

## SHIP'S PROPULSION UNIT

### Field of the invention

5 The invention relates to a ship's propulsion unit as defined in the preamble of independent claim 1.

The invention relates to ship's propulsion units such as azimuthing propulsion units as presented in US 5,403,216.

10 US 6,312,298 B1 presents in an electromotive drive system in an improved form of a propeller motor for a ship, the cooling of the motor in a simple manner is provided. For re-cooling a circulating coolant, an annular duct is provided, which is arranged inside a shaft-like supporting part on its wall. With the assistance of this supporting part, the propeller motor is arranged, gondola-like, on the lower side of the ship.

15 US 6,485,339 B1 presents an electric propulsion pod for a ship having an electric propulsion pod heat rejection member. The electric propulsion pod is attached below the ship by a hollow ship access shaft. The electric propulsion pod contains an electric motor for producing a water propulsion. The electric motor generates an amount of heat that is conducted and subsequently released into the water through the electric propulsion pod and ship access shaft surfaces. The heat rejection member is fitted for increasing the conduction and subsequent release of the electric motor heat.

20 US 7,186,156 B1 presents a propulsion unit for propelling a waterborne vessel includes an electric motor arranged to provide propulsion, and a housing arranged to contain the motor. The interior of the housing is maintained at an increased pressure of above roughly 2 bar to increase the cooling effect of a cooling gas maintained therein. An end region of the housing is provided with a heat exchange mechanism arranged to cool a cooling gas passing thereover. The  
25 heat exchange mechanism is associated with the housing such that, in use, water surrounding the housing absorbs heat therefrom.

WO0154973 presents a propulsion unit arrangement for a ship. The arrangement includes a motor unit comprising a motor housing which is arranged in the water and which comprises a motor and any control means related thereto, as well as a propeller which is arranged at a motor  
30 shaft. Said motor unit comprises an electrical motor for which the cooling is arranged to take place via the surface of the motor's whole circumference through the motor's casing structure directly into the water which surrounds said unit.

US 6,231,407 presents to improve the propulsion efficiency of a ship propulsion having a housing to be arranged on the bottom of the hull in a

gondola-like manner, with a synchronous motor in the housing, at propulsion powers of approximately 10 MW, the rotor of the synchronous motor is designed as a permanent-magnet rotor, and the stator of the synchronous motor is fitted into the housing in a form-fitting manner to be cooled through the housing wall. An additional cooling device in the form of a fan or a spray device may be provided for each winding overhang.

Publication WO 2012/123547 A1 relates to a ship comprising at least one electric motor for driving the ship, and a cooling device for cooling the at least one electric motor by means of at least one coolant. The invention also provides that the cooling device has a heat exchanger, which is designed for cooling the at least one coolant by means of seawater.

### **Objective of the invention**

The object of the invention is to provide efficient cooling of a ship's propulsion unit.

### **Short description of the invention**

The ship's propulsion unit of the invention is characterized by the definitions of independent claim 1.

Preferred embodiments of the ship's propulsion unit are defined in the dependent claims.

The propulsion unit comprises a shell structure arranged at least partly below a hull of the ship and immersible at least partly in water so that the shell structure is at least partly surrounded by water, and an electric motor for rotating a propeller outside the shell structure. The electric motor has a stator and a rotor for rotating in the stator. The electric motor is arranged in a motor housing section of the shell structure so that the stator of the electric motor is form-fitted into a cylindrical section of the motor housing section of the shell structure. The cylindrical section has a cylindrical outer surface. The shell structure includes a support section having a lower end connected to the motor housing section of the shell structure and an upper end connected to the hull of the ship.

The invention is based on using liquid in a closed liquid cooling system for transferring thermal energy from gas circulating in closed gas circulation cooling system through the electric motor to water surrounding the propulsion unit. The closed gas circulation cooling system contains gas and comprises a gas circulation means for circulating gas through channels in the electric motor. The closed liquid cooling system has an inner space containing liquid. The propulsion unit comprises a gas-liquid-heat exchanger in fluid connection with the closed gas

circulation cooling system and in fluid connection with the closed liquid cooling system for exchanging thermal energy between gas circulating in the closed gas circulation cooling system and liquid in the closed liquid cooling system. In the propulsion unit, the closed gas circulation cooling system, the closed liquid cooling system, and the gas-liquid-heat exchanger are all parts of the propulsion unit.

Because the closed gas circulation cooling system, the closed liquid cooling system, and the gas-liquid-heat exchanger are all parts of the propulsion unit, installing and mounting of the propulsion unit to a ship is easy, because no cooling lines for cooling fluid such as for cooling liquid or for cooling gas for cooling the electric propeller motor is necessarily needed between the propulsion unit and the ship.

In the propulsion unit, the closed liquid cooling system, closed gas circulation cooling system, and the gas-liquid-heat exchanger are preferably, but not necessarily, arranged at least partly enclosed by the shell structure of the propulsion unit. In the propulsion unit, the closed liquid cooling system, closed gas circulation cooling system, and the gas-liquid-heat exchanger are more preferably, but not necessarily, arranged fully enclosed by the shell structure of the propulsion unit.

“Closed gas circulation cooling system” in means in this connection for example that gas such as air present in the propulsion unit, is not let into the closed gas circulation cooling system, nor is gas discharged from the closed gas circulation cooling system into the propulsion unit.

“Closed liquid cooling system” in means in this connection for example that water surrounding the propulsion unit, when the propulsion unit is at least partly immersed in water, is not let into the closed liquid cooling system, nor is liquid discharged from the closed liquid cooling system into water surrounding the propulsion unit, when the propulsion unit is at least partly immersed in water.

In the propulsion unit, the surface of the propulsion unit is more effectively used for transferring thermal energy from the electric motor to the water surrounding the propulsion unit than in a solution where the electric motor is only cooled through the motor’s casing structure to the water surrounding the propulsion unit. Because the cooling is effective, a more powerful electric motor may be used in comparison to a solution where the electric motor is only cooled through the motor’s casing structure to the water surrounding the propulsion unit.

In a preferred embodiment of the invention the electric motor is an induction motor. In an induction motor a significant amount of thermal energy is generated in the rotor and the propulsion unit is especially advantageous, because

the propulsion unit provides for effective cooling of the rotor of the induction motor. However, the same cooling principle can be used to cool any type of electric motor, for example a permanent magnet synchronous motor.

## 5 List of figures

In the following the invention will be described in more detail by referring to the figures, of which

Figure 1 shows a first embodiment of the propulsion unit,

Figure 2 the function principle of the propulsion unit shown in figure 1,

10 Figure 3 shows the propulsion unit shown in figure 1 as seen from one side,

Figure 4 shows a variant of the first embodiment shown in figure 1,

Figures 5 to 8 show some alternative configurations of section X-X in figures 1 to 3,

Figure 9 shows the configuration of section X-X of the variant of the first embodiment shown in figure 4,

15 Figures 10 to 12 show some alternative configurations of section Y-Y in figure 3,

Figure 13 shows the configuration of section Y-Y of the variant of the first embodiment shown in figure 4,

Figure 14 shows a second embodiment of the propulsion unit,

Figure 15 the function principle of the propulsion unit shown in figure 14,

20 Figure 16 shows the propulsion unit shown in figure 14 as seen from one side,

Figure 17 shows a configuration of section X-X in figures 14 to 17,

Figure 18 shows a third embodiment of the propulsion unit,

Figure 19 the function principle of the propulsion unit shown in figure 18,

Figure 20 shows the propulsion unit shown in figure 18 as seen from one side,

25 Figure 21 shows a configuration of section X-X in figures 18 to 20,

Figure 22 shows a fourth embodiment of the propulsion unit,

Figure 23 the function principle of the propulsion unit shown in figure 22,

Figure 24 shows the propulsion unit shown in figure 22 as seen from one side,

30 24, Figures 25 to 28 show some alternative configurations of section X-X in figures 22 to

Figure 29 shows a fifth embodiment of the propulsion unit,

Figure 30 the function principle of the propulsion unit shown in figure 29,

Figure 31 shows the propulsion unit shown in figure 29 as seen from one side,  
 Figures 32 to 35 shows some alternative configurations of section X-X in figures 29 to  
 31,

Figure 36 shows a sixth embodiment of the propulsion unit,  
 Figure 37 the function principle of the propulsion unit shown in figure 36,  
 Figure 38 shows the propulsion unit shown in figure 36 as seen from one side,  
 Figures 39 to 42 shows some alternative configurations of section X-X in figures 36 to  
 38,

Figure 43 shows a seventh embodiment of the propulsion unit,  
 Figure 44 the function principle of the propulsion unit shown in figure 43,  
 Figure 45 shows the propulsion unit shown in figure 43 as seen from one side,  
 Figures 46 to 49 shows some alternative configurations of section X-X in figures 43 to  
 45,

Figure 50 shows an eighth embodiment of the propulsion unit,  
 Figure 51 the function principle of the propulsion unit shown in figure 50,  
 Figure 52 shows the propulsion unit shown in figure 50 as seen from one side,  
 Figures 53 to 55 shows some alternative configurations of section X-X in figures 50 to  
 52,

Figure 56 shows a ninth embodiment of the propulsion unit,  
 Figure 57 the function principle of the propulsion unit shown in figure 56,  
 Figure 58 shows the propulsion unit shown in figure 56 as seen from one side,  
 Figure 59 shows a configuration of section X-X in figures 56 to 58,

Figure 60 shows a tenth embodiment of the propulsion unit,  
 Figure 61 shows a configuration of section X-X in figure 60,

Figure 62 shows an eleventh embodiment of the propulsion unit,  
 Figure 63 the function principle of the propulsion unit shown in figure 62,  
 Figure 64 shows the propulsion unit shown in figure 62 as seen from one side,  
 Figure 65 shows a first configuration of section X-X in figures 63 and 64,

Figure 66 shows a first configuration of section Y-Y in figures 63 and 64,  
 Figure 67 shows a second configuration of section X-X in figures 63 and 64,  
 Figure 68 shows a second configuration of section Y-Y in figures 63 and

64,

Figure 69 shows a twelfth embodiment of the propulsion unit,

Figure 70 the function principle of the propulsion unit shown in figure 69,

Figure 71 is another view of the propulsion unit shown in figure 69, and

Figure 72 shows a configuration of section Y-Y in figures 70 and 71.

### Detailed description of the invention

In the following the ship's propulsion unit and some preferred embodiments and variants of the ship's propulsion unit will be described in greater detail.

The ship's propulsion unit (not marked with a reference numeral) such as a ship's azimuthing propulsion unit comprises a shell structure 1 arranged below a hull 2 of the ship (not marked with a reference numeral) and immersible at least partly in water (not marked with a reference numeral) so that the shell structure 1 is at least partly surrounded by water.

The propulsion unit comprises additionally an electric motor 3 for rotating a propeller 4 outside the shell structure 1. The electric motor 3 has a stator 5 and a rotor 6 for rotating in the stator 5. In the figures a propeller shaft 7 is connected to the rotor 6 for rotating with the rotor 6 as the rotor 6 rotates in the stator 5. In the figures the propeller shaft 7 is rotatable supported by means of bearing arrangements 8. In the figures the propeller 4 is attached to the propeller shaft 7.

The electric motor 3 is arranged in a motor housing section 9 of the shell structure 1 so that the stator 5 of the electric motor 3 is form-fitted into a cylindrical section 10 of the motor housing section 9 of the shell structure 1.

The cylindrical section 10 has a cylindrical outer surface 11.

The shell structure 1 includes a support section 26 having a lower end (not marked with a reference numeral) connected to the motor housing section 9 of the shell structure 1 and an upper end (not marked with a reference numeral) connected to the hull 2 of the ship. The upper end of the support section 26 may be connected to the hull 2 of the ship by means of a turning arrangement (not shown in the drawings) for turning the propulsion unit with respect to the hull 2 of the ship.

The propulsion unit comprises a closed gas circulation cooling system 12 containing gas 13 such as air and comprising a gas circulation means 14 for circulating gas 13 through channels 23 in the electric motor 3. The channels 23 through the electric motor 3 are preferably, but not necessarily, formed by at least one of channels 23 in the rotor of the electric motor 3 and a channel 23 formed by

an air gap (not marked with a reference numeral) between the stator 5 and the rotor 6 of the electric motor 3. The gas circulation means can be in the form of a separate gas circulation means or arranged in connection with the propeller shaft as in the tenth embodiment of the propulsion unit shown in figures 60 and 61.

5 The propulsion unit comprises a closed liquid cooling system 15 having an inner space (not marked with a reference numeral) containing liquid 16 such as water.

The inner space of the closed liquid cooling system 15 is preferably, but not necessarily, partly limited by the shell structure 1 of the propulsion unit so that liquid 16 in the inner space of the closed liquid cooling system 15 is in direct contact with the shell structure 1 of the propulsion  
10 unit for exchanging thermal energy between liquid 16 in the closed liquid cooling system 15 and water surrounding the propulsion unit via the shell structure 1 of the propulsion unit.

The propulsion unit comprises a gas-liquid-heat exchanger 17 in fluid connection with the closed gas circulation cooling system 12 and in fluid connection with the closed liquid cooling system 15 for exchanging thermal energy between gas 13 circulating in the closed gas  
15 circulation cooling system 12 and liquid 16 in the closed liquid cooling system 15 without mixing gas 13 circulating in the closed gas circulation cooling system 12 with circulating liquid 16 in the closed liquid cooling system 15 or vice versa.

The closed gas circulation cooling system 12, the closed liquid cooling system 15, and the gas-liquid-heat exchanger 17 are all parts of the propulsion unit.

20 The support section 26 of the shell structure 1 may be provided with an opening 18 for allowing water surrounding the propulsion unit to flow through opening 18 in the shell structure 1, when the propulsion unit is at least partly immersed in water. Such opening 18 may be closed with covering parts 36 provided with apertures 37 for enabling water surrounding the propulsion unit to enter the opening 18 via the apertures 37 and correspondingly for enabling water in the  
25 opening 18 to exit the opening via the apertures 37. It is alternatively possible that such opening 18 may be closed with covering parts 36 so that apertures 37 for enabling water surrounding the propulsion unit to enter the opening 18 via the apertures 37 and correspondingly for enabling water in the opening 18 to exit the opening via the apertures 37 is formed.

30 The lower end of the support section 26 of the shell structure 1 may be connected to the motor housing section 9 of the shell structure 1 so that an opening 18 is formed in the support section 26 of the shell structure 1. Such opening 18 may be closed with covering parts 36 provided with apertures 37 for

enabling water surrounding the propulsion unit to enter the opening 18 via the apertures 37 and correspondingly for enabling water in the opening 18 to exit the opening via the apertures 37. It is alternatively possible that such opening 18 may be closed with covering parts 36 so that apertures 37 for enabling water surrounding the propulsion unit to enter the opening 18 via the apertures 37 and correspondingly for enabling water in the opening 18 to exit the opening via the apertures 37 is formed.

The lower end of the support section 26 of the shell structure 1 may be connected to the motor housing section 9 of the shell structure 1 so that an opening 18 is formed between the support section 26 of the shell structure 1 and the motor housing section 9 of the shell structure 1 and so that a cylindrical part 19 of the cylindrical outer surface 11 of the cylindrical section 10 of the motor housing section 9 forms a part of an outermost surface (not marked with a reference numeral) of the propulsion unit, as is the case in the first embodiment of the propulsion unit shown in figures 1 to 13, in the second embodiment of the propulsion unit shown in figures 14 to 17, and in the third embodiment of the propulsion unit shown in figures 18 to 21. The outermost surface is at least partly in contact with water surrounding the propulsion unit, when the propulsion unit is at least partly immersed in water. Such opening 18 may be closed with covering parts 36 provided with apertures 37 for enabling water surrounding the propulsion unit to enter the opening 18 via the apertures 37 and correspondingly for enabling water in the opening 18 to exit the opening via the apertures 37. It is alternatively possible that such opening 18 may be closed with covering parts 36 so that apertures 37 for enabling water surrounding the propulsion unit to enter the opening 18 via the apertures 37 and correspondingly for enabling water in the opening 18 to exit the opening via the apertures 37 is formed.

Such cylindrical part 19 of the cylindrical outer surface 11 of the cylindrical section 10 of the motor housing section 9 may be provided with projecting heat-exchanging elements 20 for enhancing transfer of thermal energy between the electric motor 3 in the cylindrical section 10 of the motor housing section 9 and water surrounding the cylindrical part 19 of the cylindrical section 10 of the motor housing section 9, as is shown in figure 5.

In the propulsion unit, the closed liquid cooling system 15 may be in the form of a closed liquid tank 21 forming said inner space containing liquid 16, as is the case in the third embodiment of the propulsion unit shown in figures 18 to 21, in the ninth embodiment of the propulsion unit shown in figures 56 to 59, and in the tenth embodiment of the propulsion unit shown in figures 60 and 61. Closed liquid tank 21 means in this context that no liquid or other fluids such as

gases is during use of the closed liquid tank 21 for cooling purposes let in or let of from the closed liquid tank 21.

Such closed liquid tank 21 may be partly limited by the cylindrical outer surface 11 of the cylindrical section 10 of the motor housing section 9 so that liquid 16 in the closed liquid tank 21 is in direct contact with the cylindrical outer surface 11 of the cylindrical section 10 of the motor housing section 9 for exchanging thermal energy between the electrical motor arranged in the cylindrical section 10 of the motor housing section 9 and liquid 16 in the closed liquid tank 21 via the cylindrical section 10 of the motor housing section 9, as is the case in the ninth embodiment of the propulsion unit shown in figures 56 to 59, and in the tenth embodiment of the propulsion unit shown in figures 60 and 61.

Such closed liquid tank 21 may be partly limited by the support section 26 of the shell structure 1 of the propulsion unit so that liquid 16 in the closed liquid tank 21 is in direct contact with the support section 26 of the shell structure 1 of the propulsion unit for exchanging thermal energy between liquid 16 in the closed liquid tank 21 and water surrounding the support section 26 of the shell structure 1 of the propulsion unit via the shell structure 1 of the propulsion unit, as is the case in the third embodiment of the propulsion unit shown in figures 18 to 21, in the ninth embodiment of the propulsion unit shown in figures 56 to 59, and in the tenth embodiment of the propulsion unit shown in figures 60 and 61.

If the closed liquid cooling system 15 is in the form of a closed liquid tank 21 forming said inner space containing liquid 16, the gas-liquid-heat exchanger 17 may be formed by ducts 22 in fluid communication with the closed gas circulation cooling system 12 so that the ducts 22 extends through the closed liquid tank 21 for leading gas 13 circulating in the closed gas circulation cooling system 12 in said ducts 22 through the closed liquid tank 21 and for exchanging thermal energy between gas 13 flowing in said ducts 22 and liquid 16 in the closed liquid tank 21, as is the case in the third embodiment of the propulsion unit shown in figures 18 to 21, in the ninth embodiment of the propulsion unit shown in figures 56 to 59, and in the tenth embodiment of the propulsion unit shown in figures 60 and 61.

If the closed liquid cooling system 15 is in the form of a closed liquid tank 21 forming said inner space containing liquid 16, inner surface of the closed liquid tank 21 may be provided with projecting heat exchanging elements 32 projecting from the support section 26 of the shell structure 1 of the propulsion unit into the closed liquid tank for enhancing transfer of thermal energy between liquid 16 in the inner space of the closed liquid tank 21 and water surrounding the shell structure of the propulsion unit.

In the propulsion unit, the closed liquid cooling system 15 may be in the form of a closed liquid circulation cooling system 24 containing liquid 16 and forming said inner space containing liquid 16 and provided with liquid circulation means 25 for circulating liquid 16 in the inner space of the closed liquid circulation cooling system 24, as is the case in the first embodiment of the propulsion unit shown in figures 1 to 13, in the second embodiment of the propulsion unit shown in figures 14 to 17, in the fourth embodiment of the propulsion unit shown in figures 22 to 28, in the fifth embodiment of the propulsion unit shown in figures 29 to 35, in the sixth embodiment of the propulsion unit shown in figures 36 to 42, in the seventh embodiment of the propulsion unit shown in figures 43 and 49, in the eleventh embodiment of the propulsion unit shown in figures 62 to 68, and in the twelfth embodiment of the propulsion unit shown in figures 69 to 72.

The closed liquid circulation cooling system 24 may be partly formed by a tube section 33 having an outer surface 34 that is in direct contact with water surrounding the propulsion unit for exchanging thermal energy between liquid 16 circulating in the closed liquid circulation cooling system 24 and water surrounding the propulsion unit via the tube section 33 of the closed liquid circulation cooling system 24, as is the case in the eleventh embodiment of the propulsion unit shown in figures 62 to 68, and in the twelfth embodiment of the propulsion unit shown in figures 69 to 72. The tube section 33 may include a part in the form of a coiled tube.

If the closed liquid circulation cooling system 24 is partly formed by a tube section 33, the tube section 33 may be a part of a liquid-liquid-heat exchanger 38 that is in fluid communication with the closed liquid cooling system 15 so that liquid circulating in the inner space of the closed liquid cooling system 15 circulates through the tube section 33 of the liquid-liquid-heat exchanger 38 for exchanging thermal energy between liquid flowing through the tube section 33 of the liquid-liquid-heat exchanger 38 and water in contact with the tube section 33 of the liquid-liquid-heat exchanger 38 and surrounding the shell structure 1 of the propulsion unit.

The inner space of such closed liquid circulation cooling system 24 may be partly limited by the support section 26 of the shell structure 1 of the propulsion unit so that liquid 16 flowing in the inner space of the closed liquid circulation cooling system 24 is in direct contact with the support section 26 of the shell structure 1 for exchanging thermal energy between liquid 16 flowing in the inner space of the closed liquid circulation cooling system 24 and water surrounding the support section 26 of the shell structure 1 via the support section

26 of the shell structure 1.

The inner space of such closed liquid circulation cooling system 24 may additionally be partly limited by a part 31 of the cylindrical outer surface 11 of the cylindrical section 10 of the motor housing section 9 so that liquid 16 flowing in the inner space of the closed liquid circulation cooling system 24 is in direct contact with said part 31 of the cylindrical outer surface 11 of the cylindrical section 10 of the motor housing section 9 for exchanging thermal energy between the electric motor 3 arranged in the cylindrical section 10 of the motor housing section 9 and liquid 16 flowing in the inner space of the closed liquid circulation cooling system 24 via said part 31 of the cylindrical section 10 of the motor housing section 9 between the electric motor 3 and liquid 16 circulating in the inner space of the closed liquid circulation cooling system 24, as is the case in the fourth embodiment of the propulsion unit shown in figures 22 to 28, in the fifth embodiment of the propulsion unit shown in figures 29 to 35, in the sixth embodiment of the propulsion unit shown in figures 36 to 42, in the seventh embodiment of the propulsion unit shown in figures 43 to 49, and in the eight embodiment of the propulsion unit shown in figures 50 to 55.

Said part 31 of the cylindrical outer surface 11 of the cylindrical section 10 of the motor housing section 9 in contact with liquid 16 in the inner space of the closed liquid circulation cooling system 24 may be provided with partition elements 27 for creating several individual flows of liquid 16 along said part 31 of the cylindrical outer surface 11 of the cylindrical section 10 of the motor housing section 9, as is shown in figures 26, 33, 40, and 47.

Said part 31 of the cylindrical section 10 of the cylindrical outer surface 11 of the motor housing section 9 in contact with liquid 16 in the closed liquid cooling system 15 may be provided with projecting heat-exchanging elements for enhancing transfer of thermal energy between the electric motor 3 in the motor housing section 9 and liquid 16 in the closed liquid cooling system 15, as is shown in figures 25, 32, 39, and 46.

If the closed liquid cooling system 15 is in the form of a closed liquid circulation cooling system 24, the closed liquid circulation cooling system 24 may be provided with a first liquid tank 28, having a first inner space (not marked with a reference numeral) that forms a part 31 of the inner space of the closed liquid circulation cooling system 24, as is the case in the fifth embodiment of the propulsion unit shown in figures 29 to 35, in the sixth embodiment of the propulsion unit shown in figures 36 to 42, and in the eight embodiment of the propulsion unit shown in figures 50 to 55.

Such first liquid tank 28 is in fluid communication with the closed liquid

circulation cooling system 24 such that liquid 16 flowing in the closed liquid circulation cooling system 24 flows through the first inner space of the first liquid tank 28. The first inner space of the first liquid tank 28 is partly limited by said part 31 of the cylindrical outer surface 11 of the cylindrical section 10 of the motor housing section 9 so that liquid 16 in a first inner space of the first liquid tank 28 is in direct contact with the cylindrical outer surface 11 of the cylindrical section 10 of the motor housing section 9 for exchanging thermal energy between the electric motor 3 arranged in the motor housing section 9 and liquid 16 flowing in the first inner space of the first liquid tank 28 via said part 31 of the cylindrical outer surface 11 of the cylindrical section 10 of the motor housing section 9.

If the closed liquid circulation cooling system 24 is provided with a first liquid tank 28, the first liquid tank 28 may be additionally partly limited by the support section 26 of the shell structure 1 so that liquid 16 in the first inner space of the first liquid tank 28 is additionally in direct contact with the support section 26 of the shell structure 1 for exchanging thermal energy between liquid 16 flowing in the first inner space of the first liquid tank 28 of the closed liquid circulation cooling system 24 and water surrounding the support section 26 of the shell structure 1 via the support section 26 of the shell structure 1, as is the case in the fifth embodiment of the propulsion unit shown in figures 29 to 35, in the sixth embodiment of the propulsion unit shown in figures 36 to 42, and in the eight embodiment of the propulsion unit shown in figures 50 to 55.

If the closed liquid circulation cooling system 24 is provided with a first liquid tank 28, the first liquid tank 28 being provided with baffles 29 for guiding liquid 16 through the first liquid tank 28 to prolong the residence time of liquid 16 in the first liquid tank 28 and/or for serving as heat exchanging elements between liquid 16 flowing through the first liquid tank 28 and the support section 26 of the shell structure 1, as is the case in the fifth embodiment of the propulsion unit shown in figures 29 to 35, and in the sixth embodiment of the propulsion unit shown in figures 36 to 42.

If the closed liquid circulation cooling system 24 is provided with a first liquid tank 28, the gas-liquid-heat exchanger 17 can be formed by ducts 22 in fluid communication with the closed gas circulation cooling system 12, wherein the ducts 22 extends through the first liquid tank 28 for leading gas 13 circulating in the closed gas circulation cooling system 12 in said ducts 22 through the first liquid tank 28 and for exchanging thermal energy between gas 13 flowing in said ducts 22 through the first liquid tank 28 and liquid 16 in the first liquid tank 28, as in the eight embodiment of the propulsion unit shown in figures 50 to 55.

If the closed liquid cooling system 15 is in the form of a closed liquid

circulation cooling system 24, the closed liquid circulation cooling system 24 may be provided with a second liquid tank 30 having a second inner space (not marked with a reference numeral) that forms a part of the inner space of the closed liquid circulation cooling system 24, as is the case in the first embodiment of the propulsion unit shown in figures 1 to 13, in the fifth embodiment of the propulsion unit shown in figures 29 to 35, and in the seventh embodiment of the propulsion unit shown in figures 43 to 49.

Such second liquid tank 30 is in fluid communication with the closed liquid circulation cooling system 24 such that liquid 16 flowing in the closed liquid circulation cooling system 24 flows through the second inner space of the second liquid tank 30. The second liquid tank 30 being partly limited by the support section 26 of the shell structure 1 so that liquid 16 in the second inner space (not marked with a reference numeral) of the second liquid tank 30 is in direct contact with the support section 26 of the shell structure 1 for exchanging thermal energy between liquid 16 flowing in the second inner space of the second liquid tank 30 and water surrounding the support section 26 of the shell structure 1 via the support section 26 of the shell structure 1.

If the closed liquid circulation cooling system 24 is provided with a second liquid tank 30, the second inner space of the second liquid tank 30 may be provided with baffles 29 for guiding liquid 16 through the second inner space of the second liquid tank 30 to prolong the residence time of liquid 16 in the second inner space of the second liquid tank 30 and/or for serving as heat exchanging elements between liquid 16 flowing through the second inner space of the second liquid tank 30 and the support section 26 of the shell structure 1, as is the case in the fifth embodiment of the propulsion unit shown in figures 29 to 35, and in the seventh embodiment of the propulsion unit shown in figures 43 to 49.

If the closed liquid circulation cooling system 24 is provided with a second liquid tank 30, the gas-liquid-heat exchanger 17 can be formed by ducts 22 in fluid communication with the closed gas circulation cooling system 12, wherein the ducts 22 extends through the second liquid tank 30 for leading gas 13 circulating in the closed gas circulation cooling system 12 in said ducts 22 through the second liquid tank 30 and for exchanging thermal energy between gas 13 flowing in said ducts 22 through the second liquid tank 30 and liquid 16 in the second liquid tank 30 as in the second embodiment of the propulsion unit shown in figures 14 to 17.

In the propulsion unit the lower end of the support section 26 of the shell structure 1 may be connected to the motor housing section 9 of the shell structure 1 so that the cylindrical outer surface 11 of the cylindrical section 10 of the motor

housing section 9 of the shell structure 1 of the propulsion unit partly forms the outermost surface of the propulsion unit, as is shown in the figures. In such case the part 31 of the cylindrical outer surface 11 of the cylindrical section 10 of the motor housing section 9 forming the outermost surface of the propulsion unit may be provided with projecting heat-exchanging elements 20 for enhancing transfer of thermal energy between the electric motor 3 in the motor housing section 9 and water surrounding the part 31 of the cylindrical outer surface 11 of the cylindrical section 10 of the motor housing section 9 forming the outermost surface of the propulsion unit.

The gas-liquid-heat exchanger 17 can be a separate heat exchanger in fluid connection with the closed gas circulation cooling system 12 and in fluid connection with the closed liquid cooling system 15 as is the case in the first embodiment of the propulsion unit shown in figures 1 to 13, in the fourth embodiment of the propulsion unit shown in figures 22 to 28, in the fifth embodiment of the propulsion unit shown in figures 29 to 35, in the sixth embodiment of the propulsion unit shown in figures 36 to 42, and in the seventh embodiment of the propulsion unit shown in figures 43 to 49.

The cylindrical section 10 of the motor housing section 9 is preferably, but not necessarily, of a single-layer construction, as is illustrated in the figures. It is however obvious for a person skilled in the art that the cylindrical outer surface 11 of the cylindrical section 10 of the motor housing section 9 can for example additionally be painted.

The closed liquid cooling system 15 is preferably, but not necessarily, arranged at least partly enclosed by the shell structure 1 of the propulsion unit. The closed liquid cooling system 15 is more preferably, but not necessarily, arranged fully enclosed by the shell structure 1 of the propulsion unit, as is illustrated in the figures.

The closed gas circulation cooling system 12 is preferably, but not necessarily, arranged at least partly enclosed by the shell structure 1 of the propulsion unit. The closed gas circulation cooling system 12 is more preferably, but not necessarily, arranged fully enclosed by the shell structure 1 of the propulsion unit, as is illustrated in the figures.

The gas-liquid-heat exchanger 17 is preferably, but not necessarily, arranged at least partly enclosed by the shell structure 1 of the propulsion unit. The gas-liquid-heat exchanger 17 is more preferably, but not necessarily, arranged fully enclosed by the shell structure 1 of the propulsion unit, as is illustrated in the figures.

The closed liquid cooling system 15 is preferably, but not necessarily,

arranged fully outside the hull of the ship, as is illustrated in the figures.

The closed gas circulation cooling system 12 is preferably, but not necessarily, arranged fully outside the hull of the ship, as is illustrated in the figures.

5 The gas-liquid-heat exchanger 17 is preferably, but not necessarily, arranged fully outside the hull of the ship, as is illustrated in the figures.

The electric motor 3 is preferably, but not necessarily, an induction electric motor 3.

10 It is apparent to a person skilled in the art that as technology advances, the basic idea of the invention can be implemented in various ways. The invention and its embodiments are therefore not restricted to the above examples, but they may vary within the scope of the claims.

## Claims

1. A ship's propulsion unit such as a ship's azimuthing propulsion unit, wherein the propulsion unit comprising

a shell structure (1) arranged below a hull (2) of the ship and immersible at least partly in water so that the shell structure (1) is at least partly surrounded by water, and

an electric motor (3) for rotating a propeller (4) outside the shell structure (1),

wherein the electric motor (3) having a stator (5) and a rotor (6) for rotating in the stator (5),

wherein the electric motor (3) is arranged in a motor housing section (9) of the shell structure (1) so that the stator (5) of the electric motor (3) is form-fitted into a cylindrical section (10) of the motor housing section (9) of the shell structure (1),

wherein the cylindrical section (10) having a cylindrical outer surface (11), and

wherein the shell structure (1) includes a support section (26) having an lower end connected to the motor housing section (9) of the shell structure (1) and an upper end connected to the hull (2) of the ship,

### **characterized**

by a closed gas circulation cooling system (12) containing gas (13) and comprising gas circulation means (14) for circulating gas (13) through channels (23) in the electric motor (3), wherein the channels are formed by at least one of channels (23) in the rotor (6) of the electric motor (3) and a channel (23) formed by an air gap between the stator (5) and the rotor (6) of the electric motor (3),

by a closed liquid cooling system (15) having an inner space containing liquid (16),

by a gas-liquid-heat exchanger (17) in fluid connection with the closed gas circulation cooling system (12) and in fluid connection with the closed liquid cooling system (15) for exchanging thermal energy between gas (13) circulating in the closed gas circulation cooling system (12) and liquid (16) in the closed liquid cooling system (15), and

by the closed gas circulation cooling system (12), the closed liquid cooling system (15), and the gas-liquid-heat exchanger (17) being parts of the propulsion unit.

2. The propulsion unit according to claim 1, **characterized**

by the inner space of the closed liquid cooling system (15) being partly limited by the shell structure (1) of the propulsion unit so that liquid (16) in the

inner space of the closed liquid cooling system (15) being in direct contact with the shell structure (1) of the propulsion unit for exchanging thermal energy between liquid (16) in the closed liquid cooling system (15) and water surrounding the propulsion unit via the shell structure (1) of the propulsion unit

3. The propulsion unit according to claim 1 or 2, **characterized**

by the lower end of the support section (26) of the shell structure (1) being connected to the motor housing section (9) of the shell structure (1) so that an opening (18) for allowing water surrounding the propulsion unit to flow through opening (18) in the shell structure (1) is formed in the support section (26) of the shell structure (1).

4. The propulsion unit according to claim 3, **characterized**

by the lower end of the support section (26) of the shell structure (1) being connected to the motor housing section (9) of the shell structure (1) so that the opening (18) in the support section (26) of the shell structure (1) is formed between the support section (26) of the shell structure (1) and the motor housing section (9) of the shell structure (1) and so that a cylindrical part (19) of the cylindrical outer surface (11) of the cylindrical section (10) of the motor housing section (9) forms a part of an outermost surface of the propulsion unit, which outermost surface is at least partly in contact with water surrounding the propulsion unit.

5. The propulsion unit according to any of the claims 1 to 4, **characterized**

by the closed liquid cooling system (15) being in the form of a closed liquid tank (21) forming said inner space containing liquid (16).

6. The propulsion unit according to claim 5, **characterized**

by the closed liquid tank (21) being partly limited by the cylindrical outer surface (11) of the cylindrical section (10) of the motor housing section (9) so that liquid (16) in the closed liquid tank (21) is in direct contact with the cylindrical outer surface (11) of the cylindrical section (10) of the motor housing section (9) for exchanging thermal energy between the electrical motor arranged in the cylindrical section (10) of the motor housing section (9) and liquid (16) in the closed liquid tank (21) via the cylindrical section (10) of the motor housing section (9).

7. The propulsion unit according to claim 5 or 6, **characterized**

by the closed liquid tank (21) being partly limited by the support section (26) of the shell structure (1) of the propulsion unit so that liquid (16) in the closed liquid tank (21) is in direct contact with the support section (26) of the shell structure (1) of the propulsion unit for exchanging thermal energy between liquid (16) in the closed liquid tank (21) and water surrounding the support section (26) of the shell structure (1) of the propulsion unit via the shell structure (1) of the propulsion unit.

8. The propulsion unit according to any of the claims 1 to 4, **characterized**

by the closed liquid cooling system (15) being in the form of a closed liquid circulation cooling system (24) containing liquid (16) and forming said inner space containing liquid (16) and provided with liquid circulation means (25) for circulating liquid (16) in the inner space of the closed liquid circulation cooling system (24).

9. The propulsion unit according to claim 8, **characterized**

by the closed liquid circulation cooling system (24) being partly formed by a tube section (33) having an outer surface (34) that is in direct contact with water surrounding the propulsion unit for exchanging thermal energy between liquid (16) circulating in the closed liquid circulation cooling system (24) and water surrounding the propulsion unit via the tube section (33) of the closed liquid circulation cooling system (24).

10. The propulsion unit according to claim 9, **characterized**

By the tube section (33) being a part of a liquid-liquid-heat exchanger (38) that is in fluid communication with the closed liquid cooling system (15) so that liquid circulating in the inner space of the closed liquid cooling system (15) circulates through the tube section (33) of the liquid-liquid-heat exchanger (38) for exchanging thermal energy between liquid flowing through the tube section (33) of the liquid-liquid-heat exchanger (38) and water in contact with the tube section (33) of the liquid-liquid-heat exchanger (38) and surrounding the shell structure (1) of the propulsion unit.

11. The propulsion unit according to any of the claims 8 to 10, **characterized**

by the inner space of the closed liquid circulation cooling system (24) being partly limited by the support section (26) of the shell structure (1) of the propulsion unit so that liquid (16) flowing in the inner space of the closed liquid circulation cooling system (24) is in direct contact with the support section (26) of the shell structure (1) for exchanging thermal energy between liquid (16) flowing in the inner space of the closed liquid circulation cooling system (24) and water surrounding the support section (26)

of the shell structure (1) via the support section (26) of the shell structure (1).

12. The propulsion unit according to any of the claims 8 to 11, **characterized**

by the inner space of the closed liquid circulation cooling system (24) being partly limited by a part (31) of the cylindrical outer surface (11) of the cylindrical section (10) of the motor housing section (9) so that liquid (16) flowing in the inner space of the closed liquid circulation cooling system (24) is in direct contact with said part (31) of the cylindrical outer surface (11) of the cylindrical section (10) of the motor housing section (9) for exchanging thermal energy between the electric motor (3) arranged in the cylindrical section (10) of the motor housing section (9) and liquid (16) flowing in the inner space of the closed liquid circulation cooling system (24) via said part (31) of the cylindrical section (10) of the motor housing section (9) between the electric motor (3) and liquid (16) circulating in the inner space of the closed liquid circulation cooling system (24).

13. The propulsion unit according to claim 12, **characterized** by said part (31) of the cylindrical outer surface (11) of the cylindrical section (10) of the motor housing section (9) in contact with liquid (16) in the inner space of the closed liquid circulation cooling system (24) being provided with partition elements (27) for creating several individual flows of liquid (16) along said part (31) of the cylindrical outer surface (11) of the cylindrical section (10) of the motor housing section (9).

14. The propulsion unit according to any of the claims 8 to 13, **characterized**

by the closed liquid circulation cooling system (24) is provided with a first liquid tank (28),

by the first liquid tank (28) having a first inner space that forms a part of the inner space of the closed liquid circulation cooling system (24),

by the first liquid tank (28) being in fluid communication with the closed liquid circulation cooling system (24) such that liquid (16) flowing in the closed liquid circulation cooling system (24) flows through the first inner space of the first liquid tank (28), and

by the first inner space of the first liquid tank (28) being partly limited by said part (31) of the cylindrical outer surface (11) of the cylindrical section (10)

of the motor housing section (9) so that liquid (16) in a first inner space of the first liquid tank (28) is in direct contact with the cylindrical outer surface (11) of the cylindrical section (10) of the motor housing section (9) for exchanging thermal energy between the electric motor (3) arranged in the motor housing section (9) and liquid (16) flowing in the first inner space of the first liquid tank (28) via said part (31) of the cylindrical outer surface (11) of the cylindrical section (10) of the motor housing section (9).

15. The propulsion unit according to claim 14, **characterized** by the first liquid tank (28) being additionally partly limited by the support section (26) of the shell structure (1) so that liquid (16) in the first inner space of the first liquid tank (28) is additionally in direct contact with the support section (26) of the shell structure (1) for exchanging thermal energy between liquid (16) flowing in the first inner space of the first liquid tank (28) of the closed liquid circulation cooling system (24) and water surrounding the support section (26) of the shell structure (1) via the support section (26) of the shell structure (1).

16. The propulsion unit according to any of the claims 8 to 15, **characterized** by the closed liquid circulation cooling system (24) being provided with a second liquid tank (30),

by the second liquid tank (30) having a second inner space that forms a part of the inner space of the closed liquid circulation cooling system (24),

by the second liquid tank (30) being in fluid communication with the closed liquid circulation cooling system (24) such that liquid (16) flowing in the closed liquid circulation cooling system (24) flows through the second inner space of the second liquid tank (30), and

by the second liquid tank (30) being partly limited by the support section (26) of the shell structure (1) so that liquid (16) in the second inner space of the second liquid tank (30) is in direct contact with the support section (26) of the shell structure (1) for exchanging thermal energy between liquid (16) flowing in the second inner space of the second liquid tank (30) and water surrounding the support section (26) of the shell structure (1) via the support section (26) of the shell structure (1).

17. The propulsion unit according to any of the claims 8 to 16, **characterized**

by the gas-liquid-heat exchanger (17) being a separate heat exchanger in fluid connection with the closed gas circulation cooling system (12) and in fluid connection with the closed liquid cooling system (15) for exchanging thermal

energy between gas (13) circulating in the closed gas circulation cooling system (12) and liquid (16) in the closed liquid cooling system (15).

18. The propulsion unit according to any of the claims 1 to 17, **characterized** by the lower end of the support section (26) of the shell structure (1) being connected to the motor housing section (9) of the shell structure (1) so that the cylindrical outer surface (11) of the cylindrical section (10) of the motor housing section (9) of the shell structure (1) of the propulsion unit partly forms the outermost surface of the propulsion unit, which outermost surface is at least partly in contact with water surrounding the propulsion unit.

19. The propulsion unit according to any of the claims 1 to 18, **characterized** by the cylindrical section (10) of the motor housing section (9) being of a single-layer construction.

20. The propulsion unit according to any of the claims 1 to 19, **characterized**  
by the closed liquid cooling system (15) being arranged at least partly enclosed by the shell structure (1) of the propulsion unit,  
by the closed gas circulation cooling system (12) being arranged at least partly enclosed by the shell structure (1) of the propulsion unit, and  
by the gas-liquid-heat exchanger (17) being arranged at least partly enclosed by the shell structure (1) of the propulsion unit.

21. The propulsion unit according to any of the claims 1 to 20, **characterized**.  
by the closed liquid cooling system (15) being arranged fully outside the hull (2) of the ship,  
by the closed gas circulation cooling system (12) being arranged fully outside the hull (2) of the ship, and  
by the gas-liquid-heat exchanger (17) being arranged fully outside the hull (2) of the ship.