1. Introduction

ABB Marine’s Azipod® electric propulsion system has been on the market for some 20 years. It is successfully in daily use on some 100 ships today, on a growing fleet of cruise ships, including the world’s largest, on offshore vessels and luxury yachts, and on icebreakers and icebreaking cargo vessels plying the harshest Arctic ice conditions. Much development work has taken place over the years to guarantee that the product is efficient, reliable and safe. Recent achievements include the launching of the new Next Generation Azipod XO pod design, with new orders received.

In autumn 2008 ABB Marine officially launched their Next Generation Azipod, branded Azipod XO. X represents the new Azipod series in the 4.5 to 25 MW power range and O identifies the Open water design. Azipod is also available in an ice version, in a contra-rotating version, and in a compact Azipod C small power version. The development work of Azipod XO resulted in a design with many new innovative features further improving to the developments already incorporated in the Azipod design. The new XO pod is based on the vast experience gained from the first generation Azipod, some 200 units of which has been built with accumulated operating hours of more than 7 million hours already. The XO pod comes with the improved fuel efficiency of about 12% achieved over the years Azipod has existed, through improved hydrodynamics. The service of the new pod design is made much easier and cheaper than before. New bearing and seal arrangements have been made which allows service and even replacement to be made from inside the pod, on the bigger units. A new separate radial bearing and thrust bearing system, called hybrid bearing, has been developed for the aft non-drive-end of the shaft. There is now a separate slide thrust bearing with white metal pads and at the aft end of the propeller shaft a separate roller bearing for radial support only. The previous design used spherical roller bearings. The thrust bearing pads can also be changed from within the Azipod unit. The new design uses electric steering, a solution which came from the ABB Marine’s smaller range Azipod C units. Azipod XO was designed to include a very advanced propulsion condition monitoring system, PCMS, which monitors all vital parts of the system, from propulsion drives to the Azipod bearings. The system collects data from multiple sources, processes it and produces graphs of the system’s status for the crew to follow up. It registers the condition and wear of critical components, and provides early indication of the need for maintenance. The system also enables remote diagnostic land-based monitoring.

The strategic design changes made on the Azipod XO has resulted in improved operational performance, enhanced reliability, better maintainability and higher environmental protection. The combined results of these improvements can provide up to a 50% reduction in maintenance costs.

2. Many new Azipod XO orders placed

ABB Marine received the first orders for its new Azipod X design. The first order for the next generation Azipod was placed by a Japanese ship owner for two fast ferries. Another order received was that of the pods for the fifth vessel for Celebrity Cruises, Celebrity Reflection, under construction at Meyer Shipyards in Germany, to be delivered in 2012. Originally the cruise ship was to receive first generation Azipod VO drives, of the same type as its four sister ships in the series. But as the new version
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became available, this order was changed to a pair of new XO pods.

Another recent success story is that with Norwegian Cruise Line, which opted for the second generation Azipod XO drives for its two next-generation new buildings ordered from Meyer Werft shipyard. This news, that ABB won the over $50 million order was announced in February 2011. ABB Marine will provide power and propulsion systems for the two new cruise ship, which will become the biggest cruise ships ever built in Germany. Each vessel will have a gross tonnage volume of 143,500 GT and will be able to carry more than 4,000 passengers.

The order includes power generation and distribution systems, thruster motors, and two 17.5 MW propulsion systems including transformers, drives and Azipod XO propulsion units.

3. Improved fuel efficiency

A main idea of changing to new XO drives for Ms Celebrity Reflection, Celebrity Cruises fifth vessel in the series, was to reduce both fuel consumption and equipment costs. The propulsion power was reduced to 2x17.5 MW from approximately 2x20 MW and the maximum speed of the vessel is some two knots less than the speed of the earlier vessels. The speed was also affected by the somewhat bigger main dimensions of the vessel. However, thanks to the developments made, the smaller Azipod units performed equally well as the previous larger pods. The difference in power input was gained back through the higher efficiency of the new XO pod in spite of the smaller torque of the motor and the smaller propeller diameter.

4. Thorough laboratory testing of bearings and seals

ABB Marine has put much effort in guaranteeing and safeguarding the reliability of the Azipod product. "Over the years we had done lots of improvements on the Azipod design, but we realized that in order to achieve real development when designing the second generation Azipod we would have to start from the beginning," Jukka Varis, VP Technology at ABB Marine points out. In this R&D process ABB Marine decided to utilize well known proven technology in the components and the design, with the components either proven reliable in the first generation pods, or from other applications. Sliding bearings are proven technology applied in many applications but when ABB Marine wanted to use it as a thrust bearing in their new XO pod design very thorough testing was needed to guarantee that it is suitability for the task.

Thorough factory workshop tests were done at VTT Technical Research Centre of Finland. Two different types of thrust bearings were tested, the sliding bearing primarily intended for the new XO pod, and a roller bearing version of current type for comparison and for retrofit purposes. The two bearings were rigged against each other with a rotating shaftline in between. They were tested for full load, 1.6 times full load and even with almost 2.5 times the loads expected from real operation. Rapid load changes were also applied to simulate changing operating conditions. Using hydraulics, both axial and radial forces were induced. "The tests were very successful and gave us very good
information," Varis tells. "The roller bearing has typically a minimum oil film between the surfaces of some 2 µ to 4µ, or 0.002mm to 0.004mm. With the sliding bearings now tested the minimum thickness was some 40µ even with higher loads. We did continuous measurements of this film thickness which proved sufficient even during our toughest impact tests, which simulated extremely heavy ice loads. "The tests convinced us that the sliding bearing design has a very good safety margin for normal static and dynamic loads foreseen, against the unacceptable situation where metal would begin to slide against metal."

The new seal design developed for the new Azipod drive was also comprehensively tested during spring 2010. The seal, which in fact consists of four different lip seal to provide redundancy, is built to prevent any leaks out of the pod into the water. The seal can be changed from inside the pod through a very ingenious design, arranged by using a temporary inflatable seal placed around the pod during the operation. "This method is developed for an emergency situation. The seal would normally be changed during a dry docking," Varis notes. Expected lifetime of the seal is five years. The new seal arrangement separates the seal packages for water and bearing oil seals, meaning that it is just not possible for water to leak into the bearing or for bearing oil to leak into the sea. The seal system enables advanced condition monitoring to a degree not seen on the market. It controls the seal’s operational environment and the balance between pressure and heat, for example, is automatically optimised.

The first real ship installations with the new Azipod X will be very thoroughly tested and monitored by ABB Marine, to confirm the consistency with the laboratory tests. The wear of the thrust pads will be regularly checked. "We have learned that cautiousness is always needed and we want to ensure that our design works also in real operating conditions," Varis points out.

During the development process of the Azipod, to reach the high reliability of today, ABB has done more measurements, tests and research on pod bearings than anyone. Very thorough data collection and analysis has been done on the wear, and eventual damage of the pod units in operation.
5. **Azipod propulsion meets toughest possible operating conditions**

The concept with azimuthing propulsion using a variable speed electric motor placed inside the propeller pod which is controlled by frequency converters onboard the diesel-electric vessel, was originally invented and developed for icegoing vessel, in Finland. The Azipod has proven to be a very good solution for icebreakers and cargo vessels operating in the most extreme Arctic ice conditions. The turning pods make the vessels very manoeuvrable and since it was found out that by going astern, with the Azipod propulsion units "ahead", much less energy is needed for the vessel to proceed through ice, thanks to the pods that suck and blow the ice away from the vessel hull. This "double-acting" design, applied by Aker Arctic Technology on Arctic vessels, has proven superior and is now used in the most modern recent Arctic vessel projects. Azipod propulsion has recently been fitted on five Arctic 70.000dwt shuttle tankers, built in South Korea and in Russia, and is used on a series of Arctic container ships built in Finland and Germany, all operating in Arctic Russia. In addition, a number of icebreakers and icebreaking supply ships use Azipod propulsion. In all, some 30 dedicated icebreaking vessels have Azipod propulsion today. "Reliability and safety is a must for us," Varis points out. "If we can dimension the Azipod to reliably operate in conditions where its pod and propeller hits several meters thick ice blocks, it makes the task of dimensioning pods for open water operation much easier."

The first full scale references with the new XO pod design are for open water projects, but this design will also be applied in future icegoing Azipod XI designs.

6. **Energy efficiency improvement also for existing Azipod units**

ABB has worked together with Eniram Oy to improve the energy efficiency of Azipod installations onboard vessels by optimizing the toe (steering) angle of the installed Azipod units. It is estimated that the fuel consumption of the vessel can be reduced by up to 2% by this optimization. The savings reached have been evaluated and verified by the partners which are to develop and manufacture intelligent systems providing Azipod toe angle optimization in real-time operation based on the Eniram's VMS (Vessel Management System) currently developed for optimization of the vessel's trim.

Another improvement include a newly optimized Azipod fin shape and a new pod cap structure, called X-tail. The revised fin structure receives water flow from the propeller at a new, less acute angle, and its new curved design redirects the flow more efficiently. The unit's new X-tail, installed for the pod cap structure, straightens water flow on ejection from the Azipod propulsor, minimizing water swirling.

Royal Caribbean International’s Radiance of the Seas was the first cruise ships to benefit from the new fin shape and X-tail. The modifications to Azipod were completed during her drydock in May 2011. Her sailings from May to September witnessed the benefits when compared to a sister vessel and her previous operational portfolio: more than 2 percent in hydrodynamic efficiency improvement was achieved.

Based on the positive result from these tests, ABB will now include these features in new Azipod XO units and provide refitted services to existing vessels equipped with older Azipod VO and XO units.

7. **Background and References**

ABB’s Azipod is a podded propulsion system that can rotate through 360 degrees. An electric motor placed inside the propeller pod drives a fixed-pitch propeller. The electric motor is controlled by a frequency converter.

There are some 100 vessels fitted with Azipod drives in operation today. Already 48 cruise ships have opted for Azipod propulsion. The first cruise ships to receive the system were the last two vessels in Carnival Cruise Lines’ eight vessel Fantasy class series, with the first vessel, Elation, delivered in 1998. The two world’s largest cruise ship newbuildings, Royal Caribbean Cruise Lines Oasis of the Seas and Allure of the Seas are both fitted with three Azipod drives, each with a power of 20MW. References also include the pod
drives for six vessels for Norwegian Cruise Line, and the recent order for two more newbuildings, and the pod drives for Celebrity Cruises five recent newbuildings. In all some 240 Azipod units have been ordered, half of which has a power of 14MW or above. The cumulative operating hours have reached seven million.

The Azipod propulsion unit comes in a number of versions. The Azipod XO, for open water use, and VI, for icegoing vessels, has a power range from 4.5MW to 25MW. The Azipod CO is intended for vessel projects needing less power. There is also a nozzle version, the Azipod CZ, and a contra-rotating Azipod XC version as well. The Azipod CO and CZ utilize permanent magnet motor technology with practically zero heat losses from the rotor making it possible to cool the unit directly with surrounding sea water without compromising the output power. The Azipod XO design comes with medium voltage electric motor technology and Voltage Source Inverter (VSI) -type propulsion frequency converters. The most powerful Azipod units, so far, are those installed on Celebrity Cruises’ Celebrity Solstice series of cruise ships, each fitted with two 20.5MW units.

The Azipod XO is assembled at ABB Marine’s assembly and testing plant in Helsinki, Finland. A new factory for producing Azipod C units is finalized in Shanghai, China, with the first products delivered already in 2011. ABB has recently supplied Azipod C units to several ferries and other vessels constructed and operating in China. Construction of the new production facility began in March 2010 operations started in February 2011. ABB already employs 15,000 people in China, and has been ranked among the top ten employers by students and engineers several times.

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Fig5 The world’s two largest cruise ships fitted with three 20MW Azipod propulsion units.