



- (51) **International Patent Classification:**
B63H 23/32 (2006.01) *F16J 15/46* (2006.01)
- (21) **International Application Number:**
PCT/FI2010/050993
- (22) **International Filing Date:**
2 December 2010 (02.12.2010)
- (25) **Filing Language:** Finnish
- (26) **Publication Language:** English
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- (81) **Designated States** (unless otherwise indicated, for every
kind of national protection available): AE, AG, AL, AM,
AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ,

CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO,
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SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ,
UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

- (84) **Designated States** (unless otherwise indicated, for every
kind of regional protection available): ARIPO (BW, GH,
GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG,
ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ,
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MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,
TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW,
ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

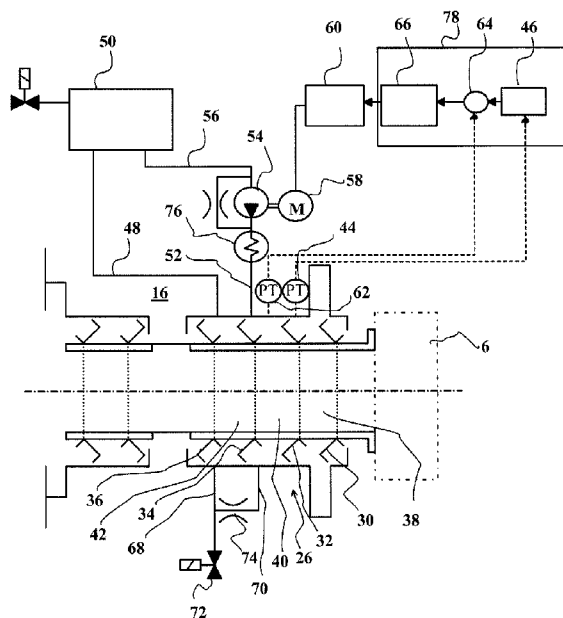
(54) **Title:** SEAL ARRANGEMENT FOR A PROPELLER SHAFT AND METHOD FOR SEALING A PROPELLER SHAFT

Fig. 2

(57) **Abstract:** The invention relates to an arrangement and method for sealing the propeller shaft (10) of a ship using sealing (26), which sealing (26) comprises a group of lip seals (30, 32, 34, 36), arranged consecutively in the direction of the propeller shaft (10) so that a seal chamber (38, 40, 42) is created between adjacent lip seals. The pressure of the first seal chamber (38) on the propeller (6) side is close to the pressure of the surrounding water at the propeller shaft (19) level and the pressure of the second seal chamber (42) furthest from the propeller (6) is adjusted to a fixed value that is lower than the pressure of the first seal chamber (38). The pressure of the third chamber (40) located between the first chamber (38) and the second chamber (42) is adjustable by pressure regulation devices to a value between the pressure values of the first (38) and the second chamber (42) by adjusting the pressure loss caused by the flow of the liquid medium.

SEAL ARRANGEMENT FOR A PROPELLER SHAFT AND METHOD FOR SEALING A PROPELLER SHAFT

The invention relates to an arrangement for sealing a propeller shaft of a ship according to the preamble part of Claim 1, and a method for sealing the propeller shaft of a ship according to the preamble part of Claim 6.

The propeller of a ship or a corresponding large watercraft is supported by bearings against the body of the ship or the propulsion unit. The propeller shaft has an arrangement of shaft seals between the body and the shaft to prevent the surrounding water from entering the body, and an arrangement of bearing seals on both sides of the bearing to prevent the bearing lubricant from leaking into the water or inside the body. The shaft seals must retain their sealing properties for as long as possible, as their reliability is of primary importance for the operation of the propulsion system and the reliability of the bearings that support the shaft. The shaft seals are located below the water surface, which means that hydrostatic pressure is directed at them. The shaft seals consist of several lip seals with seal chambers between them. This arrangement aims at distributing the total pressure differential into parts with the additional method of adjusting the pressure in the chambers by feeding air into the chambers or by connecting the chamber to an oil tank to keep the seal chamber pressure at the desired level through the hydrostatic pressure of the oil based on the force of gravity. Particularly in electric rudder propeller systems, in which the available space is very limited, all additional devices related to the shaft sealing system result in substantial space issues when using existing shaft sealing systems.

The service life of a shaft seal is affected by many factors, all of which must be brought to the best possible level. The most important factors affecting the performance and service life of the seal are the pressure differential over the lip seal, the temperature of the contact surface between the seal and the shaft, the circumferential speed of the outer surface of the shaft and the chemical impact of the lubricant affecting the seal material. The joint effect of these factors must be at an adequate and acceptable level to enable the seal to achieve its maximum service life according to its design.

The use of environmentally friendly oils, that is, biodegradable oils, sets additional requirements as their properties are more sensitive to factors such as the operating temperature.

A solution is known from the patent publication US 5,683,278 in which compressed air is used to adjust the pressure in the chambers between the seals.

The purpose of the invention is to create a new shaft sealing system, particularly suitable for limited spaces, which maintains the optimal conditions at the lip seal and maximizes the service life of the seals. The arrangement according to the invention is characterized by the features specified in the characteristics section of Claim 1. The method according to the invention is characterized by the features specified in the characteristics section of Claim 6. Other preferred embodiments of the invention are characterized by the features defined in the dependent claims.

10 An embodiment according to the invention lengthens the service life of the seal through the optimization of the operational conditions. The adjustment of the pressure in the internal chambers of the sealing system keeps the pressure differential over the lip seals as low as possible, making it optimal for the service life during the entire operational life of the system. The heat output created at the seal is transferred by the circulating oil into the frame of the rudder propeller device and further into the sea water, keeping the temperature at the seal adequately low.

The medium used to pressurize the internal chamber cools the seal interfaces to the temperature range that is optimal for the seal performance. The cooling effect particularly makes more effective the utilization of biodegradable oils, as their properties are particularly sensitive to high temperatures. Thus the solution offers better conditions for the use of environmentally friendly oils.

In applications in which the shaft sealing is located within the body of the ship or the propulsion unit, away from the immediate vicinity of the shaft and the body, the water surrounding the ship does not necessarily cool the seal adequately. An embodiment according to the invention brings the cooling to an adequate level reliably and at low costs.

The invention enables the creation of optimal conditions for the seal in varying operational environments. As the draft of the ship changes, the pressure in the seal chambers is regulated so that the pressure differential over each lip seal is as low as possible. As the temperature of the environment, particularly the temperature of the water surrounding the propeller device, varies, the temperature of the seal contact surfaces can thus be kept as low as possible. Furthermore, the pressure in the chambers can be regulated according to the

pressure of the surrounding water when the pressure variation is due to the operation of the ship. This will mainly concern CRP drives (Contra-Rotating Propeller drives) in which the pressure affecting the shaft line varies according to the ship operation condition.

5 An embodiment according to the invention introduces advantages related to manufacturing and production engineering. The same system suits many, even all, types of watercraft. An embodiment according to the invention can utilize standard seals, which guarantees availability and quality. The number of components required by the solution is small, resulting in lower costs and easier accommodation into the limited space of a rudder propeller device. The system can be designed into a modular composition, achieving benefits for the
10 assembly and maintenance phases and the acquisition of raw materials. The system also includes measurement and adjustment devices which facilitate more effective condition monitoring, creating better prerequisites for life cycle management.

In the following, the invention will be described in more detail with the help of certain embodiments by referring to the enclosed drawings, where

- 15 - Figure 1 illustrates a propeller system in which the sealing arrangement according to the invention is applied, and
- Figure 2 illustrates a sealing arrangement according to the invention.

Figure 1 is a partial schematic illustration of a ship's propulsion unit 2, comprising a propulsion unit with an implementation of an arrangement according to the invention. The
20 propulsion unit is a steering propeller device, which is attached to the ship body with a turning bearing arrangement. Such a steering propeller device is known, for example, by the product name AZIPOD®, which is a trade mark owned by ABB Oy. An electric motor 8 operating the propeller 6 is mounted inside the casing 4 of the propulsion unit 2. In this embodiment, the electric motor 8 is a synchronous motor with exciter 12 mounted to the
25 propeller shaft 10 in a well-known way. The propeller shaft 10 is supported against the casing 4 of the propulsion unit 2 at both ends. Figure 1 only illustrates the bearing 14 at the propeller end 6, comprising a roller bearing. At the other end of the electric motor 8 another bearing is used in a known manner.

The propulsion unit casing 4 comprises an intermediate compartment 16 on the propeller 6
30 side between the propeller 6 and bearing 14. The walls of the intermediate compartment 16

comprise the wall 18 on the propeller side, the outer circumference 20 of the propulsion unit end and the support structure 22 of the bearing 14. The propeller shaft 10 passes through the intermediate compartment 16 at the center of it. At the bearing end of the intermediate compartment 16 there is the outer oil seal 24 of the bearing, preventing bearing lubricating oil from leaking out of the bearing housing. Correspondingly, at the motor end of the bearing 14 there is the inner oil seal 25 of the bearing. Shaft sealing 26 is fitted at the propeller end of the intermediate compartment 16, preventing surrounding water from entering the intermediate compartment 16. The intermediate compartment 16 is thus completely sealed, and in normal operating conditions, it is also free of any liquid. The shaft sealing 26 is fitted inside the closed intermediate compartment, enabling replacement of the sealing within the compartment.

Figure 2 is a schematic illustration of the details of the shaft sealing 26 as well as the pressurization and lubrication system. The shaft sealing 26 consists of four lip seals 30, 32, 34 and 36 which are fitted consecutively in the direction of the shaft 10 so that chambers 38, 40 and 42 remain between adjacent lip seals. The pressure on outside of the lip seal 30 is the pressure resulting from the draft of the ship, for example 0.4–1.0 bar. The first chamber 38 closest to the propeller 6 is limited by the lip seals 30 and 32. The pressure on both sides of the contact surface of the lip seal 30 is essentially the same. The pressure in the first chamber 38 is constantly measured by the sensor 44. The measurement data is taken into the control unit 78. The control unit's 78 programming includes a PI controller 66, error variable management 64 and reference pressure measurement data processing 46. The control unit utilizes a software implementation, which is an inexpensive solution with no separate components. The first chamber is filled with water or oil, and its pressure essentially corresponds to the pressure of the surrounding water on the shaft line. The second chamber 42 of the shaft sealing 26, located furthest away from the propeller, is between the lip seals 34 and 36. The pressure in the second chamber is slightly higher than the air pressure in the intermediate compartment 16. The pressure in the second chamber is, for example, in the order of 0.1 bar, which pressure differential thus exists over the contact surface of the lip seal 36. The second chamber 42 is connected by a pipe 48 to the oil tank 50, which uses the force of gravity to keep the pressure of the second chamber stable at its rated value.

Between the first and the second chamber there is a third chamber 40, limited between the lip seals 32 and 34 and their contact surfaces facing the shaft. The third chamber 40 is con-

5 nected to the oil tank 50 using a pipe 52, pump 54 and pipe 56. The pressure of the third chamber 40 is constantly regulated by the motor 58 operating the pump 54. The motor is controlled by a frequency converter 60. Pressure regulation devices are used to keep the pressure of the third chamber 40 at a value that corresponds to the pressure differential between the first and the second chamber so that the pressure differentials over the contact surfaces of the lip seals 32 and 34 are roughly the same. If the pressure in chamber 42, for example, is 0.1 bar and the pressure in the first chamber 38 depending on the draft is 0.7 bar, the pressure of the third chamber 40 is regulated at approximately 0.4 bar using the pump 54.

10 The pressure of the third chamber 40 is measured by a sensor 62. The measurement data is taken to the control unit 78. The PI controller 66 of the control unit calculates the rotation speed instruction to be sent to the frequency converter 60 based on the pressure measurement data 62 and 44. The second and third chambers are connected to a tank by discharge pipes 68 and 70 through a valve 72. A choker 74 is installed to the discharge pipe 70 for

15 flow regulation. The choker is designed according to the maximum temperature of the seal chamber. The pressure regulation devices of this embodiment thus consist of a pump 54 and flow regulation choker 74. The operation of the pressure regulation devices is based on the pressure loss created by the choker 74 or another flow valve, due to the flow rate produced by the adjustable pump 54. The pressure loss created by the choker depends on the

20 oil flow rate. The desired pressure in chamber 40 can thus be achieved by regulating the rotation speed of the pump by a frequency converter. Below the pump 54 the oil flow passes through a heat exchanger 76, which enables an efficient cooling function being achieved as a pressure regulation by-product through a simple arrangement. When the oil is warm and has low viscosity, the desired pressure in chamber 40 can only be achieved

25 through a high flow rate. Due to the high flow rate, the cooling power is also at its best. When the oil is cold, the desired pressure can be achieved with a significantly lower flow rate. This means the oil that is already cool is not cooled unnecessarily. The heat exchanger may comprise, for example, a box that lies against the propulsion device frame, transferring the heat directly into the surrounding sea water. Alternatively, the oil tank can be located in the propulsion unit in an advantageous manner so that the tank is in contact with

30 the surrounding water.

The described regulation system effectively keeps the pressures and temperature of the shaft sealing chambers within their rated values, ensuring the longest possible service life.

At the same time, the use of biodegradable oils becomes possible without compromising the functionality of the sealing.

The intermediate compartment solution enables the replacement of all seals without the need for taking the watercraft to a dry dock, which makes maintenance and repair work
5 easier.

The pressure differentials over the lip seals are kept at the lowest possible level in a controlled manner as the draft of the watercraft and the weather conditions vary. As the actual pressure of the surrounding water is also constantly measured, the pressure changes due to the movements and operation of the watercraft are also taken into account, which is an im-
10 portant factor for the CRP drive.

The pressurization arrangement according to the invention is not dependent on the structure of the sealing, but can be applied to most shaft sealing arrangements. The arrangement suits different ship types and all draft levels with no need to adjust the height of the oil tank as the draft changes.

15 In summary, the arrangement requires fewer pipes, tanks, level detectors and control valves, which, together with the simple mechanical structure, lower the costs compared to a conventional system.

The arrangement includes embedded pressure and pressure level measurements and monitoring, which can be utilized for condition monitoring purposes.

20 In an alternative embodiment, a similar system can also be arranged so that a pump produces a fixed flow rate and the pressure of the seal chamber 40 is regulated so that the PI controller 66 steers an electric flow rate valve (not illustrated in the attached figures) instead of a frequency converter.

In the above the invention has been described with the help of a certain embodiment. How-
25 ever, the description should not be considered as limiting the scope of patent protection; the embodiments of the invention may vary within the scope of the following claims.

CLAIMS

1. An arrangement for sealing a propeller shaft (10) for a ship by a sealing (26), the said propeller shaft being supported against the body of the ship or propulsion unit with bearings (14), whereby the sealing (26) comprises a group of lip seals (30, 32, 34, 36) which
5 are arranged consecutively in the direction of the propeller shaft (10) so that a seal chamber (38, 40, 42) is created between adjacent lip seals, whereby the pressure of the first seal chamber (38) on the propeller (6) side is essentially close to the pressure of the surrounding water at the propeller shaft (10) level and the pressure of the second seal chamber (42) furthest from the propeller (6) is adjusted to a fixed value essentially lower than that of the
10 seal chamber (38) on the propeller side, **characterized** in that the arrangement comprises pressure regulating devices, by which the pressure of a third chamber (40), located between the chamber (38) on the propeller side and the second chamber (42) furthest from the propeller is adjustable to a value between the pressure values of the first (38) and the second chamber (42) by adjusting the pressure loss caused by the flow rate of the liquid
15 acting as a medium.
2. An arrangement according to Claim 1, **characterized** in that the pressure regulation devices are based on the pressure loss produced by a choker (74) or another flow control valve, the pressure loss being due to the flow rate produced by an adjustable pump (54).
3. An arrangement according to Claim 1, **characterized** in that the pressure regulation
20 devices are based on the pressure loss created in a separate pressure regulation valve by a fixed flow produced by a fixed displacement pump.
4. An arrangement according to any of the Claims from 1 to 3, **characterized** in that the same medium from one oil tank (50) is circulated through two or more seal chambers (38, 40, 42).
- 25 5. An arrangement according to any of the Claims from 1 to 4, **characterized** in that the medium used for pressure regulation passes through a heat exchanger (76), using the flow for cooling purposes.
6. A method for sealing a propeller shaft (10) for a ship by sealing (26), the said propeller shaft being supported against the body of the ship or propulsion unit with bearings (14), the
30 sealing (26) comprising a group of lip seals (30, 32, 34, 36) which are fitted consecutively

in the direction of the propeller shaft (10) so that a seal chamber (38, 40, 42) is created between adjacent lip seals (30, 32, 34, 36), whereby the pressure of the first seal chamber (38) on the propeller (6) side being kept essentially close to the pressure of the surrounding water at the propeller shaft level and the pressure of the second seal chamber (42) furthest from the propeller being kept at a fixed value essentially lower than that of the seal chamber (38) on the propeller side, **characterized** in that the pressure of a third chamber (40), located between the chamber (38) on the propeller side and the second chamber (42) furthest from the propeller, is constantly adjusted to a value between the pressure values of the first (38) and the second chamber (42).

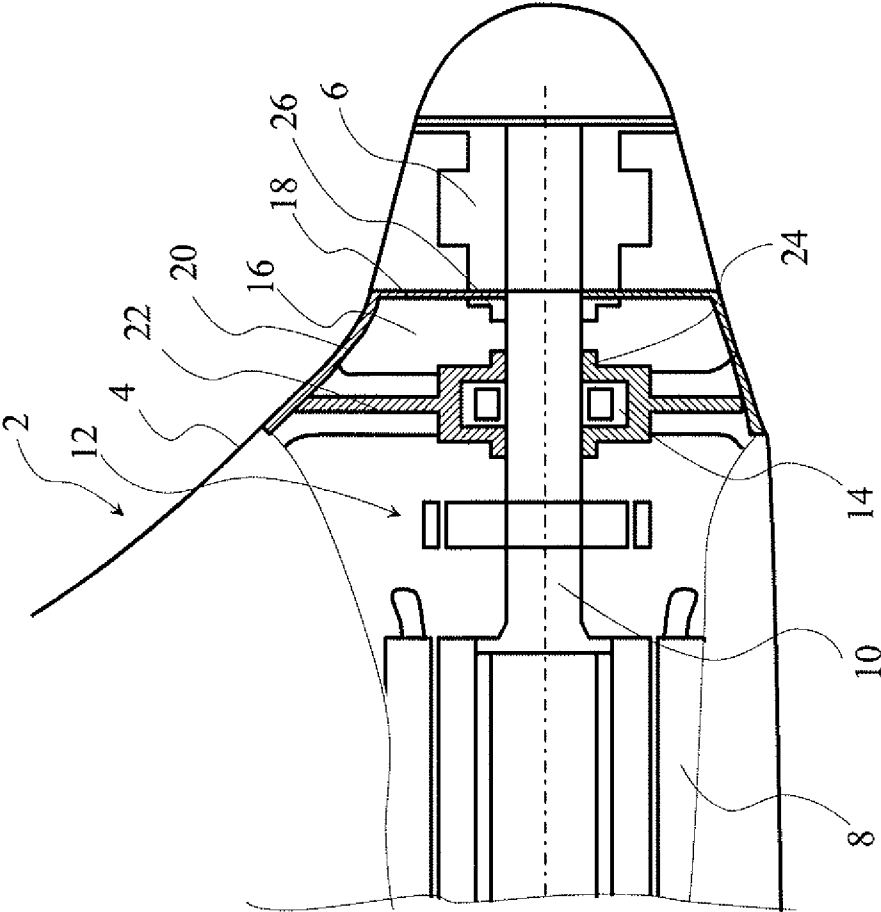


Fig. 1

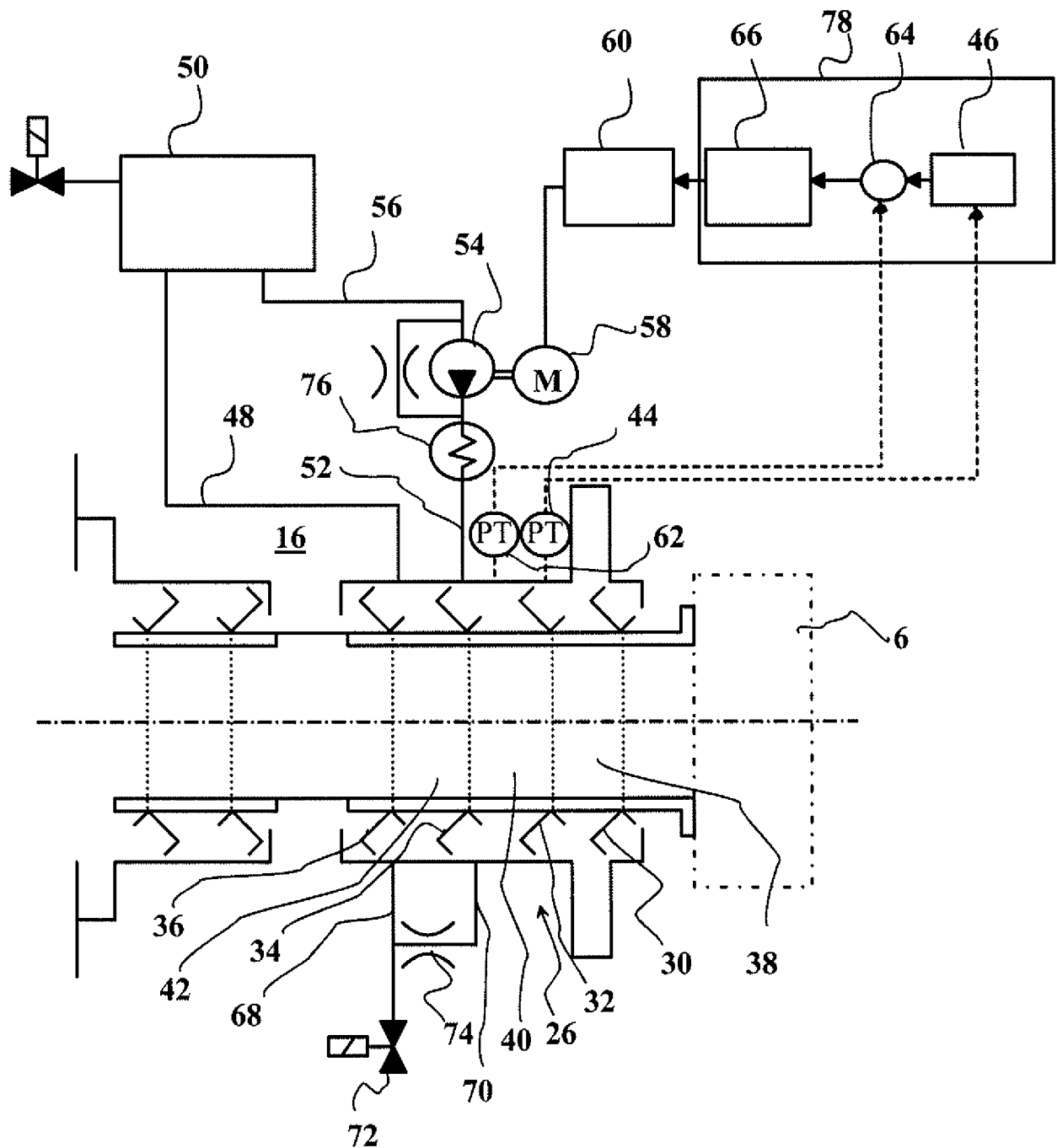


Fig. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI2010/050993

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: B63H, F16J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE, DK, FI, NO classes as above

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2003026094 A (COBELCO MARINE ENGINEERING KK), 29 January 2003 (2003-01-29); (abstract) Retrieved from: PAJ database; --	1-6
Y	EP 0480694 A1 (ELECTRICITY ASS SERVICES LTD), 15 April 1992 (1992-04-15); abstract; column 3, line 55 - column 4, line 24; column 1, line 38 - line 39; figures 3,4 --	1-6
Y	WO 0179729 A1 (RAMSAY THOMAS W), 25 October 2001 (2001-10-25); abstract; page 20, line 3 - page 21, line 11; figures 18-21 --	1-6



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Date of the actual completion of the international search

06-07-2011

Date of mailing of the international search report

22-07-2011

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INTERNATIONAL SEARCH REPORT

 International application No.
 PCT/FI2010/050993

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	DE 3817660 A1 (BLOHM VOSS AG), 7 December 1989 (1989-12-07); abstract; column 1, line 45 - line 65; figure 1 --	1-6
A	GB 2205365 A (BLOHM VOSS AG), 7 December 1988 (1988-12-07); abstract; page 1, line 21 - line 34; page 6, line 6 - line 17; figures 1,2 --	1-6
A	GB 2150234 A (HOWALDTSWERKE DEUTSCHE WERFT), 26 June 1985 (1985-06-26); abstract; page 1, line 89 - page 2, line 30; figure 1 --	1-6
A	US 5683278 A (PIETSCH GUENTER ET AL), 4 November 1997 (1997-11-04); abstract; column 1, line 52 - column 2, line 18; column 4, line 41 - line 62; figures 1,2 --	1-6
A	US 3338583 A (ISDALE JOE W), 29 August 1967 (1967-08-29); column 1, line 46 - column 2, line 14; figure 1 --	1-6
E	WO 2011062484 A2 (IHC HOLLAND IE B V ET AL), 26 May 2011 (2011-05-26); abstract; page 9, line 10 - page 11, line 6; figures 2,3 -- -----	1-6

Continuation of: second sheet

International Patent Classification (IPC)

B63H 23/32 (2006.01)

F16J 15/46 (2006.01)

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/FI2010/050993

JP	2003026094 A	29/01/2003	JP	3813842 B2	23/08/2006
EP	0480694 A1	15/04/1992	GB	2249359 A	06/05/1992
WO	0179729 A1	25/10/2001	AT	300002 T	15/08/2005
			AU	5056201 A	30/10/2001
			AU	774415 B2	24/06/2004
			BR	0110047 A	27/05/2003
			CA	2405185 A1	25/10/2001
			DE	60112067 D1	25/08/2005
			EP	1274952 A1	15/01/2003
			JP	2004501322 T	15/01/2004
			MX	PA02010132 A	19/08/2004
			US	7354046 B2	08/04/2008
			US	20050253340 A1	17/11/2005
DE	3817660 A1	07/12/1989	NONE		
GB	2205365 A	07/12/1988	DE	3718411 C2	14/08/1991
			JP	64001693 A	06/01/1989
			JP	2525225 B2	14/08/1996
			NL	193466 C	02/11/1999
			NL	8801403 A	02/01/1989
			SE	501938 C2	26/06/1995
			SE	8802046 L	03/12/1988
GB	2150234 A	26/06/1985	DE	3342297 C2	05/04/1990
			NL	8403566 A	17/06/1985
			NO	165736 B	17/12/1990
			NO	844247 A	24/05/1985
			SE	8405875 L	24/05/1985
			SE	459167 C	05/10/1989
US	5683278 A	04/11/1997	CN	1129182 A	21/08/1996
			CN	1054821 C	26/07/2000
			DE	4434261 B4	08/07/2004
			JP	2832427 B2	09/12/1998
			JP	8301186 A	19/11/1996
			NL	1001270 C2	12/11/1996
			RU	2108266 C1	10/04/1998
US	3338583 A	29/08/1967	NONE		
WO	2011062484 A2	26/05/2011	NONE		