velocity.
- 2. Pressure of the jet stream exerted on the opposing pontoon.

Modeling using CFD analysis (Computational Fluid Dynamics) and in model test basins have shown that these losses can be as high as 46% of the total net thrust produced by the propeller and nozzle.

The jet stream exiting the nozzle is diverging at a total included angle of approximately 13°. Through CFD analysis, Thrustmaster has discovered that when the jet stream is directed at an angle of not less than 7° away from the hull plating, it will no longer tend to attach itself to the hull plating. The jet will completely separate itself from the hull and will continue to move away from it.

Based on this knowledge, Thrustmaster developed azimuth thrusters with a 7° downward thrust angle. These thrusters use 83° gears instead of the conventional 90° gears. This eliminates the thrust losses described above.

In addition to this, the 7° down angle also eliminates interaction between thrusters. The jet stream from any thruster will no longer affect other thrusters when that jet stream is directed toward that other thruster. There are no “forbidden zones” required in the DP program. This substantially improves the station keeping capability of the vessel. Some of the other thruster manufacturers have tried to compensate for the Coanda effect by using their standard 90° geared thrusters and simply tilting the nozzle downward.

Tilting of the nozzle creates undesirable side effects, such as very high clearances between propeller blade tips and nozzle in the top and bottom locations, uneven propeller inflow velocities, uneven pressure distribution across propeller and nozzle disc areas, etc.

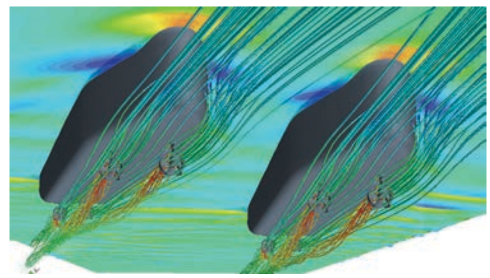


Fig. 4 - Simulation of thruster-hull interaction at full-scale ensures real-world performance of thrusters

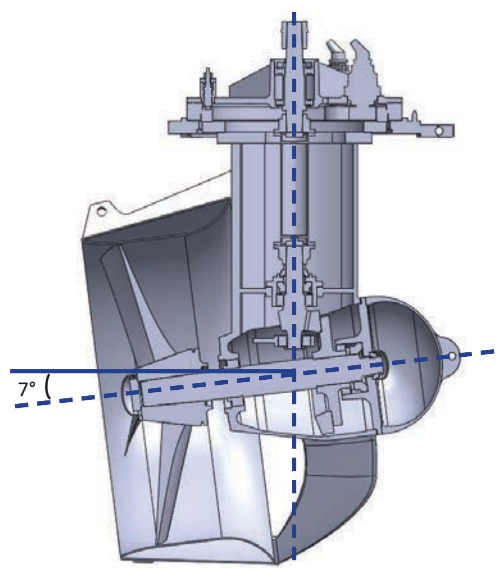


Fig. 5 - The TH5000ML with a 7° tilted propeller shaft and nozzle.

Most importantly, the maximum tilting angle is 3 to 4 degrees, which is insufficient to avoid the Coanda effect, so tilting the nozzle only is rudimentary and ineffective in avoiding the thrust losses described above.

For semi-submersible drilling rigs, Thrustmaster thrusters with a 7° down angle are much more efficient than any other thrusters.

Thrustmaster's 7° tilted thrusters propel a downward wake to eliminate hull friction drag and enable increased transit speed to an additional 1.6 knots, as recently demonstrated during sea trials on the Gusto MSC P10,000 design drillships in Ulsan, Korea.

The underwater mount azimuthing thruster can be removed and exchanged without taking the vessel out of service, or having to go into drydock.

There are three main components of the underwater installation system:

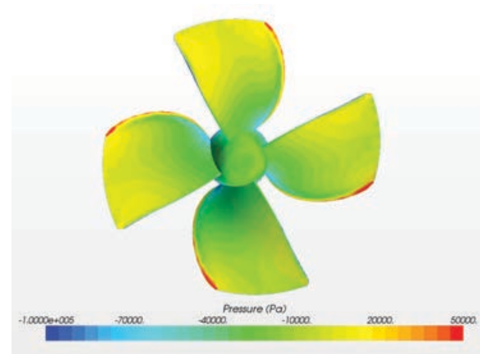
1. The receptacle with the outer cap (top),
2. The inner cap (middle),
3. The thruster (bottom).

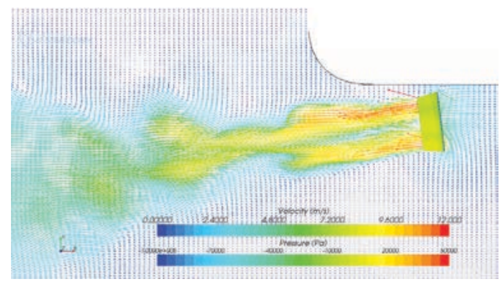
The inner and outer caps are installed at the factory and shipped to the site. Once installed into the vessel the outer cap is removed to access the inner cap. The inner cap is then removed to reveal the hydraulic steering motors and attachment for the cardan drive shaft.

Underwater mount thrusters for dynamic positioning can be installed after the vessel is launched with the assistance of a crane barge or even a vessel on-board crane. Thrustmaster also designs and manufactures the receptacles to insure a precise, accurate fit and seal integrity. The receptacles are mounted into the hull by the shipyard before launching.

A key benefit to replacing an underwater demountable azimuth thruster is that it can be done while out in the open ocean during drilling operations. With the assistance of a crane barge, a replacement thruster can easily be installed eliminating the need to dry dock the vessel.

At Thrustmaster, advanced computational fluid dynamics (CFD) simulation is an integral part of the design process for our thrusters and drive systems. Based on fundamental principles of physics and taking advantage of the ever-increasing computing power, CFD provides detailed hydrodynamic data (pressure, velocity, thrust, cavitation, circulation, temperature, etc) and enables us to design our thrusters and drive systems for best performance, maximum efficiency, and robust operation.





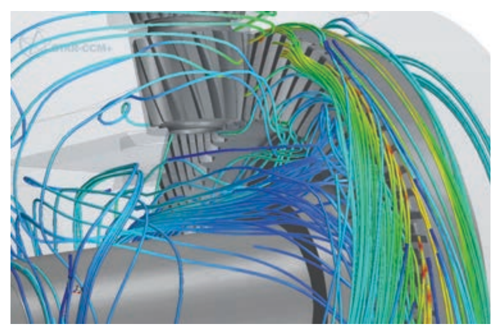
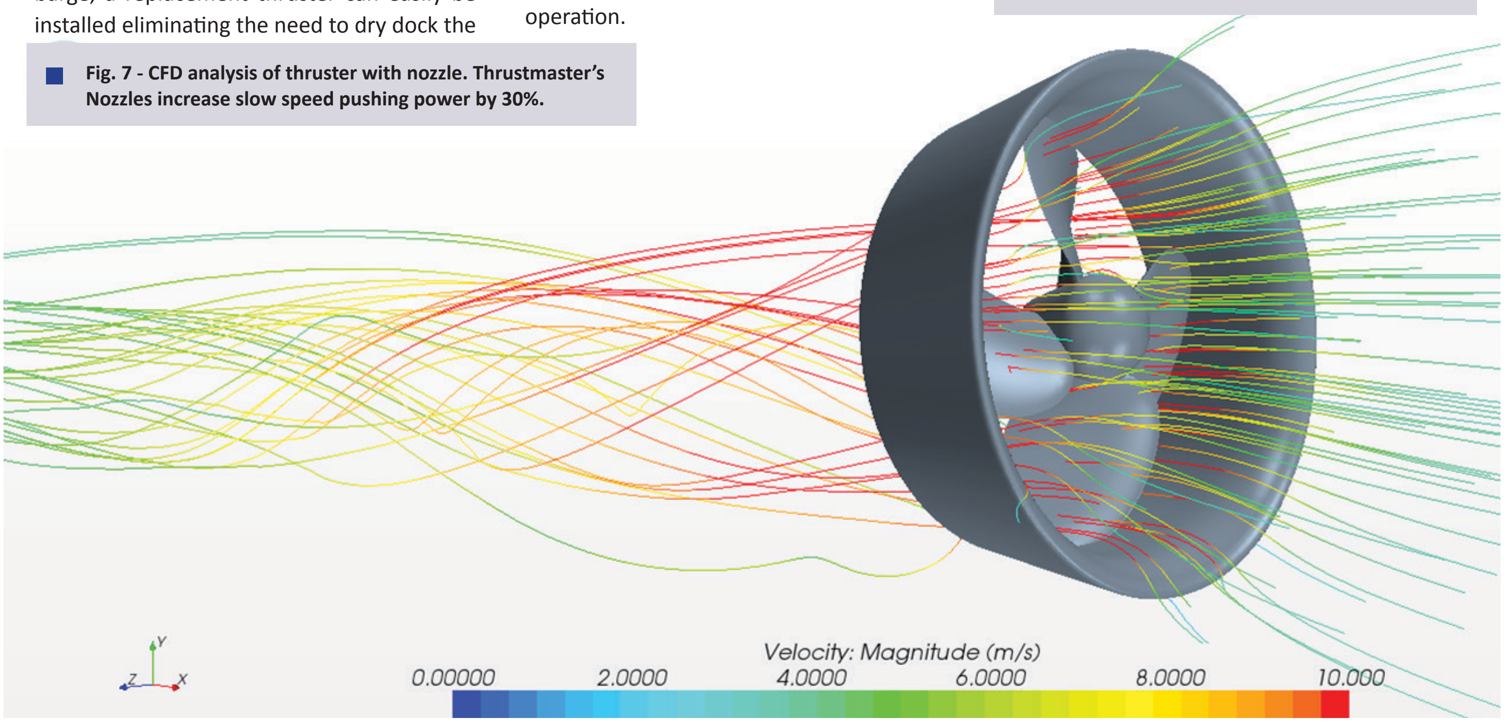


Fig. 6 - Our drive systems are designed with superior lubrication and cooling performance by leveraging advanced CFD simulation.

Fig. 7 - CFD analysis of thruster with nozzle. Thrustmaster's Nozzles increase slow speed pushing power by 30%.



OOS GRETHA

The DPS3 semi-submersible construction vessel "OOS Gretha" was launched on November 25, 2013 with six (6) Thrustmaster 5,095 HP (3,800 kW) underwater mountable azimuth thrusters model TH5000ML classed by ABS.

The semi-submersible was built at the YANTAI CIMC Raffles shipyard for operation by OOS –International B.V under contract with the Brazilian major oil company Petrobras.

CIMC Raffles said it is the first asymmetric semisubmersible unit without bracing in the world. This reduces the towing resistance and dynamic positioning load, improving self propelled transit speed from an average 8 knots to more than 12 knots.

The asymmetric pontoon outline, with pneumatic de-ballast system, also aids quick ballast adjustment, to suit heavy lifting operation.

The OOS Gretha is 137.75m long, 81m wide, 39m deep (base line to main deck), with a maximum variable deck load of 7,070-ton. It can accommodate 618 people.

The vessel has two 1800-ton offshore mast cranes, which can perform tandem lifting, and it can withstand more than 22m wave height, says CIMC. Its specification means it can work in West Africa, Brazil, Gulf of Mexico and the North Sea, added CIMC.

Thrustmaster do Brasil is providing the OOS Gretha with 24/7 product support and service with its own local team.

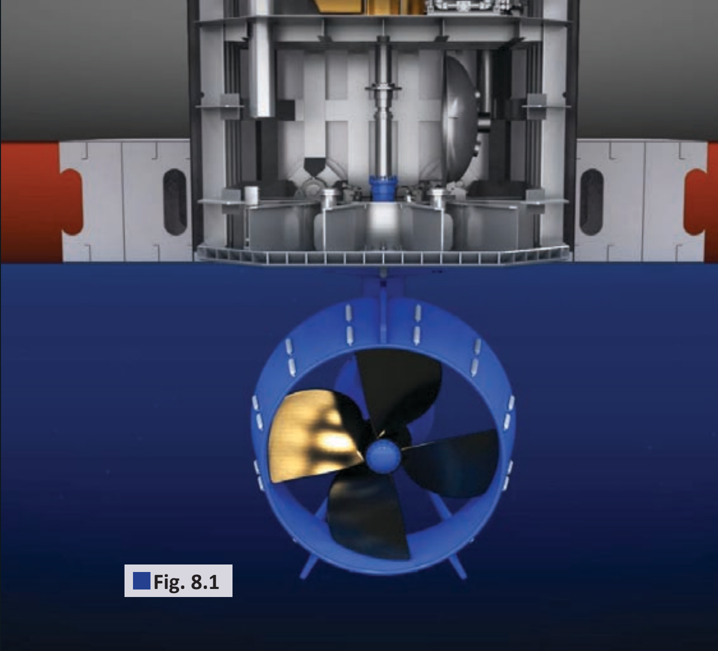


Fig. 8.1

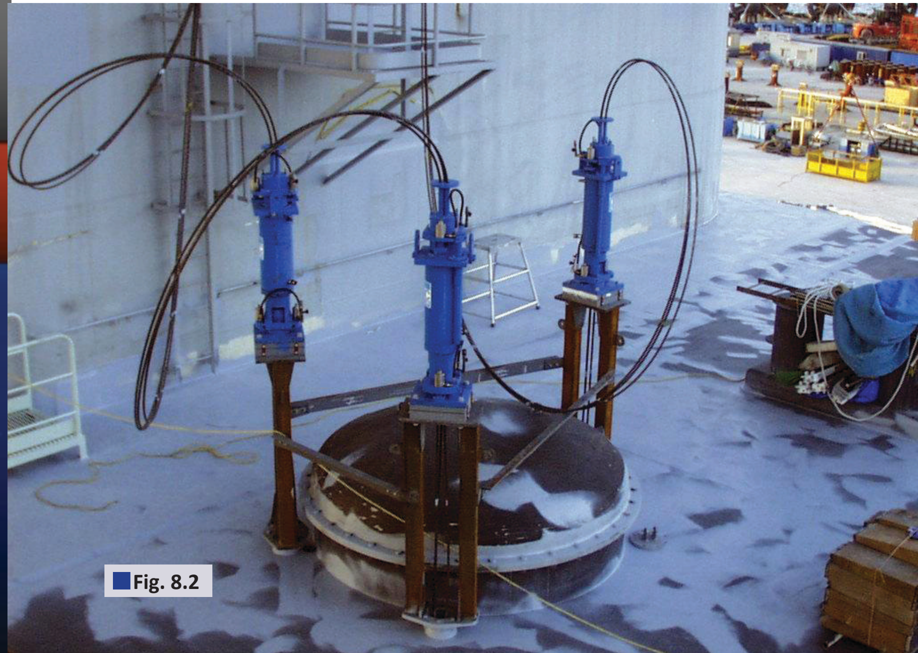


Fig. 8.2

To replace a thruster at sea, the thruster is disconnected from the receptacle (Fig. 8.1).

A dome seals the bottom opening during thruster removal.

Strand jacks are installed on top of the canister or a higher deck and their strands are attached to the thruster (Fig. 8.2).

The thruster is then lowered down (Fig. 8.3) where divers secure cables to the thruster (Fig. 8.4) from a crane for loading it on a supply vessel or barge (Fig. 8.5).

A replacement thruster is installed using the same method.

Thrustmaster's underwater mountable thrusters are provided with propeller shaft seals designed for more than 10 years life between rebuilds.

They are double mechanical face seals equipped with continuous leakage detection. Thrustmaster has been using mechanical face seals as propeller shaft seals with great success for over 30 years.

A thruster condition monitoring system can be provided as an option.

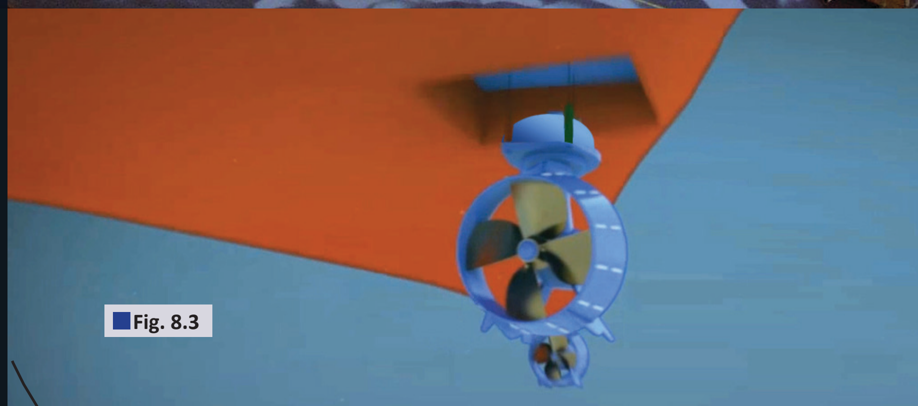


Fig. 8.3

Fig. 8.4

Fig. 8.5

Thrustmaster

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