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(54) **Integrated thermal exchanger group for organic fluid steam turbine**

(57) The invention concerns a thermal exchange Group for cooling of expanded steam in a turbine for the production of electric energy which uses a high molecular mass organic fluid. It includes a regenerator and a condenser positioned in a sole container or external housing (23) with an inlet conduct (24) for the hot steam and an outlet conduct (25) of the condense liquid. The container or housing (23) is mainly cylindrical on a horizontal axis; the condenser is placed parallel below or above the regenerator.

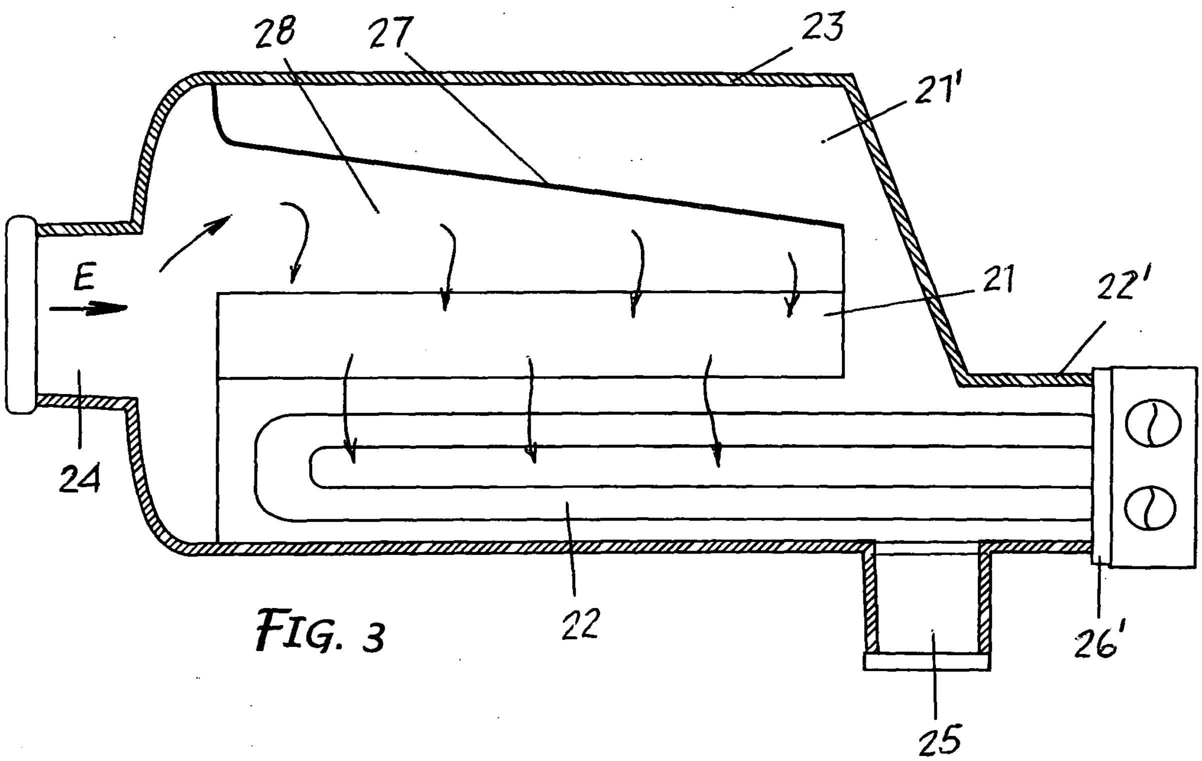

FIG. 3

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Description

Field of the Application

[0001] This invention concerns the organic fluid steam turbine section in general and refers in particular to two thermal exchange units integrated into an organic fluid turbo generator plant (ORC)

State of the Art

[0002] The use of high molecular mass organic fluids in a Rankine cycle with turbine expansion for the production of electric energy often requires the need for cooling the expanded steam in the turbine by regenerating it, that is by using the cooling heat of the steam to preheat the liquid phase of the working fluid itself, downstream of a condenser and a circulation pump.

[0003] It is in fact a typical characteristic of high mass molecular fluids that the steam cools slightly during the pressure stage in the turbine. Instead of supplying the steam directly to the condenser, the tendency is to take advantage of its high temperature to preheat the working liquid feeding the plant. The conversion yield of the cycle is, as a result, very much increased, by decreasing, in proportion to the electric capacity produced, the thermal capacity needed at the external source.

[0004] In other words, the steam on exiting the turbine is obliged to pass through two thermal exchange units represented by a so-called regenerator and followed by a condenser.

[0005] The regenerator usually requires a very large exchange surface in that the thermal exchange coefficients with a fluid in the steam phase are very low and the thermal capacity to exchange, for correct regeneration, is very high

[0006] The regenerator, consequently, is bulky and its overall size is further increased by the need to realise large sized input and output steam conducts. This, at least in applications where the volumetric deliveries of the steam are very high due to the low steam pressure, typical of turbo generators for cogeneration, fed by diathermic oil heated by biomass combustion and using silicone oil as a working fluid.

[0007] The condenser is also usually installed in a container under pressure and particular attention must be paid to the size of the input steam conducts arriving from the regenerator.

[0008] Consequently, also the condenser housing must be much larger than the exchange surfaces (e.g., the tube nest in a condenser) to allow sufficient room for the steam to flow so as not to generate excessive loss in load.

[0009] A proposal has already been put forward to install the regenerator and the condenser in a sole housing, but according to the known realisations, no effective, hoped for reduction in overall size and compactness of the thermal exchange group, has been achieved.

[0010] In these known and usually adopted realisations, regenerator and condenser are installed in cylindrical housings suitable to resist the designed pressure, with a circular cross-section and development mainly along an axis.

[0011] Usually the length of the system varies from 1 to 10 times the diameter of the housing, and the diameter of the latter is normally between 0.5 and 2.5 metres, with lengths therefore in the order of 2-10 metres.

[0012] As shown in Fig.1, indicative of a state of the art, one exchanger or regenerator 10 has a typical parallelepiped shape, with the long side parallel to the axis of a container or housing 11, for example placed horizontally so that the steam has to cross it from the top to the bottom (or from the bottom to the top).

[0013] In this case the steam in output from the turbine enters one end of the housing, on an axis according to arrow E, is deviated into a circular section 12 left free from the exchanger, through the exchanger mass 10, exits into the other free circular section 13 and continues in an axial direction to finally come into contact with the tube nest of another condenser 14 positioned in the housing 11.

[0014] It is however clear that, as explained above, the overall internal volume of the housing not used to contain the exchange masses, but used only to enable the steam to flow at the correct speed, is very large.

[0015] Even by placing the housings of the two exchanger units side by side axially and eliminating the connection between them, adopting that is, a sole housing (as already shown in Fig. 1), the regenerator-condenser assembly becomes even more bulky and/or long.

Objective and Summary of the Invention

[0016] The objective of this invention is on the other hand to provide an innovative integration solution of the two thermal exchange units, a regenerator and a condenser for the use in the above mentioned field, really reduced in overall size, thanks to a reduction of the internal unused volumes of the container or housing they are placed in, that is those volumes which are not strictly necessary to contain the exchanger masses.

[0017] This objective is achieved, according to the present invention, by an integrated group of thermal exchangers according to claim 1.

Brief Description of Drawings

[0018] The invention and the advantages it gives will be illustrated more in detail in the description which follows made with reference to the attached, indicative and not limiting drawings, in which:

Fig.1 shows a schematic view of a thermal exchanger assembly in series for the discharge of an organic fluid steam turbine according to a state of the art;

Fig. 2 shows a schematic view of an integrated group of thermal exchangers according to the invention with a regenerator placed above a condenser;

Fig. 3 shows another schematic view of another example of the integrated thermal exchangers according to the invention;

Fig. 4 shows a cross section of the group in Fig. 3;

Fig. 5 shows, in cross section, an implementation of the group in Fig.2

Fig. 6 shows, in cross section, another construction variation; and

Fig. 7 shows another example of a group of thermal exchangers with a condenser placed above a regenerator.

Detailed Description of the Invention

[0019] In compliance with the invention, a regenerator 21 and a condenser 22 are located in a single container or external housing 23 essentially cylindrical and on a horizontal axis and with a wall thickness suitable to contain the pressures involved.

[0020] As shown in the examples of the realisation, container 23 has, at one end, an inlet passage 24 for the hot steam coming, in the direction of arrow E, from the organic fluid steam turbine - not shown - and, at the bottom part, an exit passage 25 of the condense liquid as needed.

[0021] The regenerator 21, usually having a parallelepiped shape finned body in which the fluid to pre-heat is made to circulate, is placed horizontally, at an intermediate height, in the container 23 in the direction of the axis of the latter.

[0022] The condenser 22, in which a cooling liquid circulates, is made up of a tube nest supported by a tube plate 26. According to Figs. 2-6, the condenser is positioned at the bottom end of container 23 lying under the regenerator 21, and facing parallel to it.

[0023] In the example in Fig. 2, the tube plate 26 of condenser 22 has the same diameter as the container 23 and is attached to the same forming the head or bottom 23' of the part opposite to the one having the input passage 24 of the steam. In this case, the condenser 22 does not require a cover or container, so the exchanger group becomes particularly simple even if the tube plate 26 has to be of a specific thickness.

[0024] However, in one of the construction variations of the integrated thermal exchanger group taken into consideration here, the condenser 22 still maintain a partial shell, indicated by 22', which joins and integrates with the container or housing 23, extending from one head of the latter as shown in Fig.3.

[0025] Consequently and advantageously, the condenser may have a tube plate 26', with a diameter less than that of the housing and however not larger than is necessary so that it will fit on the portion of the shell 22' of the condenser. A tube plate smaller in diameter obviously means a significant reduction in its thickness, always however compatible with the resistance to the pressure of the design, an increase in facility of its working capacity plus less weight and a lower cost.

[0026] In any realisation, the upper space 21' between the regenerator 21 and container 23 (as a cross-section, a circular sector) can house a fixed baffle 27 - Figs. 3 and 4 - as long as the regenerator itself and with a thickness less than that of the external container as the difference in pressure it has to support is little. This intermediate baffle 27 is shaped with the objective of forming a conveyor 28 to correctly direct the steam entering the container 23 from the turbine to the regenerator 21.

[0027] The presence of the intermediate baffle 27, besides helping with directing the steam towards the regenerator, has the advantage of shielding and maintaining the external walls of the container colder, in that it is not directly in contact with the steam entering which is hotter. In addition it guarantees better uniformity of the temperatures of the wall of the housing, reducing in this way the possibility of warping due to dissymmetric heating.

[0028] In the thermal exchanger integrated group described above, the flow of hot steam is forced to flow crosswise through the regenerator from the top to the bottom. Therefore any liquid which might condense on the surface of the regenerator (for example, in the start up phase when the regenerator is cold) is easily expelled by the flow of steam moving in the same direction as the force of gravity and also collects in the hot well 25. Besides, the liquid side of the regenerator, as it is counter current, is traversed from bottom to top so any incondensable air or other gas is pushed away, giving the natural rise (from bottom to top) inside the mass of liquid the right of way.

[0029] The condenser 22 underneath is fed almost in a uniform fashion for all its length. The lower part of the container is used to house the tube nest of the condenser, completely without the need for its own cover as in Fig. 2, or for most of it as in Fig.3, where the condenser maintains a portion of the shell 22' which may be shaped so as to collect and expel any incondensable gasses which may get into the circuit.

[0030] Another improvement in the thermal exchange conditions to the condenser can be achieved by equipping the latter, at least in the lower section, with side walls 29 as shown in Fig. 5. These walls have the aim of compelling the steam to pass inside the tube nest flowing mainly from top to bottom. This favours the downward collection of the liquid resulting from condensation and the downward discharge of any incondensable gas present. The incondensable gas accumulated at the bottom gradually moves towards the tube plate from where it will be extracted.

[0031] Should a working fluid of a non azeotropic mixture of two or more different fluids be used, the use of containing and guide side walls 29 for downward steam flow enables the flow of the cooling liquid, water or other vehicle, to come into contact with the different parts of the condensing tube nest in an orderly fashion compared with the steam flow. In particular it will be possible to direct the flow of cooling liquid, counter current compared with the steam flow so as to take full advantage of the non azeotropic mixture to condense at varying temperatures.

[0032] In another variation, as shown in Fig. 6, regenerator 21 and condenser 22 are housed in a common container or housing 23, but this container is provided with walls 30 which set the passage of the steam, compelling it to cross first the regenerator and then the condenser in a fundamentally horizontal direction.

[0033] In another way of realisation as shown in Fig. 7, regenerator 21 and condenser 22 are housed in a common container or housing 23. But the condenser 22 is placed above the regenerator 21 with an opportune collection and discharge system 31 of the condense liquid placed between the two exchangers 21, 22. The condense liquid is in this way at a higher level from the ground than from the cases of realisations where the condenser is placed below the regenerator. In this way there is the advantage of increasing the suction height available to the pump (internationally known as NPSHa), even if in the starting phase of the plant, that is with the plant cold, the regenerator, being at a low temperature, causes a condensation of steam. The liquid which forms collects at the bottom of the housing and can be removed either by evaporation, thanks to a heater coil 32, or by means of an auxiliary pump 33. Also in this case a baffle 34 can be placed in the bottom internal part of the housing 23 so as to direct the steam from the entry E towards the regenerator.

Claims

1. Thermal exchange group for cooling of expanded steam in a turbine for the production of electric energy which uses, as an evaporable working fluid, a high molecular mass organic fluid, where said group comprises a regenerator (21) for preheating the working fluid in a liquid phase by means of hot steam exiting from the turbine, and a condenser (22) for cooling the steam to a condense temperature, **characterised in that** said regenerator and said condenser are placed in a sole container or external housing (23) with an inlet conduct (24) for the hot steam and an output passage (25) of the condense liquid, the container or housing (23) substantially being cylindrical at a horizontal axis with the hot steam inlet at a housing head or end and the liquid condense exit in a bottom section.

2. Thermal exchange group according to claim 1, wherein the regenerator extends in length and crosswise at an intermediate height of the container or external housing (23), and the condenser lies below and parallel to the regenerator starting from a head or end of the container or housing opposite the one with the hot steam inlet conduct, and wherein the regenerator defines with a top section of said container or housing, a space (21') for distributing the hot steam from the top to the bottom towards the regenerator and condenser.

3. Thermal exchange group according to claim 1, wherein the regenerator (21) extends in length and crosswise at an intermediate height of the container or external housing (23), and the condenser (22) lies above and parallel to the regenerator starting from a head or end of the container or housing opposite the one with the hot steam inlet conduct, wherein the regenerator defines with a bottom section of said container or housing, a space for distributing the hot steam from the bottom to the top towards the regenerator and condenser, and wherein a system for collecting the condense liquid is provided between the condenser and regenerator.

4. Thermal exchange group according to claim 2, wherein in the space between the regenerator (21) and the top section of the container or external housing (23) a fixed baffle (27) is positioned, forming a conveyor (28) directing incoming hot steam towards the regenerator and a barrier shielding said top section of the container or housing.

5. Thermal exchange group according to claim 3, wherein, in the space between the regenerator and the bottom section of the container or external housing (23) a fixed baffle (34) is positioned, forming a conveyor directing incoming hot steam towards the regenerator and a barrier shielding said bottom section of the container or housing.

6. Thermal exchange Group according to claims 4 and 5, wherein said baffle extends for the whole length of the regenerator defining a conduct with a cross section gradually decreasing starting from the hot steam inlet.

7. Thermal exchange group according to any of the previous claims, wherein the condenser is equipped on opposite sides with two side walls (29) forcing the steam to pass through the condenser, said side walls being in contact with at least a lower part of the condenser.

8. Thermal exchange group according to any of the previous claims, wherein the condenser (22) is made up of at least a tube nest supported by a tube

plate (26), and wherein said tube plate is associated with the container or external housing (23) forming the head or end of said housing on the opposite side from the one having the hot steam inlet conduct.

9. Thermal exchange group according to any of the previous claims, wherein in the container or external housing, between the regenerator and condenser, there are walls to compel the steam to cross the regenerator in a horizontal direction substantially.

10. Thermal exchange group according to any of the previous claims, wherein the regenerator and condenser are without a covering of their own, having in common the container or external housing as a shell.

11. Thermal exchange group according to any of the claims from 1 to 9, wherein the condenser has a section of the shell (22') which is in contact and integrates with the head or end of the container or external housing from the opposite side from the one housing the hot steam inlet conduct.

12. Thermal exchange group according to claim 11, wherein the condenser is made up of at least a tube nest supported by a tube plate (26') associated with said section of the shell (22'), said tube nest having a diameter smaller than that of the container or external housing (21)

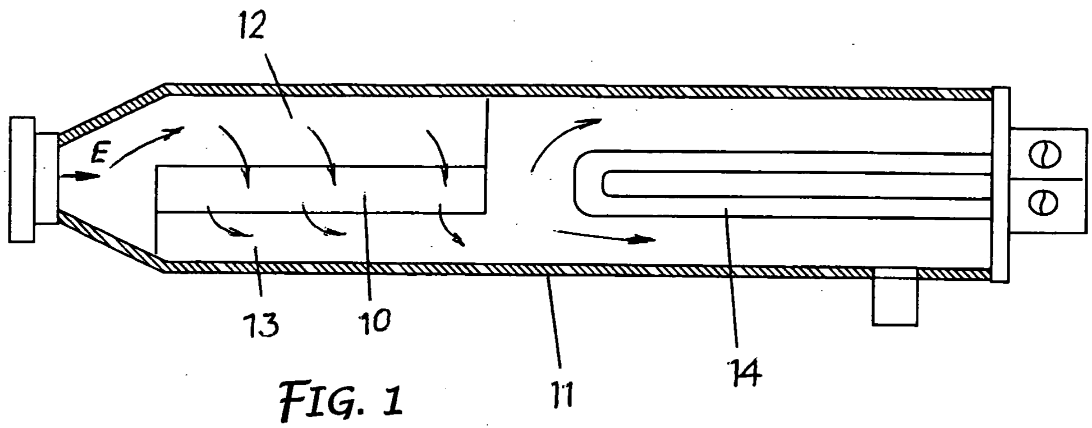
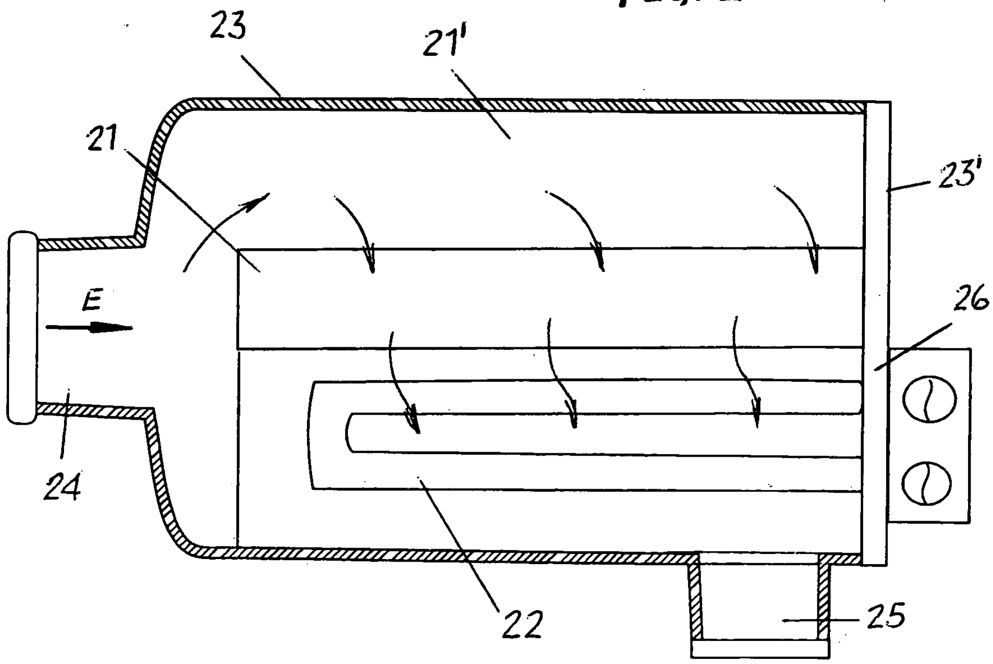


FIG. 1

PRIOR ART

FIG. 2



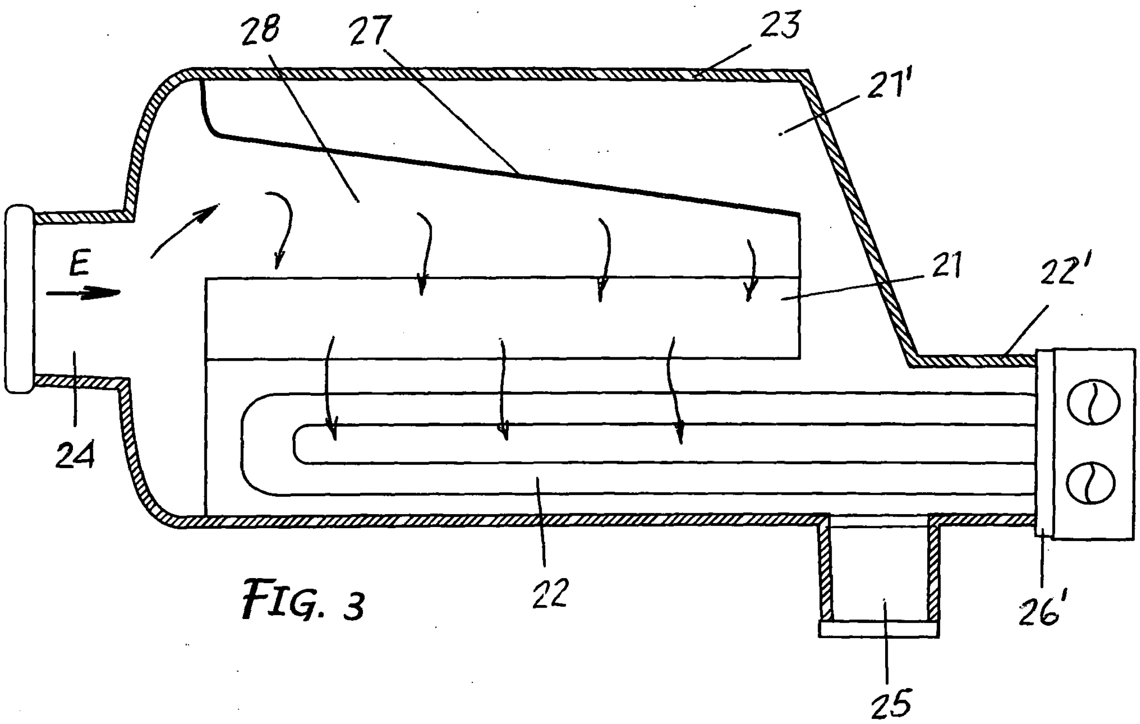
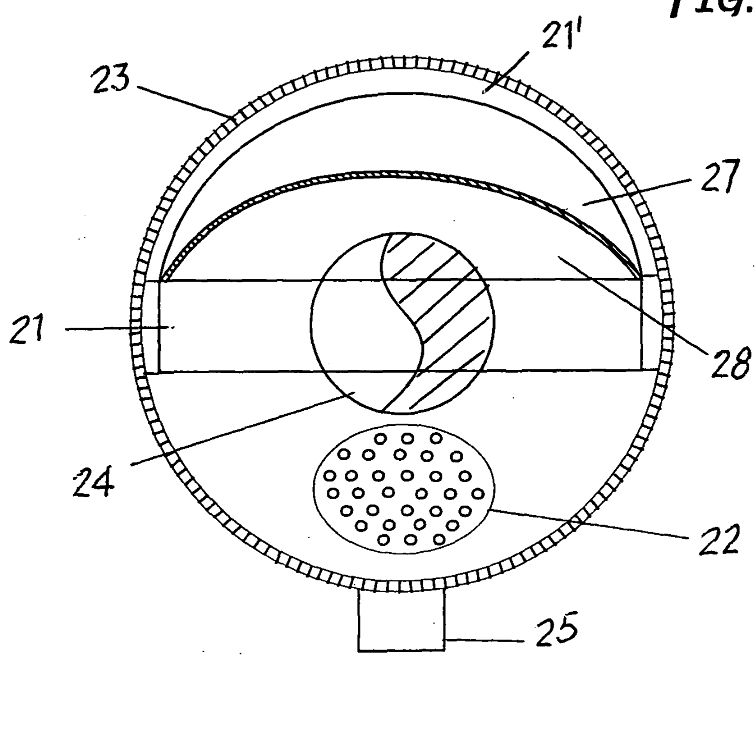


FIG. 3

FIG. 4



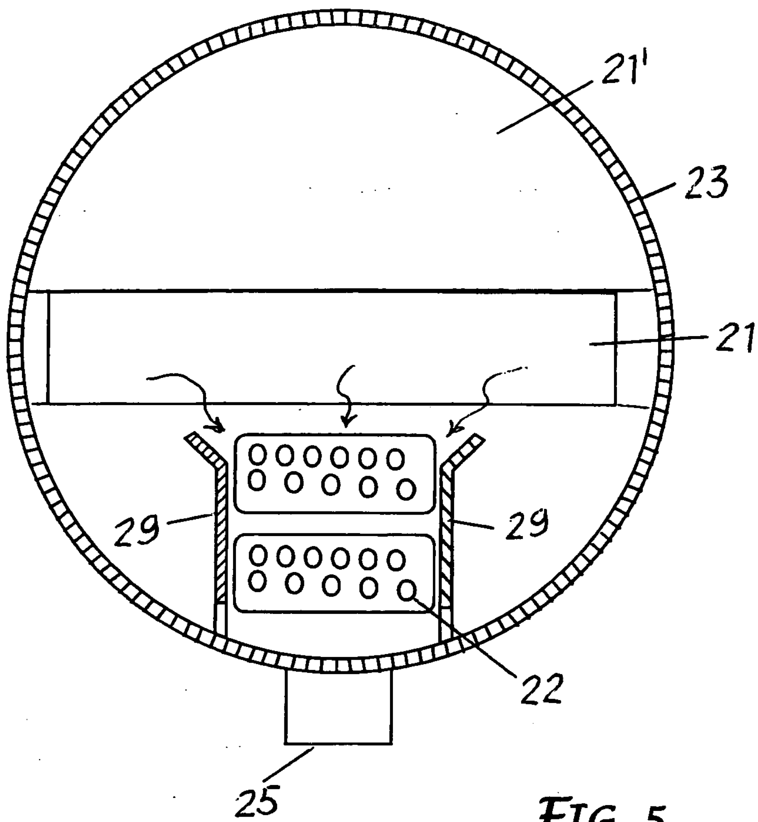
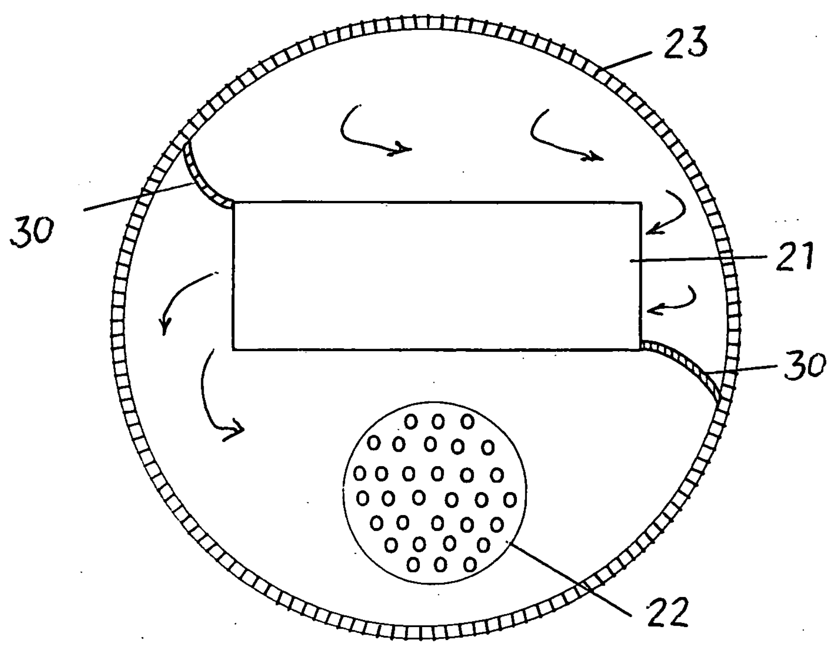


FIG. 5

FIG. 6



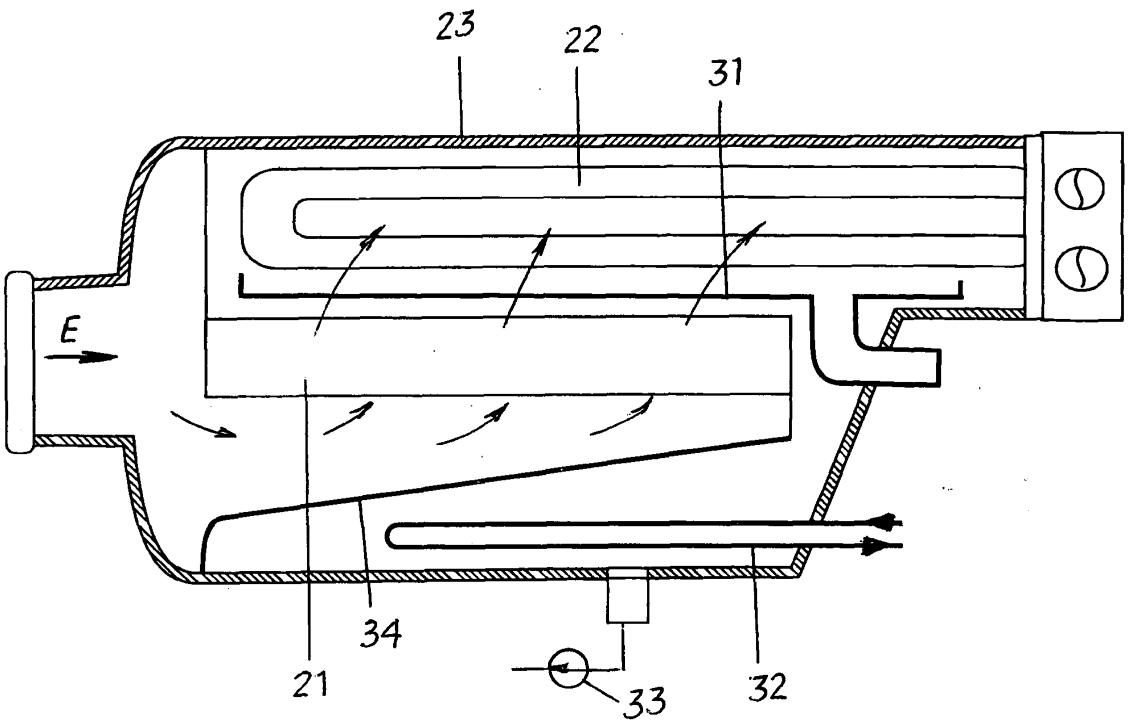


FIG. 7

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EUROPEAN SEARCH REPORT

Application Number
EP 03 42 5722

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TECHNICAL FIELDS SEARCHED (Int.Cl.7)
F01K

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	7 April 2004	Zerf, G

CATEGORY OF CITED DOCUMENTS

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