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(54) Heat exchanger for water heating apparatuses and method for producing the same

(57) A heat exchanger (1), particularly adapted for water heating apparatuses, comprises a plurality of tubes (10) for circulating a cooling fluid, including a substantially spiral-shaped central portion (11) and at least one straight end portion (12,13) extending substantially perpendicularly to the spiral-shaped portion (11). The tubes (10) are angularly offset from one another within an outer vessel (2) with the interposition of spacer means (15) so as to arrange the spiral-shaped portions (11) in adjacent parallel planes (π). Advantageously, the heat exchanger (1) allows to achieve a high ratio of heat transfer surface area to overall volume and affords compact size and lightweight features in addition to a high thermodynamic efficiency.

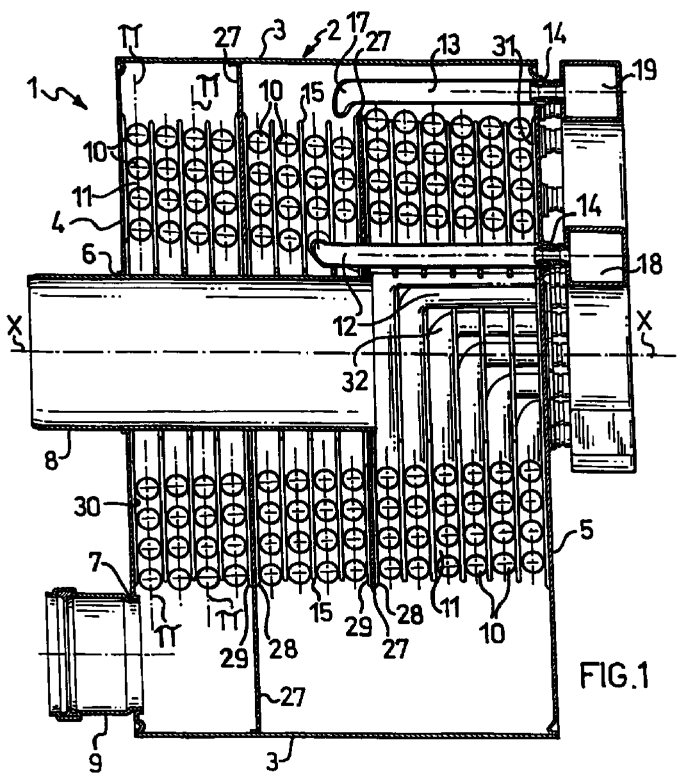

FIG.1

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Description

Background of the Invention

The present invention relates to a heat exchanger, particularly for water heating apparatuses adapted both for household applications and for residential blocks or large buildings, such as supermarkets and the like.

The invention specifically relates to a heat exchanger comprising a plurality of tubes for circulating a cooling fluid mounted within an outer vessel having an inlet opening and an outlet opening for a hot fluid flowing outside said tubes, as well as spacer means for holding the tubes at a preset distance from one another.

The invention also relates to a method for manufacturing such a heat exchanger and to a water heating apparatus incorporating the heat exchanger.

Prior Art

As is known, a primary need in the field of heat exchangers for water heating applications is that of providing apparatuses compact in size, light in weight, and economical, but capable at the same time of achieving a good thermal exchange efficiency.

A design parameter of paramount importance for a heat exchanger to meet the above requirements is the area of the thermal exchange surface and, more specifically, the ratio between the heat transfer area and the overall volume of the heat exchanger. The higher this ratio, the more compact and thermodynamically efficient the heat exchanger will be.

Known in the art are several systems aimed at maximizing the thermal transfer area of a heat exchanger, for a given volume thereof.

In particular, among the shell-and-tube heat exchangers (intending with this definition apparatuses wherein the heat transfer takes place between a fluid flowing outside the tubes and another fluid flowing inside the tube, whichever the shape of the tubes themselves), known are arrangements providing finned tubes and flattened tubes.

While essentially achieving their objective, both of the above known arrangements still exhibit, depending upon the specific end use of the heat exchanger, a number of drawbacks which have not been solved to-date.

Thus, for example, the use of a finned tube type of heat exchanger would not be suitable in the case of so-called recuperators for condensation boilers, wherein to improve the overall efficiency of the boiler, the latent heat of the flue gas sweeping the outer surfaces of the tubes is used to condense the water vapour contained therein. In this case, in fact, a special geometry must be devised, to ensure an optimum heat transfer and a prompt discharge of the condensation water, and suitable materials must be employed to withstand the corrosive action of such water. The provision of finned tubes interferes, however, with a prompt discharge of condensation water since the fins tend to hold the water therebetween, thereby lowering the heat transfer (and along therewith, the efficiency of the heat exchanger), besides increasing the risk of tube corrosion.

To mitigate this risk, it has been proposed to use tube fins of a corrosion-resistant material, such as stainless steel; this proposal, however, has the additional drawback constituted by the tendency of the fins to overheat as a consequence of the low heat-exchange coefficient possessed by steel, besides being extremely costly.

In order to increase the useful heat transfer area, it has been then proposed to adopt a heat exchanger comprising a plurality of flattened tubes helically wound one on top of the other into a vessel, as disclosed in International PCT Patent Application WO 94/16272.

A problem to be faced with this tube geometry, however, is that of assuring a uniform spacing between the tubes, so as to allow a uniform distribution of the flue gas that is of the essential to have an efficiency of a technically acceptable and predictable level.

To overcome this problem, the above-referenced patent application suggests to use ribs formed by hydraulic expansion across the flattened faces of the tubes.

Even this suggestion, while being functional to achieve its intended objective, involves a number of drawbacks.

A first drawback is related to the high manufacturing cost, due to the complex equipment required for making the tubes and forming the ribs.

A second drawback is related to the fact that the high hydraulic pressure required to form the ribs only allows the use of tubes having a limited wall thickness, which limit in their turn the maximum working pressure of the heat exchanger down to a value not exceeding 3 bar, if the flattened surfaces of the tubes are not to be distorted out of true planarity.

A third drawback is related to the large pressure drop induced by the flattened shape of the tubes in the hydraulic circuit.

A fourth drawback is related to the fact that any possible local unevenness of the tube material would adversely affect the predictability and reproducibility of the heat exchanger performance, both in terms of pressure drops on the tube side and in terms of an efficient exchange with the fluid flowing outside the tubes.

This unevenness may be due to the inherent characteristics of the material forming the tubes, or be the outcome of the cold plastic deformation operations performed on the tubes. Even the slightest variations in the thickness of the tubes or of the ribs formed in the flattened regions, in fact, is bound to result in an undesired and remarkable change of the fluid flow cross-section both within and outside the tubes.

Finally, a further drawback of the heat exchanger described in the aforementioned patent application is related to the fact that, in order to provide an even spacing between adjacent helical elements, the end portions of each element must be shaped for utmost planarity of the outer surface of the last coil in each element. This is achieved by imparting to the last coil a varying cross-section which reaches a value about twice the normal value near the cross-point with its free end.

However, this increase in cross-section will cause a velocity decrease of the fluid flowing within the tube and, hence, a decrease of the heat transfer coefficient, with an attendant risk of local overheating of the tube.

Summary of the Invention

The technical problem underlying the present invention is to provide a compact and economical heat exchanger which may assure a high thermal exchange efficiency while overcoming the drawbacks of prior apparatuses.

According to the invention, this problem is solved by a heat exchanger as indicated hereinabove, which is characterized in that each of said tubes comprises a substantially spiral-shaped central portion and at least one straight end portion extending essentially perpendicularly to said spiral-shaped portion, and in that said tubes are mounted in said outer vessel with the interposition of said spacer means so as to arrange the spiral-shaped portions in adjacent parallel planes, each of said tubes being angularly offset with respect to the adjacent tube of an angle having a predetermined span.

Throughout the following description and the appended claims, each of said adjacent parallel planes containing the spiral-shaped portions of the tubes will also be referred to as the "planes of development" of the spiral portions.

Also, the term "hot fluid" will be used to designate the flue gas issuing from a burner (in the instance of the heat exchanger being used as the primary heat exchanger for a boiler), or exhaust gases that have already delivered their sensible heat and are on the point of delivering their latent heat (in the instance of the heat exchanger being used as a regenerator for a boiler).

Preferably, the cooling fluid flowing through the tube interiors is water.

Advantageously in this invention, a heat exchanger can be provided which has a high ratio of heat transfer surface area to overall volume; accordingly, it will form a compact and thermodynamically efficient apparatus. The large beat transfer surface area afforded by the plurality of spirally laid tubes, packed together within the vessel, ensures a highly efficient transfer of heat without using finned or flattened shape tubes. The peculiar spiral lay of the tubes and their packing arrangement within the vessel provide a solution which is simple to construct, light in weight, and economical.

The heat exchanger of this invention obviates the drawbacks which have been besetting the prior art, while featuring adaptability for use in water heating apparatuses, such as instant boilers or water heaters, as well as in condenser units for refrigerating apparatus.

Advantageously, the tubes have opposite straight end portions which extend substantially perpendicularly to the plane of development of the spiral-shaped portion along a parallel direction to the longitudinal axis of the heat exchanger, from radially inward, respectively outward, sides of the spiral-shaped portion.

Even more advantageously, both the end portions of the tubes extend from the same side of the spiral-shaped portion.

In this way, the tubes are provided with respective inlet and outlet openings for the cooling fluid which are located, relative to the vessel, on opposed sides to respective inlet and outlet openings for the hot fluid flowing outside the tubes.

In this way, the heat exchanger can be provided with a single inlet/outlet zone for the cooling fluid flowing through the tube interiors, to thereby greatly simplify the heat exchanger packing operations and the operations for connecting said ends to respective manifolds for distributing and collecting the fluid.

In an alternative embodiment of this invention, the end portions of the tubes extend from opposite sides of the spiral-shaped portion.

Advantageously, the tube end portions extending radially outward with respect to the spiral-shaped portion include at least one scetion which extends radially outward in the plane of development of the spiral-shaped portions along a substantially perpendicular direction to winding direction of the spiral.

This allows the cooling fluid inlet or outlet openings, provided at the radially outward ends with respect to the spiral portion of each tube, to be aligned along an essentially semicircular line, thereby making for a particularly easy distribution and collection of the fluid flowed through the tubes.

Advantageously, the heat exchanger further includes a pair of distribution, respectively collection, manifolds for the cooling fluid which are fixed to said tubes at the locations of the inlet and outlet openings, externally of the vessel.

The provision of readily accessible manifolds from the vessel outside greatly simplifies the technological operations necessary for associating the tubes with the manifolds, and allows material of ordinary quality to be used.

Advantageously, the distribution and collecton manifolds for the cooling fluid include at least one partition plate for connecting the tubes together in series/parallel. This partition plate allows the cooling fluid to be distributed to the tube interiors along a predetermined flowpath to achieve a particularly efficient thermal exchange.

Advantageously, the heat exchanger further includes at least one annular baffle supported inside the vessel to direct the hot fluid flowing outside the tubes into a substantially zig-zag flowpath, thereby further enhancing the efficiency of heat transfer of the heat exchanger.

Preferably, the spacer means for holding the tubes at a preset distance from one another comprise respective wires which are structurally independent of the tubes. The provision of wires, interposed between the tubes independently of the latter, allows a spacing to be established between the tubes which is perfectly uniform and ensures constant and predictable performance of the heat exchanger.

In a preferred embodiment of the invention, the wires are laid into a substantially star-shaped which comprises a plurality of arms radially extending along a substantially perpendicular direction to winding direction of the spiral portions of the tubes.

Advantageously, the spacer means for holding the tubes at a preset distance from one another further include a plurality of ribs formed on opposite sides of the annular baffles.

Still more advantageously, the outer vessel includes a plurality of supporting ribs for the spiral portions of the tubes which extend from respective inner walls of oppositely located closure covers of the vessel.

The star-shaped configuration of the wires and the provision of said ribs allow maximum limitation of the contact regions between the spacer means, the annular baffles and the covers, on the one side, and the tubes, on the other side, thereby allowing the whole surface of the tubes to be put to use in the transfer of heat.

Where the heat exchanger is used as a regenerator for condensation boilers, the wire spacer means will advantageously assist in draining off the condensation water released by the flue gas.

According to a second aspect, the present invention also relates to a water heating apparatus for household applications, which is characterized by that it includes a heat exchanger as described above.

According to a third aspect, the invention relates to a method of manufacturing a heat exchanger for water heating apparatuses, which is characterized by that it comprises the following steps:

rectifying a first end portion of a tube having a predetermined length;

bending said first end portion to a substantially perpendicular direction to the remaining portion of the tube;

winding into a spiral a central portion of the tube adjacent to said first end portion;

bending a second end portion of said tube, first to a substantially radial direction and then to a substantially perpendicular direction to a plane of development of said spiral-shaped portion;

stacking together a plurality of said tubes inside an outer vessel with the interposition of spacer means, so as to arrange the spiral-shaped portions in parallel adjacent planes;

closing said vessel by a first cover provided with openings for receiving the free ends of said tube portions;

closing said vessel by a second cover provided with inlet and outlet openings for a first fluid adapted to flow outside the tubes;

connecting the opposite free ends of said tubes with respective distribution and collection manifolds for a second fluid adapted to flow inside the tubes.

According to the invention, the above sequence of steps is uncritical; thus, for example, the heat exchanger vessel could be closed at one end with the cover formed with openings for receiving the free ends of the tubes, prior to installing the tubes.

In this way, the stacking of the tubes within the vessel is carried out by inserting their free ends into the receiving openings provided in the closure cover, thereby simplifying the assembly operations.

In one embodiment, the method of this invention may include an additional step of bending the first end portion of the tube to a substantially radial direction relative to the plane of development of the spiral-shaped portion, before the coiling step.

However, this step may become necessary in some cases in order to fit inside the vessel of the heat exchanger the largest possible number of tubes without these interfering with one another, consistently with the diameter of the selected tubes and the size of the heat exchanger.

With the method of this invention, a heat exchanger can be provided which is economical, compact and thermodynamically efficient, using a simple, low-cost technology which ensures repeatability of the heat exchanger product performance on a large scale.

The use, for the aforementioned distribution and collection manifolds, of materials which have no particular characteristics of corrosion resistance, and the simplicity of the technological operations involved in assembling the tubes inside the vessel, both lead to relatively low investment costs.

Advantageously, the method of this invention includes a further step of arranging in the manifolds at least one partition plate for connecting the tubes for the cooling fluid flow in series/parallel with one another.

Still more advantageously, the method of this invention further includes a step of arranging annular baffles for directing the fluid flowed outside the tubes to follow a substantially zig-zag path.

In a preferred embodiment of the present invention, the distribution and collection manifolds for the fluid flowed through the tube interiors are fixed to the tubes by an expansion process. This cold-worked fit is specially advantageous compared to the conventional welding which has typically been used for associating the manifolds with the tubes.

In the heat exchanger of this invention, it would also be possible to provide a welding operation for associating the manifolds with the tubes. In this heat exchanger, in fact, the steam contained in the flue gas is condensed within the vessel, whereas the connections of the tubes to the manifolds are made on the vessel exterior.

Advantageously, the step of winding at least a central portion of the tubes into a spiral shape is carried out on coiling machines of the type employed for making springs or coil-shaped electric resistors, which are well known and quite reliable.

Brief Description of the Drawings

Further features and advantages of a heat exchanger according to the present invention will become more clearly apparent from the following description of a preferred embodiment thereof, given by way of illustration and not of limitation with reference to the accompanying drawings. In the drawings:

Figure 1 is a longitudinal portion view, taken along line I-I in Figure 2, of a heat exchanger according to the invention;

Figure 1A is an enlarged view of a detail of the heat exchanger shown in Figure 1;

Figure 2 is a partly cross-portional side view showing schematically the heat exchanger of Figure 1 with one of its closure covers removed;

Figure 3 is a longitudinal portion view showing schematically the path followed by the fluid flowing outside the tubes of the heat exchanger of Figure 1;

Figure 4 is a plan view showing schematically the path followed by the fluid flowing inside the tubes of the heat exchanger of Figure 1;

Figure 5 is a longitudinal portion view showing schematically another embodiment of the heat exchanger of Figure 1.

Detailed Description of a Preferred Embodiment of the Invention

In the drawing views, the reference numeral 1 generally designates a heat exchanger for water heating apparatuses, particularly adapted for use as a regenerator installed in series with a conventional type of boiler.

The heat exchanger 1 comprises an outer vessel 2 formed of a substantially cylindrical tubular body 3 which is closed at either ends by respective covers 4 and 5. The cover 4 is formed with inlet 6 and outlet 7 openings for a hot fluid.

Throughout this specification and the appended claims, the term "hot fluid" will be used to mean a fluid whose average temperature is within the range of 80°C to 1200°C.

In this case, the hot fluid is essentially a flue gas exhausted from the boiler, not shown, at a temperature on the order of 80°C to 200°C.

To facilitate the inflow and outflow of flue gas to/from the vessel 2, the heat exchanger 1 is provided with a manifold duct 8 and a tubular connection 9, conventionally attached to the cover 4 at the locations of the openings 6 and 7.

Accommodated inside the vessel 2 are a plurality of tubes 10, preferably made of stainless steel, through which tubes a suitable cooling fluid is caused to flow.

In this case, the cooling fluid is essentially the water which is has been flowed through the primary hydraulic or heating circuit of the boiler at a temperature of about 30-50°C.

The tubes 10 are each of circular cross-portion and comprised of a central portion 11 substantially laid into a spiral configuration, and of opposite ends portions 12, 13 which are substantially straight and extend perpendicularly to a plane of development, denoted by π in Figure 1, of the spiral-shaped portion 11 on inward and outward sides thereof, respectively.

The tubes 10 are stacked within the vessel 2 in an offset arrangement, each by an angle δ from its neighboring tubes, such that all the spiral-shaped portions 11 will lie in mutually parallel and adjacent planes, and all the end portions 12, 13, also parallel to one another, will lie parallel to a longitudinal axis, designated x-x in Figure 1, of the heat exchanger.

In order to allow the largest possible number of tubes 10 to be stacked together inside the vessel 2 in non-interfering relationship, the radially inward and outward end portions 12, 13 of the tubes 10 are connected to the spiral-shaped portion 11 by respective portions 32 and 17 extending outwards and inwards, respectively, from the spiral-shaped portions 11.

In particular, both portions 32 and 17 extend radially in the plane of development π of the spiral-shaped portions 11 along a substantially perpendicular direction to winding direction of the spiral coils.

In the embodiment shown, the end portions 12, 13 of the tubes 10 extend on the same side relative to the spiral-shaped portions 11, for a predetermined distance from the cover 5, after going through a plurality of openings, all designated 14, formed in the cover itself.

The free ends of the straight portions 12, 13 of the tubes 10 define inlet and outlet openings for the cooling fluid, and are fixed to a pair of manifolds 18, 19 arranged to distribute and collect the cooling fluid flowing into and out of the tubes 10.

These manifolds 18, 19 comprise respective boxlike bodies of substantially arcuate shape which are fixed to the free ends of the portions 12, 13 of the tubes 10 extending outwardly from the vessel 2 at the locations of the cooling fluid inlet or outlet openings.

In alternative embodiments, not shown, of the heat exchanger 1 of this invention, the tubes 10 could have a flattened cross-portional shape and/or the end portions 12, 13 of the tubes 10 could extend from opposite sides of the spiral-shaped portions 11.

Interposed between each spiral-shaped portion 11 and its adjacent coils are spacer means 15 which are structurally independent of the tubes 9 and adapted to hold the spiral-shaped portions 11 of the tubes 10 at a preset distance from one another.

In a specially advantageous embodiment shown in the drawing figures, the spacer means 15 consist essentially of stainless steel wires.

Preferably, the wires have a substantially star-shaped configuration having a plurality of arms 16 which are angularly offset from one another and extend radially along a perpendicular direction to winding direction of the spiral-shaped portions 11 of the tubes 10.

As shown in Figure 1A, the manifolds 18 and 19 have a plurality of tubular fittings 20 received by surface engagement inside a terminating portion of the end portions 12, 13 of the tubes 10 which extends outwardly from the vessel 2.

The fittings 20 are formed with first annular seats 21, located near their free ends, wherein respective sealing gaskets 22 are placed, and with second annular seats 23 which locate near the manifolds 18 and 19 and are engaged by respective annular ribs 24 formed by an expansion process at the terminating portions of the end portions 12, 13 of the tubes 10 extending outwardly from the vessel 2.

The manifolds 18, 19 further include a plurality of partition plates 25, 26 for connecting the tubes 10 together in series/parallel.

The vessel 2 also includes annular baffles 27 which are interposed between sets of tubes 10 and effective to create a substantially zig-zag flowpath for the hot fluid flowed outside the tubes 10. These baffles 27 are formed, on opposite sides thereof, with a plurality of substantially radial ribs 28, 29 for holding the spiral-shaped portions 11 of the tubes 10 at a preset distance from one another.

The spiral-shaped portions 11 of the tubes 10 are also held at a preset distance from the closure covers 4 and 5 of the vessel 2 by respective supporting ribs 30, 31 extending substantially along a radial direction.

In operation, the flue gas enters the heat exchanger 1 through the manifold duct 8. The flue gas is caused, by the annular baffles 27, to travel through the heat exchanger 1 along a substantially zig-zag flowpath and then to exit the heat exchanger 1 through the annular connection 9 after sweeping essentially around all of the tubes 10 mounted within the vessel 2.

Condensation water separated from the flue gas by the heat transfer process is collected at the bottom of the heat exchanger 1 and discharged through a drain outlet, not shown.

In particular, the flue gas will sweep the outer surface of the tubes 10 along alternate radially centrifugal and centripetal directions relative to the axis x-x of the heat exchanger 1.

It should be noted that the spiral-shaped spaces defined within each spiral-shaped portion 11 of the tubes 10 would not affect the flue gas flowpath because they exhibit much larger drop pressure than the drop pressure across the radial passageways defined between the spiral-shaped portions 11 themselves.

The cooling water enters the tubes 10 through the distribution manifold 18. In particular, the partition plates 25, 26 cause the water to flow through the interiors of the tubes 10 along predetermined paths, such as that shown in Figure 4.

Along this flowpath, the tubes 10 are paired fluid-mechanically in parallel, with each pair being further connected fluid-mechanically in series with the next pair of tubes 10.

In this way, the manifolds 18, 19 can function at one time as water distribution manifolds for a given pair of tubes 10 and as collectors for the water flowing out of the preceding pair of tubes 10.

The water, after flowing through all the tubes 10, leaves the heat exchanger 1 through a pair of tubes 10 whose outlet openings 14 are fixed to the collecting manifold 19.

A method according to the invention for manufacturing the heat exchanger 1 discussed hereinabove will now be described.

At an initial stage of the method, a first end portion 12 of a tube 10 is rectified, i.e. made essentially rectilinear, which portion has been cut to a predetermined length from a stock of tube coil.

Thereafter, the first end portion 12 is bent to a substantially perpendicular direction to a central portion 11 of the tube 10 adjacent thereto.

The central portion 11 is then laid into a spiral configuration by coiling equipment, e.g. of the same type as is employed for making springs or coil resistors, such that, on completion of the operation, the spiral-shaped central 11 is development in a plane π.

Preferably, before the coiling step for the spiral-shaped central 11, the end portion 12 has been bent to a substantially radial direction relative to the plane of development π so as to form the connecting portion 32.

After the central portion 11 of the tube 10 is laid into a spiral configuration, the opposed radially outward end portion 13 is bent, first to a substantially radial direction to form the connecting section 17, and then to a substantially perpendicular direction to the plane π of development of the spiral-shaped central portion 11.

On completion of these operations, the tube 10 will have its central portion 11 coiled spirally, and opposed straight end portions 12, 13 which extend substantially perpendicularly to the spiral-shaped portion.

At this point, a plurality of thus configured tubes 10 having end portions 12 and 13 of predetermined length are stacked inside the vessel 2 with the spacer means 15, in this case the star-shaped wires, interposed between each tube and the next, so that the spiral-shaped portions 11 of the tubes 10 are positioned in adjacent parallel planes π of development.

Preferably, the vessel 2 has been pre-fitted, during the step of stacking the tubes 10, with its closure cover 5 formed with openings 14 for accommodating the free ends of the tube portions 12, 13.

In this way, the insertion of the free ends of the tubes 10 through the openings 14 provided in the cover 5 can be facilitated.

In order for the tubes 10 to be properly positioned, each tube is rotated through an angle θ of predetermined width, prior to being placed above its preceding tube.

Preferably, the annular baffles 27 are also positioned inside the vessel 2 to create a substantially zig-zag flowpath for the fluid flowing outside the tubes 10.

After all the tubes 10 are stacked inside the vessel 2, the vessel 2 is closed with its opposite closure cover 4, formed with second openings 6, 7 for receiving the manifold duct 8 and tubular connection 9, respectively adapted to allow the hot fluid flowing outside the tubes 10 to go in and out the vessel 2.

The free ends of the portions 12, 13 of the tubes 10 are then conveniently cut to length such that they will extends from the cover 5 with a portion of predetermined length, and associated, as by an expansion process, with respective manifolds 18, 19 for distributing and collecting a cooling fluid adapted to flow through the interiors of the tubes 10.

These manifolds 18, 19 have been pre-fitted with partition plates 25, 26 adapted for connecting the tubes 10 in series/parallel, thereby to direct the cooling fluid flowed outside the tubes 10 along a predetermined path.

Shown schematically in Figure 5 is a further embodiment of the heat exchanger of this invention, which is suitable in particular for installation downstream of a boiler and has horizontal ducts for exhausting the flue gas.

Hereinafter, as well as in that figure, components of the heat exchanger 1 which are structurally and functionally equivalent to those previously discussed with reference to Figures 1-4 are denoted by the same references and will be no further described.

In the embodiment shown in Figure 5, the outer vessel 2 of the heat exchanger 1 is provided with oppositely located manifolds 33, 34 which are conventionally associated in coaxial relationship with the cover 4 and the opposite cover 5, respectively, and intended for allowing the hot fluid to be cooled to flow in and out.

In this case, the heat exchanger 1 is even more compact in size than the previously described embodiment and comprises a single baffle 35 supported centrally in the vessel 2 and adapted to create a twisting path for the hot fluid flowed outside the tubes 10.

In the embodiment shown in Figure 5, moreover, the baffle 35 is formed with openings, not shown, adapted to provide passageways, and support, for the straight end portions 12 of the tubes 10.

In a further modification, also not shown, the heat exchanger 1 may include additional baffles of annular shape for imparting a substantially zig-zag flowpath for the hot fluid flowed outside the tubes 10.

The advantages of this invention can be readily appreciated from the foregoing description.

These advantages include the following:

- possibility of achieving a high ratio of the heat transfer surface area to the overall volume, and this with a compact and light apparatus which is also thermodynamically efficient;
- possibility of providing a heat exchanger featuring such adaptability characteristics as to make it useful for water heating apparatuses (as a primary exchanger and/or a regenerator), as well as a condenser unit for refrigerating apparatus;
- possibility of providing a heat exchanger which can ensure consistent and predictable performance over time;
- possibility of providing an apparatus of simple construction, without resorting to expensive materials or particularly complicated processing procedures, that is an apparatus of relatively low investment and running costs;
- possibility of using high working pressures of the cooling fluid, which would vary with the thickness and diameter of the tubes but anyhow be on the order of tens of bars, so as to benefit from the consequent improved efficiency of heat transfer;
- possibility of providing a flexible apparatus which is easy to install downstream of boilers having a variety of shapes and dimensions.

Claims

1. Heat exchanger, particularly for water heating apparatuses, comprising:

    - a plurality of tubes (10) for circulating a cooling fluid mounted within an outer vessel (2) having an inlet opening (6) and an outlet opening (7) for a hot fluid flowing outside said tubes (10);
    - spacer means (15) for holding the tubes (10) at a preset distance from one another;

characterized in that each of said tubes (10) comprises a substantially spiral-shaped central portion (11) and at least one straight end portion (12,13) extending essentially perpendicularly to said spiral-shaped portion (11), and in that said tubes (10) are mounted in said outer vessel (2) with the interposition of said spacer means (15) so as to arrange the spiral-shaped portions (11) in adjacent parallel planes (π), each of said tubes (10) being angularly offset with respect to the adjacent tube (10) of an angle (θ) having a predetermined span.

2. Heat exchanger according to claim 1, wherein said tubes (10) have opposite straight end portions (12,13) extending substantially perpendicularly to said spiral-shaped portion (11) along a direction parallel to a longitudinal axis (x-x) of the heat exchanger (1).

3. Heat exchanger according to claim 2, wherein both the end portions (12,13) of the tubes (10) extend from the same side of the spiral-shaped portion (11).

4. Heat exchanger according to claim 2, wherein both the end portions (12,13) of the tubes (10) extend from opposite sides of the spiral-shaped portion (11).

5. Heat exchanger according to claims 1-4, wherein end portions (13) of the tubes (10) radially outwardly extending with respect to the spiral-shaped portion (11) include at least one section (17) radially extending in a plane of development (π) of the spiral-shaped portions (11) along a direction substantially perpendicular to the winding direction of the coil.

6. Heat exchanger according to claim 3, wherein the tubes (10) are provided with respective inlet and outlet openings for the cooling fluid positioned on an opposite side of the vessel (2) with respect to respective inlet and outlet openings for the hot fluid flowing outside the tubes (10).

7. Heat exchanger according to claim 6, further comprising a pair of manifolds (18,19) for distributing and, respectively, collecting the cooling fluid, said manifolds (18,19) being fixed to said tubes (10) out of the vessel (2) at said inlet and outlet openings.

8. Heat exchanger according to claim 7, wherein said manifolds (18,19) for distributing and collecting the cooling fluid include at least one partition plate (25,26) for connecting said tubes (10) together in series/parallel.

9. Heat exchanger according to claim 1, further comprising at least one annular baffle (27) mounted in the vessel (2) for imparting a substantially zig-zag flowpath to the hot fluid flowing outside the tubes (10).

10. Heat exchanger according to claim 1, wherein the spacer means (15) for holding the tubes (10) at a preset distance from one another comprises respective wires structurally independent of said tubes (10).

11. Heat exchanger according to claim 10, wherein said wires have a substantially star-shaped configuration and include a plurality of arms (16) radially extending along a direction substantially perpendicular to the winding direction of said spiral-shaped portions (11) of the tubes (10).

12. Heat exchanger according to claims 1 and 9, wherein the spacer means (15) for holding the tubes (10) at a preset distance from one another further comprises a plurality of ribs (28,29) formed on opposite sides of the annular baffles (27).

13. Heat exchanger according to claim 1, wherein the outer vessel (2) includes a plurality of supporting ribs (30,31) for the spiral-shaped portions (11) of the tubes (10), said ribs (30,31) extending from respective inner walls of opposite closure covers (4,5) of the vessel (2).

14. A water heating apparatus for household applications, comprising a heat exchanger according to anyone of the preceding claims.

15. A method of manufacturing a heat exchanger for water heating apparatuses, characterized in that it comprises the following steps:

- rectifying a first end portion (12) of a tube (10) having a predetermined length;
- bending said first end portion (12) along a direction substantially perpendicular to the remaining portion of the tube (10);
- winding into a spiral a central portion (11) of the tube (10) adjacent to said first end portion (12);
- bending a second end portion (13) of said tube (10), first along a substantially radial direction and then along a direction substantially perpendicular to a plane of development (π) of said spiral-shaped portion (11);
- stacking a plurality of said tubes (10) inside an outer vessel (2) with the interposition of spacer

means (15), so as to arrange the spiral-shaped portions (11) in parallel adjacent planes;

- closing said vessel (2) with a first cover (5) provided with openings (14) for receiving the free ends of said portions (12,13) of the tubes (10);
- closing said vessel (2) with a second cover (4) provided with inlet and outlet openings (6,7) for a first fluid adapted to flow outside the tubes (10);
- connecting the opposite free ends (12,13) of said tubes (10) with respective distribution and collection manifolds (18,19) of a second fluid adapted to flow inside the tubes (10).

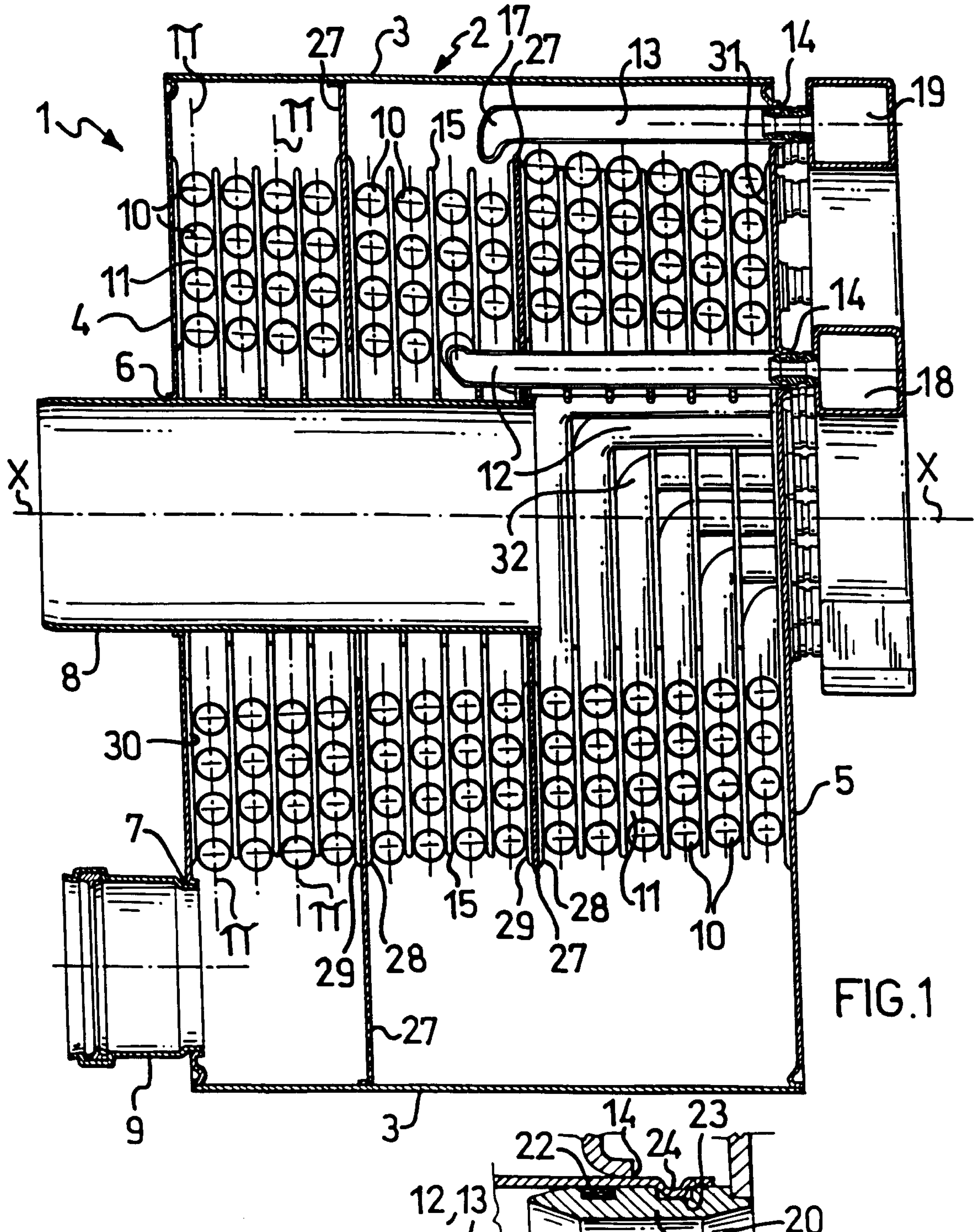
16. Method according to claim 15, characterized in that it further comprises the step of bending said first end portion (12) of the tube (10) along a direction substantially radial with respect to said plane of development (π) before winding into a spiral the central portion (11) of the tube (10).

17. Method according to claim 15, characterized in that the outer vessel (2) is closed by said first cover (5) before carrying out the step of stacking the tubes (10) therein.

18. Method according to claim 15, characterized in that it further comprises the step of providing within said manifolds (18,19) at least one partition plate (25,26) for connecting said tubes (10) together in series/parallel.

19. Method according to claim 15, characterized in that it further comprises the step of providing within the vessel (2) annular baffles (27) for imparting a substantially zig-zag flowpath to the fluid flowing outside the tubes (10).

20. Method according to claim 15, wherein the manifolds (18,19) for distributing and collecting the fluid flowing inside the tubes (10) are fixed to said tubes (10) by expanding.


1
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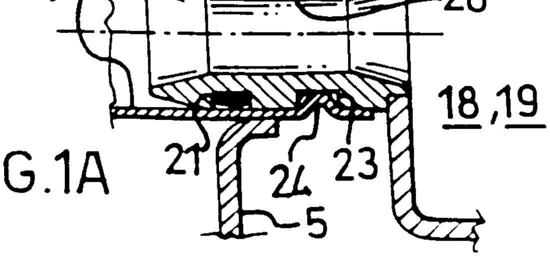
X
X

FIG.1


14
22
23
24
12,13
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18,19
21
24
23
5

FIG.1A

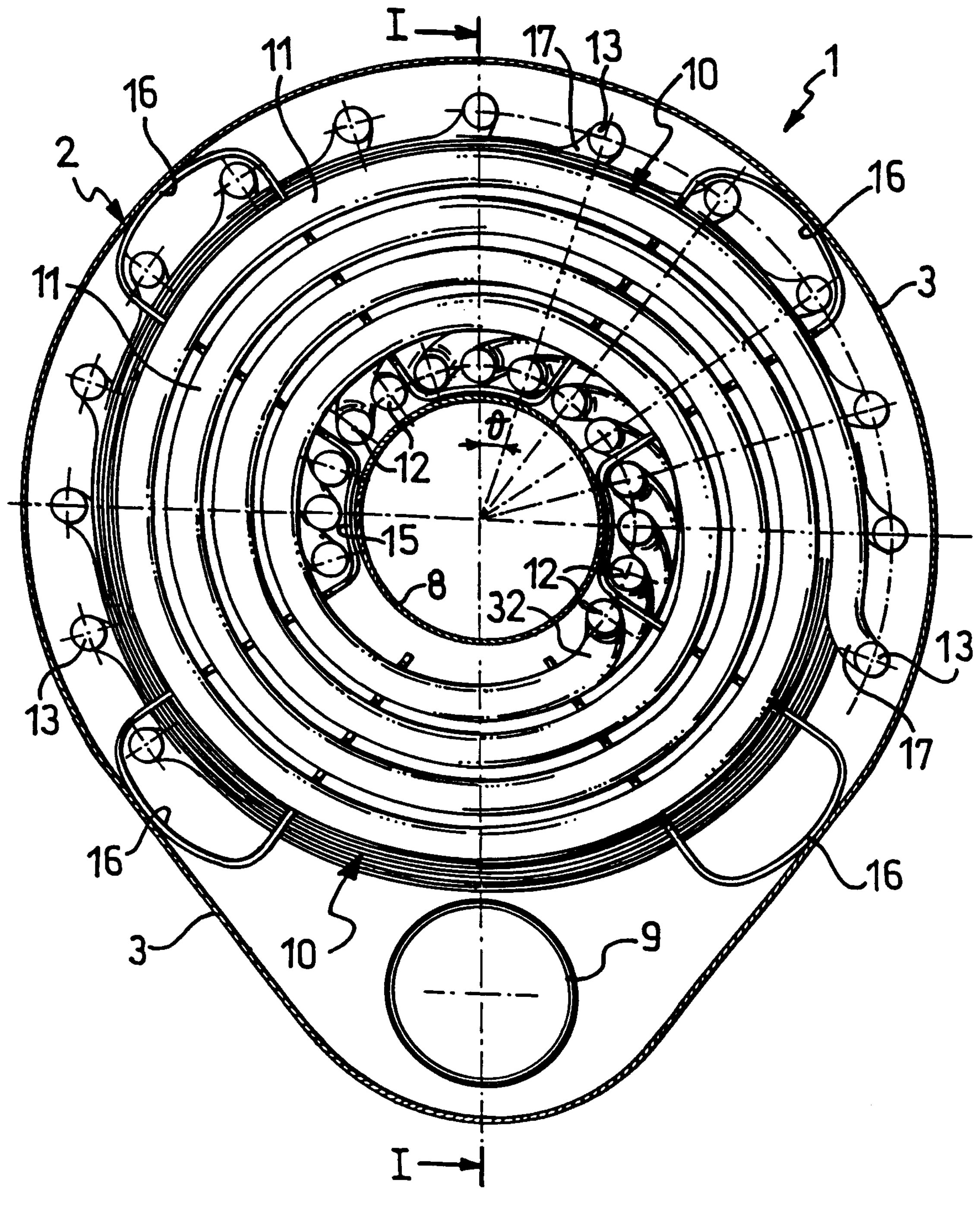

FIG.2

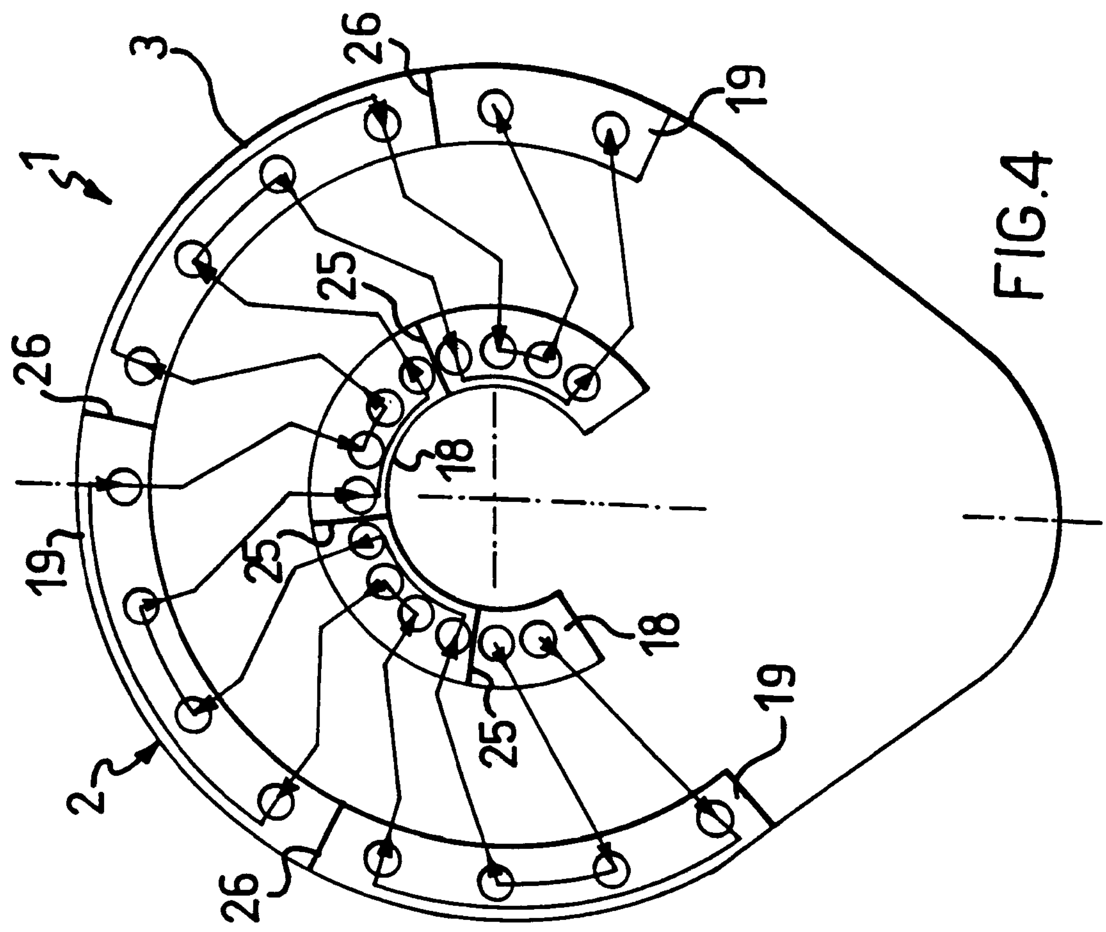

FIG.4

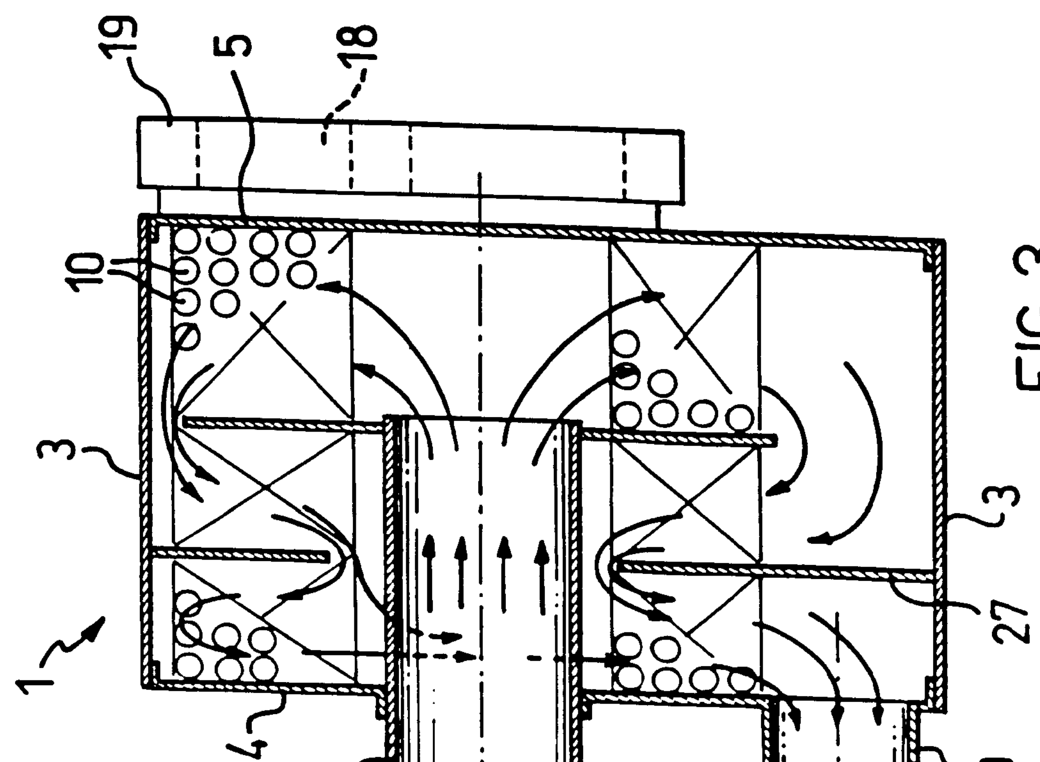

FIG.3

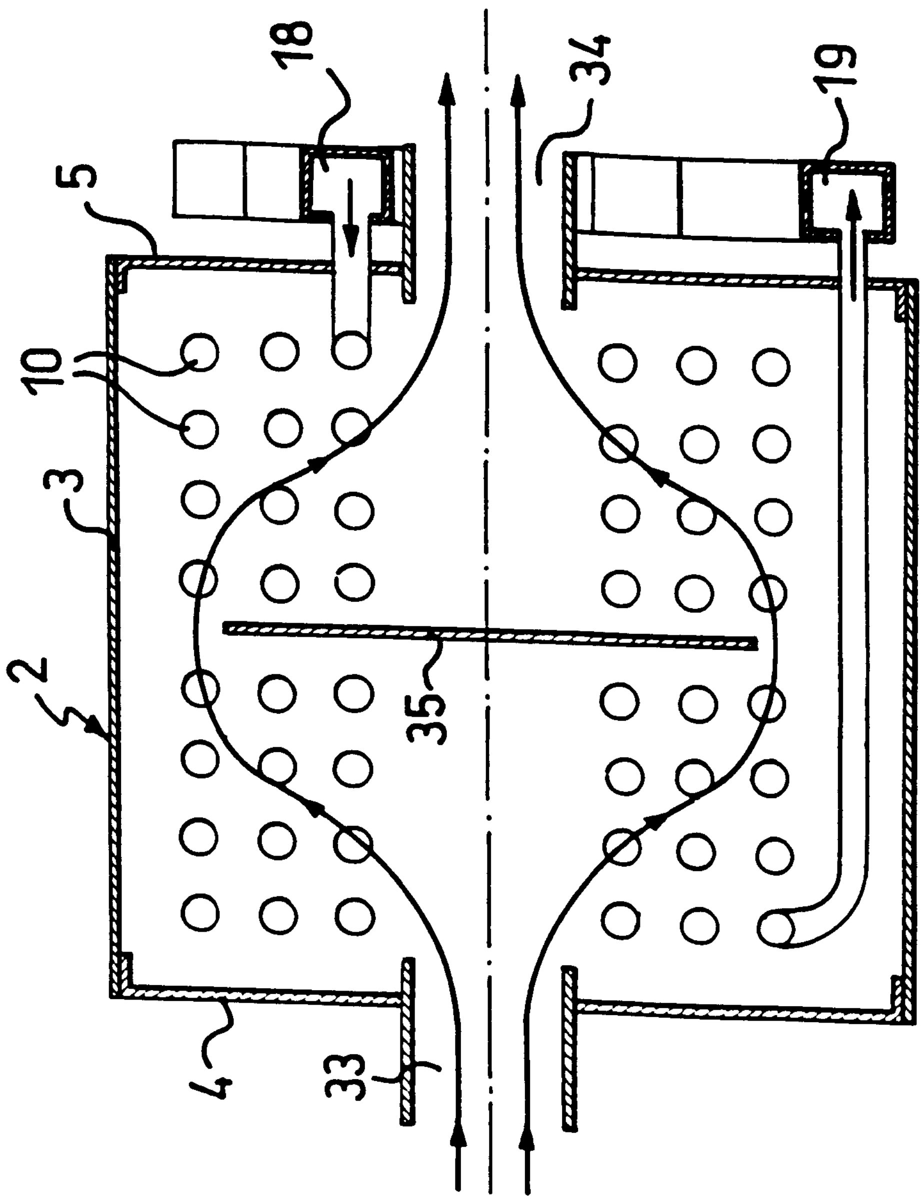

FIG.5

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 97 83 0190

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
Y	FR 2 523 286 A (WIELAND WERKE AG) 16 September 1983 * claims 1-12 *	1,2,4, 9-13	F28D7/04
A	* figures 1-4 *	3,5-8,14	
Y	US 3 499 484 A (LANZONI GIANLUIGI) 10 March 1970	1,2,4,9, 12,13	
A	* the whole document *	5-7	
Y	US 3 720 259 A (FRITZ K ET AL) 13 March 1973 * column 3, line 38 - column 4, line 33 *	1,10,11	
A	* figures 1-5 *	9	
A	US 5 109 920 A (MERRYFULL ALBERT E) 5 May 1992 * column 2, line 65 - column 3, line 48 * * figures 3-8 *	10-12, 15-20	
A	US 4 306 618 A (HONKAJAERVI MARKKU V) 22 December 1981 * the whole document *	3,6, 14-20	

TECHNICAL FIELDS SEARCHED (Int.Cl.6)

F28D
F28F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	24 September 1997	Mootz, F

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