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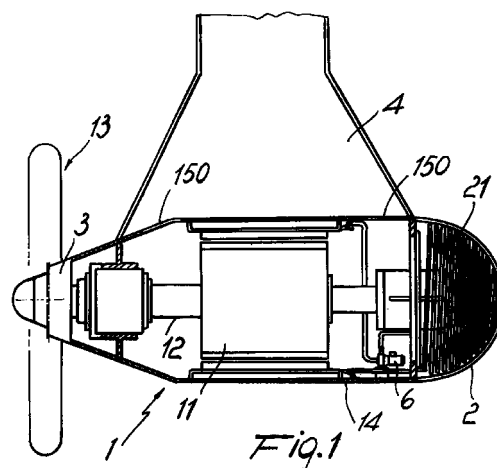
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(54) **Propulsion and steering module for naval craft**

(57) The present invention concerns a propulsion and steering module for naval craft that has the distinctive characteristic of including an innovative cooling system in which the cooling liquid circulates in the inner casing of the motor (11) without being in contact with the moving or live parts of the motor itself. The liquid is cooled using at least one heat exchanger (21) mounted in at least one end of the module.



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Description

[0001] The present invention relates to a propulsion and steering module for naval craft, in particular surface naval craft.

[0002] The use of modules for surface naval craft that simultaneously have the functions of the main propulsion unit and main steering unit is widely known in the art. See for example patent CA 1.311.657.

[0003] These modules are generally formed by a submerged pod able to rotate in relation to the longitudinal axis of the naval craft, containing inside it a conventional type of synchronous electric motor on the shaft of which at least one main propulsion propeller is mounted. Cooling is provided using a forced air system that circulates air inside the pod. This solution offers the following advantages, amongst others, compared to direct propulsion systems, whether diesel or diesel/electric: greater hydrodynamic efficiency, greater manoeuvrability even at low speeds and high turning angles, reduction of the space occupied inside the hull, elimination of rudders and related steering means, elimination of stern manoeuvring propellers and reduction of noise and vibration.

[0004] U.S. patents 5.417.597 and 5.632.658 describe combat naval craft in which the main propulsion is assigned to modules of this type. In particular, U.S. 5.417.597 describes a naval destroyer with modular construction in which the main propulsion and steering functions are assigned to a module that contains a liquid-cooled conventional-type synchronous electric motor. The way in which cooling is provided is not described. U.S.P. 5.632.658 describes a surface naval craft characterised by the fact that the propulsion is provided using a module on which tractor podded propellers are mounted. The electric motor installed in the pod and its cooling system are of conventional type. The utility model DE 29619385 describes a propulsion module characterised by having a twin propeller system driven by an electric motor and two stabilising fins positioned on the pod to improve hydrodynamic efficiency. The cooling system of the motor is not specified.

[0005] EP 590867 describes a propulsion unit in which a multiple winding synchronous motor is housed in a submerged pod and cooled using air circulated inside the pod by special ducts. The fans and heat exchangers required for the cooling are located in the hull. The technical publication "New Type of permanent field machines for diesel electric propulsion systems" (P. Anderson, U. Gragen - AES '97 - Paris, 13, 14 March 1997) describes a synchronous motor with permanent magnets for use in the propulsion unit described in DE 29619385. In accordance with that described in the article, the cooling of the motor is assigned to the wall heat exchanger between the pod casing and seawater. This system does not guarantee complete cooling of the motor, in particular its upper parts, given that the upper part of the casing is not in contact with the water but

fixed to the shank of the pod.

[0006] The main task of the present invention is to provide a propulsion and steering module for naval craft in which cooling of the motor is performed without contact with the active parts of the motor itself and is improved in relation to the conventional cooling systems. As part of this task, one object of the present invention is to provide a propulsion and steering module for naval craft in which it is possible to eliminate the ventilation ducts for cooling the power and control electronics, thus increasing the free space in the hull of the naval craft.

[0007] Another object of the present invention is to provide a propulsion and steering module for naval craft in which the number of conductors for transmitting electricity to the motor is significantly reduced compared to the case in which the cycle converter is housed inside the hull.

[0008] This task, together with these and other objects that shall emerge more clearly hereinafter are achieved by a propulsion and steering module for naval craft characterised by an innovative cooling system in which the cooling liquid circulates in the inner casing of the motor without being in contact with the active parts of the motor itself. The liquid is cooled using at least one heat exchanger mounted in at least one end of the submerged module.

[0009] A further aspect of the present invention resides in the fact that the outer casing of the central part of the pod also forms the outer casing of the motor, thus forming a highly compact propulsion module that is also easy to assemble.

[0010] A further aspect is constituted by the fact that the electrical motor is a multielectronic motor with permanent magnets.

[0011] Yet another aspect of the present invention resides in the fact that the power and control electronics (inverters) of the motor are housed in the shank of the module, since the liquid cooling system makes it possible to eliminate the bulky ventilation ducts and auxiliary equipment, freeing further space inside the hull. As a further advantage, having the inverters inside the stem makes it possible to have just two conductors (DC buses) for transmitting electricity instead of between five and eight as normally required to power the motor with the cycle converter housed inside the hull.

[0012] Yet another aspect of the present invention resides in the fact that the supporting and thrust bearings of the motor shaft are cooled by the same liquid cooling system as the motor.

[0013] Further characteristics and advantages shall emerge more clearly from the description of a number of preferred but not exclusive embodiments of the propulsion and steering module for naval craft according to the invention, illustrated purely by way of example and without limitation with the aid of the attached drawings in which:

Figure 1 shows a longitudinal section of the propulsion and steering module according to the invention;

Figure 2 shows a longitudinal section of the central part of the pod formed by the electric motor, the outer casing of which forms the outer surface of the pod itself;

Figure 3 shows a longitudinal section of the motor's cooling system;

Figure 4 shows a transverse section of the casing of the electric motor with the cooling liquid's inlet and outlet manifolds;

Figure 5 shows a cross section of the heat exchanger.

[0014] With reference to the mentioned figures, the propulsion and steering module for naval craft of the invention comprises: a watertight submerged pod 1 containing an electric motor 11 on the shaft 12 of which at least one propeller 13 is mounted; a substantially vertical support 4, the lower part of which is fixed to said pod 1 and the upper part of which is connected to the hull of said naval craft in such a way as to be able to rotate in relation to the longitudinal axis of the hull. Said pod 1 comprises: a central part 14 comprising an electric motor 11, said electric motor 11 being liquid cooled; two end parts 2 and 3, on at least one of which at least one propeller 13 is mounted and in at least one of which a heat exchanger 21 is mounted in which the cooling liquid of the motor 11 is circulated. The cooling liquid circulates by means of a pump 6, for example, housed inside the pod.

[0015] It is possible, for safety reasons, to circulate the liquid using two or more pumps that split the load in order to guarantee minimum circulation of the liquid in case of faults of one pumps. At low speeds (up to 35% of maximum speed) cooling of the motor can, however, also take place independently of operation of the pump 6.

[0016] The outer casing of the electric motor 11 appropriately defines the outer surface of the pod 1. In this case, and with reference to Figure 2, said central part 14 comprises an outer casing 15 formed by the outer casing of said electric motor 11, an inner casing 16 of said motor 11 in which a liquid cooling circuit is provided, a stator 17, a rotor 18 and a transmission shaft 12 coupled with at least one supporting bearing 120 and at least one thrust bearing 121, and means 19 for ensuring a watertight seal. In this way, given that the engine casing forms the casing of the pod itself, the latter can be mounted directly on the shank, reducing the difficulty and time required for assembly and installation. Indeed, in the systems of conventional type, the stator, rotor and, generally speaking, all the components of the motor, must be assembled inside the pod.

[0017] The stator 17 is mounted appropriately on elastic suspension 170 that makes it possible to dampen the vibration generated by the motor. It has in

fact been seen that the vibration generated by the motor and transmitted to the hull when using elastic suspension for the stator bearing is lower than the most rigorous standards.

[0018] In order to ensure that the inside of the pod can be inspected, the outer casing 15 features holes 150 that bring the inside of the pod 1 into communication with the inside of the support 4. This characteristic represents a significant advantage compared to the systems of the prior art in that it enables access to the pod, with suitable precautions, during navigation as well, something that is not possible in the systems of the prior art due to the mass of air conveyed by the forced ventilation cooling system.

[0019] The electric motor is preferably a multielectronic motor with permanent magnets. In this case, the central part 14 of the pod 1 comprises an outer casing 15 formed by the outer casing of said electric motor 11, an inner casing 16 of said motor 11 in which a liquid cooling circuit is provided and on which the magnetic units of the stator 17 are mounted as well as a rotor 18 comprising a rotor pole ring 180 with permanent magnets. A multielectronic motor with permanent magnets, for adaptation to suit requirements, is described in the publication "Novel technologies with PM-machines for ship propulsion" (M. Radaelli, L. Sozzi, P. Erhart - AES '97 - Paris, 13, 14 March 1997). This type of motor has the considerable advantage of enabling individual units with a relatively low power output compared to the total power of the motor to be put out of service, while keeping the other units in operation. This ensures operation of the motor even in the event of local faults with relatively low losses of the power supplied. Good speed of the naval craft is therefore always guaranteed. Moreover, it is possible to operate inside the pod without having to dismantle it for any repairs to one or more units. The modular construction makes it possible to obtain high efficiency (in the order of 90-95%) even at low speeds, optimising the use of the modules.

[0020] The heat exchanger can be mounted in the forward part of the pod, as shown in Figures 1 and 3, although it can also be mounted in the astern part or in both the end parts 2 and 3. The same applies to the propeller, which can be mounted on the end part 3 working in thrust, or in the end part 2 working in traction or in both.

[0021] The heat exchanger 21 can, for example, be formed by one or more tubes in contact with the inner wall of said end part 2 or 3, and/or one or more half-tubes welded on the inner wall of said end part 2 or 3. With reference to Figures 3-5, the heat exchanger is formed by a tube wound in a spiral or half-tubes welded on the inner surface of the end part 2; circulation is obtained by means of a pump 6 that sends the cool liquid through the line 40 to the manifold 100 that distributes the cool liquid in the ducts made in the inner casing 16. The manifold 200 collects the hot liquid in outlet that is sent along the line 50 to the pump 6 that then sends it

to the heat exchanger 21.

[0022] As a further preferred aspect of the present invention, the power and control electronics (inverter) of the motor are housed inside the shank 4. This is possible since the shank 4 does not feature the bulky ventilation ducts necessary in the conventional propulsion modules. The electronics can be cooled appropriately by the cooling liquid that uses the heat exchanger 21 before the liquid is sent to the motor itself.

[0023] If necessary, a further heat exchanger dedicated to cooling the electronics can be mounted on the inner surface of the stem. It may indeed be appropriate to keep the two cooling circuits separate given that the electronic components are more sensitive to temperature. As a further advantage, housing the electronics in the stem makes it possible to free further space inside the ship. In this case in fact, only the AC/DC rectifier is installed in the hull. Moreover, it becomes possible to have just two conductors (DC buses) between the fixed part (hull) and rotating part (pod and stem) for transmitting electricity compared to the five or eight required for the synchronous motors of conventional type and compared to the six required for conventional permanent magnet motors with the electronics housed in the hull.

[0024] The cooling circuit can also be used for cooling one or more supporting or thrust bearings. In the case where the electronics have a dedicated cooling circuit, the bearings are appropriately cooled by the cooling circuit of the motor.

[0025] It is possible to appropriately use common demineralised water as a cooling liquid since it is not in contact with electrically active parts in either the motor or electronics.

[0026] Using a permanent magnet multielectronic motor with a power of 8 MW at 150 rpm, with an efficiency of 95%, the pod has a maximum external diameter of approximately 2 m and a length of approximately 8 m. The dimensions, in terms of surface area, of the end part 2 are sufficient, sizing the pipe system of the heat exchanger appropriately, to cool the electric motor even with seawater temperatures of 30°C.

[0027] The propulsion and steering module for naval craft as conceived is capable of numerous modifications and variants that are all within the inventive concept; moreover, all the details may be substituted by other technically equivalent elements.

[0028] In practice, the materials used as well as the contingent dimensions and shapes can be varied without limitation to suit requirements providing they are compatible with the specific use.

Claims

1. Propulsion and steering module for naval craft comprising: a watertight submerged pod (1) containing an electric motor (11) on the shaft (12) of which at least one propeller (13) is mounted; a substantially vertical support (4), the lower part of which is fixed

to said pod (1) and the upper part of which is connected to the hull of said naval craft in such a way as to be able to rotate in relation to the longitudinal axis of the hull; characterised by the fact that said pod (1) comprises: a central part (14) comprising an electric motor (11), said electric motor (11) being liquid cooled; two end parts (2, 3), on at least one of which at least one propeller (13) is mounted and in at least one of which a heat exchanger (21) is mounted in which the cooling liquid of the motor (11) is circulated.

2. Propulsion and steering module as in claim 1 characterised by the fact that the outer casing of said electric motor (11) defines the external surface of the pod (1).
3. Propulsion and steering module as in one of the previous claims characterised by the fact that said central part (14) comprises an outer casing (15) formed by the outer casing of said electric motor (11), an inner casing (16) of said motor (11) in which a liquid cooling circuit is provided, a stator (17), a rotor (18) and a transmission shaft (12) coupled with at least one supporting bearing (120) and at least one thrust bearing (121), and means (19) for ensuring a watertight seal.
4. Propulsion and steering module as in one or more of the previous claims characterised by the fact that the heat exchanger (21) is connected to the cooling circuit made in the inner casing (16) by means of a pump (6), manifolds (100, 200) and ducts (40, 50).
5. Propulsion and steering module as in one or more of the previous claims characterised by the fact that the stator (17) is mounted on elastic suspension (170).
6. Propulsion and steering module as in one or more of the previous claims characterised by the fact that holes are provided on said outer casing (15) bringing the inside of the pod (1) into communication with the inside of the support (4).
7. Propulsion and steering module as in one or more of the previous claims characterised by the fact that said electric motor (11) is of the multielectronic type with permanent magnets.
8. Propulsion and steering module as in claim 7 characterised by the fact that the central part (14) of the pod (1) comprises an outer casing (15) formed by the outer casing of said electric motor (11), an inner casing (16) of said motor (11) in which a liquid cooling circuit is provided and on which the magnetic units of the stator (17) are mounted, as well as a rotor (18) comprising a rotor pole ring (180) with

permanent magnets.

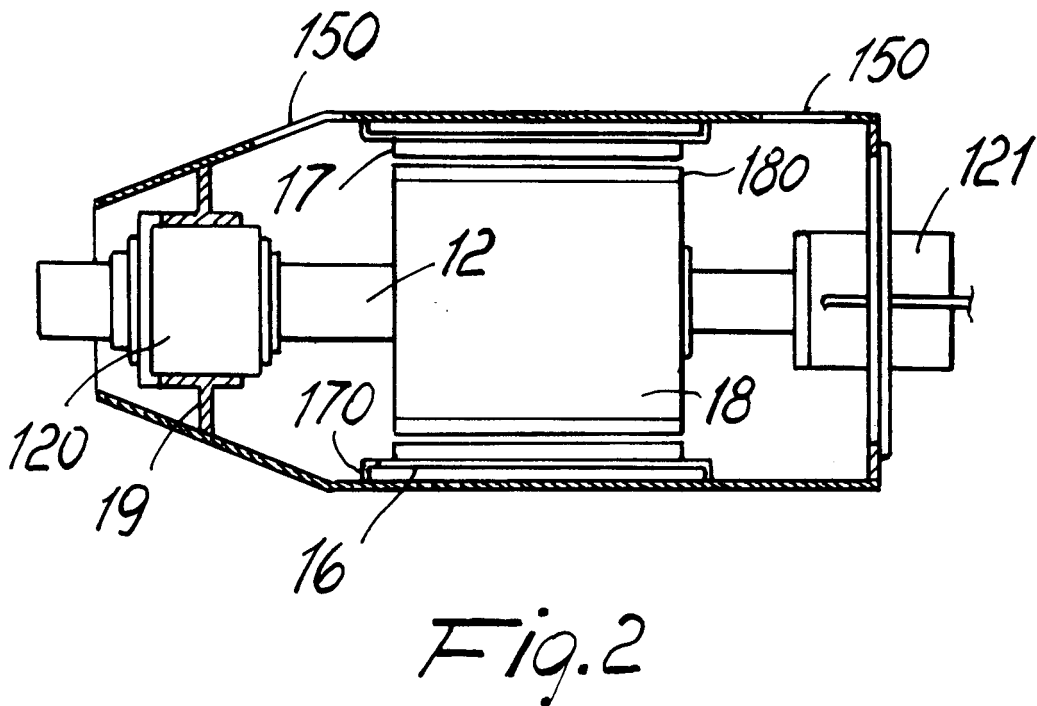
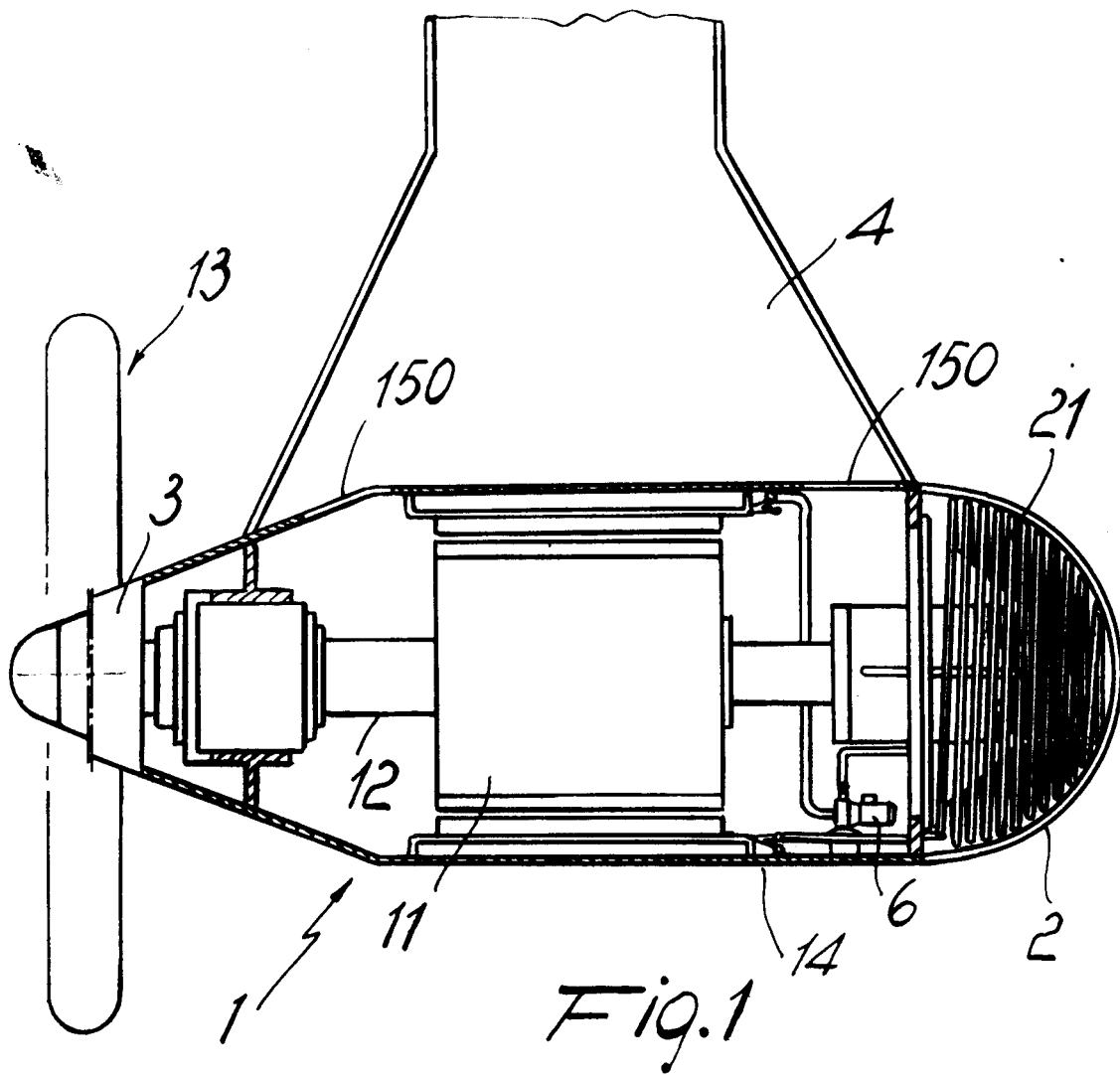
9. Propulsion and steering module as in one or more of the previous claims characterised by the fact that the heat exchanger (21) is located in the forward end part (2) of the pod (1). 5
10. Propulsion and steering module as in one or more of the previous claims characterised by the fact that the heat exchanger (21) is formed by one or more pipes in contact with the inner wall of said end part (2) or (3). 10
11. Propulsion and steering module as in one or more of claims 1 to 9 characterised by the fact that said heat exchanger (21) is formed by one or more half-pipes welded on the inner wall of said end part (2) or (3). 15
12. Propulsion or steering module as in one or more of the previous claims characterised by the fact that the electronics necessary to operate the electric motor (11) are located inside the support (4) and are cooled by the liquid cooling circuit that uses the heat exchanger (21). 20
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13. Propulsion and steering module as in one or more of the previous claims, characterised by the fact that at least one of said supporting or thrust bearings is cooled by the liquid cooling circuit that uses the heat exchanger (21). 30
14. Propulsion and steering module as in one or more of the previous claims, characterised by the fact that it comprises two cooling circuits, one for the bearings and one for the motor/electronics. 35

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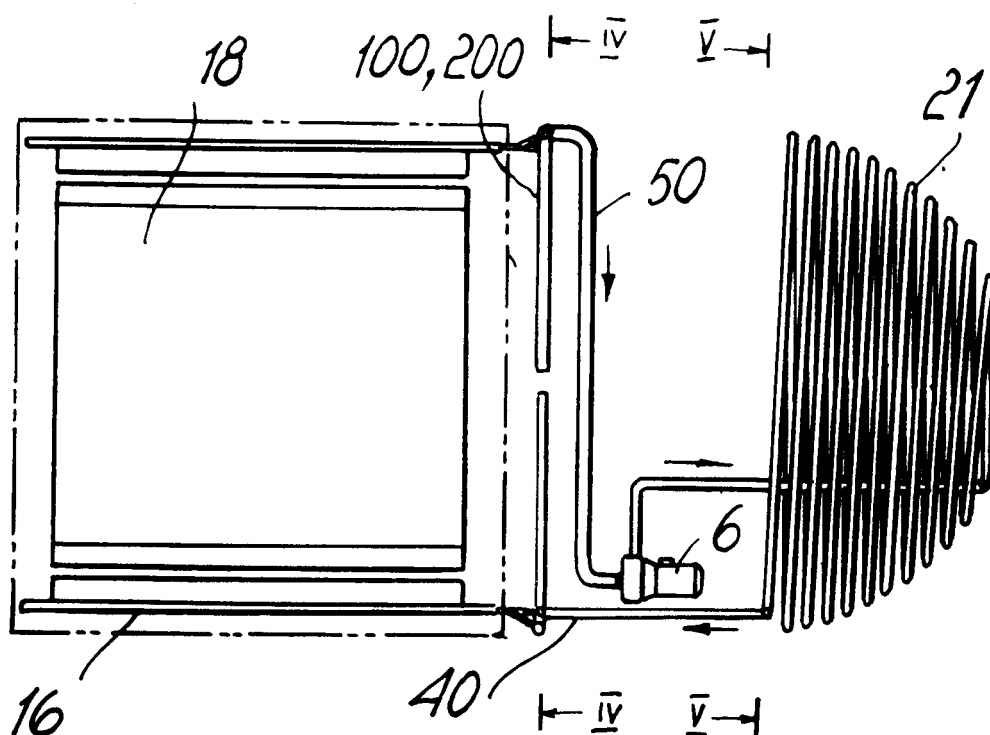


Fig. 3

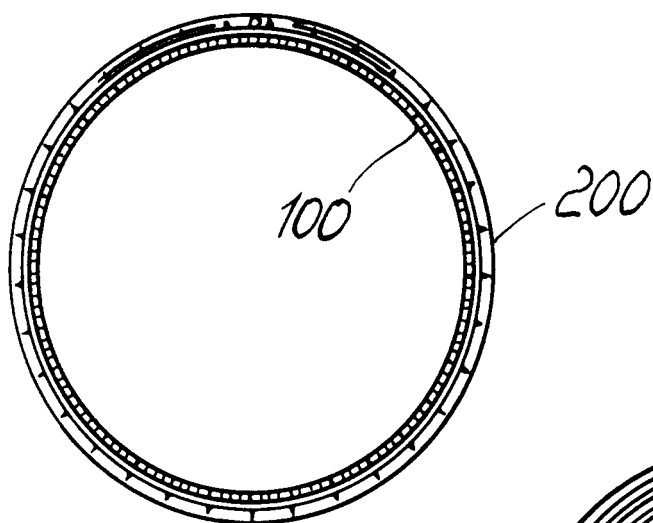


Fig. 4

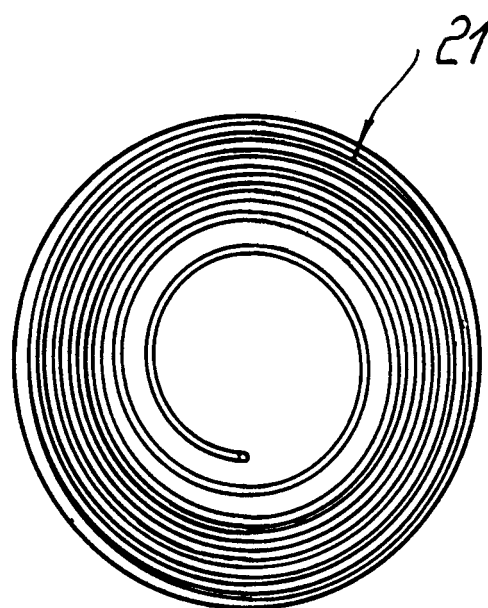


Fig. 5



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EUROPEAN SEARCH REPORT

Application Number
EP 98 20 4306

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The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 20 May 1999	Examiner DE SENA, A
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03/82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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