



UNIVERSITÀ  
DEGLI STUDI DI TRIESTE

*Vittorio BUCCI*

**Progetto di impianti di propulsione navale**

## **8.5 PROPULSORI AZIMUTALI**

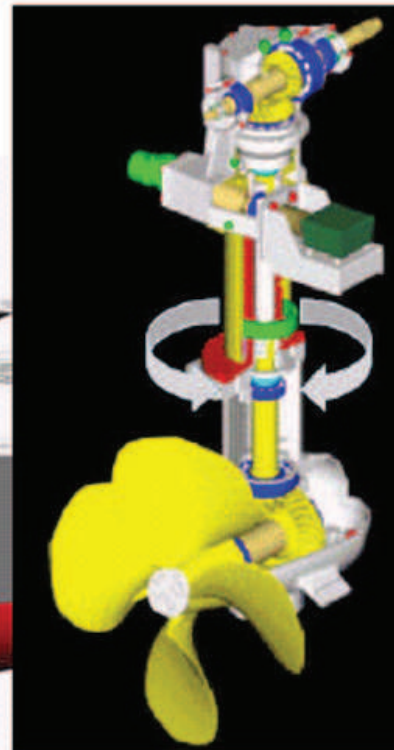
---

Anno Accademico 2017/2018

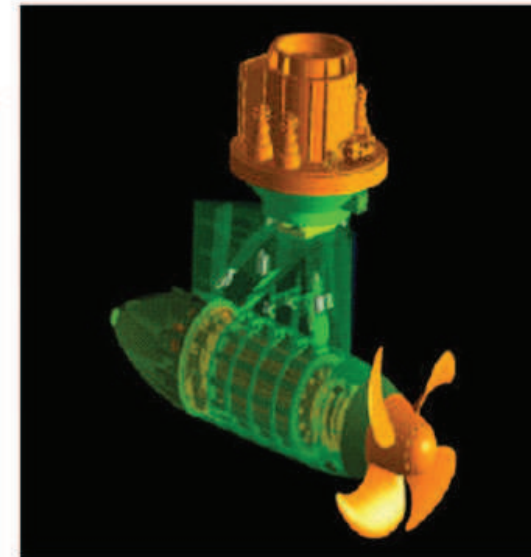
# Impianti di propulsione navale



Shaft Line

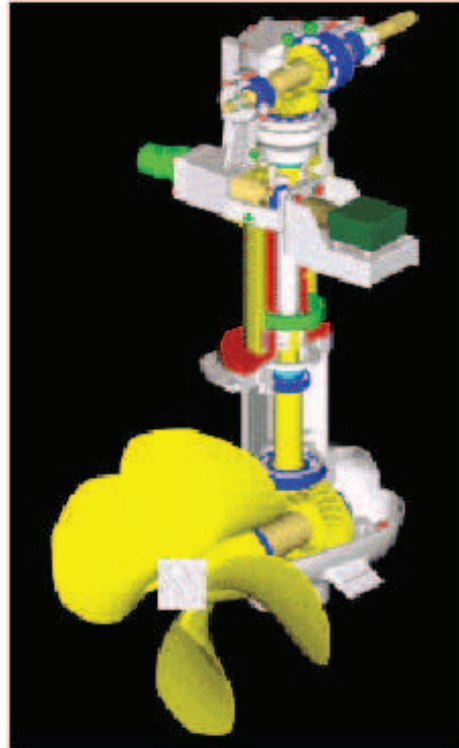


Azimuth



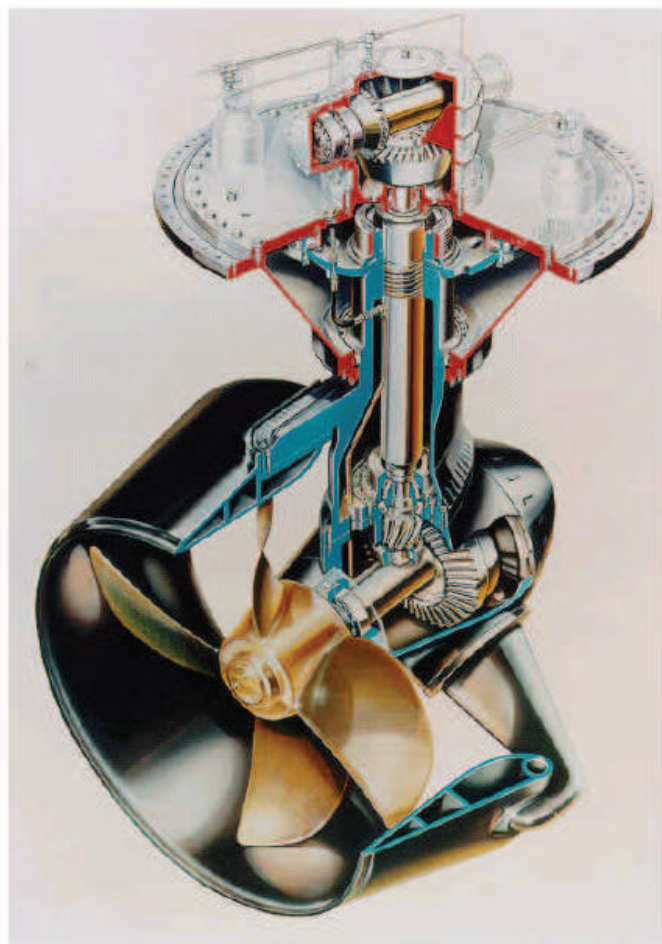
Pods

# Impianti di propulsione navale



*Example of a Z-shaped azimuth thruster, showing main elements such as, propeller, shafts, shaft sealing, the two gears, and a minimum of six shaft bearings. The underwater house and gear houses are filled with lubricating oil.*

# Impianti di propulsione navale



Data: 15/03/2007



# Impianti di propulsione navale

## LIPS STEERABLE THRUSTERS



Retractable steerable thruster.



Modular steerable thruster.



Underwater demountable steerable thrusters.



Compact thruster.



Containerised steerable thrusters.



Can-mounted modular steerable thruster.

### Steerable thrusters

With steerable thrusters thrust can be applied in any direction; achieving superior manoeuvrability. Lips steerable thrusters are durable and reliable.

- High thrust to power ratio
- Modular flexible design or compact standard design
- Fixed pitch propeller or controllable pitch propeller
- With or without nozzle
- Variable propeller diameter
- Maintenance friendly
- Low operational costs

Lips modular thruster range:

#### Modular steerable thrusters

- Flexible design, L-drive and Z-drive
- Electric pumps for steering and lubrication
- Various shaft arrangements
- Diesel or electric driven up to 7000 kW

- Optional mounting can available

#### Retractable steerable thrusters

- L-drive and Z-drive
- Retraction system with cylinders or spindles
- Electric driven up to 7000 kW

### Underwater demountable steerable thrusters

- L-drive and Z-drive
- Stable three-wire handling
- Electric driven up to 7000 kW

### Containerised steerable thrusters

- L-drive
- Customised container
- Electric driven up to 7000 kW
- Optional retractable

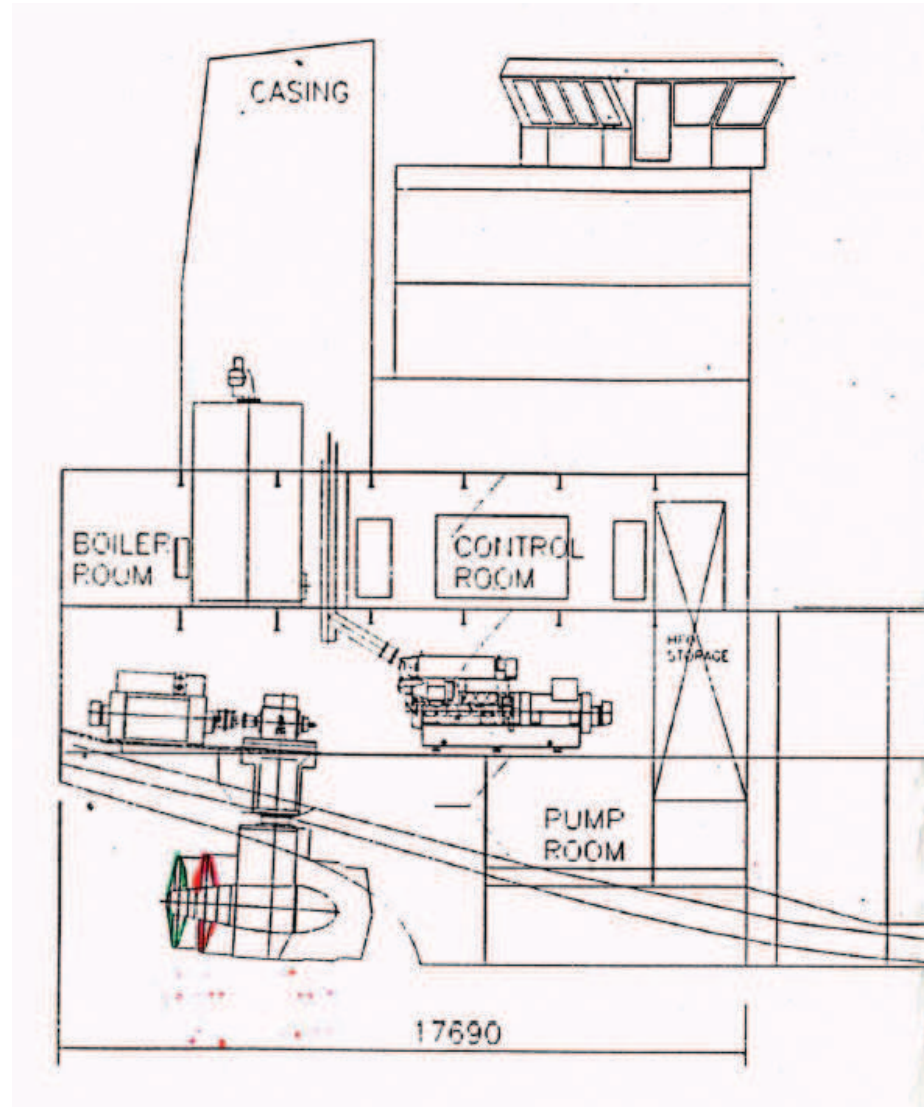
### Lips compact thrusters

- Weld-in design, optional can-mounted design
- Easy mounting
- Robust design
- High thrust to power ratio
- Standardised Z-drive design
- Diesel driven up to 3000 kW
- Maintenance friendly

# Impianti di propulsione navale

**Nave cisterna da 4000 tpi con  
propulsore azimutale a Z con  
eliche controrotanti**

Data: 15/03/2007

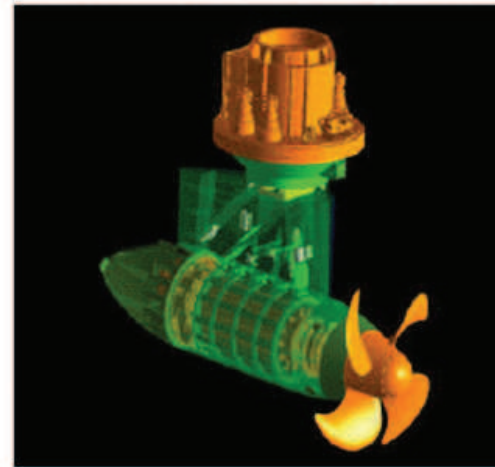


# Impianti di propulsione navale

**Azipod - ABB**



**SAM/JC-L - DOLPHIN**



**SSP**



**Compact Azipod - ABB**



**Mermaid - RR**

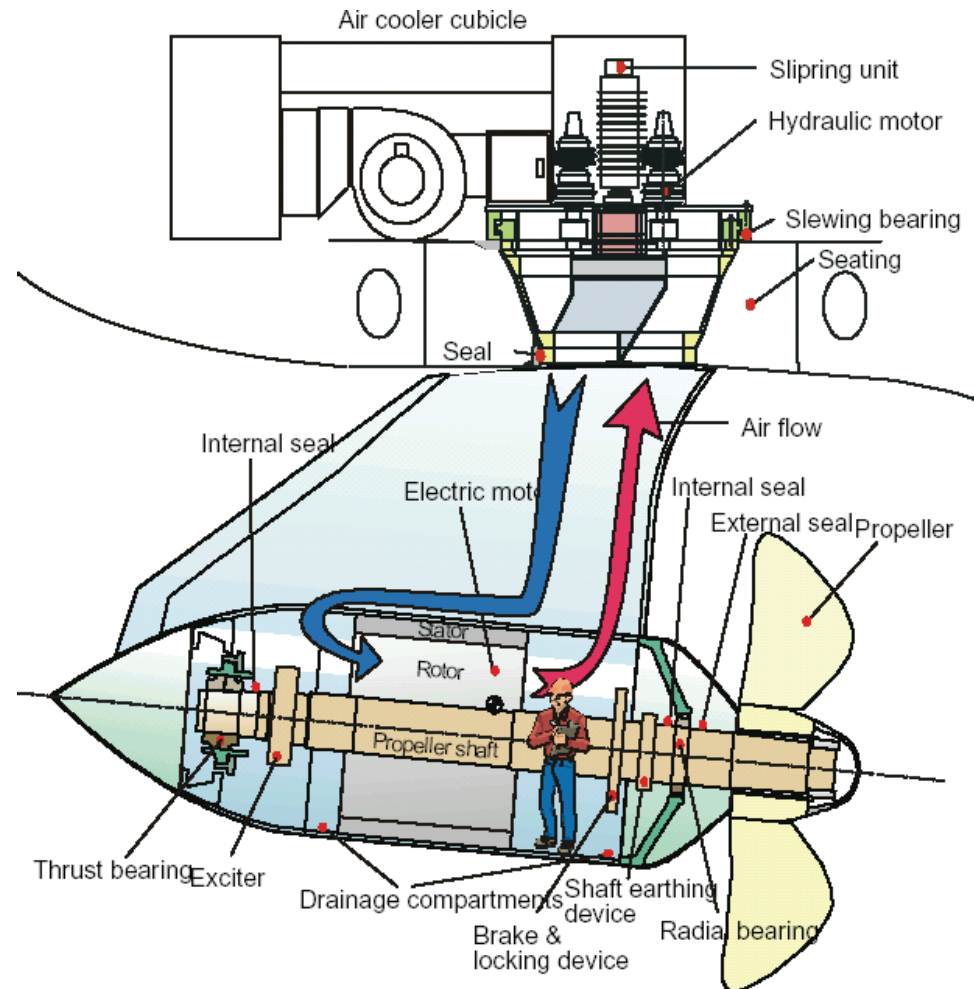




# Impianti di propulsione navale

## Propulsori tipo POD.

**Il POD di propulsione è un dispositivo, sistemato sotto la poppa della nave, che combina la funzione propulsiva con quella di governo. Il componente principale, che dà il nome al sistema, è il POD, ossia una gondola immersa di forme avviate contenente il motore elettrico di propulsione che aziona direttamente un'elica a passo fisso. La funzione di collegamento fra gondola e scafo è svolta da un gambo a sezione alare, solidale con la gondola. L'assieme gondola + gambo è in grado di ruotare per 360° orientando la spinta dell'elica e svolgendo così le funzioni di timone.**



# Impianti di propulsione navale

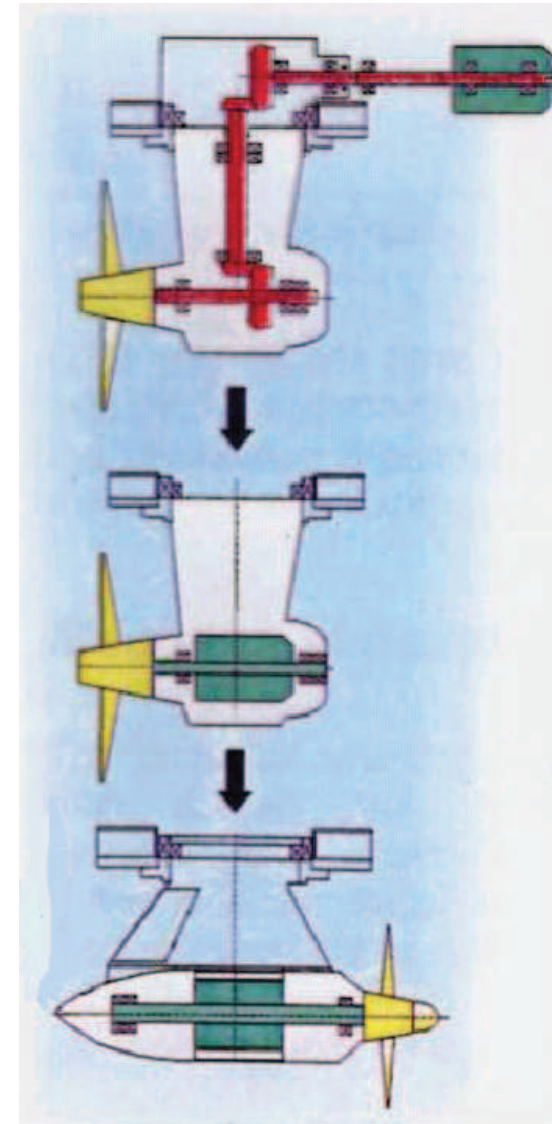
Il POD rappresenta uno sviluppo del concetto di propulsore azimutale, largamente sperimentato e tutt'ora in uso.

La principale limitazione del propulsore azimutale è costituita dal fatto che gli ingranaggi conici non possono trasmettere potenze superiori ad un certo valore (circa 10 MW).

Sostituendo agli ingranaggi un motore elettrico alloggiato nel POD immerso e direttamente collegato all'albero portaelica si eliminano le perdite di potenza create dagli ingranaggi e si ottiene un dispositivo più semplice dal punto di vista meccanico.

I primi tipi di POD erano ad elica spingente. Il passo successivo è stato quello di portare l'elica in posizione prodiera (elica traente) al fine di migliorarne il rendimento e diminuire i livelli di vibrazione.

Un ulteriore affinamento è costituito dall'applicazione, sul bordo d'uscita del gambo del POD, di un timone a flap, destinato ad entrare in funzione alle alte velocità. Tramite un sistema di controllo, si combina l'azione del flap con la rotazione dell'intero POD. In tal modo si riducono al minimo i fenomeni di cavitazione e si mantengono in ogni condizione prestazioni ottimali in termini di manovrabilità.





# Impianti di propulsione navale

## Propulsione diesel-meccanica con elica a pale orientabili

### Propulsione diesel-elettrica.

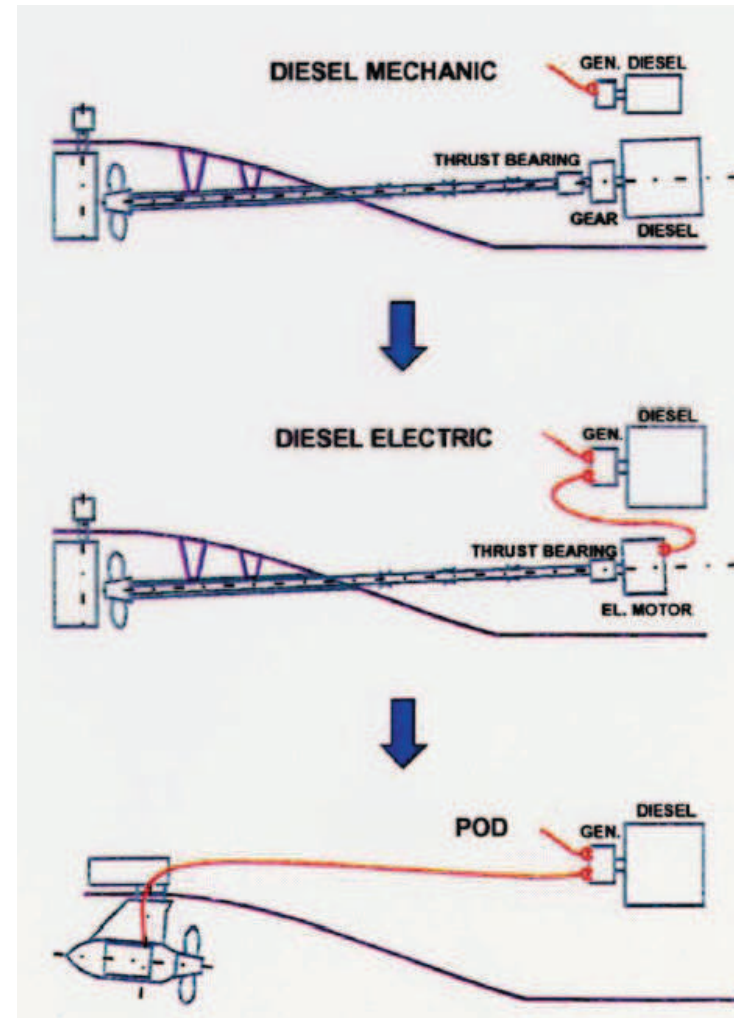
Vantaggi sulla propulsione diesel-meccanica:

- flessibilità nella sistemazione dell'apparato motore;
- riduzione dei consumi di combustibile e delle emissioni inquinanti per navi a profilo di utilizzo fortemente variabile;
- minori costi di manutenzione

### Propulsione con POD.

Vantaggi ulteriori sulla propulsione diesel-elettrica:

- miglior utilizzo dello spazio entro la scafo causa i minori ingombri dell'impianto;
- campo di scia sull'elica più uniforme;
- miglior rendimento idrodinamico (minor potenza propulsiva a parità di velocità);
- minori livelli di vibrazione e rumore;
- minor numero di componenti (eliminazione di alberi porta-elica e intermedi con relativi cuscinetti, braccetti e fuoriuscite, eliche a pale orientabili, riduttori di giri, timonerie, eliche di manovra poppiere);
- migliore manovrabilità;
- mantenimento della governabilità anche alle velocità più basse;
- minori distanze di arresto in emergenza;
- pacchetto propulsivo sotto responsabilità di un unico fornitore;
- tempi e costi di installazione ridotti.



# Impianti di propulsione navale

**Durante la fase di progetto della nave, è estremamente importante giungere all'ottimizzazione delle forme di carena in funzione dell'applicazione del POD.**

**La mancanza di appendici quali i timoni, i braccetti portaelica, le fuoriuscite e le eliche di manovra poppiere comporta di per sè una notevole diminuzione della resistenza.**

**Un'ulteriore riduzione viene conseguita disegnando una carena i cui longitudinali poppiere favoriscano un flusso più avviato, cosa resa possibile dal fatto che la carena, in questo caso, non deve avere il volume necessario per sistemare il motore di propulsione quanto più a poppa possibile, come è prassi consueta.**

**Stime e prove sperimentali alla vasca dimostrano che la potenza richiesta può ridursi anche del 15%, a parità di velocità, in confronto con le soluzioni convenzionali.**

**In ogni caso, le valutazioni sul risparmio di potenza devono essere fatte fra carene entrambe ottimizzate per i rispettivi tipi di propulsione (rispettivamente POD ed elica convenzionale).**

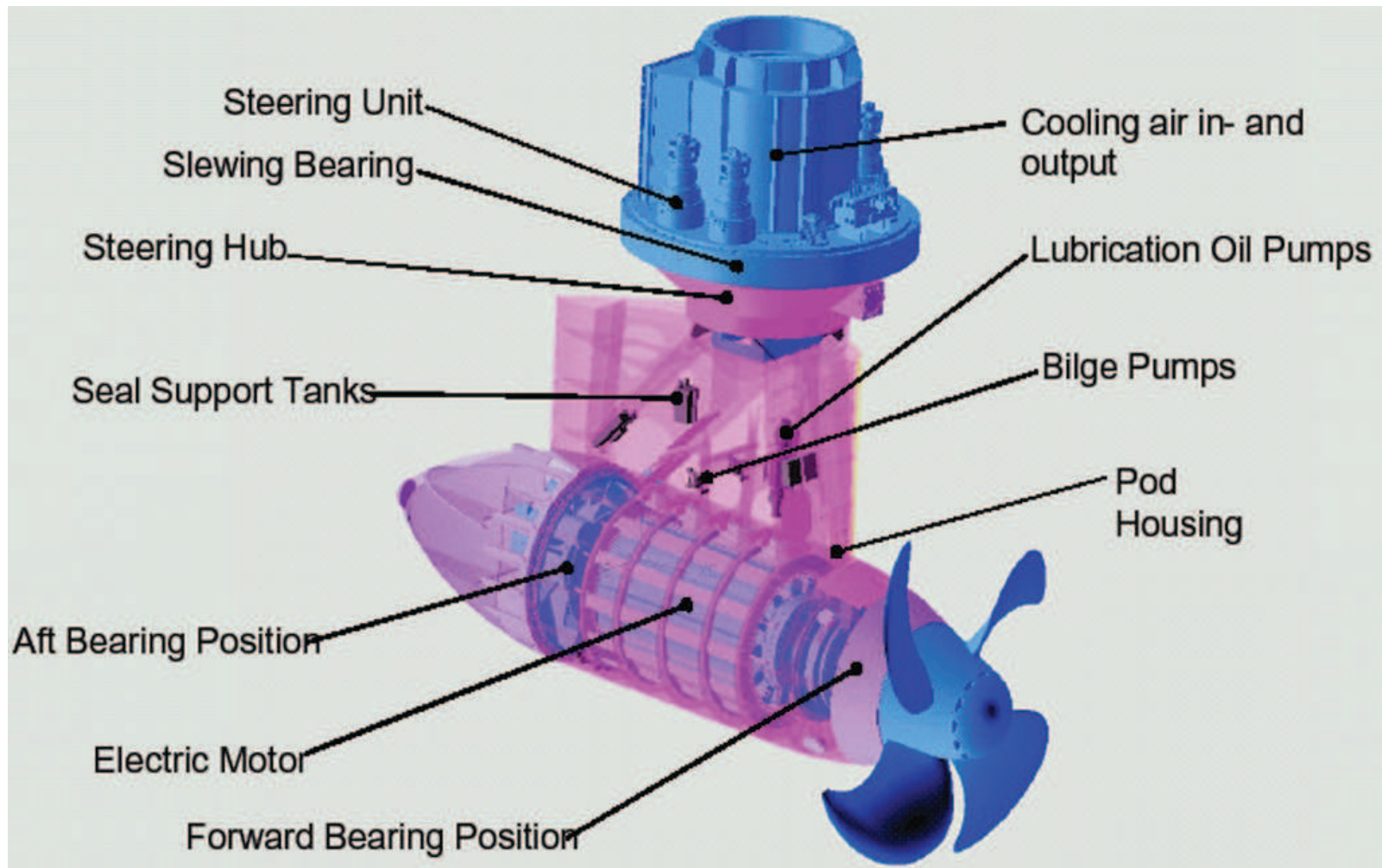
**E' molto facile, per i costruttori di POD, vantare forti incrementi di rendimento paragonando una carena ottimizzata per il POD con una carena tradizionale poco efficiente !**

# Impianti di propulsione navale

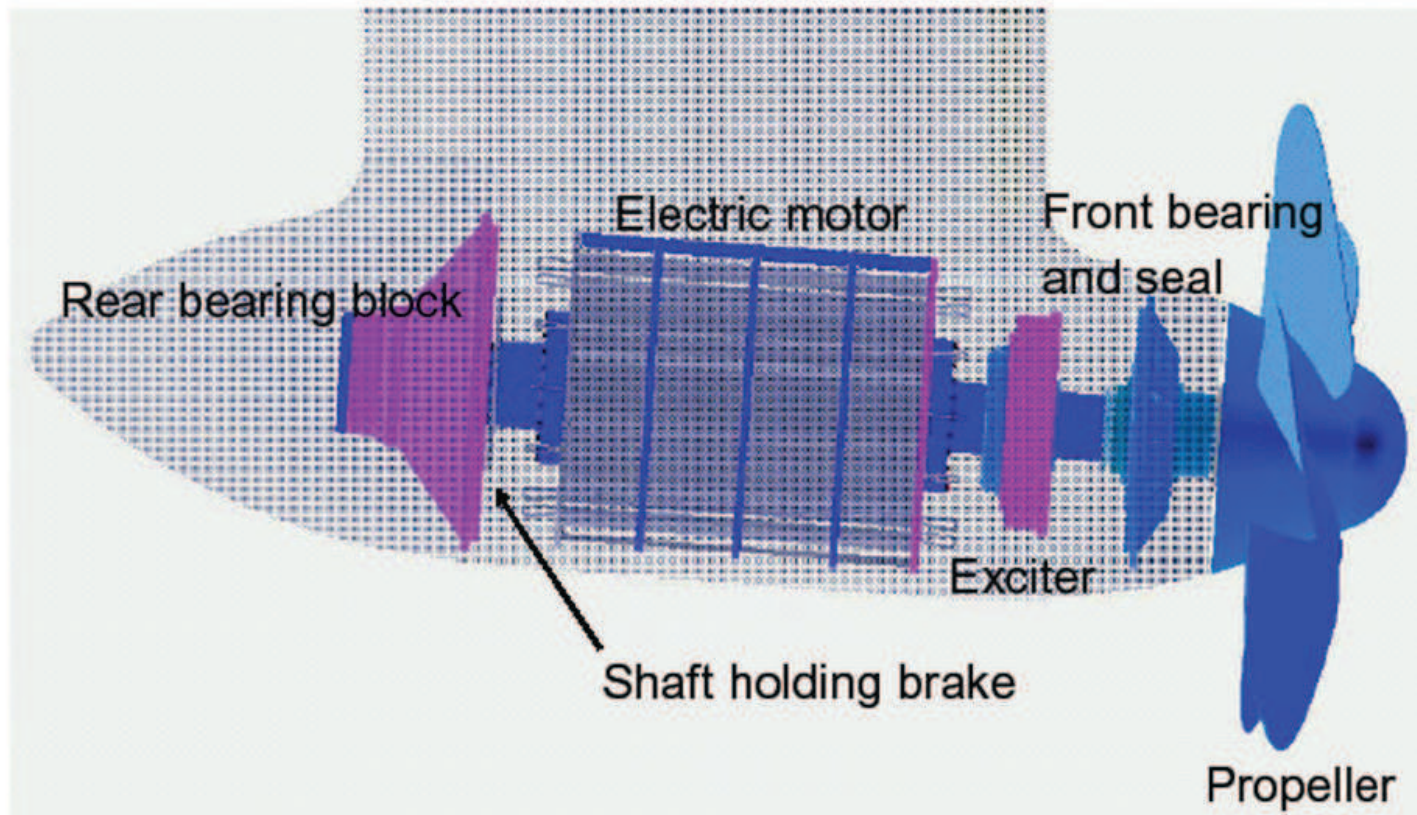
## Componenti principali del sistema situati all'esterno dello scafo:

- Motore elettrico in corrente alternata alimentato a frequenza variabile, con singolo o doppio avvolgimento. Lo statore del motore è fissato all'interno del POD. In alcuni tipi di propulsori (Rolls-Royce Mermaid) il montaggio dello statore è a forzamento entro l'involucro del POD. Ciò contribuisce a ridurre il fabbisogno di aria per il raffreddamento del 25-40 %. Il raffreddamento del sistema è effettuato in questi casi da una combinazione di circolazione interna d'aria e flusso esterno di acqua di mare. Il propulsore POD Siemens SSP fa uso di un motore elettrico sincrono a magneti permanenti che non necessita di eccitatrice. Il motore inoltre, essendo raffreddato dal flusso esterno dell'acqua mare, è privo del circuito d'aria per il raffreddamento.
- Albero portaelica sul quale è calettato il rotore del motore elettrico. L'albero è supportato da cuscinetti radiali. La spinta dell'elica è assorbita da cuscinetti assiali. Tutti i cuscinetti sono di tipo volvente (a sfere o a rulli). In alcuni tipi di propulsori (Siemens SSP), il rotore del motore è fissato all'albero tramite giunti a lamelle in grado di assorbire le dilatazioni termiche del rotore senza sovraccaricare i cuscinetti reggispinta.

# Impianti di propulsione navale

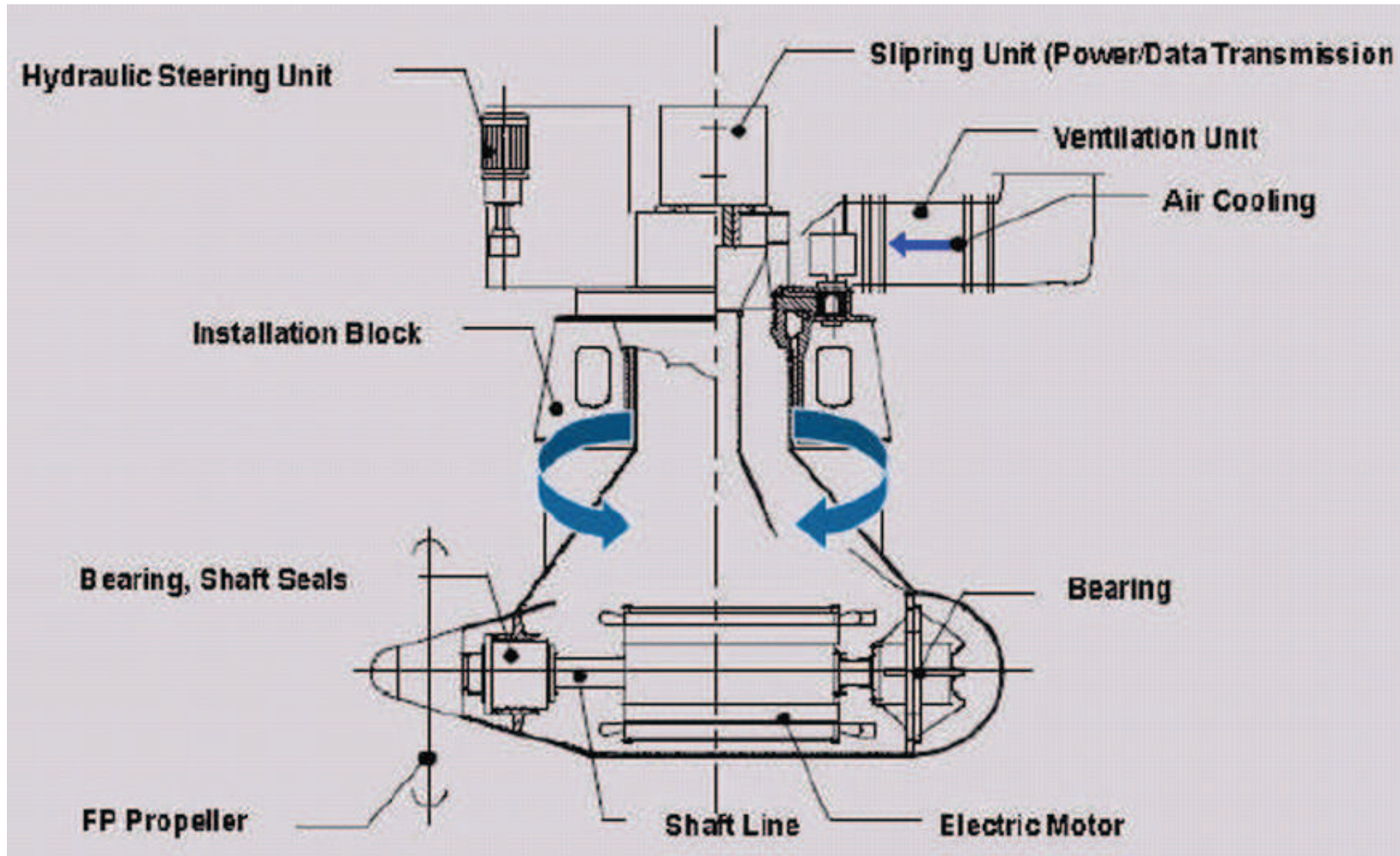


# Impianti di propulsione navale





# Impianti di propulsione navale



# Impianti di propulsione navale

- **Dispositivi ausiliari solidali con l'albero:** eccitatrice per il motore elettrico, freno e blocco meccanico dell'albero, dispositivo di messa a terra dell'albero. L'eccitatrice magnetizza il rotore del motore elettrico. Il freno e il blocco meccanico sono usati per impedire all'albero di ruotare mentre sono in corso lavori di manutenzione. Il dispositivo di messa a terra dell'albero impedisce danni ai cuscinetti causati dalle correnti disperse.
- **Elica di propulsione.** L'elica può essere in configurazione spingente (elica all'estremità poppiera del POD), traente (elica all'estremità prodiera del POD), tandem (due eliche equirostanti a ciascuna estremità del POD: soluzione adottata dal propulsore Siemens SSP). Sono allo studio configurazioni con eliche controrotanti. Dal punto di vista costruttivo, si possono avere eliche monoblocco (mozzo e pale fuse di pezzo) o eliche composite (le pale sono imbullonate al mozzo). In quest'ultimo caso, le pale possono essere sostituite singolarmente a nave galleggiante. In entrambi i casi il mozzo è montato a forzamento sul cono dell'albero portaelica tramite manicotto tipo SKF.

# Impianti di propulsione navale

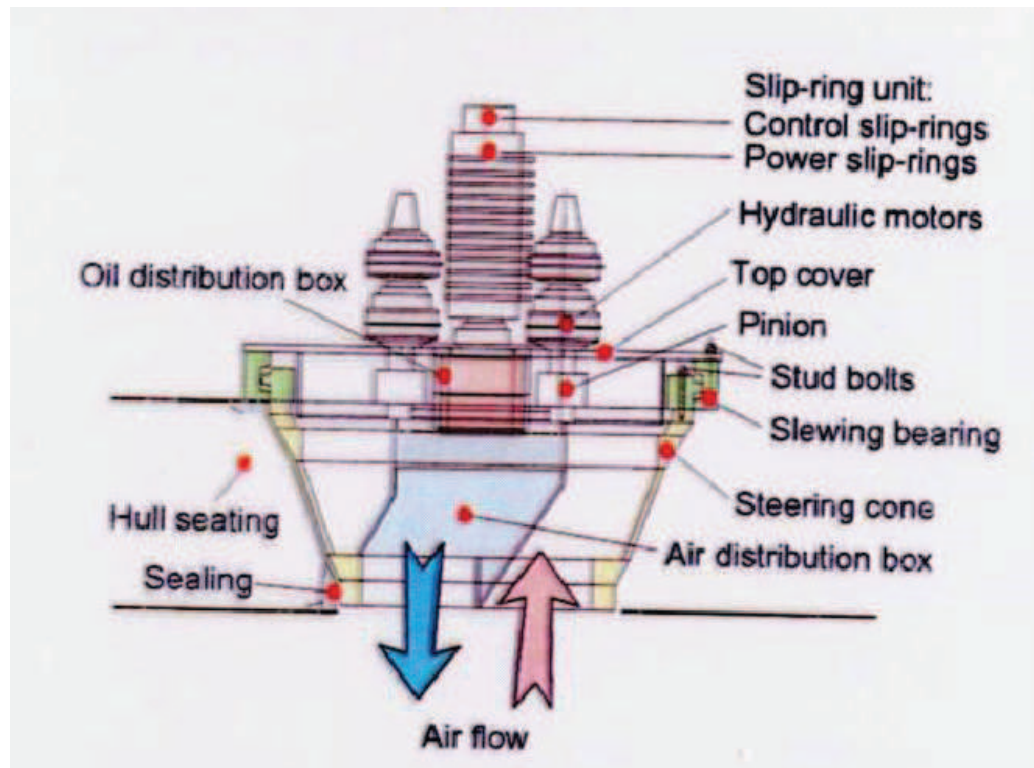
- **Tenute dell'albero portaelica.** Il sistema di tenute è progettato in modo da evitare fuoriuscite di olio in mare e consiste in una serie di tenute facciali e a labbro con spazi intermedi vuoti a cui si aggiunge una tenuta di emergenza di tipo gonfiabile.
- **Impianto di drenaggio.** All'interno del POD è previsto un impianto di drenaggio con due pompe che mandano i liquidi aspirati ad una cassa posta all'interno dello scafo. Dalla cassa i liquidi confluiscono nell'impianto sentina della nave. I liquidi possono essere costituiti da perdite d'olio dell'impianto della timoneria, acqua od olio provenienti dalle tenute, acqua di condensa che si raccolgono in due compartimenti posti nella parte inferiore del POD alle estremità del motore elettrico.

## **Componenti principali del sistema situati all'interno dello scafo:**

- **Sistema di supporto del POD.** La virola su cui poggia il POD è un tamburo cilindrico in acciaio fucinato, fornito dal costruttore del POD e saldato alla struttura dello scafo durante la costruzione della nave. Sulla virola viene montato un cuscinetto rotante circolare il cui anello interno sopporta il gambo del POD.

# Impianti di propulsione navale

- Timoneria. Il POD viene posto in rotazione da motori idraulici azionati da olio in pressione pompato da un'unità idraulica di potenza dotata di pompe a portata variabile. L'unità idraulica è sistemata all'interno dello scafo. Gli alberi dei motori idraulici muovono dei pignoni che ingranano sull'anello interno del cuscinetto rotante con il quale è solidale il gambo del POD. Il gambo è dotato di un sistema di tenute ad olio per evitare l'ingresso dell'acqua nello scafo.



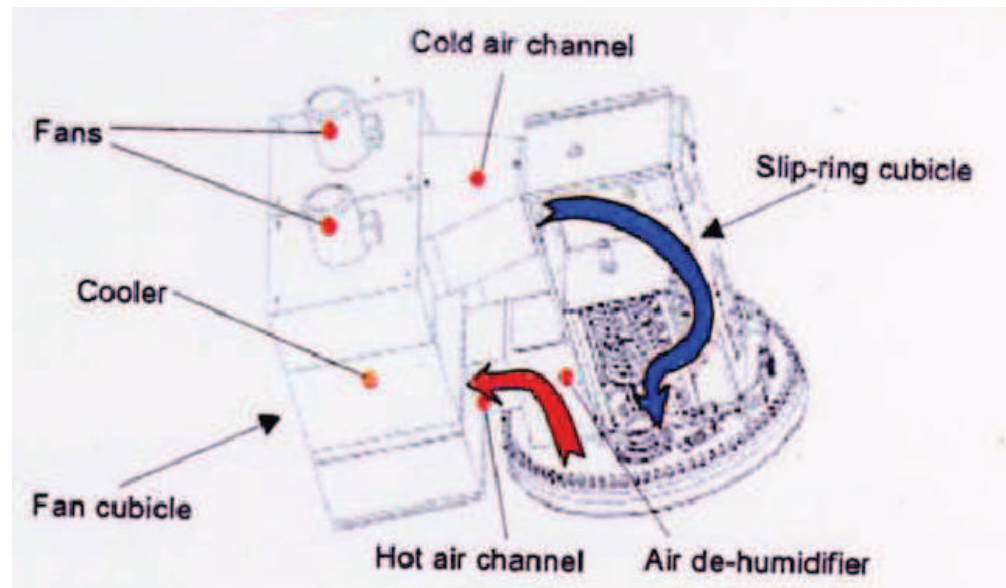
# Impianti di propulsione navale

- Sistemi rotanti di trasmissione della potenza elettrica e dei segnali di automazione. Poichè il POD deve essere in grado compiere un numero illimitato di rotazioni di  $360^\circ$ , è necessario provvedere al trasferimento della potenza elettrica e dei segnali di automazione fra la parte fissa e la parte rotante del POD in modo da evitare l'attorcigliamento dei cavi. Tale funzione è svolta da due sistemi di anelli rotanti con spazzole, l'uno riservato alla trasmissione della potenza e l'altro a quella dei segnali.
- Giunto rotante per il trasferimento dei fluidi. Il trasferimento dei fluidi fra la parte fissa e quella rotante del POD richiede l'installazione di un giunto rotante dotato di più canali con sistemi di tenuta: ogni canale è riservato ad un tipo di fluido (olio di lubrificazione dei cuscinetti, olio delle tenute dell'albero, liquidi pompati dall'impianto di drenaggio, aria).



# Impianti di propulsione navale

➤ Impianto di raffreddamento dell'aria. Nella maggior parte dei POD, il raffreddamento del motore elettrico avviene tramite circolazione forzata d'aria in circuito chiuso. Questa soluzione è stata adottata nei POD ABB Azipod e Rolls-Royce Mermaid mentre è assente nei POD Siemens SSP. Il modulo di raffreddamento dell'aria è posto entro lo scafo al di sopra del POD e contiene i refrigeranti dell'aria, i filtri, i ventilatori di mandata e le condotte di connessione con il POD. Appositi canali ricavati entro il gambo del POD provvedono ad inviare l'aria raffreddata al motore elettrico e quindi a riportarla nuovamente nel modulo di raffreddamento.



# Impianti di propulsione navale

**I componenti per l'alimentazione elettrica dei propulsori tipo POD non differiscono da quelli in uso nella propulsione elettrica convenzionale. L'impianto elettrico di bordo comprenderà :**

- **gruppi generatori mossi solitamente da motori diesel ma, in alcuni casi, anche da turbine a gas. Oltre i 4 MW di potenza installata, la centrale sarà del tipo in media tensione (3.3, 6.6 oppure 11 kV);**
- **quadri elettrici principali, generalmente in numero di due o più, per la distribuzione dell'energia ai vari utenti di bordo, inclusi i POD, secondo il principio della "power station" centralizzata;**
- **ove necessario, trasformatori di propulsione per l'alimentazione a tensione ridotta dei convertitori di frequenza;**

# Impianti di propulsione navale

➤ **convertitori di frequenza scelti in base alla potenza e al tipo di impiego del POD. Si potranno adottare :**

✓ **sincroconvertitori per applicazioni di ogni tipo, specie su navi da crociera, con potenze fino a 30 MW (Rolls-Royce Mermaid);**

✓ **cicloconvertitori per applicazioni che richiedono il 100% del momento torcente a zero giri (rompighiaccio) ma anche per applicazioni meno impegnative (navi da crociera) con potenze fino a 30 MW (ABB-AZIPOD, Rolls-Royce Mermaid);**

✓ **convertitori PWM per potenze fino a circa 10 MW (ABB-AZIPOD, Rolls-Royce Mermaid).**

# Impianti di propulsione navale

## ➤ motori elettrici del tipo :

✓ **sincrono con eccitazione, alimentato da sincroconvertitore, cicloconvertitore oppure convertitore PWM; (NB: nelle lezioni sulla propulsione elettrica si è detto che il PWM alimenta i motori asincroni: si aggiunge che il PWM può alimentare anche i motori sincroni. Vedi, ad es., AZIPOD Project Guide pag. 46).**

✓ **sincrono a magneti permanenti (POD Siemens SSP);**

✓ **asincrono alimentato da convertitore PWM**

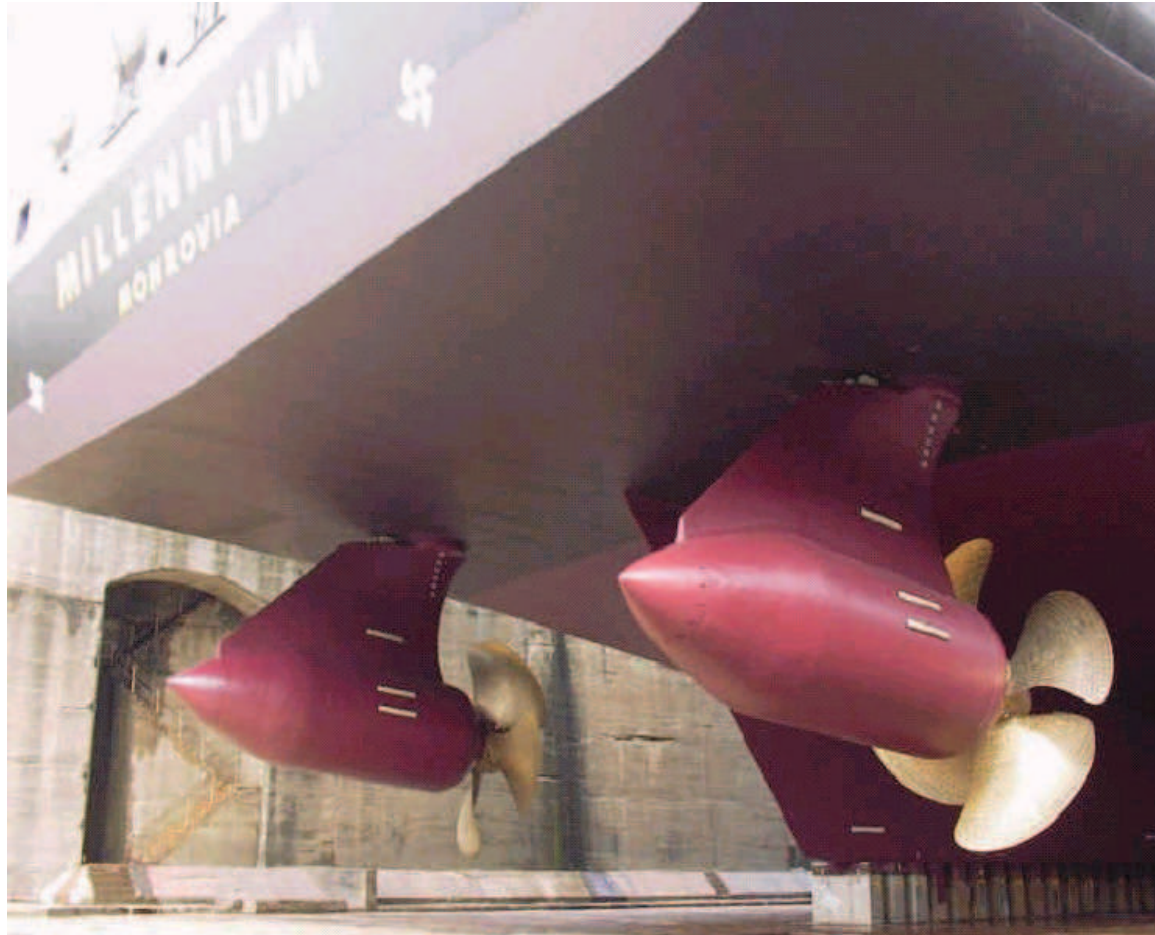
➤ **filtri armonici, ove necessari per la riduzione della distorsione armonica introdotta nella rete elettrica di bordo dai convertori di frequenza.**

**Qualora la generazione elettrica, come nella maggioranza dei casi, sia in media tensione, la rete in bassa tensione sarà alimentata da trasformatori di distribuzione.**

**Le centraline idrauliche che azionano i dispositivi di governo dei POD sono alimentate in bassa tensione.**

# Impianti di propulsione navale

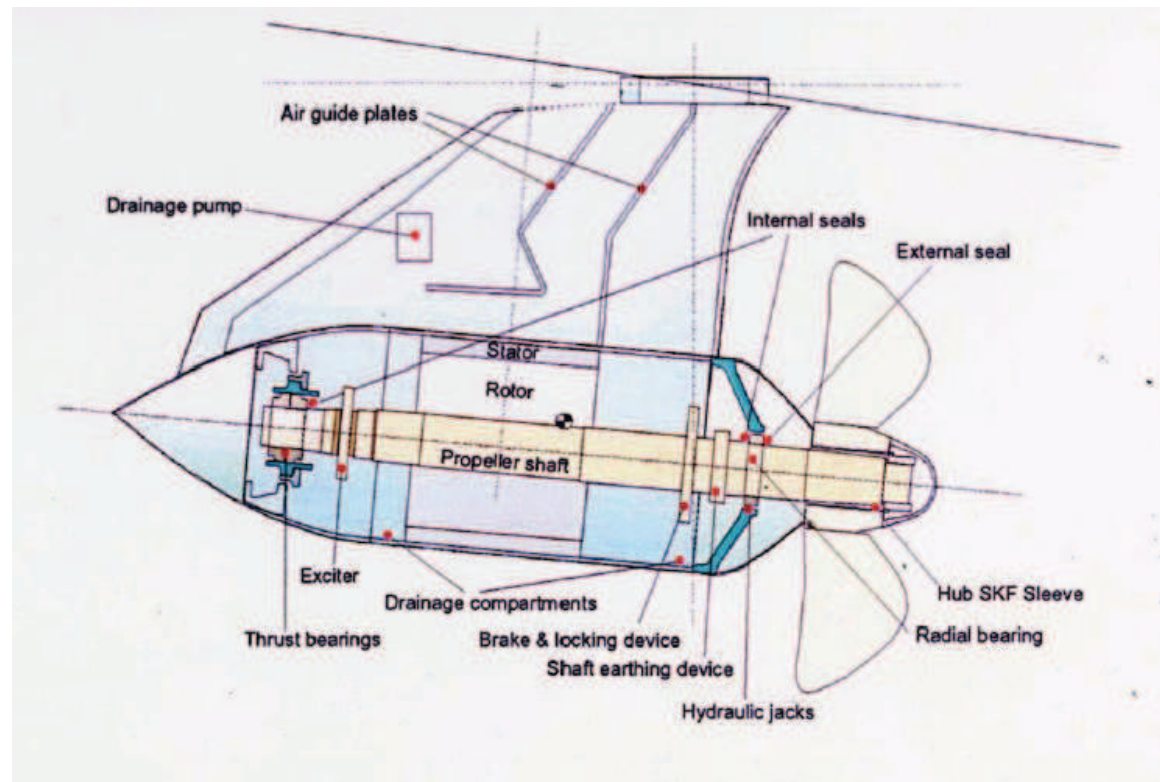
## Rolls-Royce Mermaid





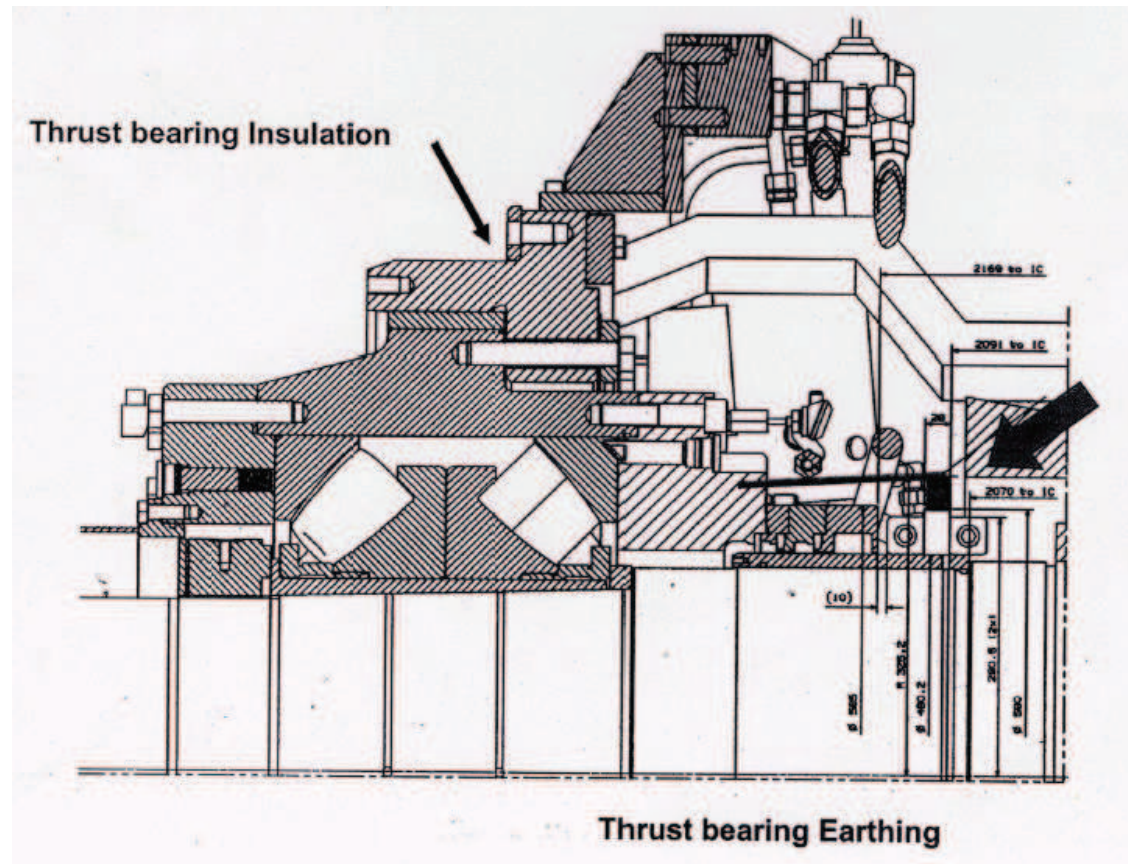
# Impianti di propulsione navale

## Rolls-Royce Mermaid



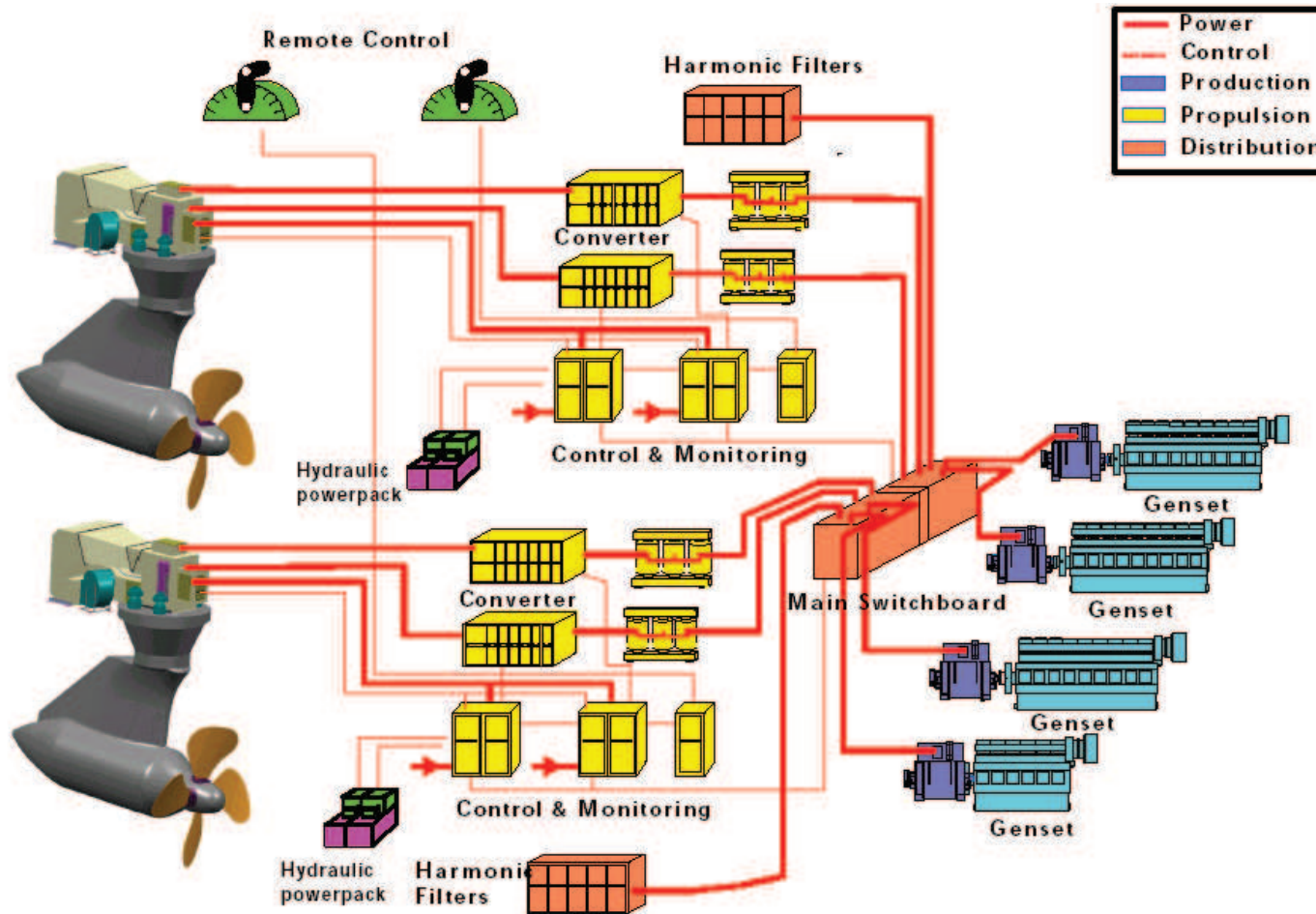
# Impianti di propulsione navale

## Rolls-Royce Mermaid



# Impianti di propulsione navale

## Rolls-Royce Mermaid





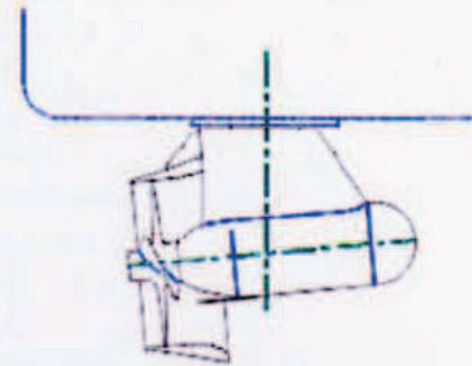
# Impianti di propulsione navale

## Rolls-Royce Mermaid

### ● Low speed, maximum thrust

This design is used on Offshore rigs or any other application where high thrust is required in conjunction with dynamic positioning. As you see these units are equipped with a nozzle for highest possible thrust.

*Interaction tests are used to find interaction between the unit and the pontoon where normally "coanda effects" cause thrust reduction. Earlier conventional thrusters have solved this by deflecting guide vanes to direct the slipstream of the propeller downwards. Tilted nozzles have also been used to get the same effect. A more effective and safe way is to tilt the thruster unit slightly downwards. This causes problems for conventional geared thrusters where there are difficulties to manufacture gears with angles larger than 90 deg. Mermaid units can be designed for inclined operation during 360 degrees rotation to minimise thrust drop due to interaction with pontoon. This together with the higher power that can be used on electrical Mermaid thrusters gives solutions with **fewer numbers of thruster units** on the rigs. In comparison between 4 Mermaid units positioned in each corner of the rig and 6 conventional thrusters, the thrust reduction, partly depending on interaction with the pontoon but primarily depending on interaction between thruster units, was found to be **about 10% larger**, as an average value, for the conventional system compared to the Mermaid system. In addition 3-5% losses in bevel-gears and bearings can be expected. **Totally we estimate an improvement of about 10-15%** in efficiency compared to a conventional solution.*



# Impianti di propulsione navale

## Rolls-Royce Mermaid

### ● Single screw, medium speed

This design is used on Tankers or any other single screw application.

*For a single screw ship it is very important to integrate the Pod body as much as possible as an extension of the ship's hull. In this design the Pod will be steerable up to  $\pm 110^\circ$ . By removing the conventional rudder, resistance will be reduced and also gives the possibility to increase the size of the propeller. By also tilting the Pod unit a bit upwards the total gain in efficiency is estimated to about 3-6%. The hull lines for a conventional vessel are somewhat restricted since the propulsion engine/motor is placed as aft as possible within the hull. With Pod propulsion without these restrictions, it would be possible to gain another 3-5% in efficiency. In addition the mechanical losses will be decreased with a Pod solution. **Totally we estimate an improvement of about 6-11% in efficiency compared to a conventional direct drive solution.***





# Impianti di propulsione navale

## Rolls-Royce Mermaid

### ● Twin screw, high speed

This design is used on Cruise vessels, Ro-Ro's or any other twin screw application.

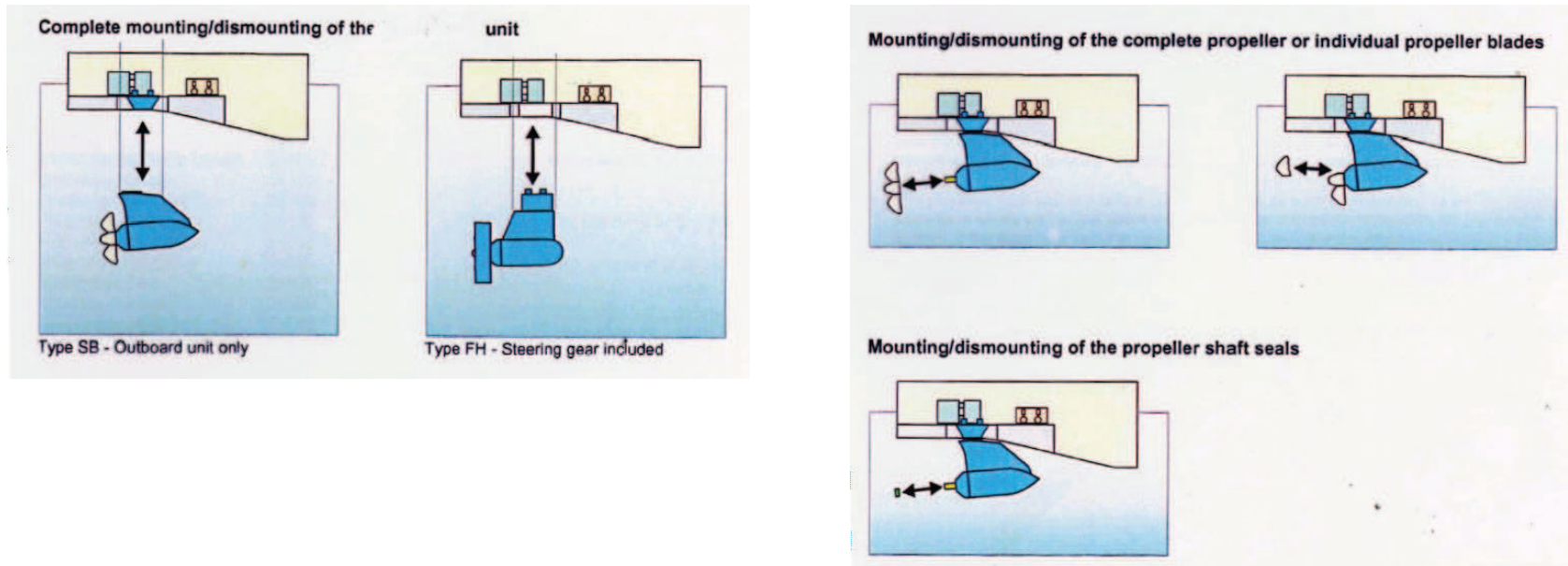
*By using a twin Pod solution it is possible to reduce hull design work, as the aft hull structure will be a simple pram type stern with fairly horizontal lines at the aft end. Model tests on a large cruise vessel designed for 23 knots were conducted with two different hulls, one optimized for conventional propellers and the other optimized for Pod. In this test by looking at the required propeller power, the Pod propulsion was 14% more efficient compared to the conventional vessel. This figure corresponds to about 15% in the motor. In this test we did not try to find the most effective position for the Pod which we know has a significant effect (especially at higher ship speeds) and therefore we believe even greater improvements can be expected. Of these 14%, about 6-8% were gained by more efficient hull, 4-6% by reduced appendages (shafting, stern tunnel thruster, rudder) and 1-2 % by tilting the unit optimally in the water flow.*





# Impianti di propulsione navale

## Rolls-Royce Mermaid



L'unità propulsiva può essere progettata per:

- montaggio / smontaggio subacqueo dell'unità completa
- sostituzione subacquea separata dell'elica, delle pale dell'elica e delle tenute

# Impianti di propulsione navale

**Nave da crociera con  
due propulsori ABB -  
AZIPOD da 14 MW  
ciascuno**

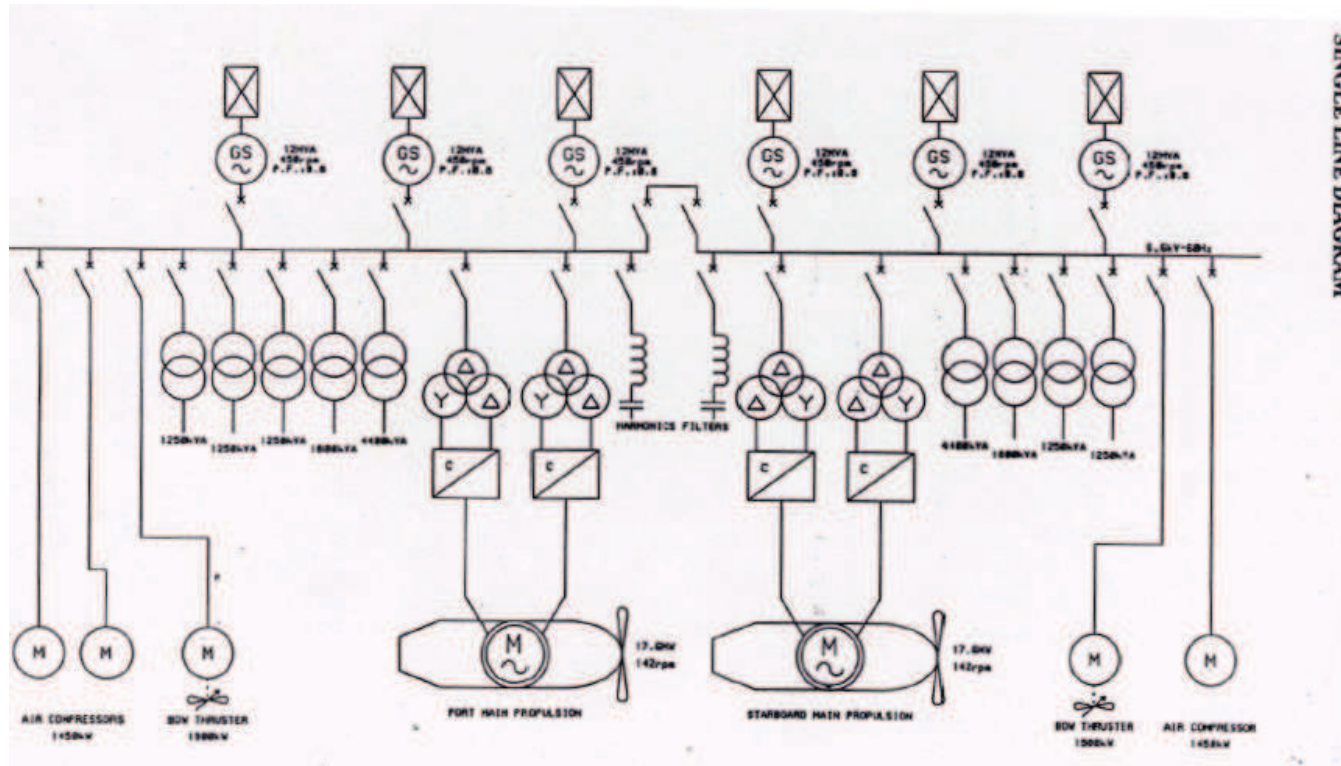


Data: 15/03/2007



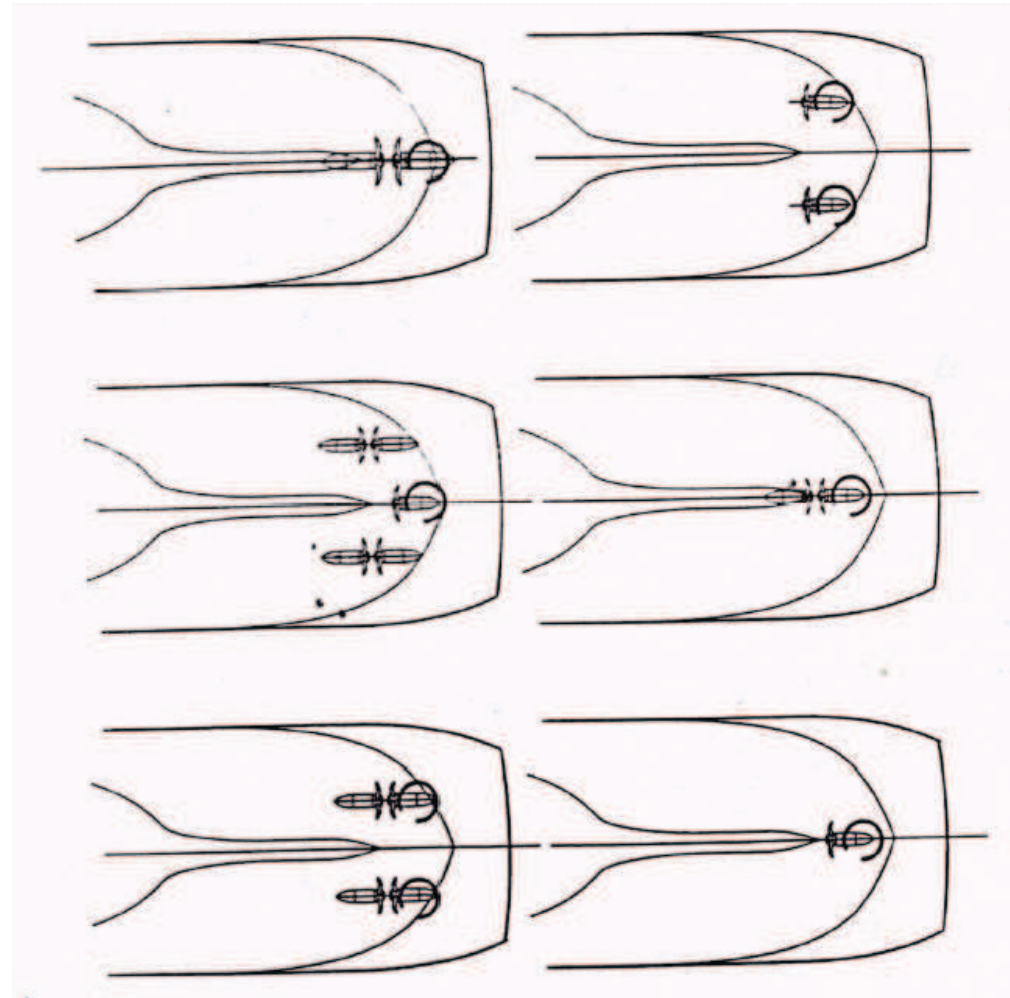
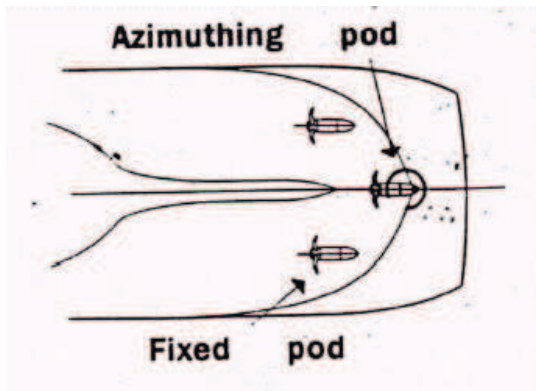


# Impianti di propulsione navale



# Impianti di propulsione navale

## Different Pod concepts



# Impianti di propulsione navale

## **CODED Machinery and Hybrid Propulsion**

**Wärtsilä has developed a new propulsion and machinery concept for the next generation of fast cruise ships. The concept features a Combined Diesel-Electric and Diesel-Mechanical (CODED) power plant with a hybrid propulsion arrangement consisting of two electrical pods and one mechanically driven feathering CP propeller.**

### **The CODED concept**

**The CODED machinery offers the benefits normally associated with conventional diesel-electric machinery, but at a lower price:**

- **Flexibility: the installed prime mover capacity can be used for different purposes in different situations**
- **The diesel engines can be run at constant speed and at more efficient loads to achieve optimum specific fuel oil consumption**
- **Freedom in location of main engines**



# Impianti di propulsione navale

**Since a large portion of the propulsion power is mechanical, the downsides associated with diesel-electric power plants– high cost and transmission losses – are reduced. On the other hand, the presence of diesel-electric machinery removes the need for the separate auxiliary generating sets necessary with conventional diesel-mechanical propulsion.**

## **Hybrid propulsion**

**An essential aspect of the benefits of CODED machinery is the possibility to use a hybrid propulsion setup consisting of two azimuthing electrical pods and a mechanical propeller. This arrangement offers very high propulsion efficiency. The possibility to split the load between three propellers instead of two yields better propeller open water efficiency, especially in the case of high power applications. Furthermore, the single-skeg hull form without any open shaft lines has lower resistance than a twin shaft line arrangement.**

**The twin pods, which can be turned 360 degrees, gives the hybrid propulsion setup better manoeuvring characteristics, making the need for side thrusters in the stern obsolete.**

# Impianti di propulsione navale

## Machinery operation philosophy

The operation philosophy is an essential part of the new concept.

The centreline mechanically driven propeller is of the feathering type. This is only used at high speeds and feathered at low and medium speeds. The feathered mode (pitch changed to align the blades with the water flow) results in significantly less resistance than for a windmilling propeller. At low speeds, the vessel is driven by the pods alone.

This ensures that low engine load on the mechanical diesel engines is never encountered while also avoiding any negative effects associated with low load operation, such as increased fuel consumption. Furthermore, the risk of pressure side cavitation is also reduced since the CP propeller is never operated at low pitch and high rpm. These potential problems have been some of the drawbacks normally associated with conventional diesel-mechanical propulsion for ships operating at a wide range of speeds.

# Impianti di propulsione navale

## Efficiency Rudder

**Steering with pods in high seas has been claimed to reduce the speed more than steering with conventional rudders /Trägårdh 2002/. This has been remedied in the new CODED concept by applying a Lips Efficiency Rudder behind the centreline propeller.**

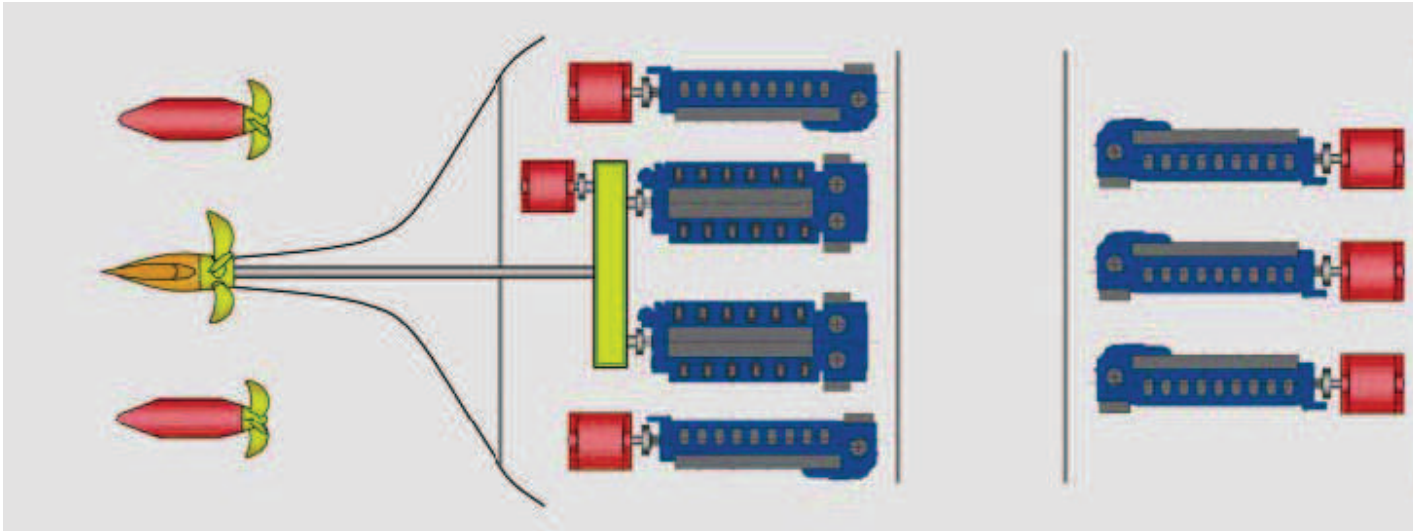
**At high speeds the ship is steered with the efficiency rudder and the pods are locked in their position. Speed loss in rough seas is therefore reduced. The rudder is not a must, but the Lips Efficiency Rudder offers other benefits as well. The improved wake field, for example, results in lower pressure impulses, which is a big benefit in a cruise ship where low noise is important. The Efficiency Rudder also improves propulsion efficiency and the rudder area can be kept small to keep resistance low. This still creates enough steering power since the rudder is only used at high speeds.**

# Impianti di propulsione navale



**Hybrid propulsion in high-speed mode (left) and in low-speed mode (right) with centre propeller feathered.**

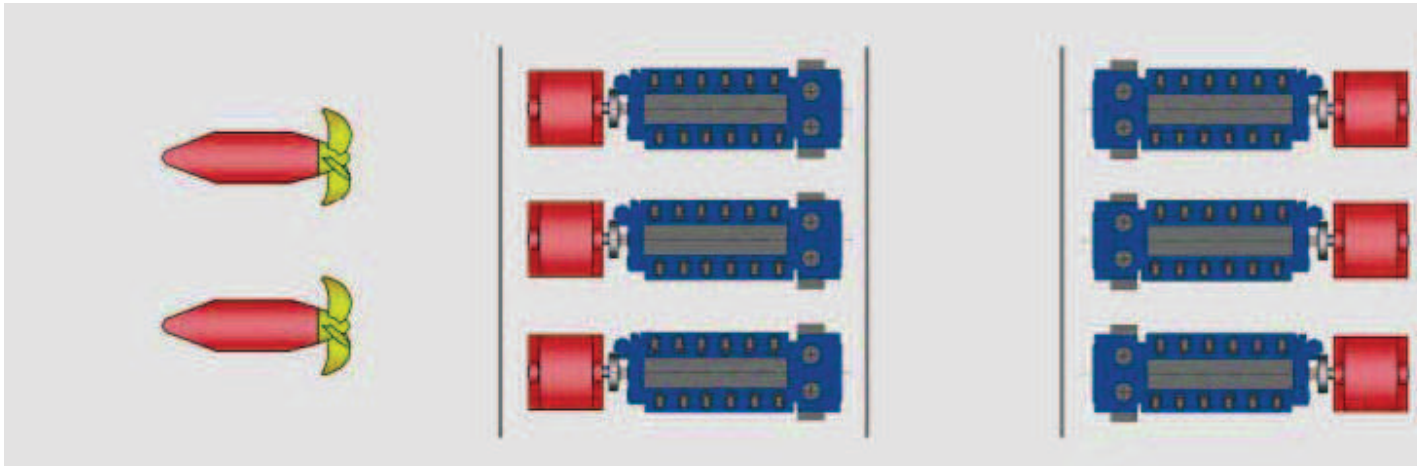
# Impianti di propulsione navale



**The selected machinery with two Wärtsilä 12V46 engines and five Wärtsilä 9L46 generator sets with a total power of 72 MW.**

**A power take-in is applied to meet the redundancy target (service speed maintained in case any one engine is out of operation).**

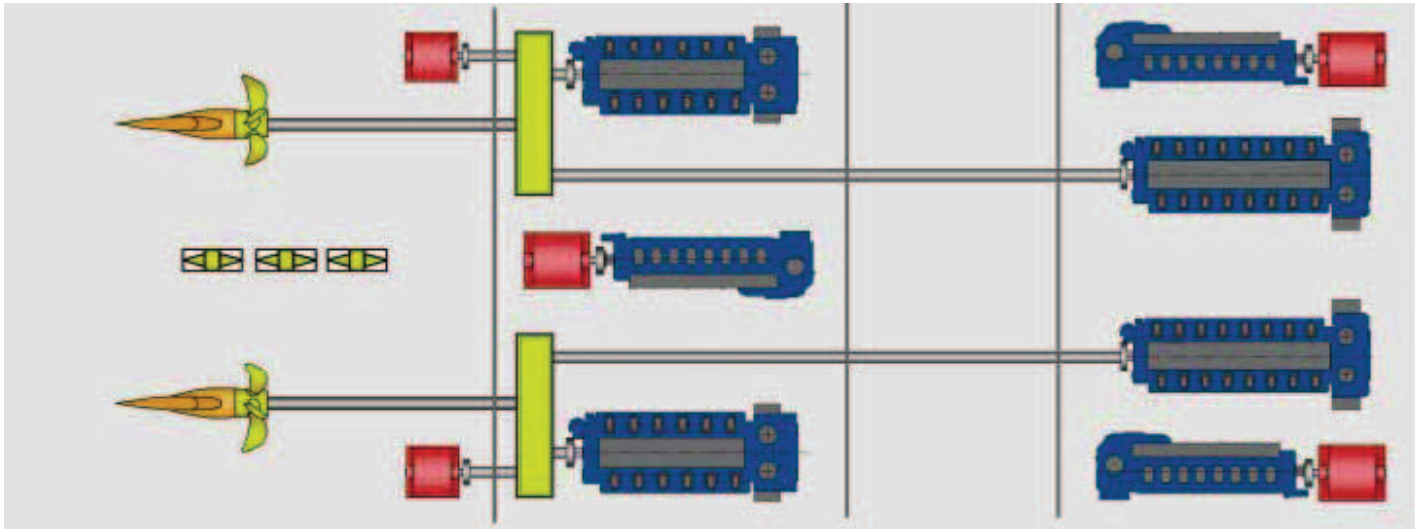
# Impianti di propulsione navale



**Diesel-electric machinery**



# Impianti di propulsione navale



**Diesel-mechanical machinery**

# Impianti di propulsione navale

## Main Dimensions

Gross tonnage	90,000	GT
Length, oa	294	m
Length, dwl	280	m
Beam, hull	32,2	m
Depth, bulkhead deck	10,6	m
Draught, dwl	8,0	m
Passengers	2700	persons
Passengers cabins	1050	pcs
Crew	900	pcs
Crew cabins	500	pcs
DWT	7000	ton

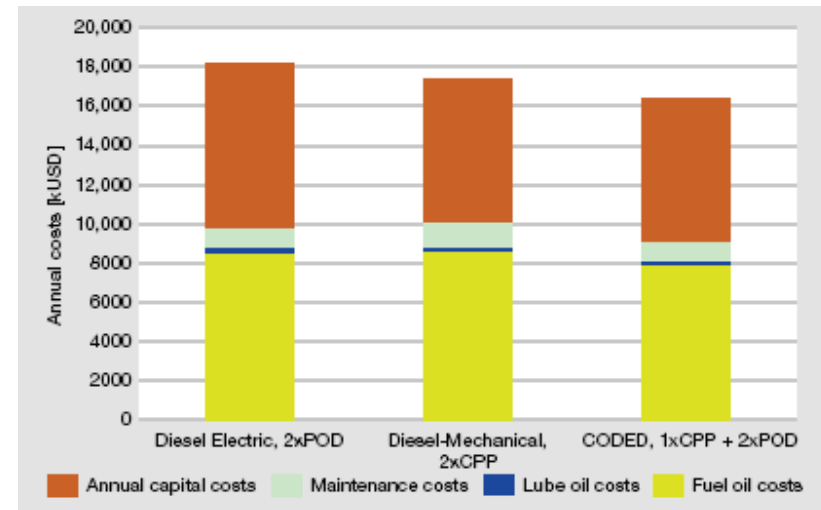
## Main characteristics of the 90,000 GT Panamax cruise ship

### Machinery-related costs

Capital cost at 8% annual interest and amortization over eight years.  
The HFO price is assumed to be 150 USD/ton.

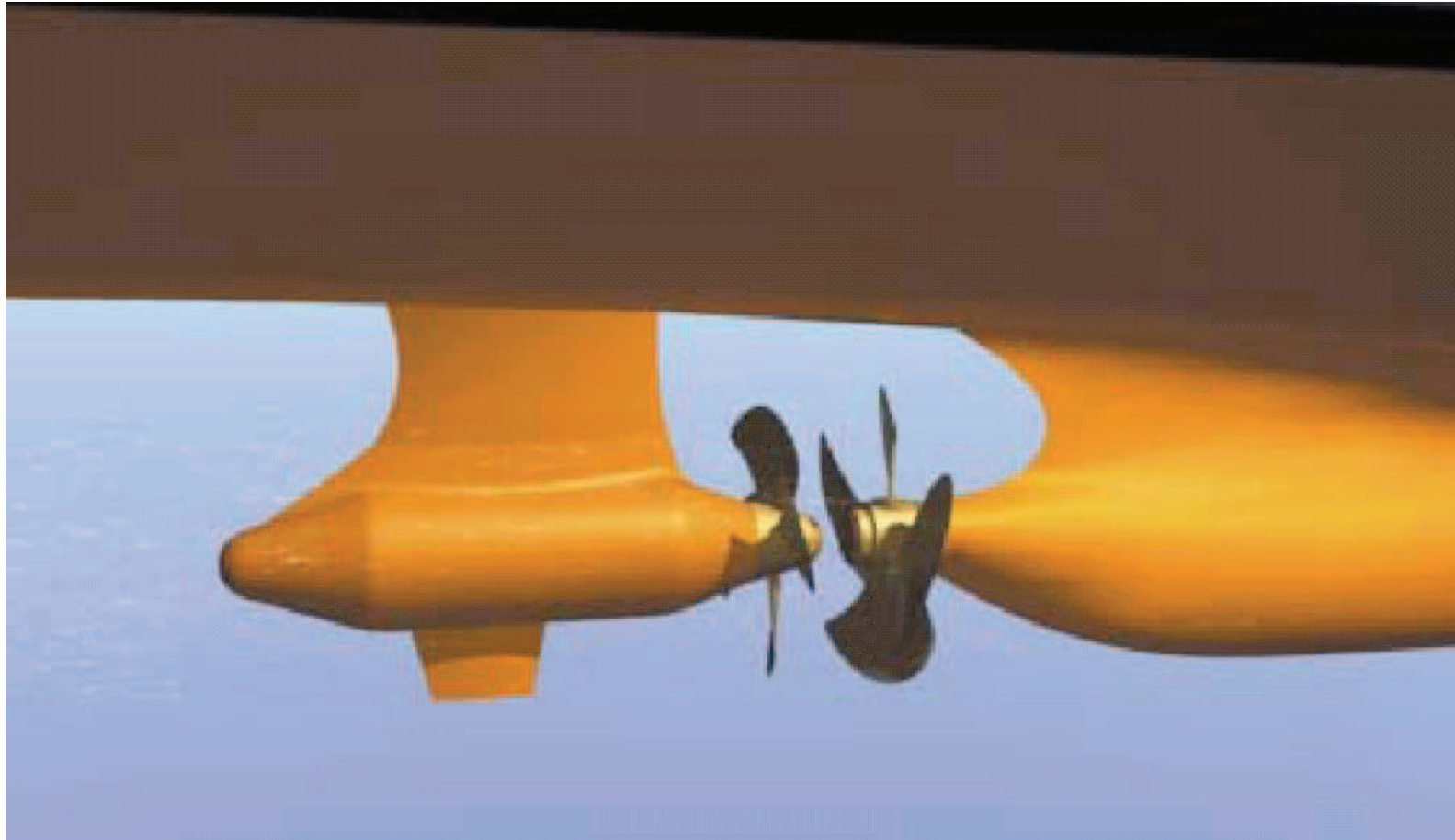
Data: 15/03/2007

Machinery power		Diesel-electric	Diesel-mechanical	CODED
<b>Installed engine power</b>				
Mechanical propulsion engines	kW	–	2 x 12,600 2 x 16,800	2 x 12,600
Generating set power	kW	6 x 12,600	3 x 8400	5 x 9450
Total generating set power	kW	75,600	25,200	47,250
Total installed engine power	kW	75,600	84,000	72,450
<b>Propulsion power</b>				
Pod power	kW	2 x 22,500	–	2 x 12,000
Mechanical propulsion power	kW	–	2 x 29,400	1 x 25,200
Total propulsion power	kW	45,000	58,800	49,200
Available propulsion power with 15% engine margin	kW	45,000	48,500	44,800
<b>Thruster power</b>				
Bow thrusters	kW	3 x 2000	3 x 2000	3 x 2000
Stem thruster	kW	–	3 x 2000	–



# Impianti di propulsione navale

## Latest Developments in Azipod Technology



# Impianti di propulsione navale

**Wärtsilä has been studying alternative new machinery solutions for fast RoPax vessels under the joint Finnish shipbuilding research projects SeaTech 2000+ and EMPRO.**

**One of the most promising concepts is a hybrid machinery, where mechanical propulsion is combined with an electrically powered contra-rotating propeller (CRP). This machinery solution is well suited to a vast range of large ferries and RoRo vessels with high power demands.**

**A new RoPax vessel has been designed with Kvaerner Masa-Yards Technology to illustrate the new concept.**

**The new Wärtsilä RoPax concept is intended for fast cargo and passenger transports and it utilises the new combined diesel-electric and diesel-mechanical (CODED) machinery concept. The ship is fairly large compared to other high-speed ships, having a gross tonnage of about 37,000 GT, and it is be able to maintain a service speed of 30 knots.**

**It features a full-displacement hull type with a very long and slender form to minimise resistance. The ship can either be outfitted with 300 cabins for overnight trips or alternatively with only day passenger facilities for shorter routes. The main characteristics of the vessel are given in Table 1.**

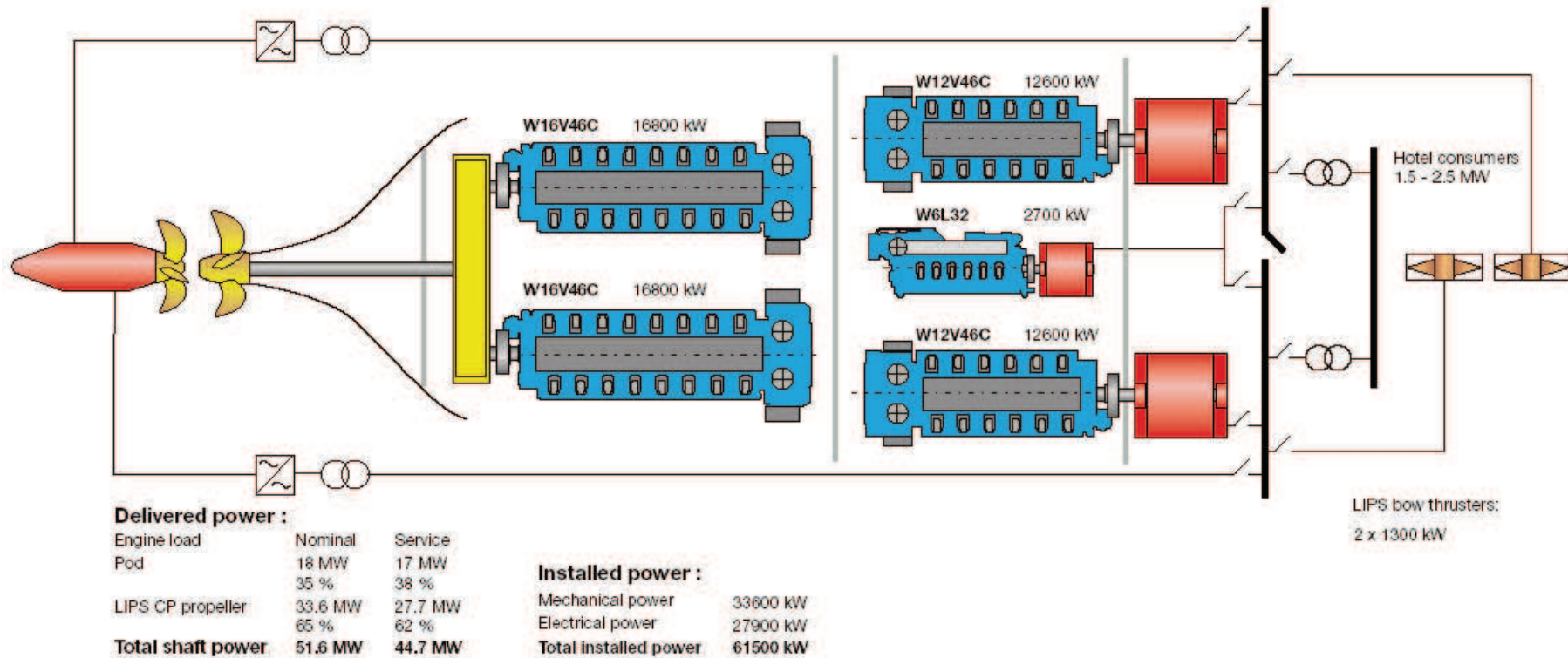
# Impianti di propulsione navale

Gross tonnage	37,000	GT
Length	220.0	m
Breadth, max	30.0	m
Draught, design	6.5	m
Cargo	1500	lane meters for trailers
	350	cars
Passengers	2000	persons, short-route version
	900	persons, overnight version
Cabins	300	pcs, overnight version
Speed, service	30	knots (85 % MCR)

*Table 1 Main dimensions and properties.*



# Impianti di propulsione navale



# Impianti di propulsione navale

## Machinery and propulsion

The RoPax vessel has a CODED machinery solution featuring a diesel-mechanical part driving a conventional propeller and a diesel-electric power plant powering both an electric pod and the hotel load.

This machinery has the latest in environmentally friendly technology, such as EnviroEngines equipped with common rail and Compact SCR units. The ship has two large Wärtsilä 16V46 engines for the mechanical propulsion, two Wärtsilä 12V46 engines driving one generator each, and one small Wärtsilä 6L32 generating set. The total installed power is 61.5 MW. All engines run on HFO to offer low fuel costs.

The RoPax vessel benefits from a novel propulsion solution with a contra-rotating fixed pitch propeller (FPP) mounted on an electrical pod located directly behind a conventional controllable pitch propeller (CPP) mounted on the centreline skeg. This configuration offers better hydrodynamical efficiency, compared to a conventional vessel with twin screws on long open shafts supported by brackets, for the following reasons:

- The aft propeller takes advantage of the rotative energy left in the slipstream of the forward propeller when it turns in the opposite direction. This improves the rotative efficiency of the propulsion.

# Impianti di propulsione navale

- **The single skeg hull form offers a more favourable wake than an open shaft line, resulting in better hull efficiency.**
- **The resistance of the single skeg hull form with a single pod is lower than that of a twin-screw hull with two open shaft lines, two rudders and many appendages.**

**The new concept reduces the total delivered power ( $P_d$ ) demand at the propeller by more than 10 % compared to a conventional solution.**

**However, the delivered power is not the whole truth; it is the brake power demand at the diesel engine that determines the fuel consumption. The transmission efficiency must therefore also be taken into account. The losses associated with electrical propulsion are about 8 %, compared to about 3 % for mechanical propulsion.**

**When optimising the machinery configuration for overall economical performance, the investment cost must be included as well. The best hydrodynamical efficiency is theoretically achieved with a power split of 50/50 between the pod and the mechanical propeller. However, the higher transmission losses and much higher capital cost of the electrical propulsion part means that more power should be on the mechanical propeller for the best economical performance. The pod power should not be too low though, because then the full benefits of the CRP concept will not be achieved.**

# Impianti di propulsione navale

**The power of the pod is under 40 % of the total propulsion power in service conditions for the proposed RoPax vessel. Since most of the power, more than 60 %, is on the mechanical propeller, the transmission losses and the capital costs are lower than in the case of a fully electrical propulsion system and only slightly higher than for a diesel-mechanical arrangement.**

**However, due to its low fuel costs, the proposed machinery offers the lowest total annual costs for the intended service. Moreover the total installed power can be much lower.**

**Although only part of the power is electrical the proposed CODED machinery still offers most of the benefits of a fully electrical power plant. Both the pod and the entire hotel load are supplied by the same power plant. The electrical capacity is designed to cover the load at full speed at sea. Since full pod power is not needed while manoeuvring, no extra generator capacity needs to be installed for the bow thrusters.**

**The large diesel generators with low fuel consumption supply most of the electrical power. The small genset is intended for use in port when the only electrical load consists of a 1.5-2.5 MW hotel load. This would give a very low engine load, if one of the large Wärtsilä 46 engines was used. Low engine load is not recommended for long periods of time. The 6L32 engine can also be used at full speed and to reduce the load jump between the large engines at part load.**

**The pod is used for steering the vessel and can be turned 360° when manoeuvring.**

# Impianti di propulsione navale

**This means that the manoeuvring characteristics of the vessel are excellent, which is important for short turnaround time in port. No separate stern thrusters are needed, which avoids extra resistance and costs.**

**The proposed machinery arrangement also offers a certain degree of redundancy since the machinery is divided into two separate compartments. If the mechanical engines are damaged, then the diesel-electric power plant and the pod will provide the hotel and propulsion power needed to operate the ship. On the other hand, if the electric power plant is damaged, then the ship can be propelled back to port with the mechanical engines. The emergency generator can be used to steer the vessel by turning the pod, which can function as a rudder also without any power on the propeller.**

# Impianti di propulsione navale

## Avarie dei propulsori POD

**I POD di propulsione non sono di per sè un prodotto completamente innovativo: di fatto essi sono il frutto di una combinazione di sistemi e tecnologie già presenti in campo navale (essenzialmente motori elettrici di propulsione alimentati da convertitori di frequenza e propulsori azimutali).**

**Nonostante ciò, essi hanno subito, specie nei primi tempi della loro entrata in servizio, alcune avarie che hanno interessato :**

- **l'impianto elettrico;**
- **i cuscinetti di supporto e reggispinta;**
- **le tenute dell'albero portaelica;**
- **la contaminazione dell'olio lubrificante con acqua e particolato.**

**Le avarie di tipo elettrico sono state causate da elevate temperature o surriscaldamenti locali degli avvolgimenti, dovute perlopiù a dimensionamento inadeguato degli avvolgimenti stessi e deficienze del sistema di raffreddamento.**

**In alcuni casi si sono avuti problemi di corrosione dei cuscinetti dovuti a correnti disperse lungo l'albero portaelica.**

**Le avarie ai cuscinetti sono state causate da carenze di progettazione relative alla disposizione, al tipo e alla taglia dei cuscinetti impiegati.**



# Impianti di propulsione navale

**Non si è tenuto nel debito conto che, rispetto ai cuscinetti a strisciamento, i cuscinetti volventi risentono in misura maggiore l'azione di carichi anomali, di vibrazioni e di contaminazioni dell'olio lubrificante.**

**In particolare, sono stati trascurati gli effetti di fattori quali:**

- **i carichi sui cuscinetti originati dai fenomeni di precessione che insorgono durante la rotazione del POD;**
- **i carichi assiali sui cuscinetti originati dall'allungamento differenziale dell'albero portaelica dovuto ai gradienti termici;**
- **la contaminazione dell'olio lubrificante dei cuscinetti con acqua e particolato. L'acqua può provenire dalle tenute o dall'umidità presente nell'aria di raffreddamento. In ogni caso si rende necessario migliorare il sistema di trattamento del lubrificante, depurandolo dall'acqua mediante filtri coalescenti o separatori e adottando filtri autopulitori con maglie di dimensioni adeguate per la filtrazione delle particelle estranee.**

**Le tenute dell'albero portaelica del POD, per quanto non differiscano dalle normali tenute degli alberi convenzionali, risultano più critiche per le difficoltà di accesso e manutenzione e per il fatto che un loro cedimento determina rischi di avarie per i componenti elettrici e i cuscinetti volventi situati nelle loro vicinanze. Nel confronto di tali rischi, si sono rivelate efficaci le tenute gonfiabili di emergenza.**

# Impianti di propulsione navale

**Molte delle difficoltà riscontrate nell'esercizio derivano proprio dalle difficili condizioni di accessibilità dei componenti installati all'interno del POD. Non essendo progettati per essere ispezionabili durante la navigazione, i POD possono essere controllati dal personale di macchina solo durante le soste.**

**Molte operazioni di manutenzione richiedono lo sfilamento dell'albero portaelica, operazione che può essere effettuata solo con la nave in bacino e che richiede l'impiego di attrezzature speciali e personale del costruttore dell'impianto.**

**Il superamento dei problemi di esercizio dei POD potrà avvenire solo quando il grado di affidabilità dei suoi componenti risulterà decisamente migliore dell'attuale. A tal proposito si riporta nel seguito l'opinione di un Registro di Classifica (Lloyd's Register).**

# Impianti di propulsione navale

## Comportamento a velocità costante: cavitazione e pressioni indotte sullo scafo.

- i rilievi sperimentali indicano che i propulsori POD presentano caratteristiche di cavitazione superiori rispetto ai propulsori convenzionali;
- gli impulsi di pressione dovuti alla rotazione delle pale dell'elica, la cavitazione e le forze integrate sullo scafo sono inferiori;
- è lecito attendersi che, a causa della minore cavitazione, l'erosione delle pale dell'elica sia inferiore.

## Comportamento a velocità costante: carichi dinamici.

- a velocità costante, i carichi dinamici dell'elica sono inferiori rispetto ai propulsori convenzionali a causa della maggiore uniformità del campo di scia;
- ciò implica minori sollecitazioni a fatica del corpo poppiero, dell'elica, dell'albero dell'elica e del macchinario propulsivo;
- tuttavia, in condizioni di manovra, tale situazione cambia significativamente.

# Impianti di propulsione navale

## Comportamento in manovra: prestazioni.

- **è ampiamente provato che le navi con POD posseggono capacità di manovra superiori rispetto alle navi convenzionali;**
- **tali capacità sono dovute al fatto che i POD generano le forze e i momenti necessari alla manovra in misura più elevata rispetto alla combinazione convenzionale di elica e timone;**
- **la stabilità di rotta può soffrire qualora il progetto del corpo poppiero e dello skeg sia ottimizzato esclusivamente al fine di ridurre la resistenza nave e migliorare il campo di scia attorno al POD.**

## Comportamento in manovra: carichi di fatica.

- **i carichi sul POD, sia statici che dinamici, cambiano notevolmente con l'angolo di barra. La possibilità di cavitazione aumenta assieme ai corrispondenti carichi dinamici;**

# Impianti di propulsione navale

## Comportamento in manovra: carichi di fatica.

- **i cambiamenti dei carichi sul POD determinano direttamente cambiamenti simili dei carichi sulla struttura e sul macchinario;**
- **per una nave il cui profilo di utilizzo comporta molte manovre, ciò implica carichi di fatica relativamente elevati su tutti i componenti del POD.**

## Regolamenti e standards: perdita del sistema di governo.

- **i propulsori POD sono in grado di esercitare un rilevante momento di “steering” ad angoli di barra diversi da zero;**
- **in caso di perdita del sistema di governo, il POD si stabilizzerà ad un angolo diverso da zero determinando sul sistema un rilevante momento torcente, dipendente dal progetto;**
- **pertanto, la perdita dell’azione di governo è un problema di sicurezza notevole per una nave con POD. Tuttavia, gli attuali requisiti dei registri tengono in sufficiente conto la necessità di ridondanza del sistema di governo.**

# Impianti di propulsione navale

## Osservazioni conclusive.

- **le navi con POD sono dotate di prestazioni in manovra superiori, cosa che contribuisce ad operazioni più sicure in porto, in acque ristrette e in emergenza;**
- **i propulsori POD e i loro sistemi di governo debbono essere più robusti rispetto a quelli convenzionali a causa delle forze e dei momenti significativamente più elevati che si sviluppano al variare dell'angolo di barra;**
- **la relativa inaccessibilità dei macchinari del POD richiede che il sistema sia più affidabile. Senza significativi miglioramenti nell'affidabilità del sistema, i benefici economici dei POD saranno eliminati dalla loro indisponibilità operativa;**
- **il POD ed il corpo poppiero devono essere progettati in modo integrato ed ottimizzato: solo così possono essere realizzati miglioramenti significativi;**
- **Il progetto del corpo poppiero deve essere migliorato dal punto di vista della stabilità di rotta;**



# Impianti di propulsione navale

## Osservazioni conclusive.

- **i problemi incontrati dal macchinario propulsivo e dagli alberi portaelica dei POD indicano che la conoscenza delle effettive condizioni di carico dei macchinari è ancora carente;**
- **l'applicazione dei requisiti e degli standard di sicurezza nelle fasi di progettazione e realizzazione è un elemento importante per assicurare buone caratteristiche "RAM" (affidabilità, disponibilità, manutenibilità) ai propulsori POD;**
- **l'importanza dell'elemento umano nel raggiungimento delle condizioni di sicurezza ed economicità è ancor più rilevante nelle navi con POD.**

# Impianti di propulsione navale

**The Azipod propulsion system combines the advantages of various conventional propulsion systems available today:**

- **Excellent dynamic performance and manoeuvring characteristics, ideal even in harsh arctic and offshore environments.**
- **Eliminates the need for long shaft lines, rudders, transverse stern thrusters, CP propellers and reduction gears.**
- **Allows more simple ship hull design.**
- **Combined with the power plant principle, it offers not only new dimensions to the design of machinery and cargo spaces, but also reduced levels of noise and vibration, less downtime, as well as increase safety and redundancy.**
- **Operational flexibility leads to lower fuel consumption, reduced maintenance costs, less exhaust emissions and increased redundancy with less installed power.**

# Impianti di propulsione navale

- **Less engine cylinders to maintain according to less installed power.**
- **The Azipod unit itself has a flexible design. It can be built for pushing or pulling, open water or ice conditions. The Azipod can be equipped with skewed propellers, with or without a nozzle.**
- **Excellent wake field due to improved hydrodynamics.**

# Impianti di propulsione navale

## **Azipod Propulsion**

**Azipod (Azimuthing Podded Drive) is a podded electric propulsion system. Pod unit is azimuthing (rotating round vertical axis) through 360 and it is available for powers up to 30 MW.**

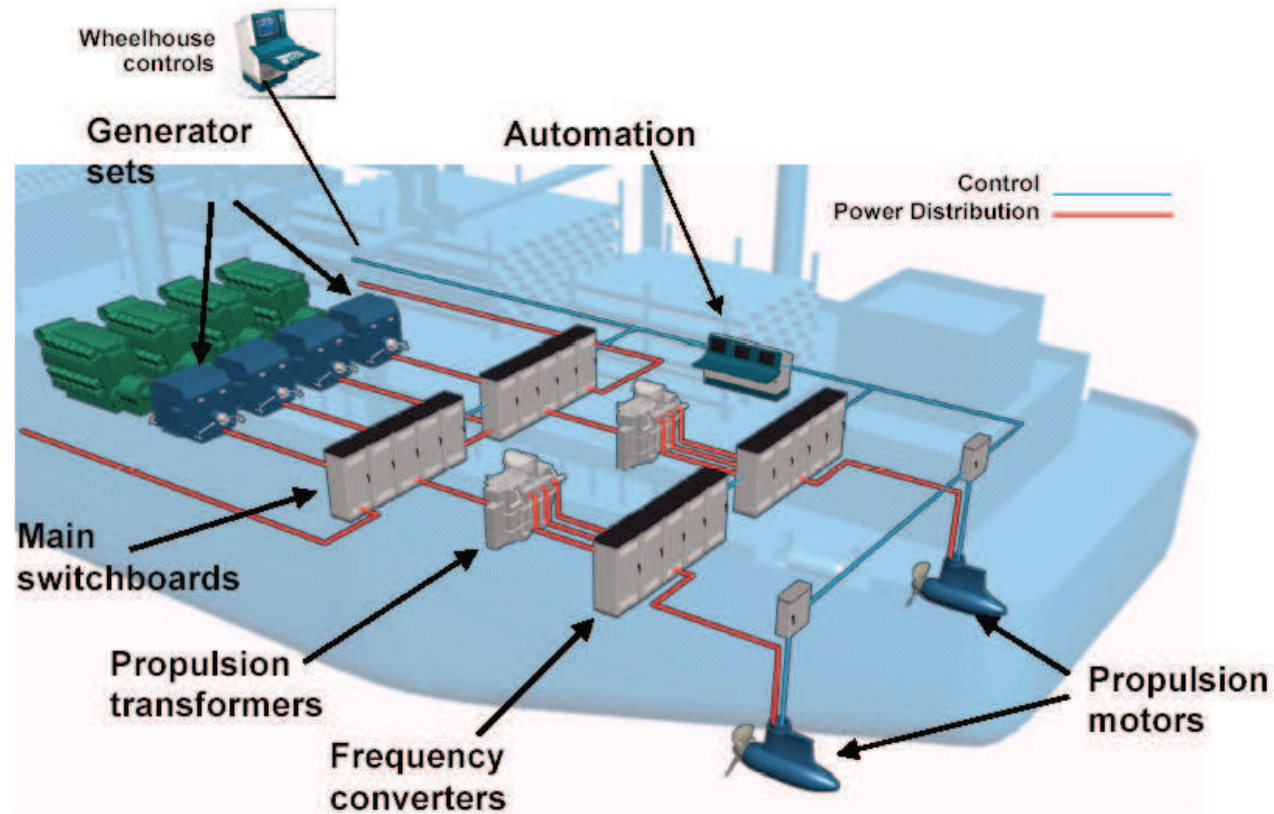
**Azipod propulsion system consists of Azipod propulsion unit, ACS Series Marine Drive, propulsion transformers if needed, control system and power plant (generators, switchboards etc.).**

**Propulsion motor can be asynchronous or synchronous type depending on the application.**

**Podded propulsion motor drives a fixed pitch propeller directly and is able to reach full torque to both directions also at slow speed. Over torque can also be utilized e.g. in icegoing vessels.**

**Steerable Azipod propulsor gives an excellent manoeuvring ability due to optimal thrust to any direction and fast change of direction of rotation of the propeller.**

# Impianti di propulsione navale



Typical Azipod Propulsion System and Power Plant



# Impianti di propulsione navale

## Azipod Concepts

**Azipod propulsion units can be used in different vessel concepts. It is ideal for cruise vessels and meets requirements of any other ship types and gives several advantages on tankers, Ice-breakers, container ships and Ropax ferries.**

**Until now Azipod propulsion units have been installed in single, twin and triple podded solution. CRP Azipod propulsion concept is especially developed for Ro-Ro, Ropax and Cargo vessels.**

**Azipod propulsion units are also available for ice-going vessels and in solutions where the maximum bollard pull comes up to the most important feature, Azipods can be equipped with a nozzle as well.**

## Single and Twin Azipod Propulsion

**Single Azipod solution is mostly used in cargo vessels e.g. tankers. Twin Azipod solution is widely used in cruise ferries and is an excellent propulsion system when increased manoeuvrability and high redundancy is needed.**

# Impianti di propulsione navale

## **CRP Azipod Propulsion**

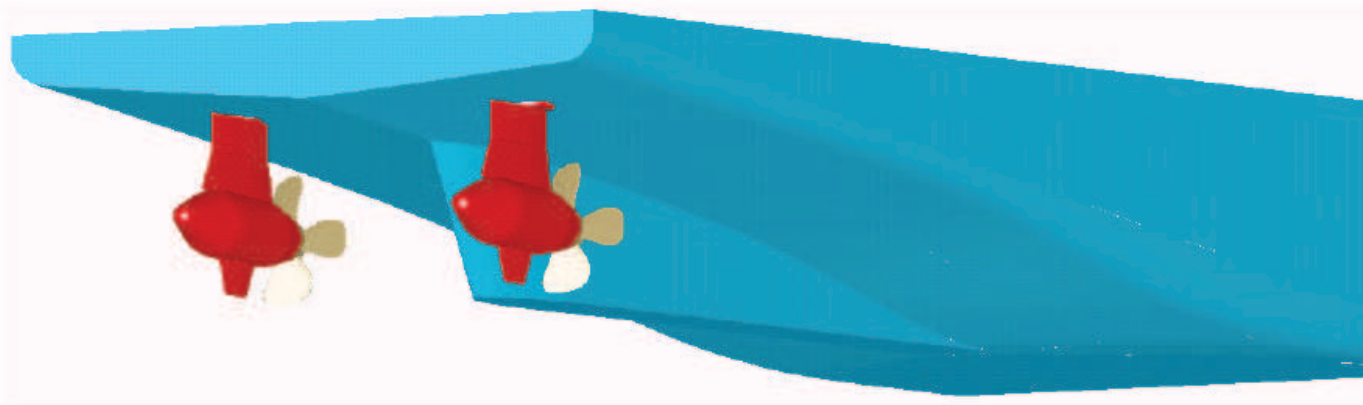
**CRP Azipod propulsion concept (CRP=Contra Rotating Propellers) is a competitive solution against conventional systems for high speed container and Ropax vessels. The concept has one conventional shaftline with fixed pitch or CP-propeller and behind that CRP Azipod acts as a rudder and contra rotating propeller. The concept offers an increased manoeuvrability and redundancy comparing to rigid shaftline vessels. CRP concept eliminates one shaftline and stern thrusters comparing to a twin shaftline vessel.**

**According to the model tests CRP concept has a very high hydrodynamical efficiency compared to the conventional mechanical shaftline vessel. By combining the hydrodynamical efficiency and the advantages of electrical power plant the total efficiency gain against the conventional mechanical shaftline is significant.**

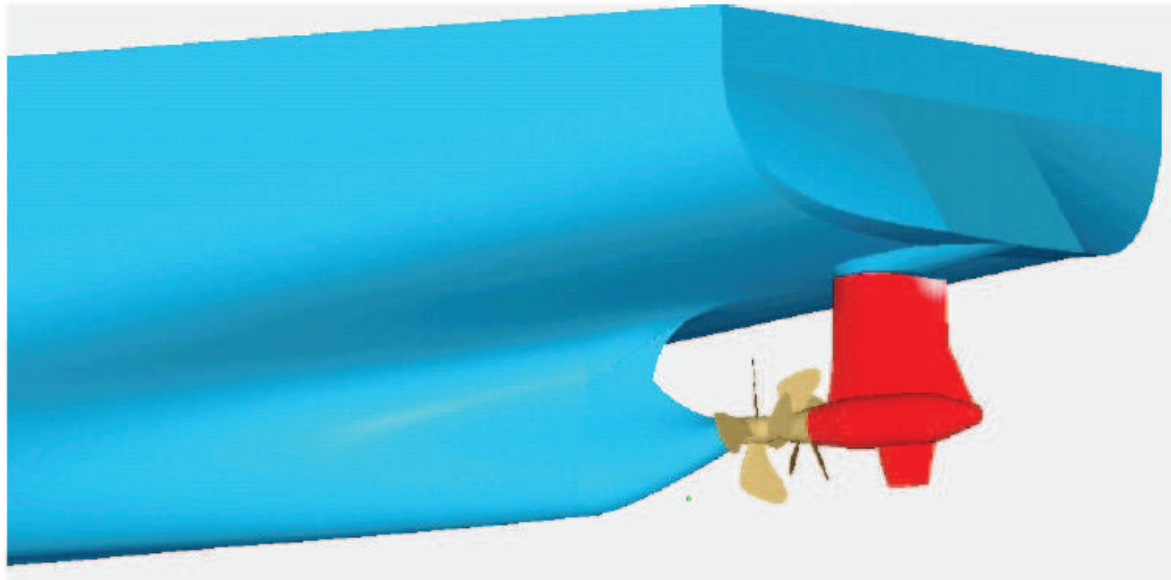
**The needed propulsion power is 10...15% less which means lower fuel consumption and less installed diesel engine cylinders to maintain. The more variable operation profile of the vessel, the bigger are the savings.**

**There is also a possibility to utilize saved space reached by CRP Azipod solution for another function.**

# Impianti di propulsione navale



**Twin Azipod  
propulsion**



**CRP Azipod  
propulsion**

# Impianti di propulsione navale

## **Compact Azipod propulsion**

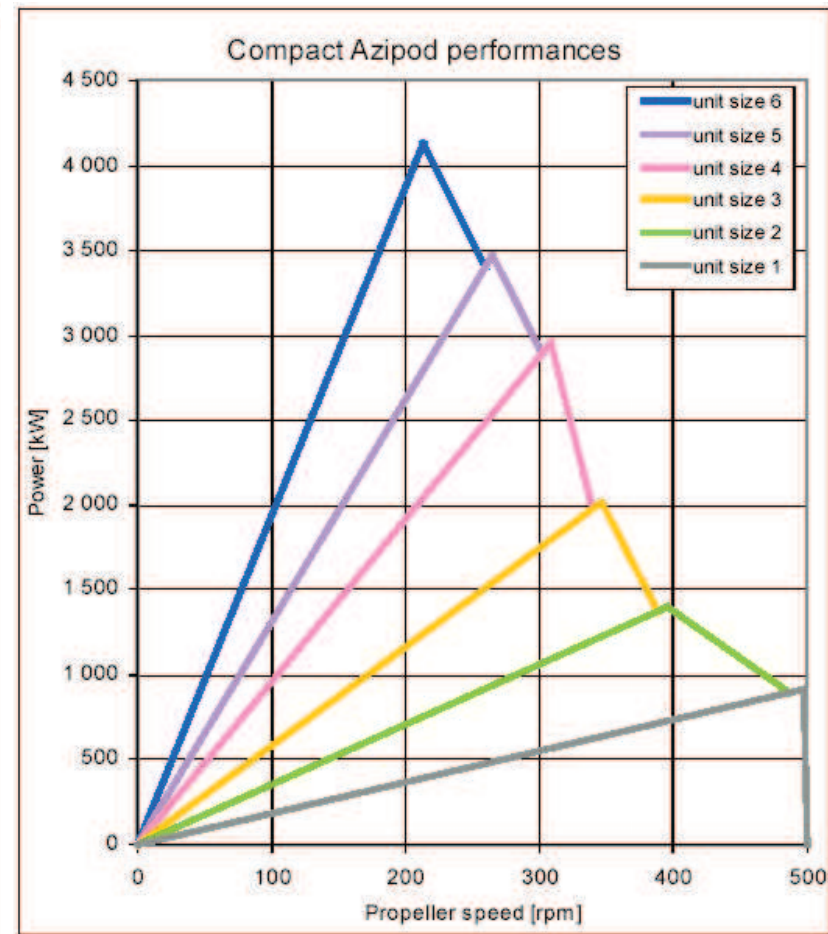
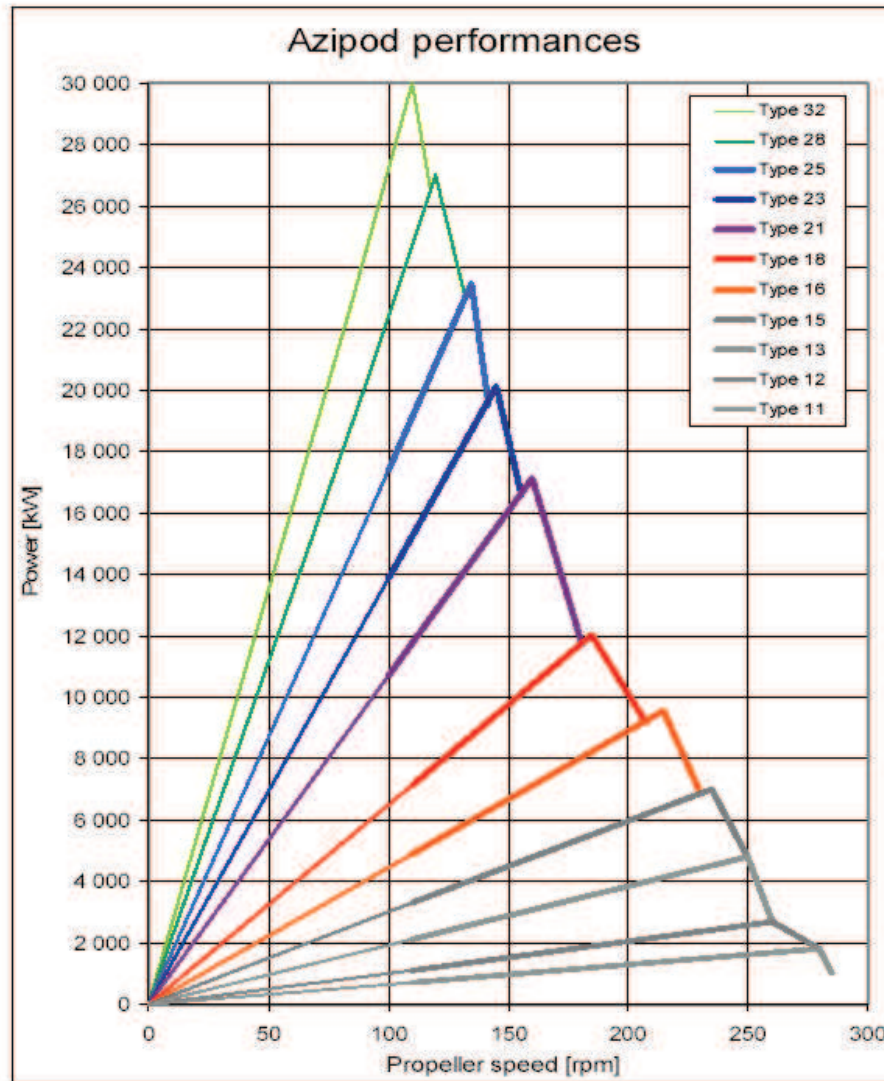
**Compact Azipod is an excellent propulsion system for many kind of vessels (e.g. cruise yachts, multi-purpose vessels and smaller cargo vessels) when power demand is 0,5...4 MW.**

**It has a simple modular construction which gives many benefits during building phase and maintenance of the vessel. Just-In-Time delivery and installation is ideal with Compact Azipod system.**

**Easy to install with space saving features and best available manoeuvring ability makes Compact Azipod as a competitive solution.**

**When high ice-class is needed, the Large Azipod is recommended instead of Compact Azipod.**

# Impianti di propulsione navale



Data: 15/03/2007



# Impianti di propulsione navale

## AZIPOD STRUCTURE

### Main units

Azipod propulsion consist of seven main units consisting of modules and system ancilliaries.

Each unit includes several modules.

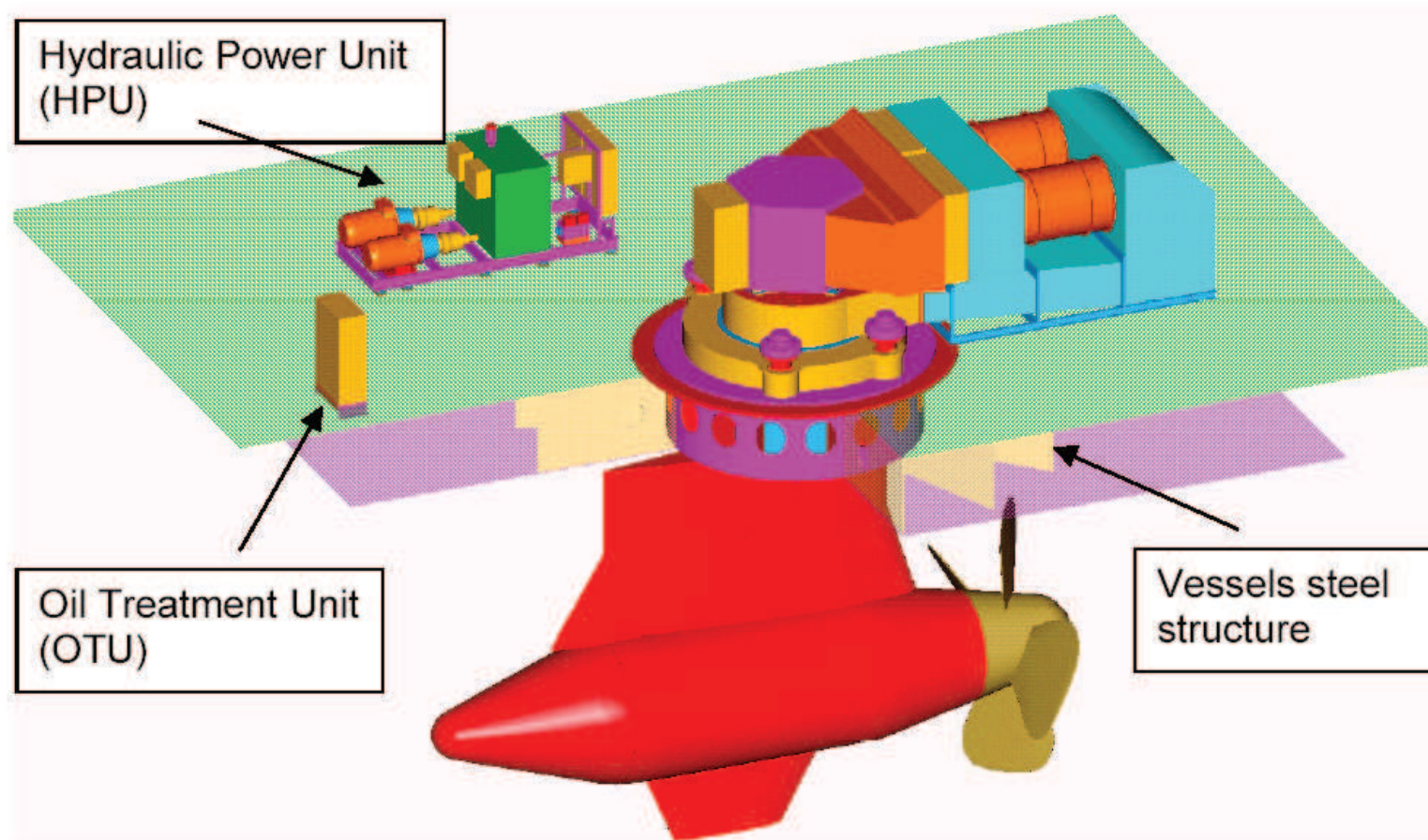
Units and associated modules are shown in the following table.

Azipod main Units and Modules							
UNITS							
	AZU	STU	TRU	CAU	HPU	OTU	AIU
	Azipod Unit	Steering Unit	Transfer Unit	Cooling Air Unit	Hydraulic Power Unit	Oil Treatment Unit	Information Unit
M	Pod Housing	Mounting Block	Frame	Frame	Frame	Frame	
O	Motor	Turning Shaft	Swivel	Fan	Tank	Filter	
D	Exciter	Slewing Bearing	Power Transfer	Heat Exchanger	Main Pump	Heat Exchanger	
U	Thrust Bearing	Turning Shaft Seal	Data Transmission	Filter	Flushing Pump		
L	Propeller Bearing	Steering Gear	Inner Foundation	Air Channel	Heat Exchanger		
E	Shaft	Steering Motor	Outer Foundation		Servo		
S	Shaft Seal		Connecting Duct		Valve Block		
	Propeller				Starter		
	Rope Cutter						

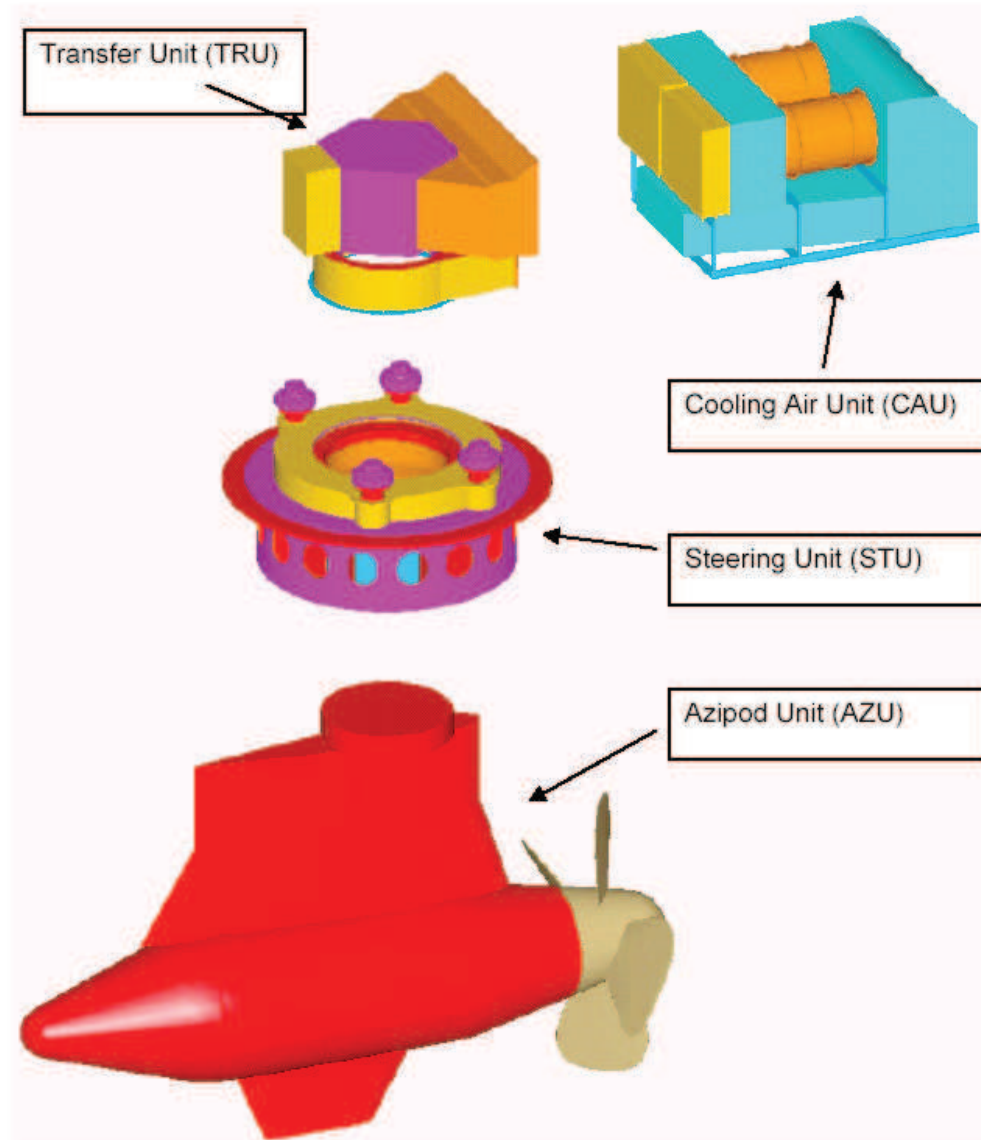
# Impianti di propulsione navale

MASSES FOR MAIN UNITS OF TYPICAL AZIPOD INSTALLATION								
Metric tons								
	tons	tons	tons	tons	tons	tons	tons	tons
<b>AZIPOD TYPE</b>	<b>COMPLETE ex. Propeller</b>	<b>AZU (Azipod Unit), Excluding propeller</b>	<b>STU (Steering Unit), incl. Mount. Block</b>	<b>TRU (Transfer Unit)</b>	<b>CAU (Cooling Air Unit)</b>	<b>HPU (Hydraulic Power Unit)</b>	<b>OTU (Oil Treatment Unit)</b>	<b>OTHER ANCILLIARIES</b>
11 ICE	28...53	5...22	12...18	2	3...4	3	1	2...3
12 ICE	35...73	7...34	15...25	2...3	4	3	1	3
13 ICE	40...115	8...66	17...31	4	4...5	3...4	1	3...4
15 ICE	90...145	50...80	21...46	5	5	4	1	4
16	115...165	61...85	36...58	5...6	5...6	4...5	1	4
18	145...205	78...115	44...67	6	7	5	1	4
21	165...245	90...135	50...82	7	8...9	5	1	4...6
23	210...290	115...180	67...102	7	9	5	1	6
25	275...380	155...200	88...145	9	11...12	5...6	1	6...7
28	355...475	210...255	110...185	10	12	6	1	6...7
32	465...655	270...360	155...250	10...15	15	7	1	7

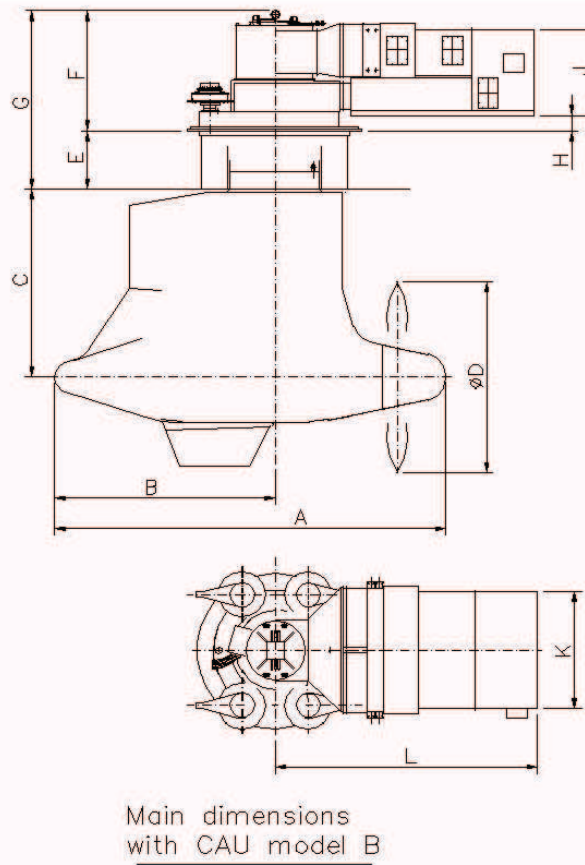
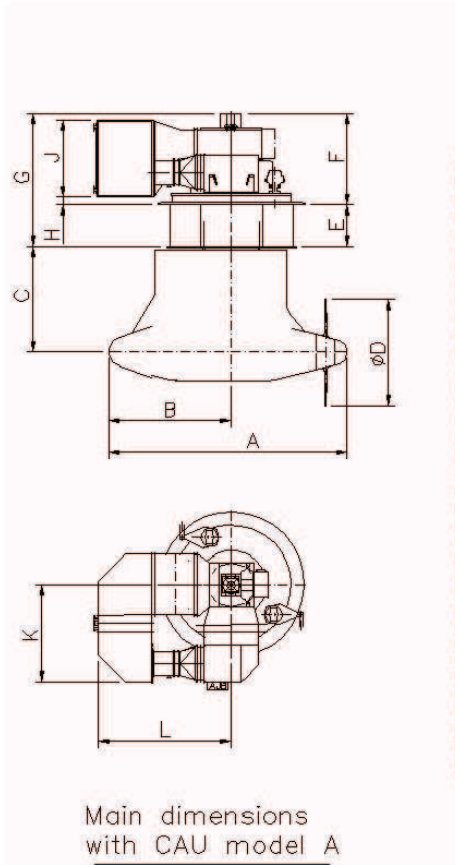
# Impianti di propulsione navale



# Impianti di propulsione navale



# Impianti di propulsione navale



TYPE	MAIN DIMENSIONS OF TYPICAL AZIPOD INSTALLATION												
	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]
11*	6200	3250	1800...2100	2000...2300	800	2050	2850	250	1800	2500	3500		
12*	6400	3350	2000...2350	2200...2600	1000	2200	3200	300	2300	2900	4000		
13*	7000	3600	2150...3000	2400...3300	1200	2200	3400	300	2300	2900	4000		
13	7000	3600	2150...3000	2400...3300	1200	2200	3400	350	1700	2350	4250		
15	8500	4900	2400...3450	2700...3800	1200	3100	4200	350	2500	2950	6200		
16	9000	5000	2600...3900	2900...4300	1450	3000	4450	350	2500	2950	6200		
18	9550	5250	2950...4350	3300...4800	1450	3000	4450	450	2500	2950	6200		
21	11750	6450	3400...5250	3800...5800	1750	3500	5250	450	2700	3450	7700		
23	13000	6900	3750...6800	4200...6400	1750	3550	6300	450	2700	3450	7700		
25	13000	6900	4100...6150	4600...6800	2000	4550	6550	550	3600	4450	8000		
28	14100	7600	4500...6750	5000...7500	2500	5050	7550	550	4000	6800	8000		
32	15200	8200	5850...7850	6500...8500	2800	5500	8300	650	4000	7500	9000		

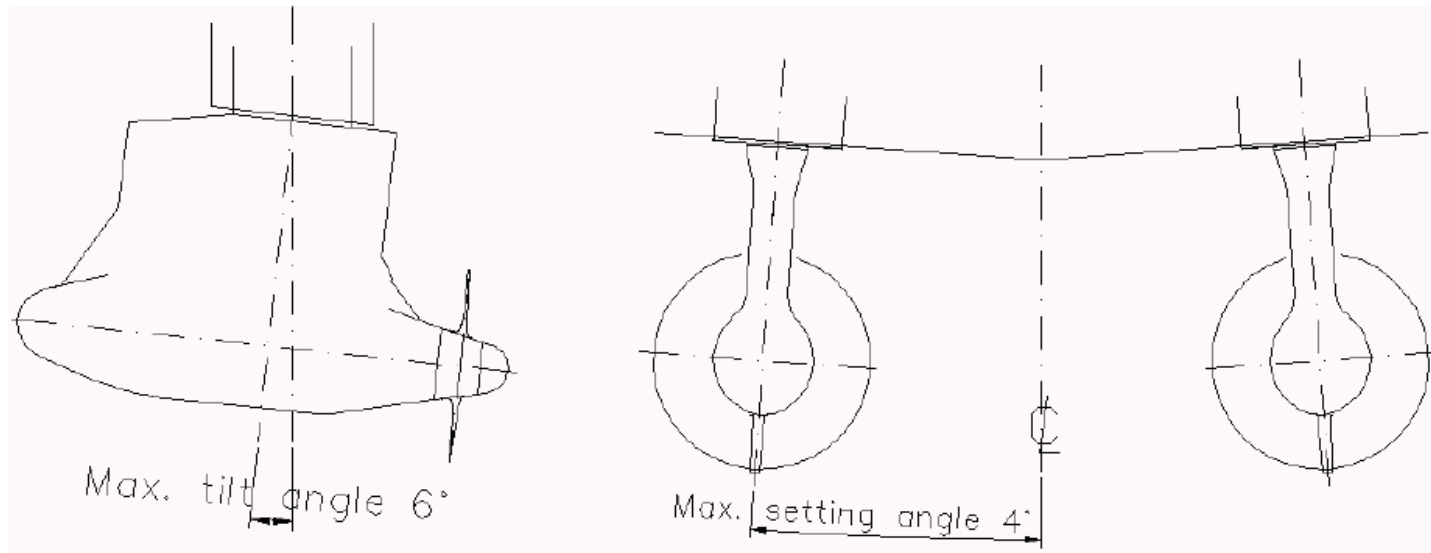
XX\* = CAU Model A

Dimension C depends on the vessels lines, dimensions, structure, propeller diameter, etc.



# Impianti di propulsione navale

## Azipod unit orientation



# Impianti di propulsione navale

## Hydrodynamics

**Azipod propulsion offers very good manoeuvring ability, but also much higher hydrodynamical efficiency than conventional propulsion systems. Depending on the solution typical Azipod system reaches 15 per cent hydrodynamical efficiency gain compared to conventional twin shaft solution and CRP Azipod up to 20 per cent respectively.**

## Azipod location on the vessel hull

**It is important to place the Azipod to the correct location on the vessels hull. Typically any part should not come out from the side or transom. According to experience in twin Azipod solution it is recommended to locate pods as far to astern and as close to sides as possible. Azipods have to be located so far from each others that sufficient clearance between Azipods is maintained at any steering angles (recommended 500 mm). For more accurate design, hull shape of the vessel and water flow must be considered.**

# Impianti di propulsione navale

## Propeller

**Azipod propellers are fixed pitch propellers because of the propeller speed and torque control by frequency converter. Typical installation of the Azipod has pulling type propeller with a monoblock or a built-on-blades propeller. Pushing type and propeller with nozzle are also available as an option. Nozzle is typically used when high bollard pull feature is needed. In ice-going vessels the propeller is typically stainless steel without nozzle and in open water versions bronze. To gain the optimal efficiency, the propeller is to be designed as tailor made.**

## Forces to vessel hull

**Forces from the propulsion unit must be transferred to vessel hull steel structure. During the design period ABB delivers the calculated forces and bending moments and the recommended principle drawing of pod mounting. Pod is to be connected to vessels hull with mounting block module (including to the Steering Unit STU).**

# Impianti di propulsione navale

## **Vibration and noise**

**Azipod system generates much less vibration and structure born noise than conventional propulsion systems. This is due to optimized speed of the propeller especially in slow speed and manoeuvring situations. Also the power plant concept and the absence of shaft lines gives more benefits respectively.**

## **Corrosion protection**

**Azipod corrosion protection is performed with galvanic zinc anodes. Material selection is based on both sea and fresh water environments.**

## **Azipod room**

**Units of Azipod system are easy to install appropriately just-in-time and location of main units gives extra freedom to design more efficient lay-out of the ship. It is recommended to reserve sufficient space for maintenance and overhaul for certain components and modules of the Azipod.**

# Impianti di propulsione navale

## SYSTEMS AND INTERFACES

### Transfer Unit (TRU)

**Transfer Unit consist of Slip Ring Module, Swivel Module and air channels and foundations.**

**Slip Ring Module includes also a steering angle indicator equipped with mechanical and electronic indication.**

### Slip Ring Module

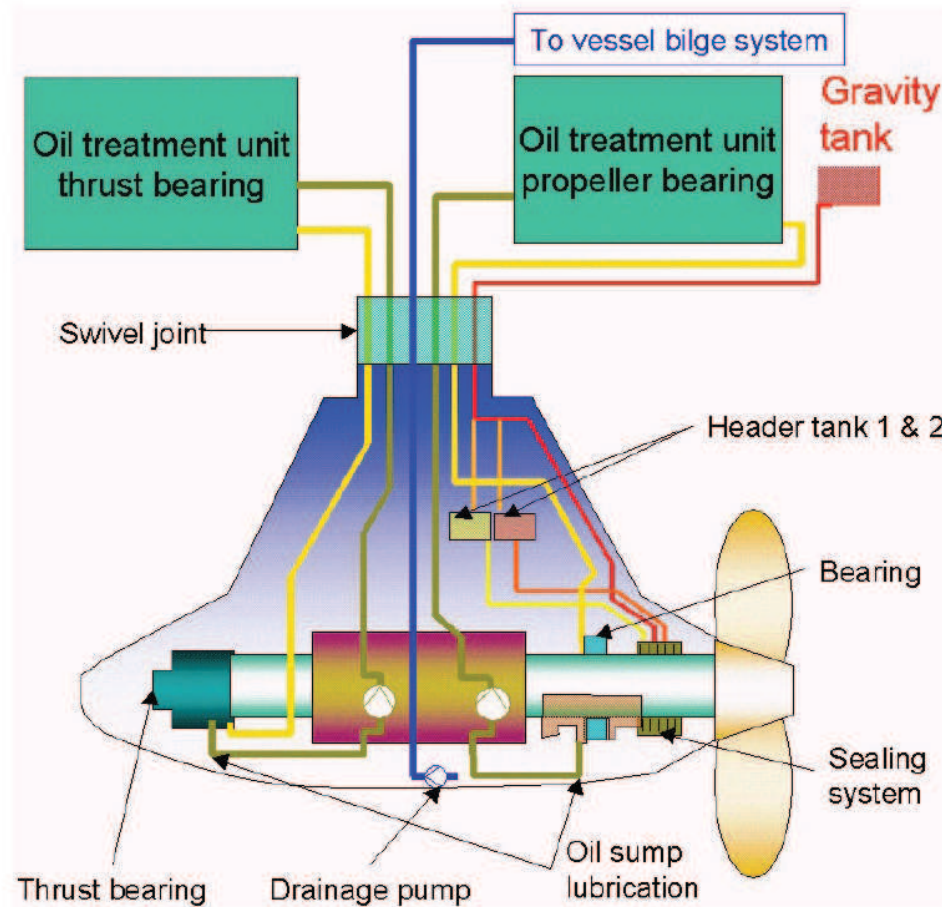
**Slip Ring Module consist of power slip rings for propulsion motor, excitation machine and ancillaries such as pumps located inside the Azipod. It includes also control data transmission sliprings.**

# Impianti di propulsione navale

- **The layout of the propeller shaft system features two end supports to the shaft line: a. Propeller bearing and b. Thrust bearing**
- **The thrust bearing unit is an integrated assembly located on the non-drive end of the Azipod (inside the pod cap).**
- **Ahead/Astern thrust forces (axial forces) generated by the propeller are received by the thrust bearing unit.**
- **Transverse forces (mass of the rotor and the shaftline, propeller side forces) are supported by the thrust bearing unit and the propeller bearing. Roller-type bearings are used. Roller-type bearings have small internal clearances, which is important for retaining the correct air gap for the motor and the operation of shaft seal.**
- **Due to their different configuration, the thrust and propeller bearings each have their own lubrication oil systems. The oil volumes are separated one from the other.**

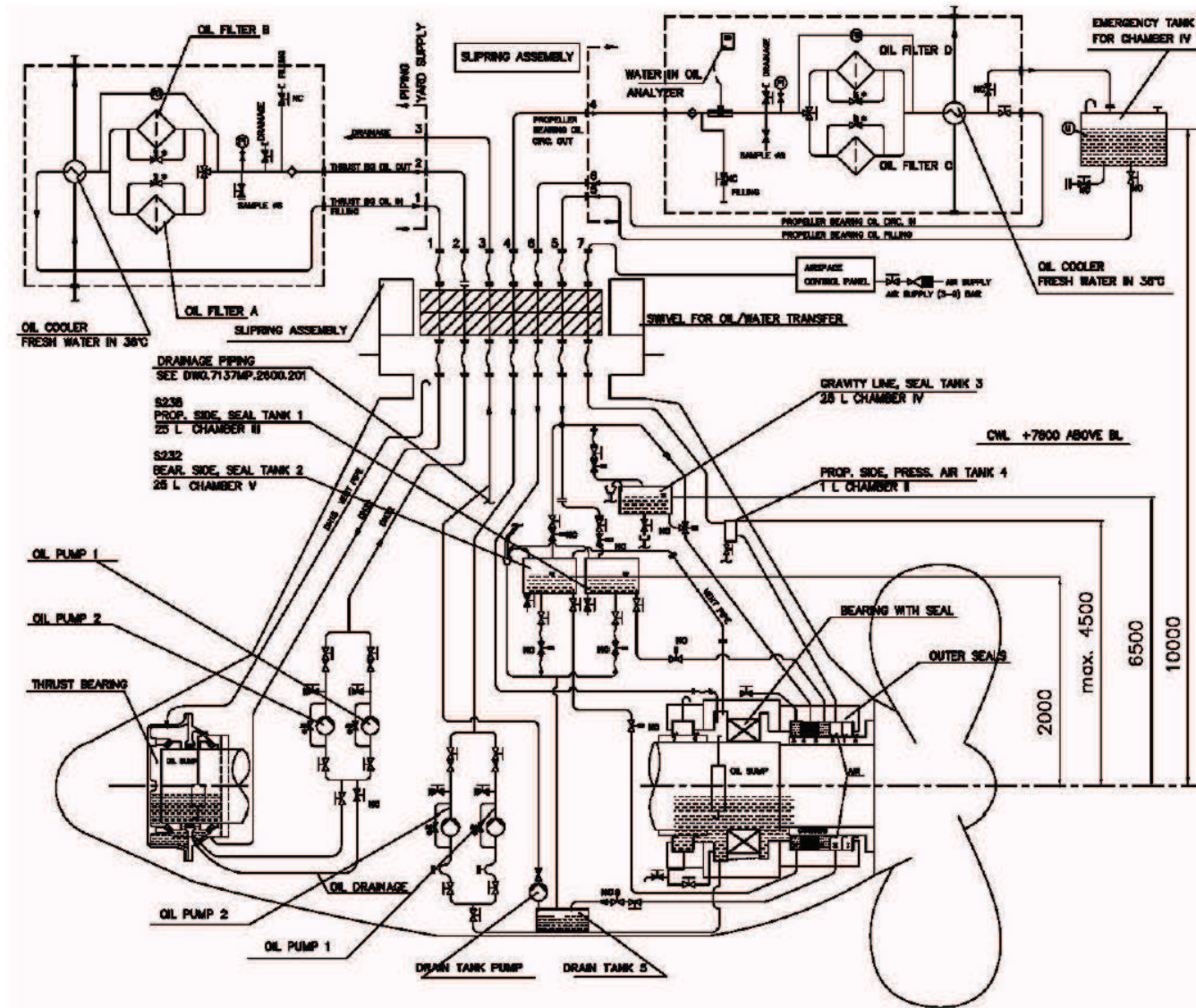


# Impianti di propulsione navale



# Impianti di propulsione navale

Shaft lube oil diagram



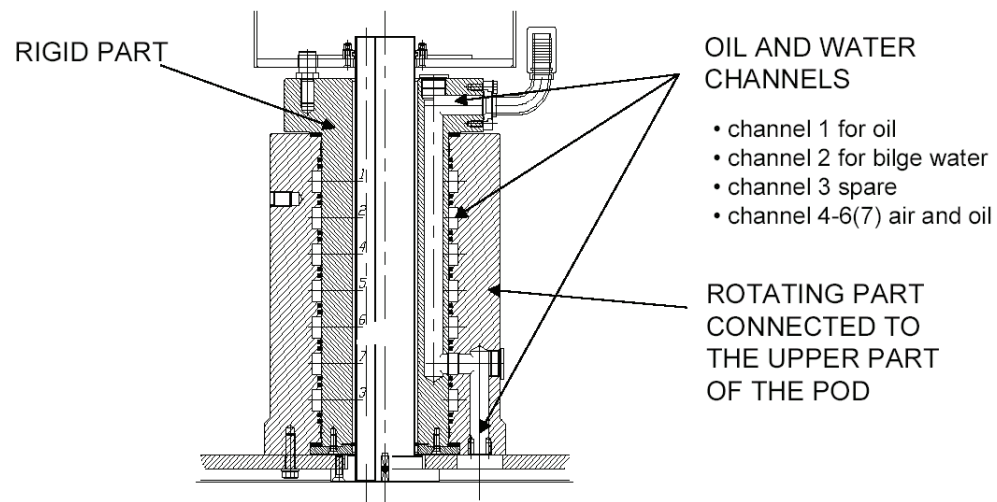
# Impianti di propulsione navale

## Swivel

**Swivel in Transfer Unit (TRU) is functioning as a rotary coupling for fluids between rigid part of TRU and rotating Azipod Unit. It serves systems to transfer various fluids from Azipod Unit to Azipod room and vice versa.**

**The swivel consist of rigid part connected to TRU and rotary part fixed to the Azipod upper part. Between those two blocks are the liquid channels with sliding seals. Pipes from Azipod room are to be connected to the top of rigid part by connection pipes including the TRU. From Azipod side the pipes are connected to the rotary block by hoses.**

## The Fluid Swivel



# Impianti di propulsione navale

## Cooling system

- **The cooling air system is used for Azipod propulsion motor cooling. It consists of closed air circulation through Azipod Unit and Cooling Air unit (CAU). Air to water heat exchangers are used to transfer heat energy to the cooling water system of the vessel.**
- **The CAU consists of following modules: Frame, Heat Exchanger Module, Fan Module, Channel Connecting Module with connecting flanges and flexible bellows. Model A is equipped with single fan-line or twin fan-line as one upon the other and model B with single fanline or twin fan-line as side by side. The unit is also equipped with instrumentation components such as humidity detector and position for smoke detector.**
- **The Filter Module is generally fitted into tailored air ducting.**
- **Fan line operation: according to redundancy requirements the CAU can be equipped with one or two fan lines. Each line consist of two fans in series. Normally only one fan line is on duty and dampers close the other one, if available.**

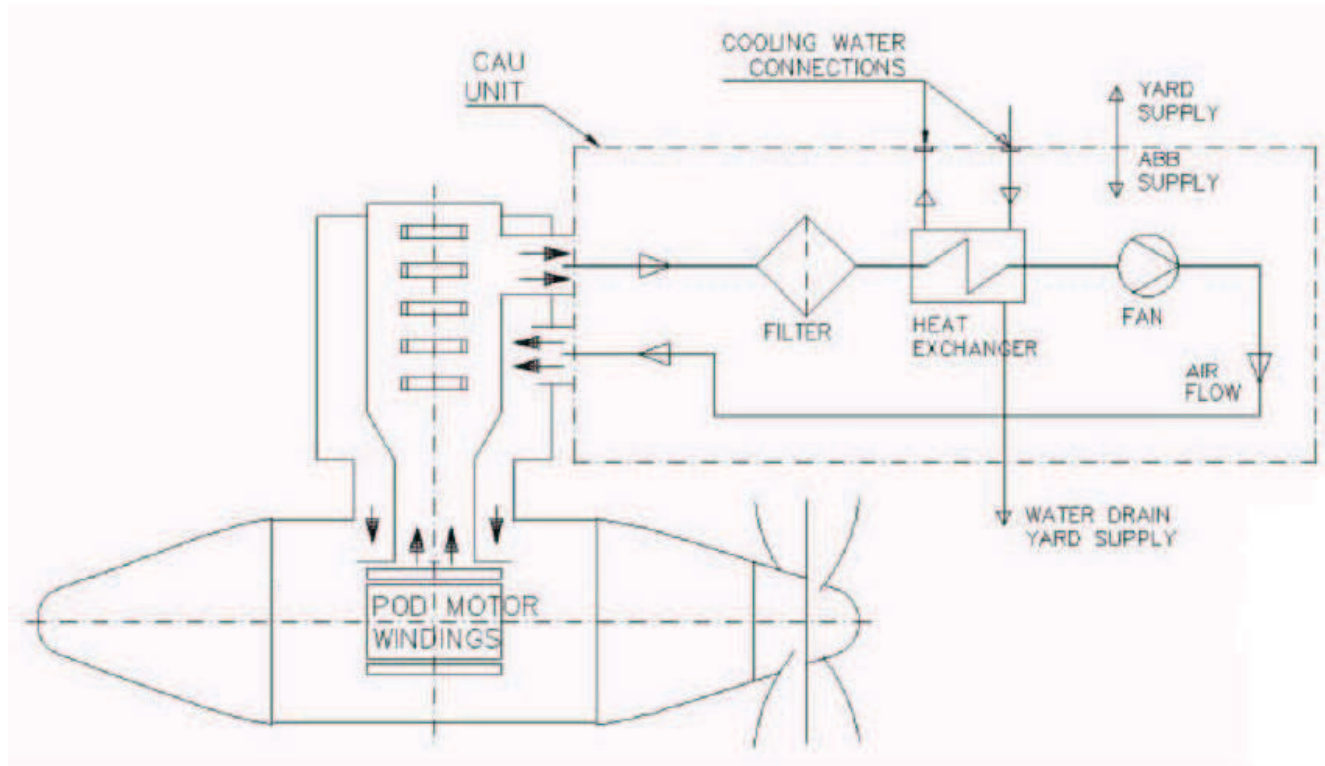
# Impianti di propulsione navale

- **The heat exchangers are mounted into the respective air channels. The exchangers are built with DIN-standard type water connection flanges. Standard water pressure class is 6 bars. Air bleeding nipples and leakage detectors are provided. The necessary piping is to be provided by the shipyard. Pressure and temperature sensors are to be included in the ship piping and provided by shipyard.**
- **The cooling fans are provided with their impeller, motor and housing including vibration isolators, connection box for straight electric power supply, SPM measuring terminals for each Motor. Instrumentation components are provided to be connected to the ship's MAS (machinery automation system). It includes sensors wired to a junction box. One temperature sensor is provided for monitoring propulsion motor outlet and other one for inlet temperature. There are also sensors for cooling water pressure and indicators for heat exchanger leakage water level. If one heat exchanger coil is leaking, other coils are still operating normally. Humidity sensor indicates an alarm in MAS. Position for smoke detector is provided although the detector itself is to be provided by the shipyard. Smoke detector function shall be part of vessels own fire alarm system.**

# Impianti di propulsione navale

## Azipod cooling air system

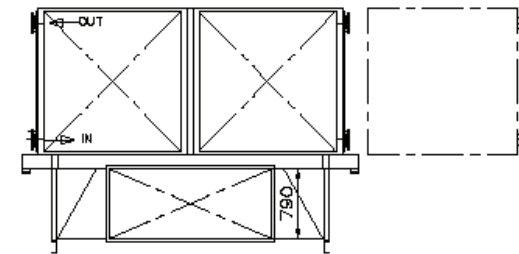
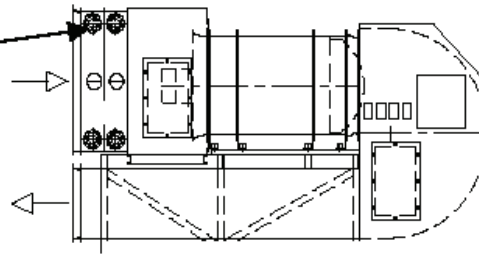
- Air temp to be cooled: +70 °C
- Air temp after cooling: +45 °C
- Fresh-Cooling water inlet: +36 °C



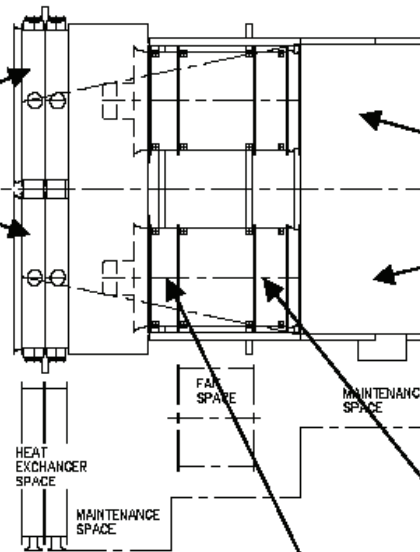


# Impianti di propulsione navale

TUBE COOLERS  
WITH RIBS  
(Cu/Al)



2+2 HEAT  
EXCHANGERS  
100 + 100 %  
(60 + 60 %)



A

B

TWO FAN LINES  
100 + 100 %

(AIR FILTERS  
BUILT INTO DUCTING)

FAN 2

FAN 1

# Impianti di propulsione navale

## Steering system

**Azipod system offers steering features to fulfill SOLAS requirements in normal and emergency operating conditions. In addition it provides excellent manoeuvrability and redundancy for the vessel.**

## Description

**Steering of Azipod as a rudder is carried out by a hydraulically powered steering gear. The main principle is that Hydraulic Power Unit (HPU, one unit per Azipod) generates needed pressure, which operates hydraulic motors (2 ... 5 pcs per Azipod). The hydraulic motors rotate steering gear wheel via pinion shafts. Hydraulic pumps in HPU are driven by their own electric motors. Hydraulic Power Unit is also equipped with one flushing pump, which circulates oil from tank to the covers of the hydraulic motors and so balances temperature differences. The flushing pump is started, if one of the main pumps is started. Control panel located on the bridge controls pump motor starters. There are also panels in engine control room and local panel in Azipod room. One pump unit is supplied from main LV-switchboard and the other one normally from the Emergency Switchboard.**

# Impianti di propulsione navale

**In normal operation one pump module per HPU is used for one Azipod, and the other pump module is standby. Turning speed with one pump module running is 2.5 /s. Two pump modules can be run parallel e.g. during manoeuvring, Azipod turning speed will then be 5/s.**

**It is possible to have an optional function in situations where very fast turning speed is to be needed. Steering mode with turning speed 7.5 /s can be achieved with two thirds of the maximum steering torque. In this option each hydraulic steering motor is equipped with a two-speed valve, so the Azipod turning speed can be increased 1,5 times in a manoeuvring situation.**

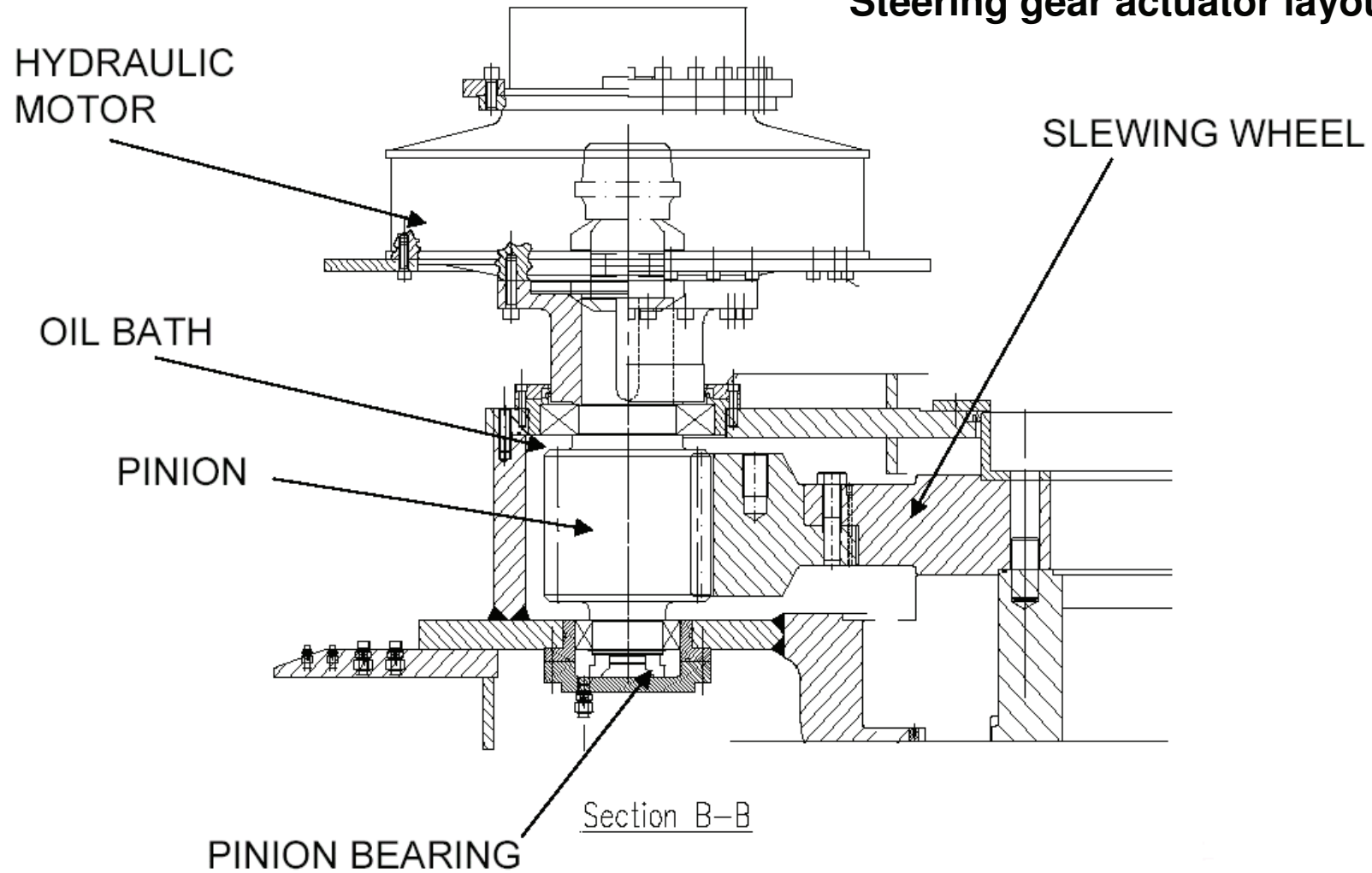
**Turning rates, (per each Azipod-unit)**

- **Normal azimuthing / 1 pump: 2,5 degr./sec.**
- **Normal azimuthing / 2 pump: 5,0 degr./sec.**
- **Manoeuvring with 2 pumps and limited torque: 7,5 degr./sec, option**

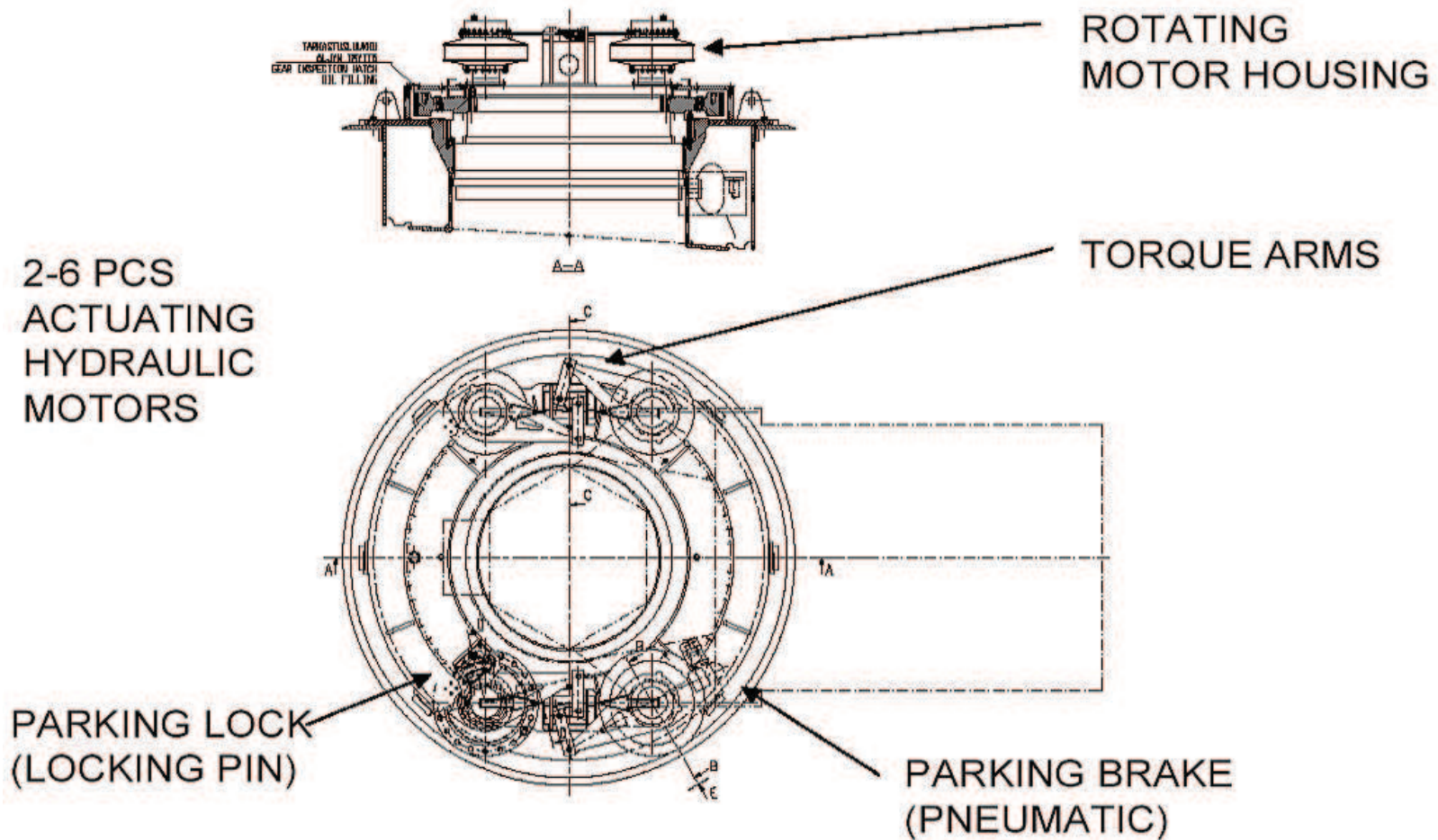
**Normal pump control mode is remote control from the bridge, but local control can be selected from pump motor starter, where local/ remote- switch is located. Local steering can be selected from pump servo unit. If a power failure alarm occurs in the running pump module, the standby pump module will be started automatically after a short delay.**

# Impianti di propulsione navale

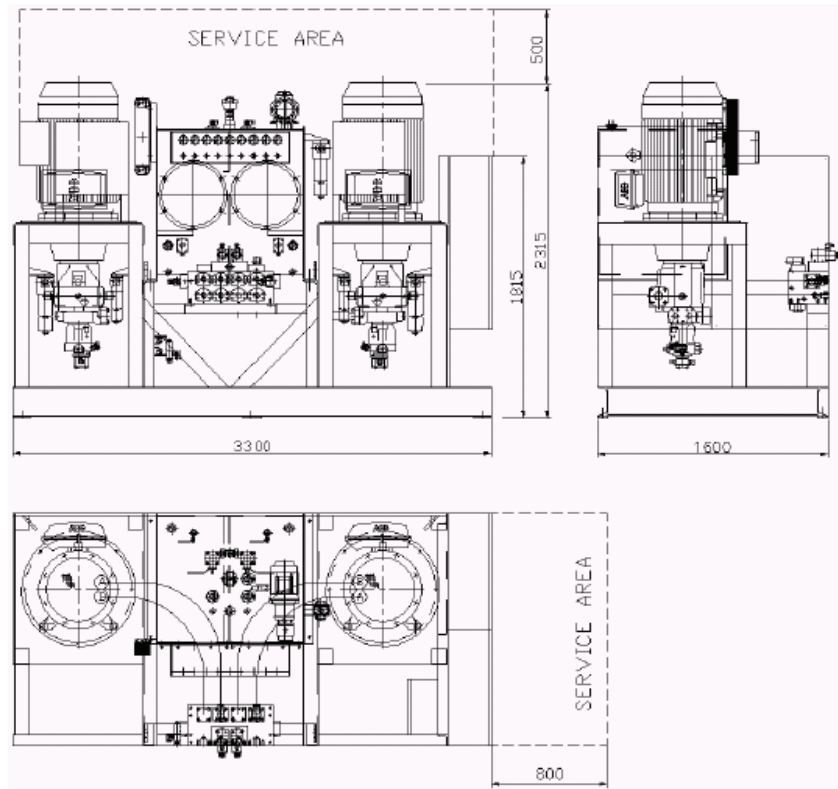
Steering gear actuator layout



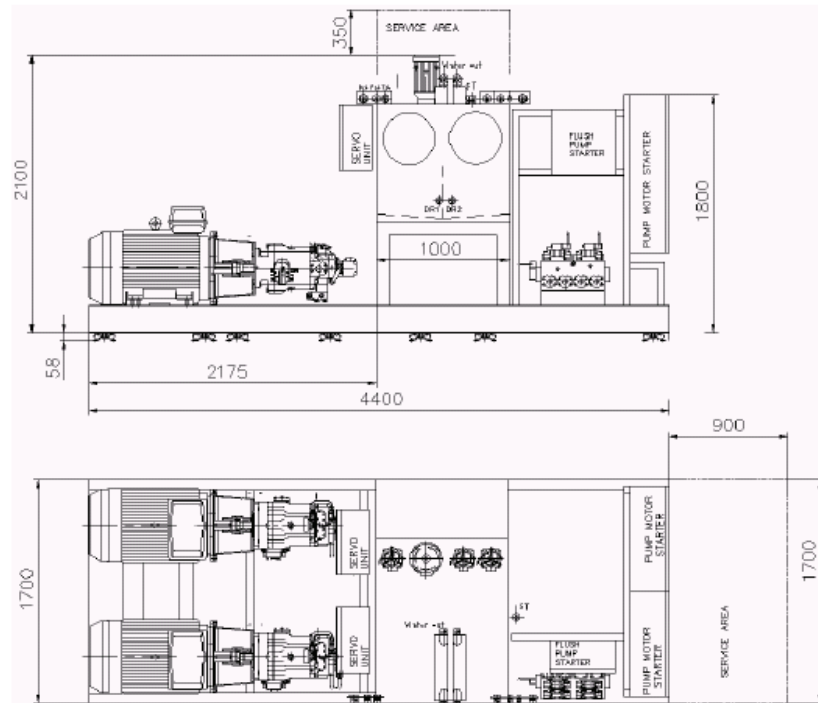
# Impianti di propulsione navale



# Impianti di propulsione navale



**HPU (Hydraulic Power Unit), Model A**



**HPU (Hydraulic Power Unit), Model B**



# Impianti di propulsione navale

## **Azipod Data Transmission system**

**Azipod data transmission system is needed to ensure the specified operation of the propulsion and to avoid failures.**

**Propulsion drive control system and machinery automation system have several indications and protective functions which need information of components inside the Azipod.**

**Azipod data transmission system collects all this information and delivers it out of the Azipod.**

**Measured values are typically winding temperatures, bearing lubrication oil levels and temperatures, propeller shaftline seal oil tank levels as well as seal system oil valve status information. Seal system valve remote control is to be operated also through data transmission system.**

**Azipod data transmission system has two clearly separated parts, transmitting end inside Azipod and receiving end in AIU (Azipod Information Unit) in Azipod Room. Between those in transfer unit there is a data slipping module to take care of the transmission when propulsor is rotating.**

# Impianti di propulsione navale

## **Azipod Information Unit (AIU)**

**In Azipod room, there is a cubicle, that is called AIU (Azipod Information Unit) which acts as an interface to propulsion drive and MAS (Machinery Automation System). It also includes instruments (front door panels and meters for rpm and power) for local control of steering, propulsion drive and magnetic valves in shaftline seal system.**

**All data points which are needed for propulsion drive unit purposes, are cabled to AC800 (propulsion application controller remote I/O unit) in AIU. Those are mainly related to propulsion and bearing system. All outgoing signals are to be sent via Ethernet bus-lines to PCU (Propulsion Control Unit).**

**Depending on the Data Transmission system type, the information to MAS can be sent through AIU (ZMC/CMC- and RMB/SAE –systems) or straight from junction box in Transfer Unit (Hard wired system).**

**AIU needs a 230 VAC UPS Secured supply.**

# Impianti di propulsione navale

## **Propulsion Control Unit (PCU)**

**Near propulsion drive unit there is a cubicle that is called PCU (Propulsion Control Unit).**

**That unit is to serve propulsion drive. Necessary sensors like propulsion motor winding temperatures, bearing temperatures and bearing oil levels are to be sent by Ethernet busline via AIU to PCU. There is busline or hard wired connection provided between MAS - PCU – AIU.**

## **Sensor information for MAS (Machinery Automation System)**

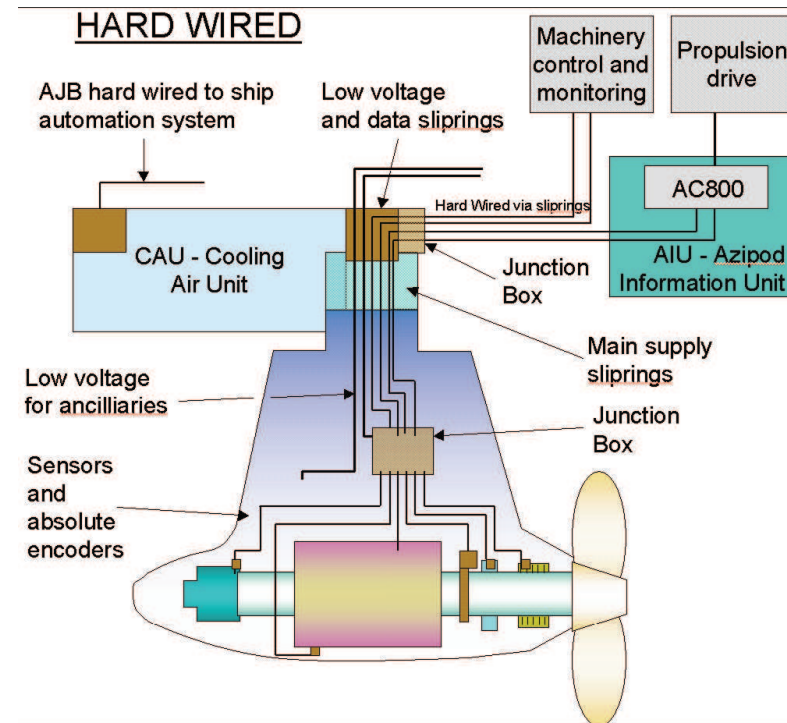
**It is highly recommended that the supplier of MAS provides remote I/O- cubicle into the Azipod room, where all these signals can be connected. Also to that same remote I/O cubicle, all other sensors needed for MAS purposes and coming from Azipod room can be cabled easily. These are coming mostly from cooling, steering and bearing oil filtration & cooling systems.**

# Impianti di propulsione navale

## Data transmission system types

The simplest system is hard wired, in which the number of features is limited. It is still suitable and the only possible system for smaller sizes of the Azipods, in which there is not enough space for human entry into the pod.

No special data transfer systems are used in Azipod Unit. Sensors are “hardwired” through the slipring module and Junction Box in Transfer Unit to the Azipod room, where signals are sent further on via AIU and buslines. Some information is to be sent directly through Junction Box to MAS.

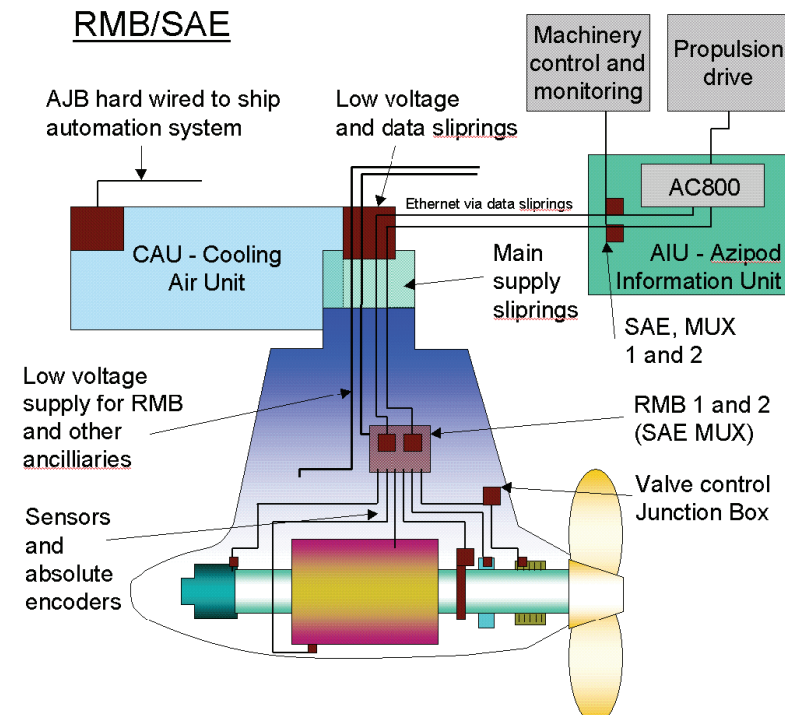


# Impianti di propulsione navale

## Data transmission system types

More features for control and measuring are available in RMB/SAE –system. It is a modular system with extensions, but still it doesn't have the possibility for vibration measurement or camera monitoring.

When Azipod Unit has several points to measure, it would be reasonable to reduce the amount of cables and sliprings in transfer unit. It can be carried out by using a programmable SAE-multiplexer based remote measurement system. In this type of system the remote measurement equipment consists of a multiplexer inside the Azipod located in the RMB (Remote Measurement Box) and a demultiplexer outside the pod in the Azipod room.

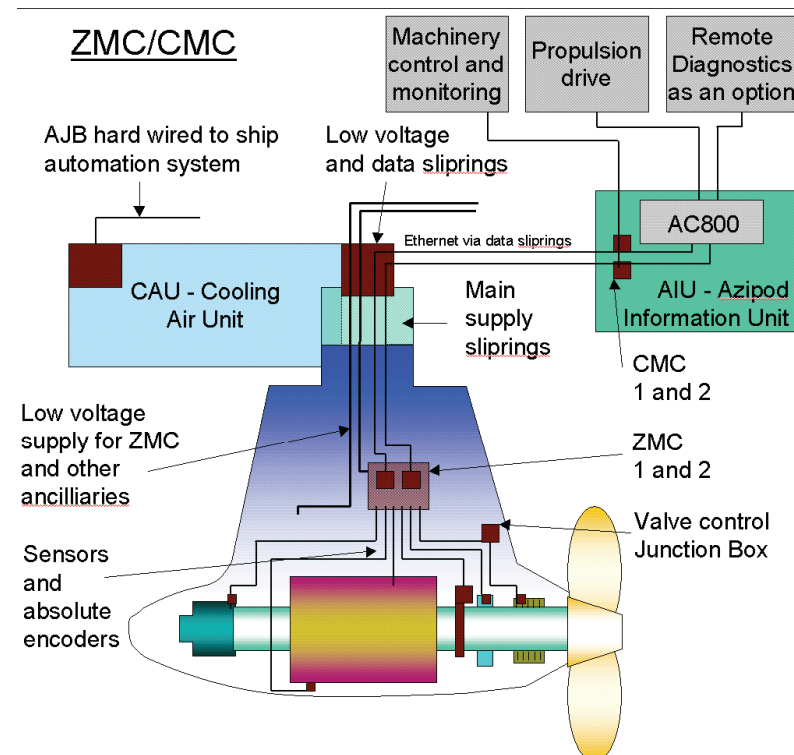


# Impianti di propulsione navale

## Data transmission system types

The most enhanced system is **ZMC/CMC** – system where also the above mentioned features are available.

In the most enhanced control and monitoring system to reduce the amount of slirings and cabling, the computer based **ZMC/CMC** -system with Ethernet and Serial Line is to be utilized. Data transmission system has remote measurement equipment consisting of **ZMC** inside Azipod and **CMC** in **AIU** in Azipod room. Azipod Unit and **AIU** are connected together by ethernet-bus. This system is typically used in cruise vessels





# Impianti di propulsione navale

## **Azipod Control System**

**Azipod Control System performs two separate main functions, Remote Control of propulsion (thrust and steering) (propulsion thrust and steering) and Monitoring. The Remote Control System (RCS) provides the functions for controlling the thrust and steering (Azimuthing) of each Azipod.**

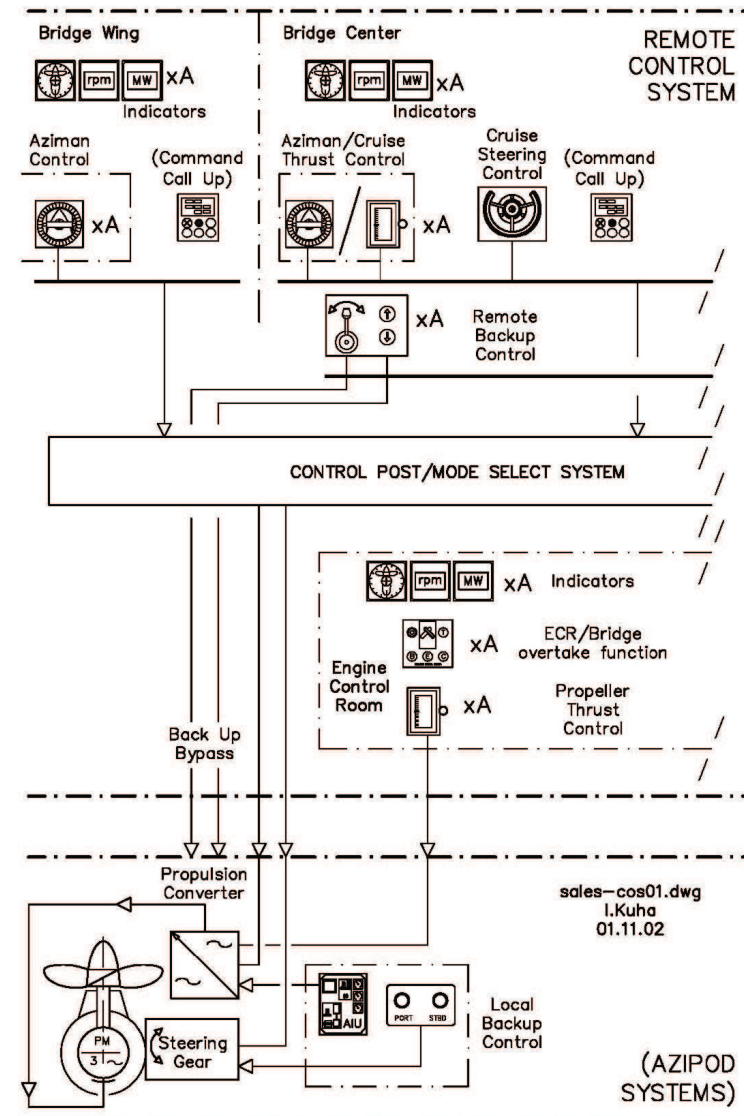
**As well as the control post take over function between Remote Control posts. With the azimuthing and thrust control system the operator is able to conduct all control functions for the propulsion, such as azimuthing angle and thrust setting. This control system includes all necessary levers and panels for safe and easy control of the Azipod propulsion.**

**The second function of the Azipod control is to monitor the current status of the whole Azipod propulsion system to assure safe operating conditions and to give necessary information to the user.**

# Impianti di propulsione navale

## Typical control outline scheme

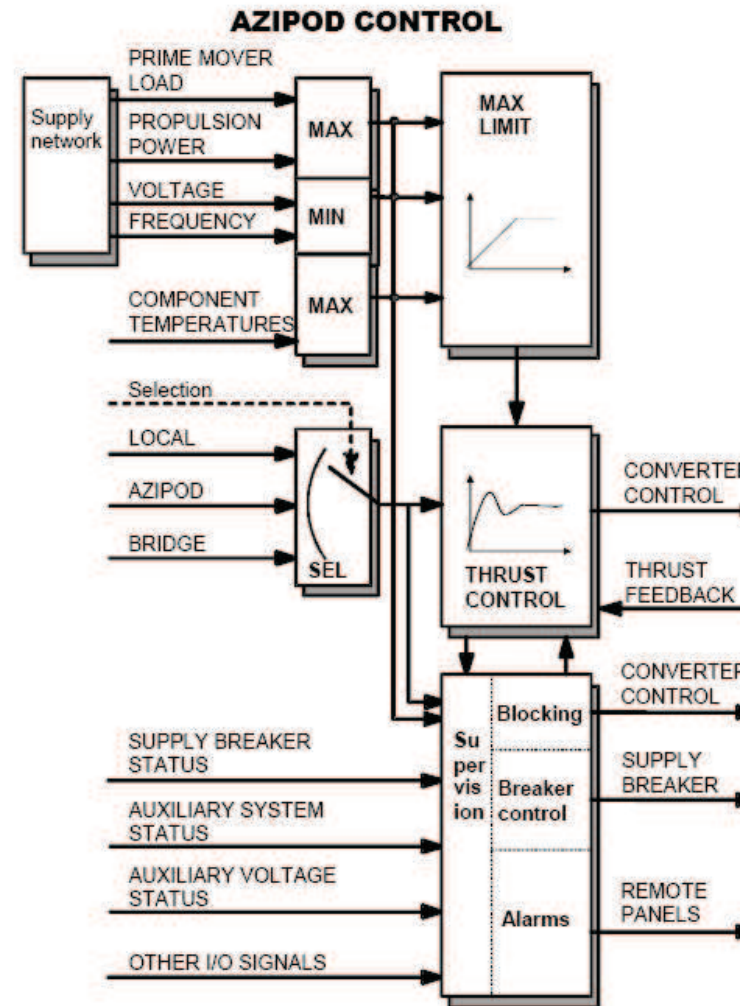
The typical azimuthing and control system layout includes three control posts in the Bridge, one post on each Bridge wing and the main control post in the wheelhouse center. This configuration also includes a control post in the Engine Control room and one in each Azipod room. Actual layout will vary according to applied hardware components and outfitted control posts. (Thrust / Steering management and alarm panels are not shown). One Azipod interface is shown.



# Impianti di propulsione navale

## Control System Functions

- Azimuth angle and thrust control
- Control post selection
- Supply breaker remote control, start/stop sequences
- Component protection
- Power limitation safety functions
- Connections to other ship monitoring systems like machinery automation (MAS)



# Impianti di propulsione navale

**The basic task for Azipod Control system is to provide required thrust in the required direction according to operator's commands. To carry out this task, control system reads commands from remote control instruments and runs steering gear and propulsion drives accordingly. The control system also gives feedback information to operator.**

## **Steering Control**

**The Azipod control processes the selected angle reference and runs commands of steering gear according to that reference.**

## **Thrust Control**

**The Azipod control processes the selected power or speed reference so that it will not exceed limits. Prime movers set the limits for increase and decrease ramp slope of speed reference. Available electrical power defines the maximum thrust.**

# Impianti di propulsione navale

## Protective functions and alarms

The propulsion system includes several protective functions. Some of them are internal propulsion protections to avoid overloading of the components. Others are for external system protections to help other ship systems.

A major goal for the external system protections is to prevent “black out” situations. In normal conditions the propulsion system is the biggest consumer in the electric network of the ship. Therefore Azipod control must assure that the propulsion system itself does not generate black out conditions.

In order to know the amount of the available power and the number of generators connected, the propulsion system supervises the status of the supply network. The status signals for the breakers as well as generator loads are essential for network monitoring.

## Power Limitation

Overload prevention or component malfunction may require propulsion power reduction. Possible reasons for reduction are explained in the following sections.

# Impianti di propulsione navale

## **Available Power in Supply Network**

**Azipod control calculates constantly the available power for propulsion system. Available power depends on the generators and consumers connected to network.**

## **Prime Mover Overload Limit**

**The prime mover load limit control works in such way that the power of any prime mover will never exceed nominal value.**

## **Supply Network Frequency and Low Voltage Limit**

**If the prime movers are overloaded, network voltage or frequency drop under normal values. In that case Azipod Control reduces propulsion power to decrease prime mover load to anacceptable level.**



# Impianti di propulsione navale

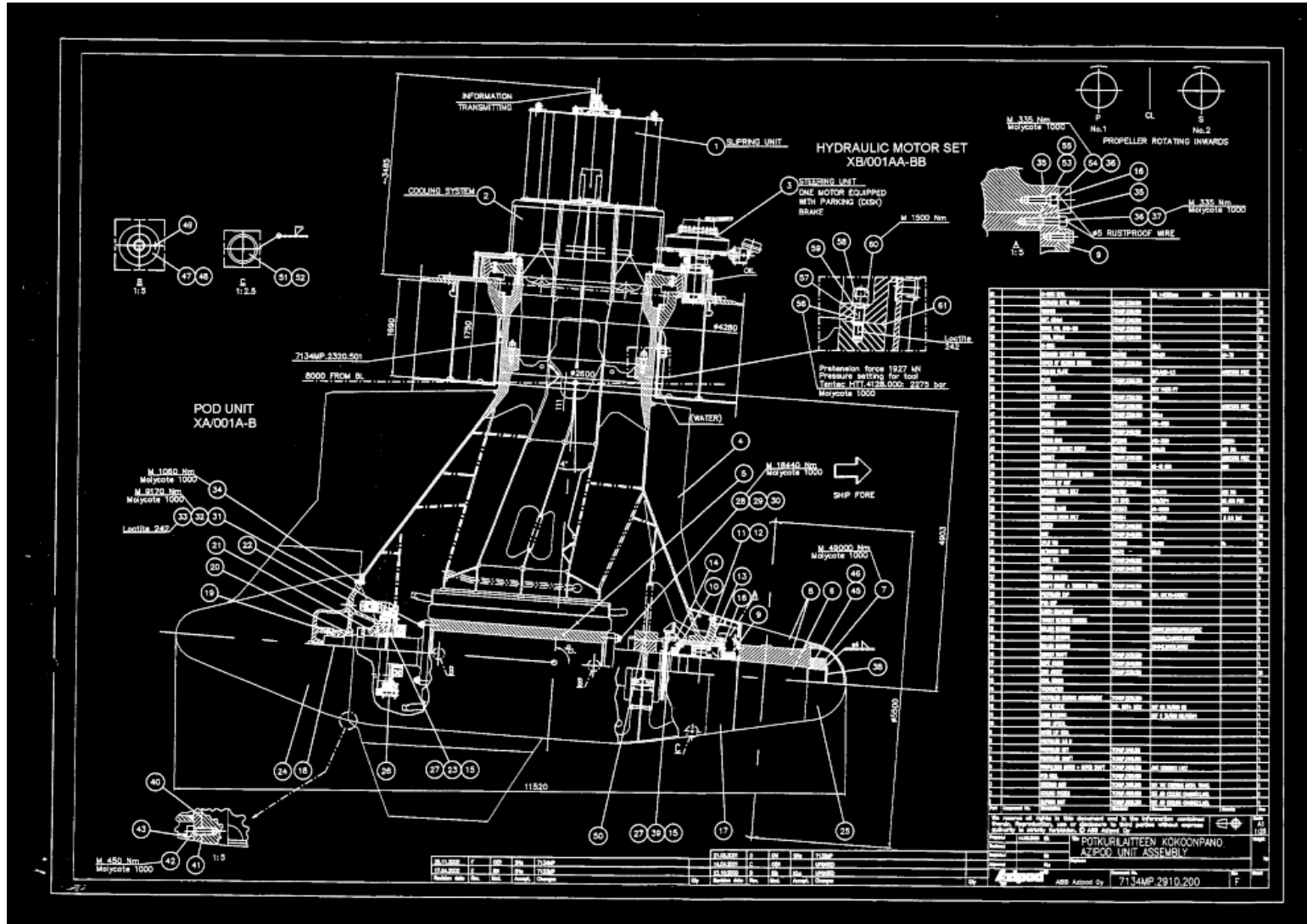
## **Internal Limits**

**There are several drive protection functions that may reduce propulsion power. If the internal supervision system finds a failed auxiliary device or component overload, Azipod control automatically starts to decrease propulsion power.**

## **Safety System Override**

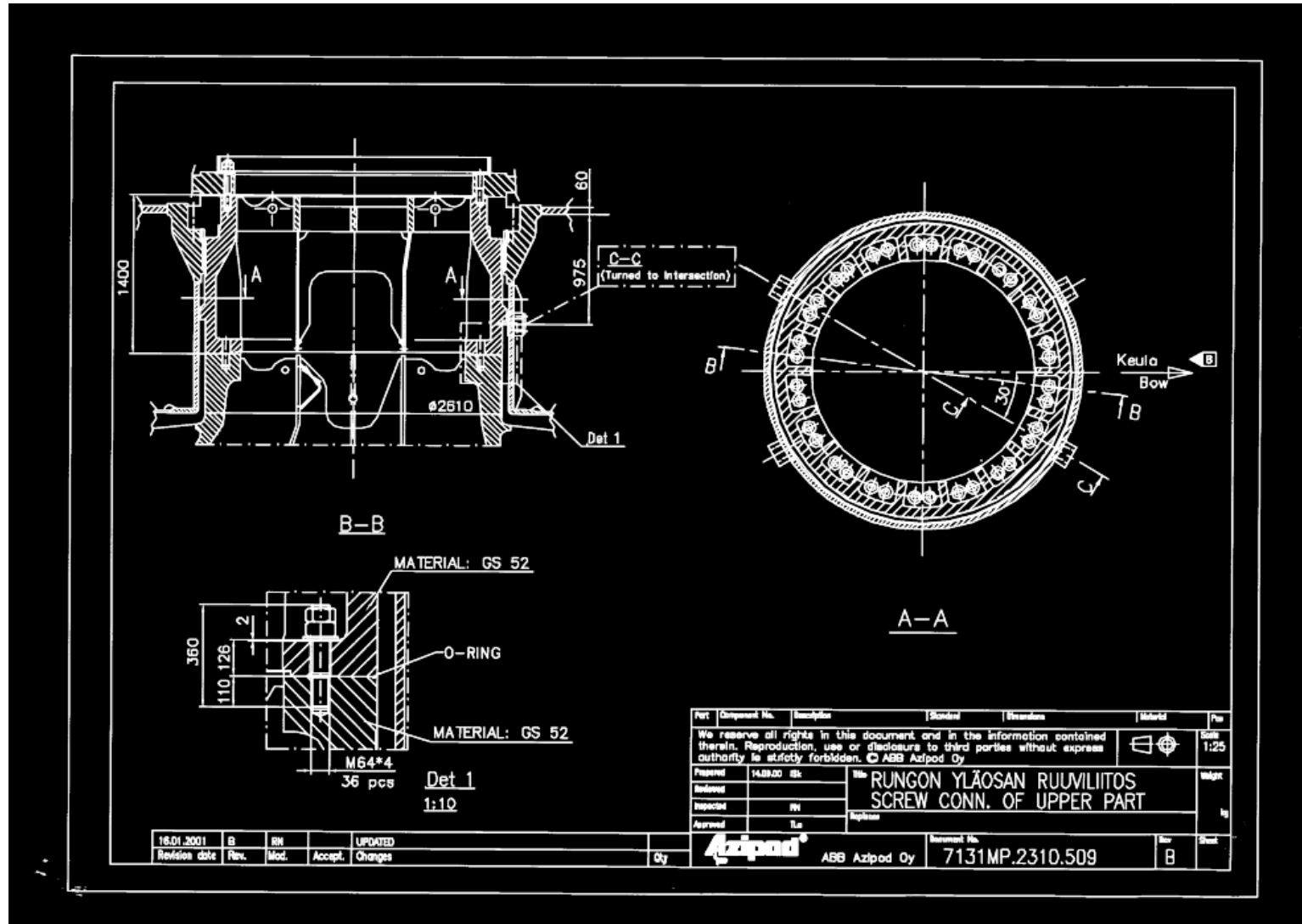
**If it is necessary to maintain propulsion at any cost, operator may override certain safety functions of the Azipod control.**

# Impianti di propulsione navale



Data: 15/03/2007

# Impianti di propulsione navale

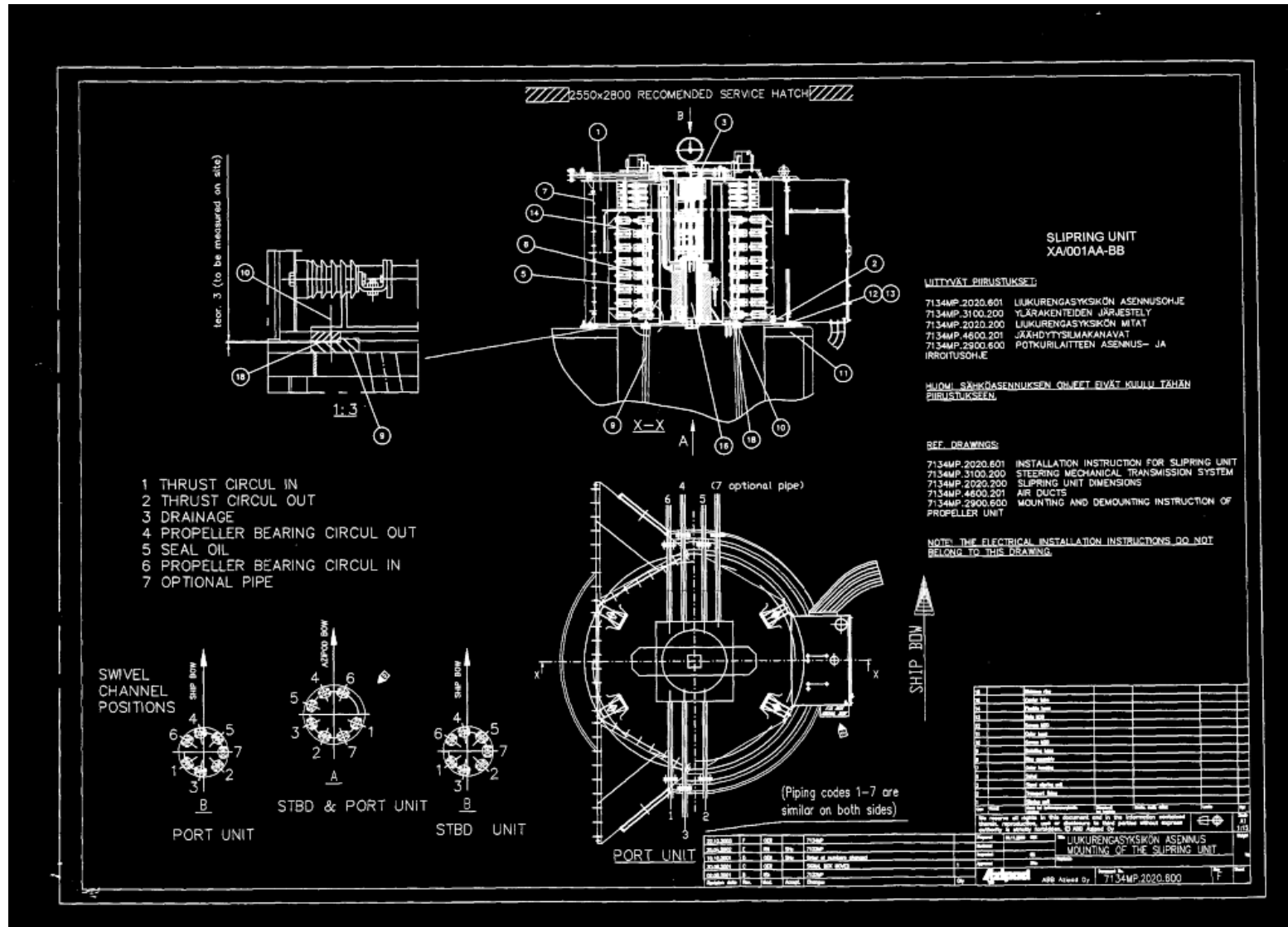


Data: 15/03/2007





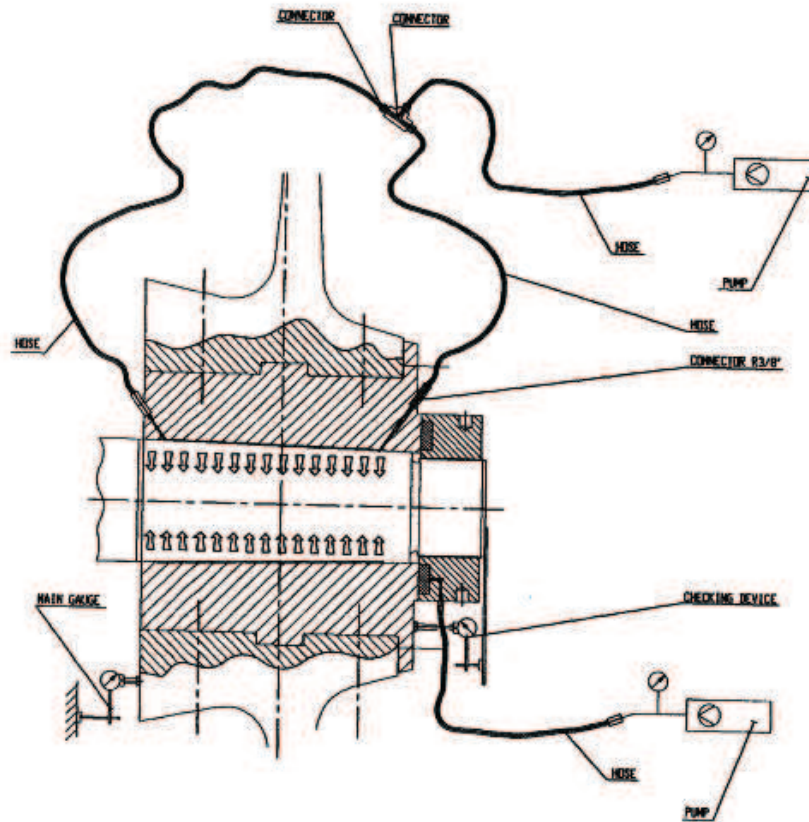
# Impianti di propulsione navale







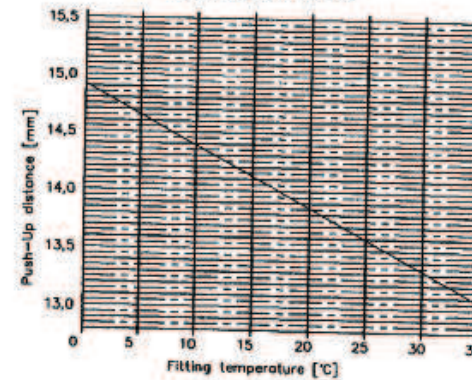
# Impianti di propulsione navale



## CONE JOINT OF PROPELLER, PUSHING UP

- The pushing up will be done by oil injection method  
Pressure class of equipment is at least 600 bar
- **PRIOR TO PUSH UP**
  - Make sure that the components must have been in the same ambient conditions for sufficient time for their temperature to stabilize
  - Assembly is made as shown in drawing
    - Propeller is pushed on cone so far as possible
    - Nut is turned in position
  - The nut is pressurized up to 24,7 bar when starting point load will be more than 572 kN
  - Measurement devices are adjusted to zero
  - The pressure in the nut is raised, then the pressure in the cone and then by turns until the propeller is moved to right position and measurement devices indicates required transition as presented in graphic below: (14,92 mm at 0°, 13,07 mm at 30°) Working pressure may not be more than 800 bar.
  - The pressure in the cone is extracted
  - The pressure in the nut is extracted  
The measurement devices must be observed
  - The hoses are disconnected and bores are blanked off

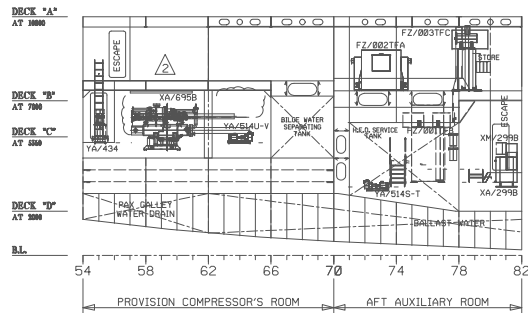
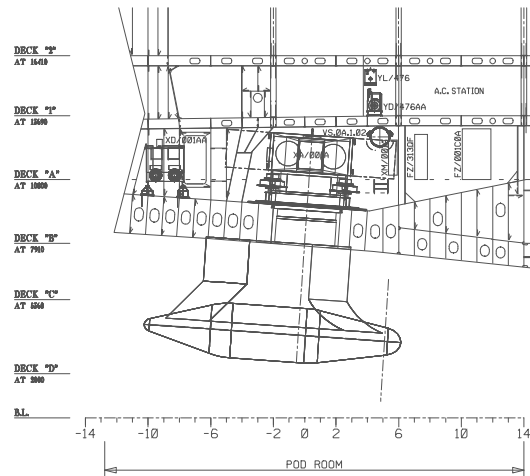
PUSH UP DISTANCE IN VIEW OF THE FITTING TEMPERATURE



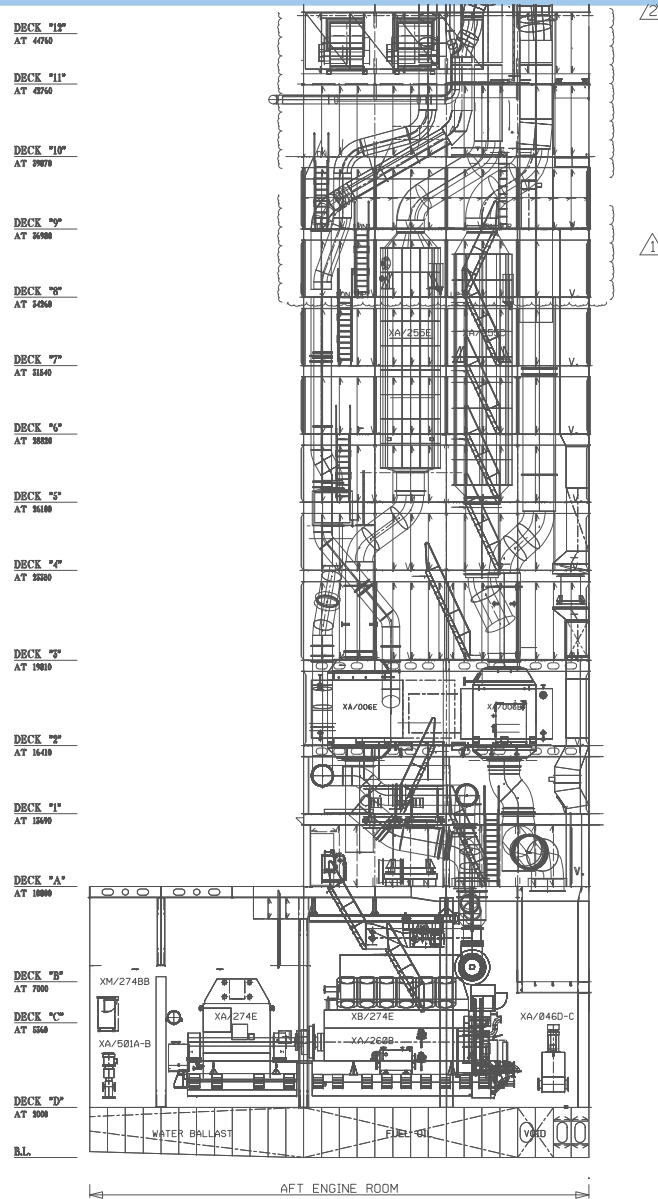
We reserve all rights in this document and in the information contained therein, reproduction, use or disclosure to third parties without express authority is strictly forbidden. © ABB Azpod Oy						Scale AS 1:5	
Project	14.04.2007	DR	DR	7134MP	POTKURIN ASENNUS JA IRROITUS Propeller mounting and dismounting		
Revised		DR	DR	7133MP			
Revised		DR	DR	7132MP			
Revised		DR	DR	7131MP			
Revised		DR	DR	UP007B			
Material part	Rev	Material	Rev	Material			
					Document No.	7134MP.2100.600	1/2

# Impianti di propulsione navale

PORT LONGITUDINAL SECTION

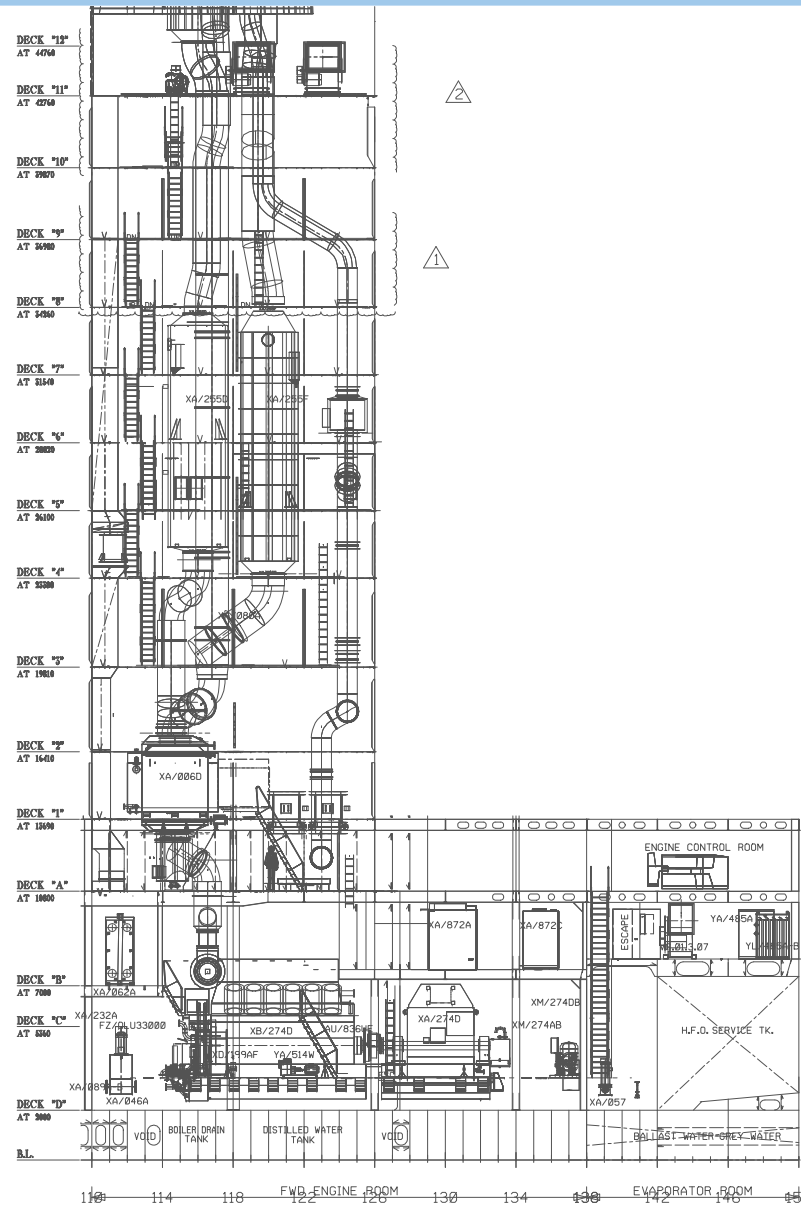


# Impianti di propulsione navale



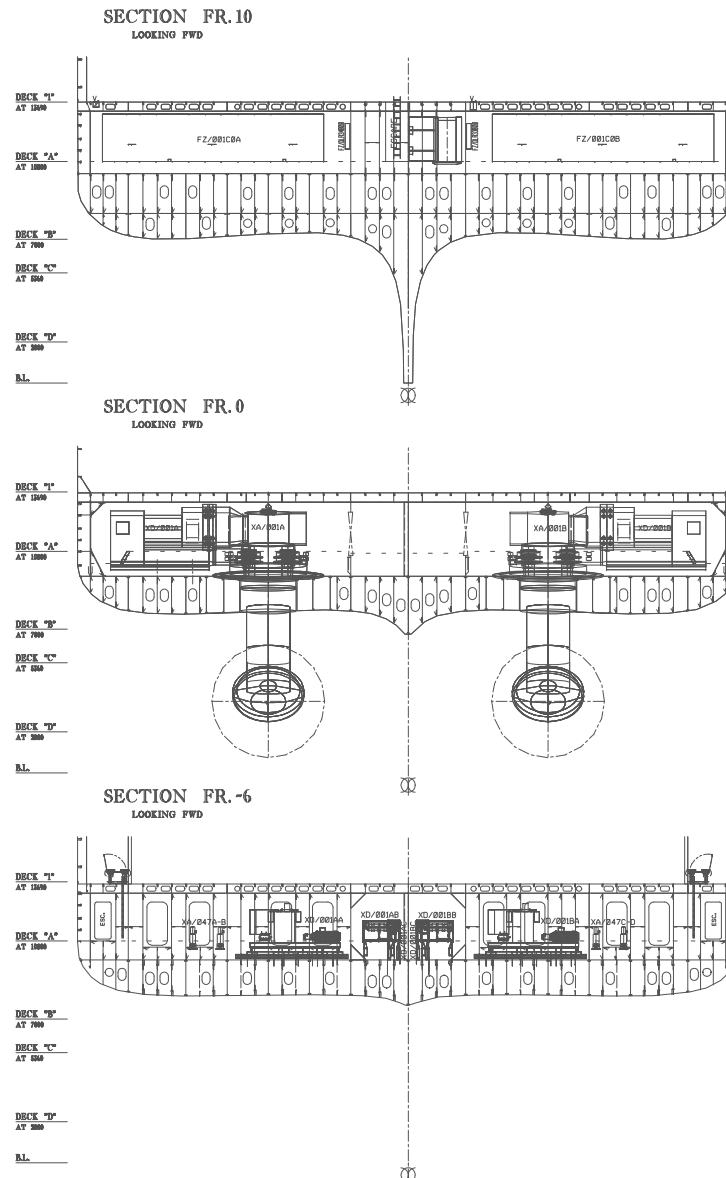
Data: 15/02/2007

# Impianti di propulsione navale



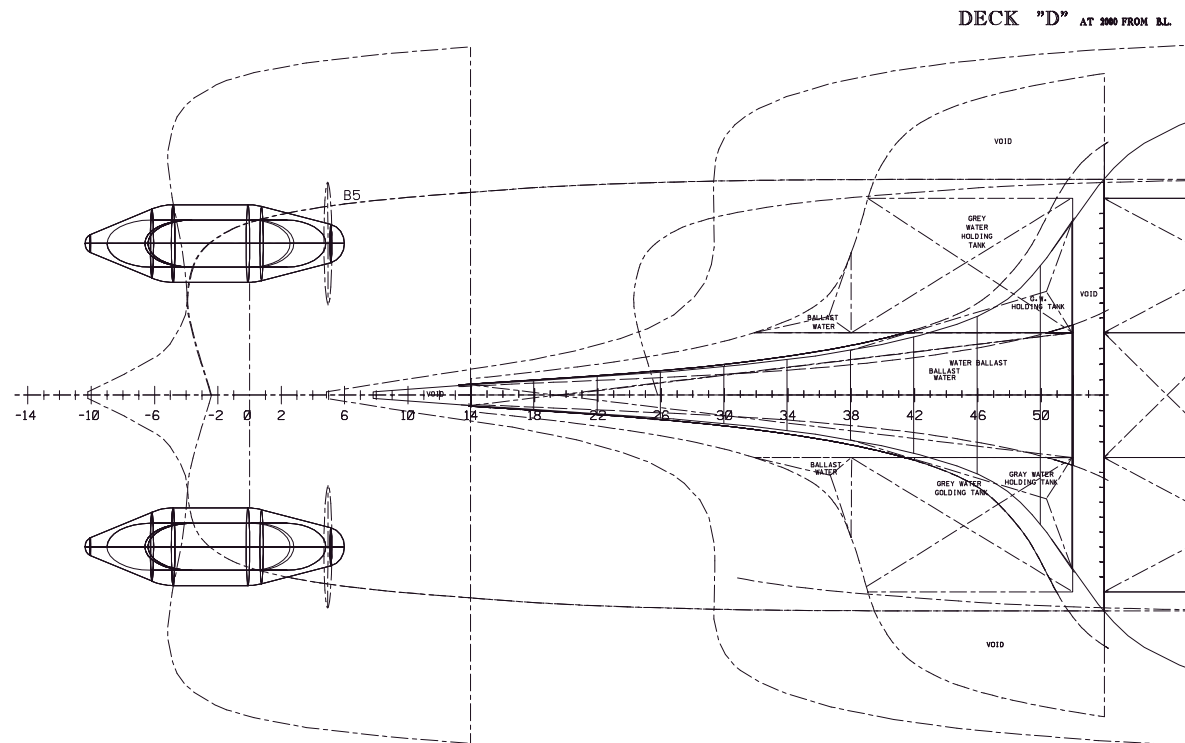
Data: 15/02/2007

# Impianti di propulsione navale

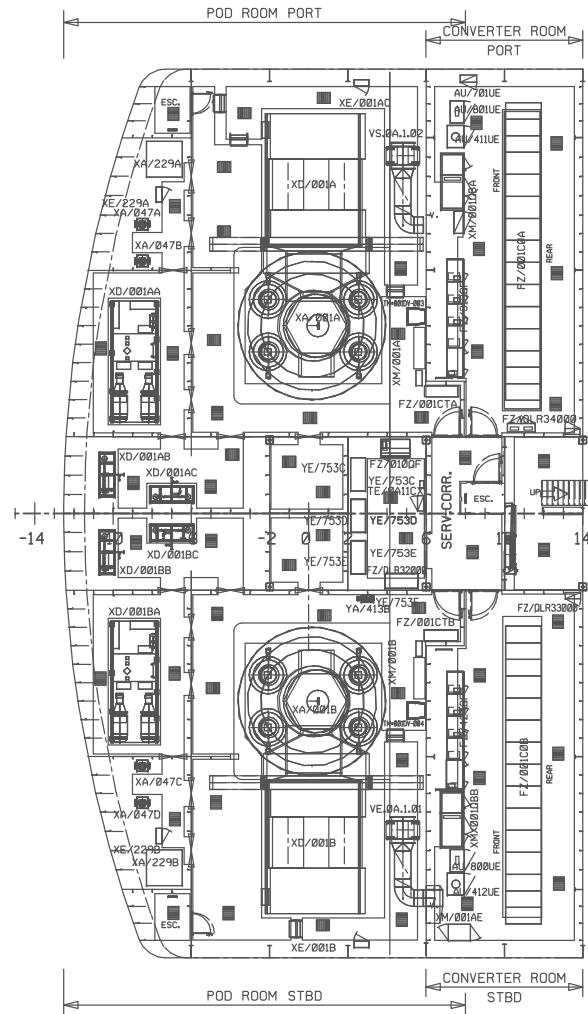




# Impianti di propulsione navale

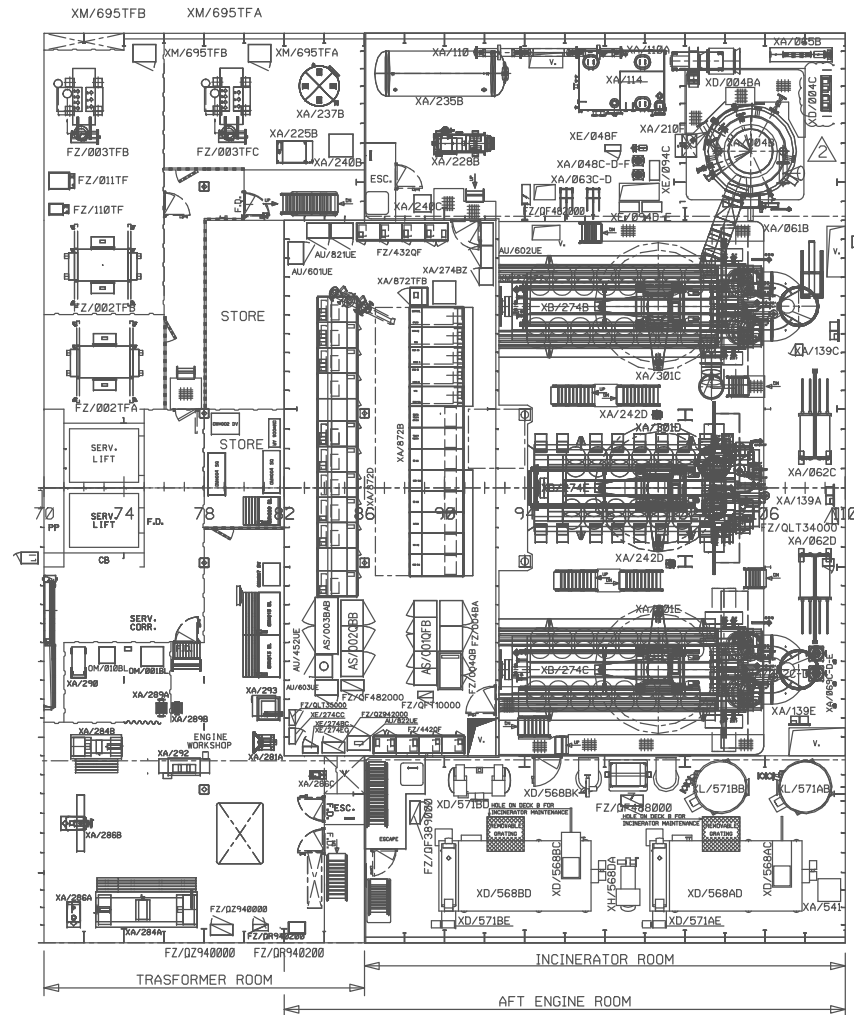


# Impianti di propulsione navale



DECK "A" AT 10600 FROM BL.

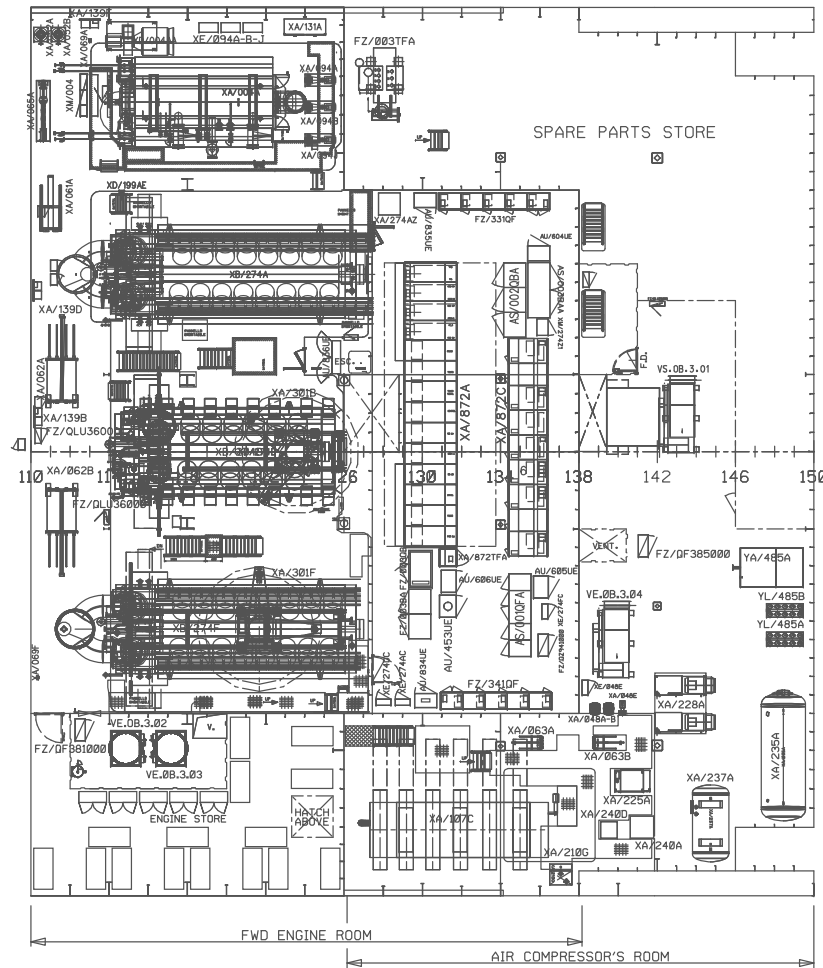
# Impianti di propulsione navale



DECK "B" AT 7000 FROM BL.

# Impianti di propulsione navale

DECK "B" AT 7000 FROM BL.



Data: 15/02/2007