

ABSTRACT

The invention relates to a hybrid propulsion system that comprises a main diesel engine (17) for driving the marine turbine (8) and an electric motor (15). The electric motor (15) has a nominal output that constitutes at least 20 % of the nominal output of the main diesel engine (17). The electric motor (15) remains continuously switched on and maintains, together with a variable-pitch propeller (7), the main diesel engine (17) at a favorable operating point. The combination of the main diesel engine (17) and the electric motor (17) also allows for a more economical design or operation of the propulsion system.

Description

Hybrid propulsion system for ships

5 The propulsion system for large cargo ships, for example container ships, normally provides one slow-running diesel engine for each ship propeller, with this slow-running diesel engine supplying all the propulsion power for this propeller. The propulsion
10 power of the diesel engine starts at about 10 to 15 MW. The diesel engines that are used operate on the two-stroke principle. The high power that is required and the low rated rotation speed result in a large swept volume, and thus a large physical volume with a large
15 mass.

A correspondingly large amount of space must be provided in the ship's hull for the diesel engine or, for a multishaft propulsion system, the diesel engines,
20 to be precise at a point which is located close to the stern with respect to the overall length. The engine room is located at a point which intrinsically would be particularly highly suitable for being loaded with containers. There is also a large amount of unused dead
25 space.

The heavy weight of the diesel engine means that the hull must be reinforced to a considerable extent at the relevant points.

30

As in the case of all internal combustion engines, the relative fuel consumption also varies in the case of ship diesel engines as a function of the operating point, that is to say of the rotation speed. The
35 rotation speed range which is best with regard to the fuel consumption occurs at about 85 to 90% of the rated rotation speed for which the diesel engine is designed. At lower rotation speeds, the fuel consumption is

WO 02/47974

PCT/DE01/04556

- 1a -

worse. The ship's captain must therefore keep the propulsion system as close as possible to this optimum operating point.

- 5 Variable-pitch propellers, in which the angle of the blades of the ship propeller can be controlled as a function of the torque,

provide a certain capability to vary the operating point in the direction of better fuel consumption, even in poor load situations. Nevertheless, the optimum operating point cannot be achieved in all movement
5 conditions.

In addition to the poor fuel consumption at rotation speeds below the rated rotation speed, considerable thermal loads also occur at low rotation speeds, such
10 as those which are required in the lower speed of motion range when the ship is being accelerated. In order to accelerate the ship, the diesel engine has to emit a high torque at a low rotation speed, that is to say it runs at a low rotation speed with a high
15 cylinder charge. The thermal load on the cylinder heads is correspondingly high.

Despite all these disadvantages, the ship diesel engine in container ships is used virtually exclusively, since
20 its procurement costs are very low. The diesel engine is robust and can be produced in countries with low wages, which reduces the production costs.

Besides the diesel drive for ships, it is also known
25 from practice for electric motors to be used for driving the ship propeller. The electrical power for the propeller motor is produced by means of a diesel generator system. High-speed four-stroke diesel engines can be used in this case, which have a considerably
30 better power-to-weight ratio than slow-running diesel engines. Their rotation speed is higher by a factor of approximately 4 to 10 than the rotation speed of the diesel engine for the ship propeller.

35 Furthermore, converters based on semiconductors can be used to always operate the diesel engine for the diesel generator system independently of the load at that

WO 02/47974

PCT/DE01/04556

- 2a -

rotation speed at which the fuel consumption with respect to the output power is optimum.

This propulsion system concept makes it possible to avoid thermal problems resulting from low rotation speeds and high cylinder charges.

5 The considerable advantages of an electrical propulsion system are countered by comparatively high investment costs, which are considerably greater than the costs involved for a diesel engine that drives the ship propeller directly.

10

Finally, a mixed propulsion system is known from practice, which provides a slow-running diesel engine for the ship propeller as the main propulsion device. In addition, a comparatively small electric motor is
15 coupled to the propeller shaft, as a booster. The electric motor power is at most 10% of that of the diesel engine. The booster motor is used in particular in the low rotation speed range in order to avoid thermally overloading the main propulsion system
20 diesel. A further purpose of the booster motor is to improve the control system dynamic response, for example in operating situations when the propeller is partially moving in and out of the water owing to heavy sea states.

25

Against this background, the object of the invention is to provide a ship propulsion system which is more economic overall than the known systems, to be precise from the viewpoint of fuel consumption in operation, of
30 the available useful area, as well as the investment costs for the ship's hull and the propulsion system during construction of the ship.

According to the invention, this object is achieved by
35 the ship propulsion system as claimed in claim 1.

The ship propulsion system according to the invention uses a combination of an electrical drive and a diesel

WO 02/47974

PCT/DE01/04556

- 3a -

drive for the ship propeller. The electric motor is relatively large and provides a significant proportion of the total propeller torque with respect to the

torque which is supplied by the diesel engine. Nonetheless, when considered overall, the electrical power of the electric motor is still relatively small, so that the investment costs can be kept low, compared
5 to a propulsion system operating entirely with electric motors.

The electric motor replaces, so to speak, one or more cylinders of the slow-running diesel engine, which
10 becomes correspondingly shorter and lighter, compared to a ship in which this propulsion power originates exclusively from a slow-running diesel engine. The reduction in volume and mass for the main diesel is greater than the weight and space required for the
15 electric motor and its power supply. Both the electric motor and its power supply can be accommodated in the dead space which would otherwise exist within the engine room.

20 The reduction in the space required for the main diesel engine, compared to a propulsion system in which the propulsion power is provided mainly by the slow-running diesel engine, considerably increases the cargo capacity without changing the ship dimensions.

25 Furthermore, the diesel generator system can be accommodated virtually anywhere in the ship's hull, that is to say even at points which are not particularly well suited in any case for accommodating
30 containers or other cargo.

The mixed propulsion system with the relatively high electrical propulsion power, in conjunction with the variable-pitch propeller, now also makes it possible to
35 achieve an advantageous regulated fuel consumption by the main diesel engine in virtually all operating situations.

In particular, it is possible to overcome the thermal load on the main diesel engine during starting and acceleration of the ship, thus considerably improving

the life and reducing the amount of maintenance work for the main diesel engine.

The new propulsion system concept is also suitable for conversion or upgrading of existing ships, without needing to enlarge the engine room.

By way of example, this propulsion system concept allows a seagoing ship to be converted to a ship which can pass through ice, or even to an ice-breaking cargo ship. All that is necessary for this purpose is to reinforce the hull in the appropriate areas of the bow and of the bottom of the ship, as well as the flanks, for ice operation.

Virtually no changes are required to the main diesel for the propeller shaft or shafts. In particular, the power is increased without enlarging the engine room.

The shaft system is upgraded as appropriate for the greater total propulsion power, and the additional electrical propulsion system is installed. The space required for the additional electric motor and for the diesel generator system is small with respect to the dead space available in the engine room. The additional devices can generally be accommodated without any problems.

The new propulsion concept also makes it possible to give an existing container ship or cargo ship a higher cruise speed. For this purpose, as mentioned above, the shaft system is reinforced, possibly with a variable-pitch propeller being fitted, and the propeller shaft being provided with the electric motor. In this case as well, the diesel generator system can be accommodated in the engine room or at some other point, once again without any difficulties.

A ship that has been converted in this way is able to achieve higher cruise speeds when moving freely, without any changes to the external dimensions.

5 It is also possible to use the new propulsion system concept to enlarge the cargo volume rather than to increase the cruise speed when moving freely of a cargo ship, if this is what is required. This is done by lengthening the ship's hull to correspond to the
10 desired volume. The main diesel is retained, and is assisted in the manner according to the invention by an electrical propulsion system. There is no need to enlarge the engine room in this case either, that is to say the main diesel remains in the same place. It is
15 sufficient to match the shaft system to the increased torque, to provide a variable-pitch propeller and to install the diesel generator system.

As is evident, upgrading can be carried out in one of
20 the directions mentioned above at any time comparatively easily, without any major changes being required in the area of the engine room or of the main diesel engine or engines.

25 In addition, developments of the invention are the subject matter of dependent claims. In this case, those feature combinations to which no express exemplary embodiment relates shall also be regarded as being claimed.

30

An exemplary embodiment of the subject matter of the invention is illustrated in the drawing, in which:

Figure 1 shows a ship which is equipped with the
35 hybrid propulsion system according to the invention, in the form of a highly schematic longitudinal section, and

Figure 2 shows the outline circuit diagram of the hybrid propulsion system according to the invention.

Figure 1 shows a highly schematic illustration of a container ship 1 with a ship's hull 2 and a superstructure 3. The ship's hull 2 is cut away in the area of an engine room 4. The illustration is not to
5 scale at all, with the only aim being to show the essential items.

The engine room 4 has an engine room deck 5 and is closed in the forward direction, in the direction of
10 the ship's bow, by a bulkhead 6. It is closed in the rearward direction by the corresponding stern part of the ship 1. A ship propeller 7 is arranged in a known manner in an area of the stern that is shown, and is connected to a propeller shaft 8 such that they rotate
15 together. The ship propeller 7 is what is referred to as a variable-pitch propeller, that is to say a propeller with propeller blades 9 whose pitch can be varied. A rudder 11 is fitted downstream from the propeller 9, such that it can swivel.

20

The propeller shaft 8 passes through a propeller shaft pipe 12, which is supported by means of at least one support 13 in the interior of the ship. The propeller shaft pipe 12 is followed by a radial bearing 14, which
25 is likewise mounted on the engine room deck 5 and is used to absorb some of the radial force of the ship's shaft 8. As it continues, seen in the direction of the bow of the ship 1, there is an electric motor 15, whose rotor shaft is formed by the propeller shaft 8.

30

The electric motor 15 may be a synchronous machine, an asynchronous machine or a DC machine. In any case, it is a slow-running motor, which preferably acts directly on the propeller shaft 8, without any intermediate
35 gearbox.

WO 02/47974

PCT/DE01/04556

- 7a -

Finally, the propeller shaft 8 is also supported by a further bearing 16, which is likewise mounted on the engine room deck 5

and absorbs the axial forces and radial forces, that is to say the thrust produced by the propeller 7.

Finally, at the end, the propeller shaft 8 is connected
5 to a slow-running main diesel engine 17, whose
crankshaft drives the propeller shaft 8 either directly
or via single-stage step-down gearing. The main diesel
engine 17 is a two-stroke diesel engine and typically
10 has a rated power of at least between 8 and 13 MW. The
present-day power range for single engines extends up
to about 70 MW for cargo ships.

A schematically indicated control drive 18 is provided
for controlling the ship propeller 7.

15

The power supply for the electric motor 15 is provided
by a diesel generator set 19 which, in the illustrated
exemplary embodiment, is arranged on a gallery deck 20
in the engine room 4. This diesel generator set 19 has
20 a diesel engine 20 as well as an electricity generator
22. The diesel engine 21 is a high-speed diesel engine
which operates on the four-stroke principle.

Two or more diesel generator sets may also be used
25 instead of a single diesel generator set 18, and are
connected in order to supply electricity depending on
the power demand.

The electric motor 15 and the main diesel engine 17
30 form a hybrid propulsion system for the ship propeller
7. The rated power of the electric motor 15 represents
at least 20 percent of the rated power that the main
diesel engine 17 can emit. This means that, when the
maximum torque is applied to the ship propeller 7,
35 approximately 20 percent of the torque is provided by
the electric motor 15, while the rest is produced by
the main diesel engine 17.

The illustration in Figure 1 is not to scale to the extent that the volume of the main diesel engine 17 is very much greater than the volume of the diesel engine 21 for the diesel generator set 18, but it would be
5 virtually impossible to show this in comparison to the main diesel engine 17.

The electric motor 15 is operated during every operating phase of the ship propulsion system and is
10 controlled overall such that the main diesel engine 17 is thermally loaded as little as possible and/or has as good a fuel consumption as possible.

The electrical equipment for operating the hybrid
15 propulsion system is shown in highly schematic form in Figure 2.

The diesel set 18 feeds its electrical power to an electrical power supply system 23. Electrical power for
20 further electrical devices is tapped off from the power supply system 23 via a switch 24. The power supply system 23 is also connected via a switch 25 to a converter 26, which produces field energy for the electric motor 15 via a cable 27. The field energy for
25 a synchronous machine is produced via a converter 28, which is likewise connected to the power supply system 23 via a switch 29. The electrical power for the electric motor 15 is measured at the input of the converter 28, and is passed to a central controller 32,
30 by means of a control line 31.

The central controller 32 uses a control line 33 to control the converter 28, and a control line 34 to control the converter 26. Via a line 35, the central
35 controller 32 also detects the rotation speed of the electric motor 15, that is to say of the propeller shaft 8.

WO 02/47974

PCT/DE01/04556

- 9a -

The central controller 32 is also connected via lines 36 to the command bridge, an alarm system, a remote maintenance device and other such devices. The central

controller 32 also determines the fuel consumption of both the main diesel engine 17 and of the diesel set 18 and controls the entire system so that the overall fuel consumption is optimized. Finally, the central
5 controller 32 also provides the control function for the control drive 18.

The hybrid propulsion system according to the invention occupies a very small amount of space in comparison to
10 the main diesel engine 17. It is therefore possible to upgrade existing seagoing ships with the hybrid propulsion system according to the invention. This upgrading is carried out without the engine room occupying any larger amount of space. The additional
15 facilities, such as the electric motor 15 and the diesel set 18, can be accommodated without any problems in the dead space in the engine room which is not used by the main diesel engine 17.

20 By way of example, it is thus possible to convert an existing seagoing ship to a ship which is capable of passing through ice, or even into an icebreaker. The propulsion power is stepped up for this purpose by additionally coupling an electric motor to the
25 respective propeller shaft. If this has not already been done, the ship propeller is converted to a variable-pitch propeller, and the additionally required diesel generator set is installed. The propeller shaft pipe and the shaft bearings may possibly need to be
30 reinforced, to match the increased propulsion power.

The bow, the bottom of the ship in the bow area and the flanks of the ship must, of course, also be reinforced for a ship which is capable of passing through ice or
35 for an icebreaker.

The hybrid propulsion system concept according to the invention also makes it possible to increase the

WO 02/47974

PCT/DE01/04556

- 10a -

propulsion power retrospectively for an existing ship, in order to achieve higher cruise speeds. This is done by converting the propulsion

system of the ship in the same way as that already explained above.

5 Finally, it is feasible to use the hybrid propulsion system according to the invention to increase the propulsion power to such an extent that it is possible to enlarge or lengthen the ship's hull in order to increase the cargo area, with the same cruise speed.

10 The propulsion system concept according to the invention can be used not just for single-shaft systems but also for multishaft systems. Furthermore, it is also feasible for the electric motor to be coupled to the propeller shaft via a gearbox rather than being
15 arranged directly on the propeller shaft. Finally, it is feasible for the electric motor to be coupled to the crankshaft of the main diesel engine, to be precise on the opposite side from the propeller shaft.

20 If single-stage gearing is connected between the electric motor and the propeller shaft, it may be possible to use an even smaller electrical machine in some circumstances. A hybrid propulsion system comprises a main diesel engine for driving the ship's
25 shaft, and an electric motor. The electric motor has a rated power which corresponds to at least 20% of the rated power of the main diesel engine. The electric motor is switched on all the time and, in conjunction with a variable-pitch propeller, ensures that the main
30 diesel engine is kept at an advantageous optimum operating point. The combination of the main diesel engine and the electrical drive thus, overall, allows more economic construction and operation.

Patent Claim

1. A ship propulsion system for seagoing ships (1),
having at least one ship propeller which is driven
5 via a propeller shaft (8), having a slow-running
main diesel engine (17) which has a predetermined
rated power and which is coupled to the propeller
shaft (8) in order to supply power to the ship
propeller (7), having an electric motor (15) which
10 has a predetermined rated power and which is
coupled to the propeller shaft (8) in order to
supply power to the ship propeller (9), having an
electricity generator system (22) for producing
electrical power for the electric motor (15), and
15 having a fast-running diesel system (21) for
driving the electricity generator system (22),
characterized in that the rated power of the
electric motor (15) is at least 20% of the rated
power of the main diesel engine (17), in that the
20 pitch of the propeller blades (9) of the ship
propeller (7) can be varied by means of a control
drive (18), and in that the ship propulsion system
has a control device (32), by means of which the
torque which is emitted from the electric motor
25 (15) and the ship propeller (7) can be controlled
such that the slow-running main diesel engine (17)
can be operated as close as possible to an optimum
operating point which can be predetermined.

Patent Claims

1. ~~A ship propulsion system for seagoing ships (1),~~
having at least one ship propeller which is driven
5 via a propeller shaft (8), having a slow-running
main diesel engine (17) which has a predetermined
rated power and which is coupled to the propeller
shaft (8) in order to supply power to the ship
propeller (7), having an electric motor (15) which
10 has a predetermined rated power and which is
coupled to the propeller shaft (8) in order to
supply power to the ship propeller (9), having an
electricity generator system (22) for producing
electrical power for the electric motor (15), and
15 having a fast-running diesel system (21) for
driving the electricity generator system (22),
characterized in that the pitch of the propeller
blades (9) of the ship propeller (7) can be varied
by means of a control drive (18), and in that the
20 ship propulsion system has a control device (32),
by means of which the torque which is to be
emitted from the electric motor (15) and the ship
propeller (7) can be controlled such that the
slow-running main diesel engine (17) can be
25 operated as close as possible to an optimum
operating point which can be predetermined.
2. The ship propulsion system as claimed in claim 1,
characterized in that a control device (32) is
30 provided in order to control the torque which is
emitted from the electric motor (15) such that the
slow-running main diesel engine (17) is operated
as close as possible to a predetermined operating
point.

35

May 09, 2003

2000P20445WO

- 14 -

7. A method for upgrading a seagoing ship with a ship propulsion system as claimed in one of claims 1 to 4, in which the ship's hull (2) is reinforced in order to make the seagoing ship capable of passing through ice.

8. ~~A method for upgrading a seagoing ship with a ship propulsion system as claimed in one of claims 1 to 4, in which the ship propeller (7) is replaced by a ship propeller (7) whose propeller blades (9) are controllable, and a control drive (18) is installed for the propeller blades (9).~~

May 09, 2003

New patent claims 8 to 11

8. A method for operating a seagoing ship which is equipped with a ship propulsion system as claimed in one of claims 1 to 7, in which, at a given ship speed without any acceleration, the electric motor (15) and the ship propeller (7) are controlled such that the total fuel requirement for the slow-running main diesel engine and for the diesel generator system (19) is minimized.
9. A method for increasing the propulsion power of an existing seagoing ship (1) having a ship propulsion system as claimed in one of claims 1 to 7, by means of at least one electric motor (15), which has at least one shaft system (7, 8, 12, 14) with a propeller shaft (8) for driving a ship propeller (7) and has at least one slow-running main diesel engine (17) for driving the propeller shaft (8), in which method an electric motor (15) is provided, whose rated power is at least 20% of the rated power of the slow-running main diesel engine (17) which is intended to be supplemented by the electric motor (15), in which a diesel generator system (19) is installed, in which the shaft system (7, 8, 12, 14) is matched to the total power of the electric motor (15) and of the slow-running main diesel engine (17), and in which an electrical control and regulation device (32) is installed, in order to control the torque which is to be emitted from the electric motor (15) to the propeller shaft (8).
10. A method for upgrading a seagoing ship with a ship propulsion system as claimed in one of claims 1 to 7, in which the ship's hull (2) is reinforced in

- 16 -

order to make the seagoing ship capable of passing through ice.

- 5 11. A method for upgrading a seagoing ship with a ship propulsion system as claimed in one of claims 1 to 2, in which the ship propeller (7) is replaced by

AMENDED SHEET

2000P20445WO
PCT/DE01/04556

DE0104556

- 17

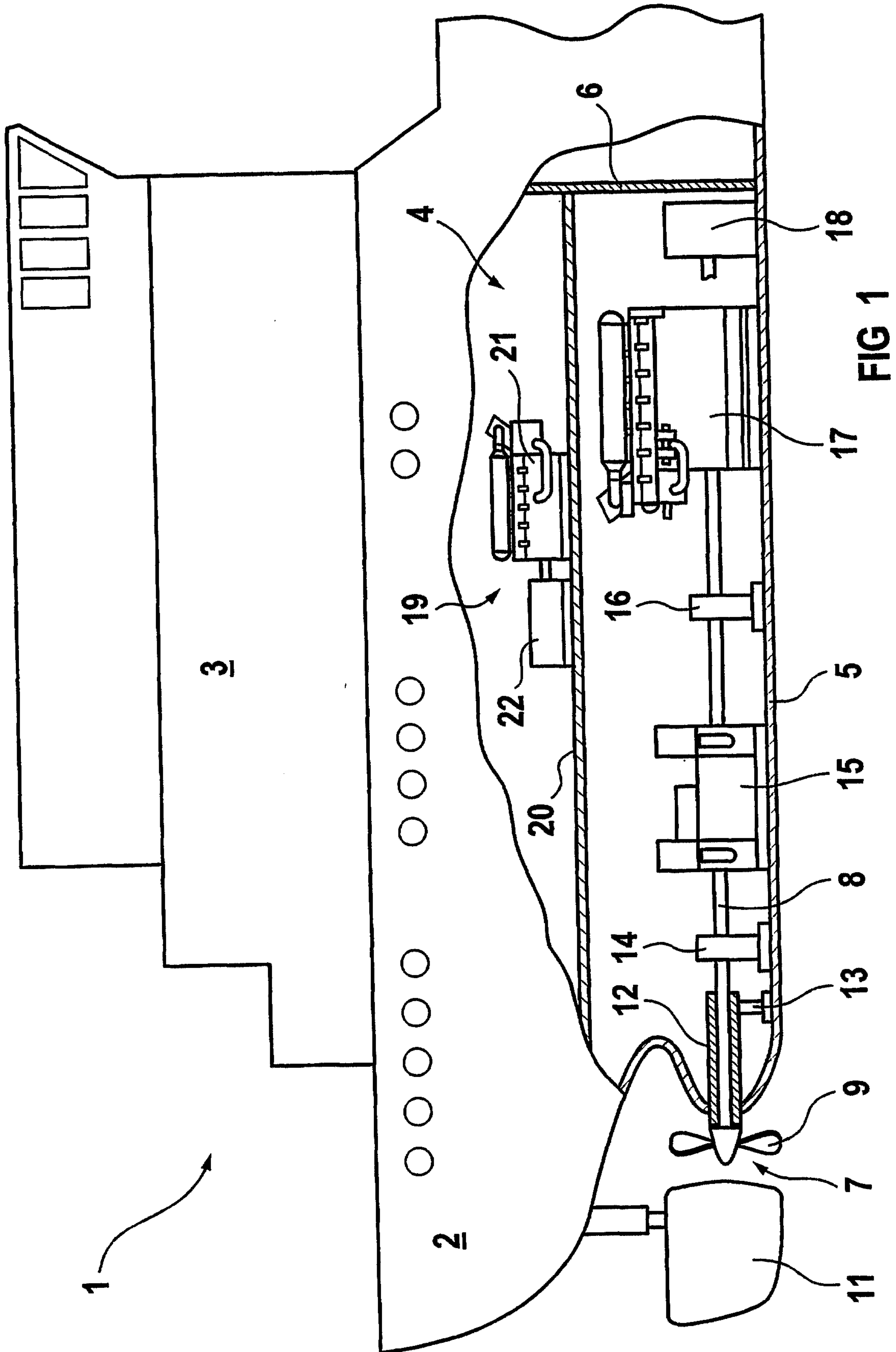
a ship propeller (7) whose propeller blades (9)
are controllable, and a control drive (18) is
installed for the propeller blades (9).

Fetherstonhaugh & Co.
Ottawa, Canada
Patent Agents

AMENDED SHEET

WO 02/47974

1/2



2 / 2

