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(54) **Surface condenser**

(57) A vacuum surface condenser is provided including a shell (1) having a steam inlet (4) and a condensate outlet (5). A tube bundle (7) is disposed within the shell (1) and comprises individual tubes (9), each formed with a corrugated structure. The corrugated structure is defined by successive ridges (11) and grooves (12) formed on the inner (14) and outer (15) surfaces of the respective tubes (9).

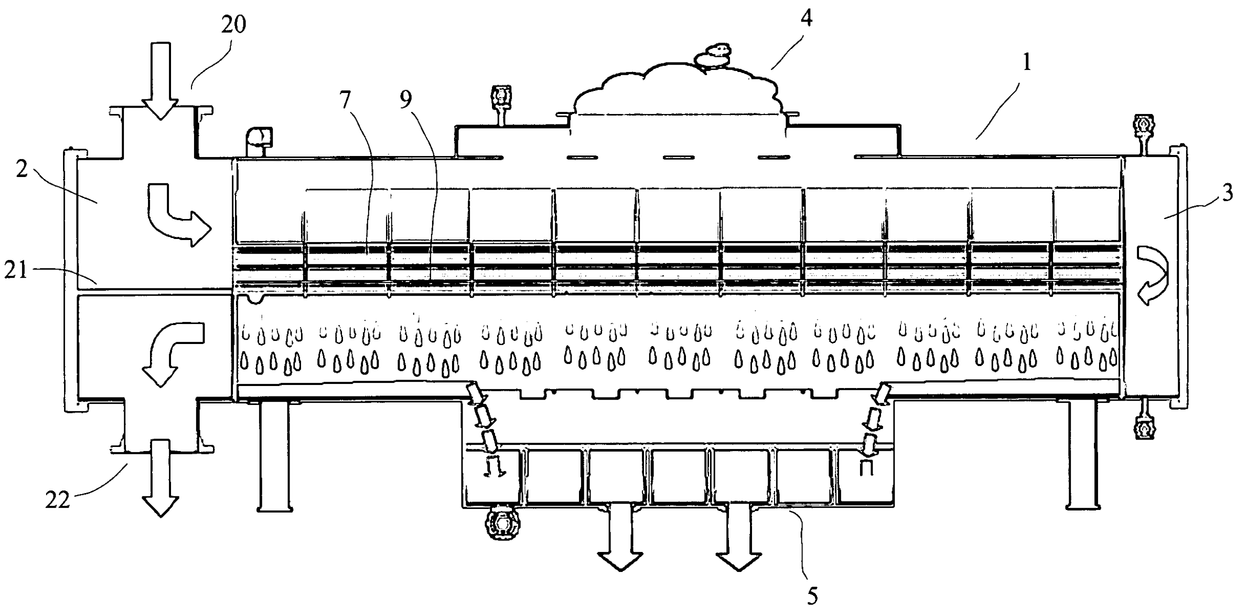

Fig. 1

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Description

[0001] The present invention relates to a surface condenser of industrial scale, in particular condensers of the type used in conjunction power plants, co-generation plants, turbo-generators in ships and the like. In particular, the invention relates to vacuum surface condensers, in which a tube bundle provides a large surface area for condensation of steam on the outer surfaces of the tubes.

[0002] The United States patent US 1,745,857 discloses a vacuum surface condenser, by which the flow of steam into the condenser and over the tube bundle is directed by a special arrangement of baffles to direct the steam passage over all axial portions of the tubes.

[0003] The object of the present invention is to improve efficiency of such vacuum surface condensers, in particular to improve the heat exchange capacity between steam and the cooling medium within the tubes. Another object of the present invention is to reduce the dimensions and weight of such surface condensers, which conventionally are very large and often difficult to transport and assemble at the plant site.

[0004] In accordance with the present invention, a surface condenser is provided as defined in claim 1. A combined cycle power plant is subject of claim 10. Embodiments of preferred embodiments are defined in the subclaims.

[0005] The present surface condenser according to claim 1 comprises a shell having water boxes at opposite ends thereof. A tube bundle is supported within the shell and extends between the water boxes, where at least a portion of the individual tubes of the tube bundle are formed with a corrugated structure.

[0006] The combined cycle power plant according to claim 10 comprises at least a steam generator, a steam turbine and a vacuum surface condenser. The vacuum surface condenser of the combine cycle power plant comprises a shell including water boxes at opposite ends thereof, and a tube bundle disposed within the shell and extending between the water boxes, wherein at least a portion of the individual tubes of the tube bundle are formed with a corrugated structure

[0007] The corrugated structure of the surface condenser is preferably formed as alternating ridges and grooves on the outer surface as well as the inner surface of the tubes. Compared to the conventional straight tubes with flat surfaces of the prior art, the present corrugated tubes offer a certain flow resistance to steam passage over the outer surfaces as well as resistance to cooling water passage within the tubes. The resulting turbulence in flow of both steam and water increases thermal efficiency of heat transfer.

[0008] The increased pressure drop across the heat exchanger in the steam flow as well as in the coolant water caused by the increased flow resistance is not substantial.

[0009] As a result, a condenser with the same thermal power rating can now be constructed with such corrugated tubes, where the dimensions and weight of the condenser is greatly reduced by 20 to 40 %. Seen in another way, when a conventional condenser with straight tubes is re-fitted with a tube bundle having corrugated tubes as defined herein, the thermal capacity can be increased on the order of 30 % or more.

[0010] The present invention can preferably be used in combined cycle power plants, that are small or medium sized and are used to produce electricity and heat. For such power plants the vacuum surface condenser according to the present invention has many advantages. One of them is that the vacuum surface condenser can be manufactured on the company area and then be transported on public roads to the location of the combined cycle power plant.

[0011] Because of this the quality of manufacturing can be enhanced and thus the quality of the vacuum surface condenser. Further the costs of manufacturing can be reduced.

[0012] Standard he vacuum surface condensers maybe replaced with new vacuum surface condensers. It is possible to upgrade older units to the new design. According to the invention a retubing, refurbishment and replacement is possible while at the same time the efficiency and power is increased.

[0013] If an old condenser is replaced by a new one according the invention, the new one maybe mounted in the factory and transported to the site of the combined cycle power plant.

[0014] A vacuum surface condenser according to the invention is preferably also used on ships as part of an auxiliary power system on a ship. The use of a vacuum surface condenser with corrugated tubes as described here makes it possible to user shorter condensers. This leaves more space for transporting goods etc. on the ship.

[0015] These and other objects and advantages of the present invention will become apparent in the following description of embodiments taken in conjunction with the drawings.

Fig. 1 shows a longitudinal section through a preferred embodiment of the condenser according to the present invention;

Fig. 2 shows a perpendicular cross section of the embodiment of Fig. 1, where the arrangement of the tubes within the tube bundle is shown;

Fig. 3 shows a detailed view of the corrugated tube design according to one embodiment of the present invention.

DESCRIPTION OF EMBODIMENTS

[0016] Fig. 1 illustrates one embodiment of the present invention, comprising an industrial scale condenser. A tube bundle 7 formed of the plurality of tubes is disposed within a shell 1 of the vacuum surface condenser. Water boxes 2, 3 are located at either end of the tube bundle for supply and discharge of cooling water.

[0017] Steam to be condensed enters the shell 1 through an upper inlet opening 4, where a vacuum is maintained within the shell 1 in the region about the tube bundle 7. Water, which condenses on the outer surfaces of the individual tubes 9, collects at the bottom of the shell 1 and discharges through the outlet opening 5.

[0018] As mentioned, such large scale condensers are frequently employed in conjunction with power generation plants, co-generation plants, etc. Cooling water enters the water box 2 through an inlet 20, where it is directed by a baffle 21 into an upper portion of the tubes 9. In water box 3 (to the left in Fig. 1), the cooling water is deflected to return through the lower lying tubes 9 of the tube bundle 7. The cooling water is then discharged from the water box 2 at the outlet 22 and in typical applications will circulate in a closed circuit. The discharged cooling water is commonly sent to a cooling tower or an air fan cooling system in closed circuit operation. Sea water or river water can alternatively be used for cooling, where available.

[0019] One preferred configuration of the tubes 9 within a tube bundle 7 is shown in Fig. 2. In this example, the shell has a length of 4 m and a diameter of 1.48 m. The shell encloses 1100 tubes each having a diameter of 25.4 mm. Cooling water is passed through the upper tubes in one direction, where water is deflected and flows in counter direction for the second pass through the lower tubes. The arrangement of the tubes in sections, with spaces there between, has been found to be particularly efficient for the condensation process.

[0020] According to the present invention, it is been found to be advantageous to provide the individual tubes 9 with a corrugated structure as shown in one embodiment in Fig. 3. The tubes are preferably formed of refined metal. The material is selected according to the water quality or source. The material may be refined steel. In the extrusion phase the tubes can be twisted to form the corrugated structure. The term 'corrugated structure' used herein is to be understood as a succession of ridges 11 and grooves 12 as seen in a longitudinal cross section of the tube 9 as shown in Fig. 3. The ridges 11 and grooves 12 can be formed as wrinkles, folds, riffles or the like.

[0021] The ridges or grooves can run smoothly in a wavelike structure, or they can have peaks and valleys, with edges. The tubes are also preferably of such a material that they can withstand operation with sea water as a cooling medium.

[0022] In the present embodiment, it is preferred that substantially all of the tubes 9 in the tube bundle 7 have such a corrugated structure, however in any case at least a portion of the tubes will have the corrugations. In the embodiment of Fig. 1, the corrugated structure extends substantially over the entire length of the tubes, although it is also possible that the corrugated structure only be provided in certain sections of the axial length of the tubes. Such sections for example would preferably be in the regions within the shell where the flow velocity of the steam is the highest.

[0023] In the presently preferred embodiment, shown in Fig. 3, the corrugations have a pitch P, defined as a distance between successive grooves 12 or between successive ridges 11. Preferably, the pitch P is uniform along the axial length of the tube, however the pitch may vary from section to section of the tube.

[0024] The configuration of the ridges and/or grooves shown in Fig. 3 defines a helical pattern, which progresses above the axis of the tube in longitudinal direction. The helical corrugations maybe arranged on the inside of the tube and/or on the outside of the tubes. The helical pattern develops as a right hand or left hand turn along the tube axis. In this embodiment, the turn is continuous in one direction. This has many advantages. One advantage is that a cleaning of the inside is accomplished by the streaming cooling medium. When other structures are used small particles can deposit on the inside of the tubes more easily. The self-cleaning effect of this embodiment is achieved by a high level of turbulence and by the helical structure. This reduces a fouling effect. Especially preferred are corrugations on the inside and the outside of the tubes and both having a helical structure.

[0025] In other embodiments the turn may be not continuous in one direction. It is possible to alternate the turn direction along the length of the tube. It is also contemplated to provide other patterns other than helical. For example, a meandering structure can be achieved by alternating the left hand and right hand turning of the tube during formation.

[0026] As is apparent in Fig. 3, both the inside surface 14 and the outer surface 15 of the tubes comprise ridges 11 and grooves 12, which causes an irregular flow of gas or fluid along the surfaces. As a consequence, cooling water flowing within the tube will create turbulence at the inside surface wall to a certain extent. Such turbulence more thoroughly mixes the cooling water at the inner wall of the tube, which has the result that the heat transfer from the coolant medium to the wall surface is more effective.

[0027] The same effect occurs on the outer surface of the respective tubes, where any gas or steam passing over the outer surface is better mixed compared to the case in the prior art, where the outer surface of the straight tubes is smooth. Although flow resistance is slightly increased through the corrugated structure, the improved heat transfer caused by the turbulence overrides the disadvantage of increased pressure drop.

[0028] In addition to developing turbulence in the respective tube side flow and shell side flow, the corrugated structure also increases the total surface area of the tubes available for heat transfer. The magnitude of the surface area increase will depend upon the dimensions of the grooves 12 and ridges 11. As will be readily understood by the skilled person, with deeper grooves and higher ridges, the total surface area available per unit length of the tube will increase.

[0029] In the embodiment shown in Fig. 3, the tube has a nominal diameter of 25.4 mm. The pitch P in this example is 18 mm. The corrugation depth T in Fig. 3 is 0.7 mm. The depth T is defined as the radial distance from the bottom of a groove 12 on the inside surface 14 of the tube to the top of the ridge 11 on the outer surface 15 of the tube. The corrugation depth T is preferably in a range of 0.5 to 0.9 mm.

[0030] For industrial scale condensers, as illustrated in the embodiment of Fig. 1, the diameter of the individual tubes is preferably in the range of 22 to 28 mm. For such tubes, and for applications, in which a regular helical pattern of the corrugation is employed, the pitch P of the helical pattern is advantageously in the range of 15 to 21 mm.

<u>EXAMPLES</u>

[0031] In the following, two examples are given of practical applications in existing power plant operations. Assuming the given power rating of the condensers, the dimensions and characteristics of a conventional condenser with plain or straight tubes is compared to the dimensions of a condenser with corrugated tubes according to the present invention. This allows a determination of the corresponding reduction of size of a condenser to achieve the same effect.

Example 1

[0032] A condenser dimensioned for a steam flow of 32 t/h at a condensation pressure of 0.068 bar is considered. Sea water is employed as the cooling medium, the inlet/outlet temperatures being 27°/32.5°C.

[0033] For this system, the total length of the conventional condenser could be reduced from 5.6 m to 4.2 m, a reduction of 25 %. The heat exchanger surface is reduced from 715 m^2 to 500 m^2, a reduction of 30 %. The overall weight of the condenser reduces from 14 t to 11 t, or is 21 % lighter.

Example 2

[0034] This condenser unit is designed for a greater steam flow capacity of 320 t/h. The condensation pressure is 0.0456 bar. Again, sea water is used as the cooling medium and the inlet/outlet temperatures are 20.4°/28.1°C.

[0035] The diameter of the condenser shell is reduced from 5.2 m to 3.6 m, a reduction of 30 %. The heat exchanger surface reduces from 10,100 m^2 to 6,700 m^2 or a reduction of 34 %. Most dramatically, the weight of the condenser unit reduces from 270 t to 140 t or is 48 % lighter.

[0036] As the skilled person can readily take from these examples, the same cooling capacity can be achieved with greatly reduced size and weight of the condenser, which is allowed by the provision of corrugated tubes throughout the entire tube bundle. The reduced size of the condenser has the further advantage of being more economical in manufacture and transportation to the plant site. Installation time and special equipment for handling of the condenser can also be minimized.

Claims

1. A vacuum surface condenser comprising a shell (1) including water boxes (2, 3) at opposite ends thereof, and a tube bundle (7) disposed within the shell (1) and extending between the water boxes (2, 3), wherein at least a portion of the individual tubes (9) of the tube bundle (7) are formed with a corrugated structure.

2. Surface condenser of claim 1, wherein substantially all of the tubes (9) of the tube bundle (7) have a corrugated structure.

3. Surface condenser of claim 1 or 2, wherein the corrugated structure extends over more than one half of the length of the tubes (9), preferably over substantially the entire length of the tubes (9).

4. Surface condenser according to any one of the claims 1 to 3, wherein the corrugated structure is defined by alternating ridges (11) and grooves (12) formed in axial direction on the inner (14) and/or the outer (15) surfaces of the respective tubes (9).

5. Surface condenser of claim 4, wherein the ridges (11) and/ or the grooves (12) define a helical pattern axially developed about the tube (9) on the inner surface (14) of the tube (9).

6. Surface condenser of claim 4 or 5, wherein the ridges (11) and/ or the grooves (12) define a helical pattern axially developed about the tube (9) on the outer surface (15) of the tube (9).

7. Surface condenser of claim 5 or 6, wherein the diameter of the tubes (9) is in range of 22 to 28 mm and the pitch (P) of the helical pattern is in the range of 15 to 21 mm.

8. Surface condenser according to any one of the claims 1 to 7, wherein the radial distance from the bottom of a groove (12) on the inside the surface (15) to the top of a ridge (11) on the outer surface (15) of the tubes is in range of 0.5 to 0.9 mm.

9. Surface condenser according to any one of the preceding claims, wherein the corrugated structure is

adapted to be cooled by sea water.

10. Surface condenser according to any one of the preceding claims, wherein the dimensions of the condenser are such that it is transportable on a van.

11. Combined cycle power plant with a at least a steam generator, a steam turbine and a vacuum surface condenser, wherein the vacuum surface condenser comprises a shell (1) including water boxes (2, 3) at opposite ends thereof, and a tube bundle (7) disposed within the shell (1) and extending between the water boxes (2, 3), wherein at least a portion of the individual tubes (9) of the tube bundle (7) are formed with a corrugated structure.

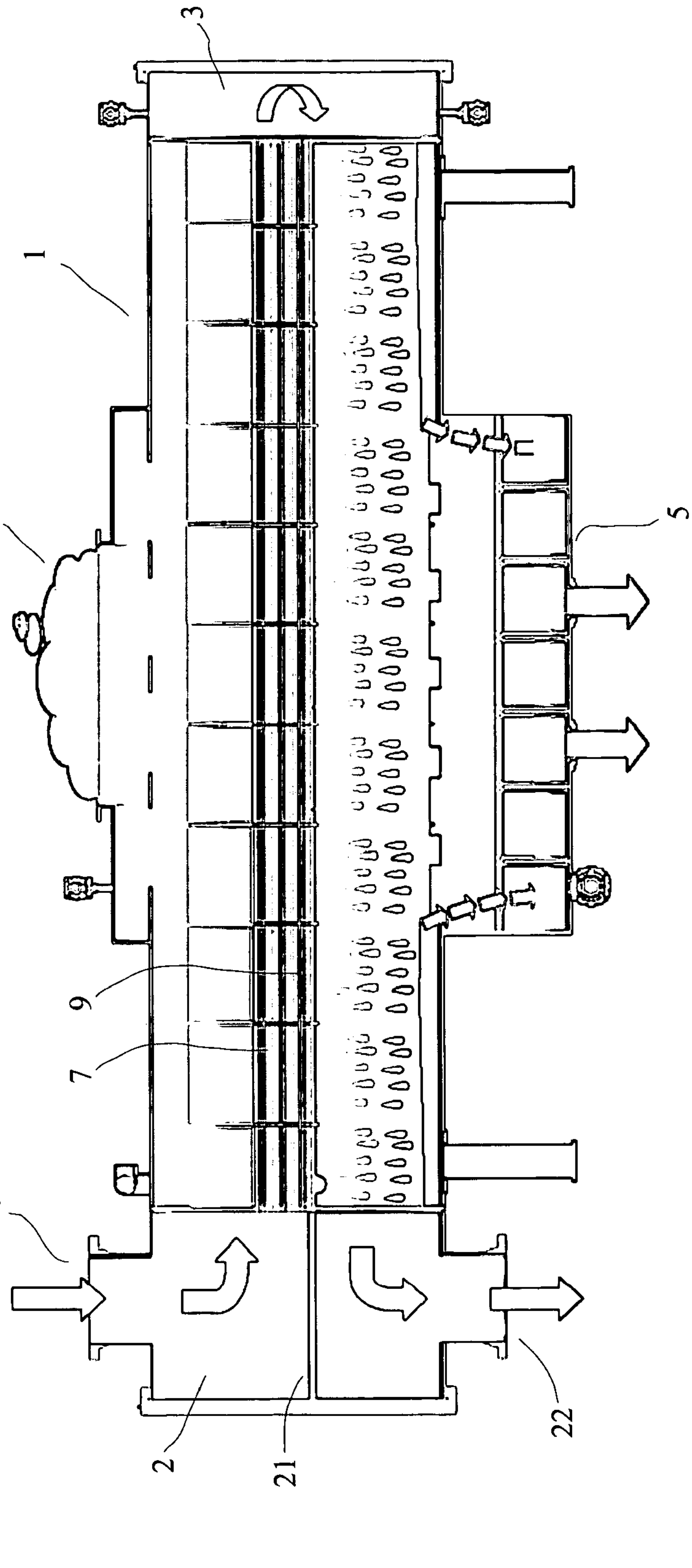

Fig. 1

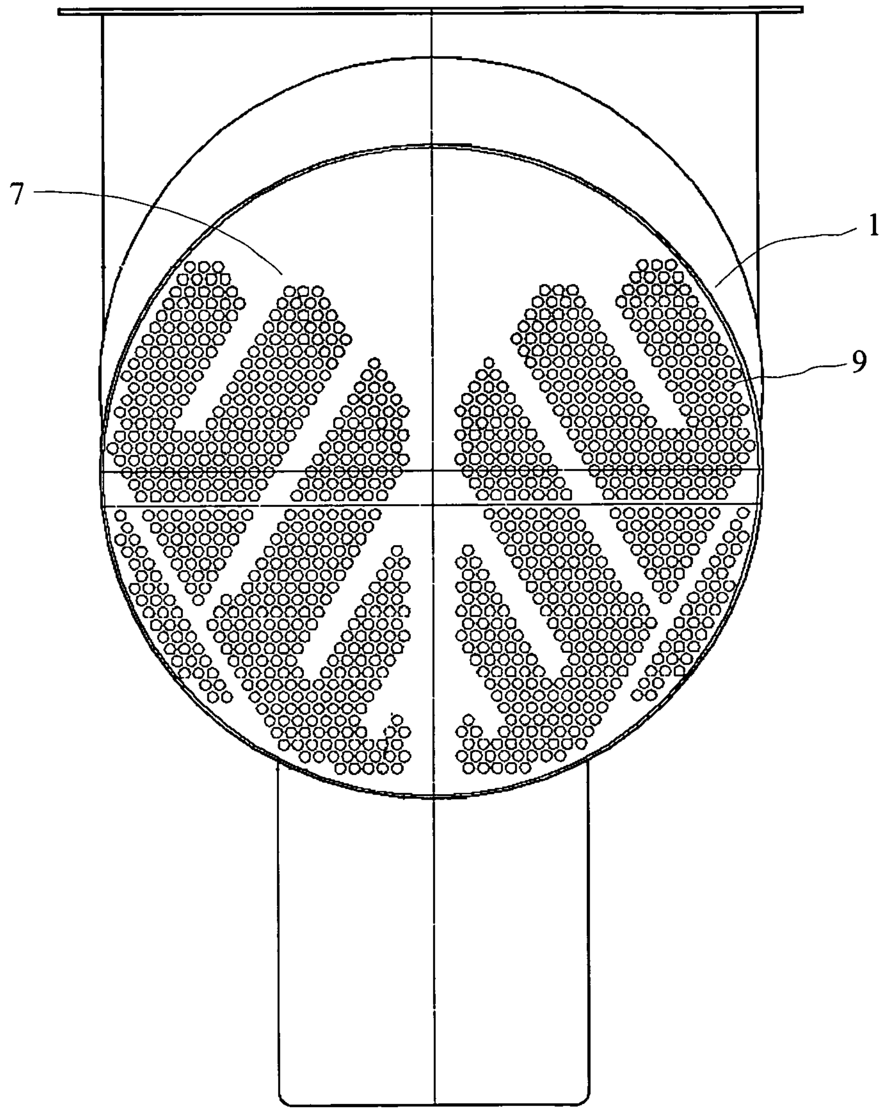

Fig. 2

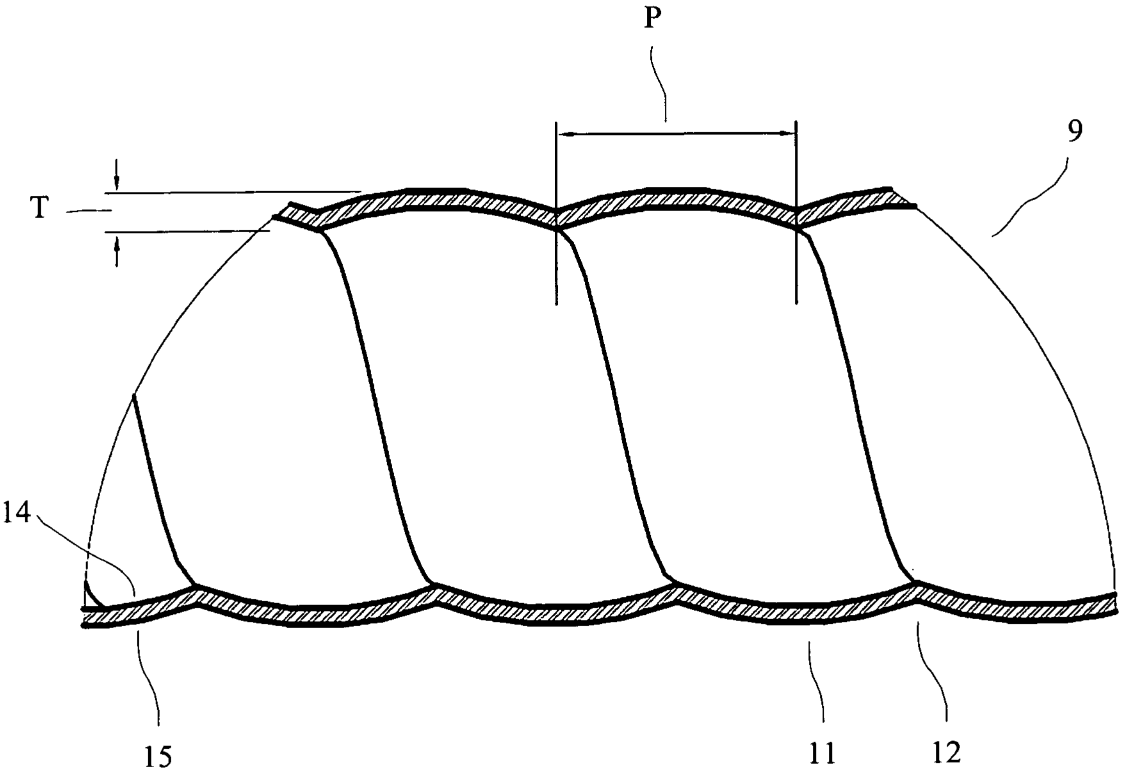

Fig. 3

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EUROPEAN SEARCH REPORT

Application Number
EP 05 02 6438

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	18 April 2006	Van Dooren, M

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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EPO FORM 1503 03.82 (P04C01)

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