(19)

SUOMI - FINLAND
(FI)

PATENTTI- JA REKISTERIHALLITUS
PATENT- OCH REGISTERSTYRELSEN
FINNISH PATENT AND REGISTRATION OFFICE

(10) **FI 130622 B**

(12) **PATENTTIJULKAISU**
PATENTSKRIFT
PATENT SPECIFICATION

(45) Patentti myönnetty - Patent beviljats - Patent granted **15.12.2023**

(51) Kansainvälinen patenttiluokitus - Internationell patentklassificering - International patent classification
F28D 7/16 (2006 . 01)
F28F 9/013 (2006 . 01)

(21) Patenttihakemus - Patentansökan - Patent application 20175826

(22) Tekemispäivä - Ingivningsdag - Filing date **15.02.2016**

(23) Saapumispäivä - Ankomstdag - Reception date **18.09.2017**

(41) Tullut julkiseksi - Blivit offentlig - Available to the public **18.09.2017**

(86) Kansainvälinen hakemus - Internationell ansökan - International application **15.02.2016 PCT/EP2016/053200**

(32) (33) (31) Etuoikeus - Prioritet - Priority

18.02.2015 DE 102015102312 P

(73) Haltija - Innehavare - Holder

1• Hugo Petersen GmbH , Rheingaustraße 190-196 , 65203 WIESBADEN , (DE)

(72) Keksijä - Uppfinnare - Inventor

1• FANI YAZDI , Sayyed Ahmad , WIESBADEN , (DE)
2• SCHULZE , Axel , IDSTEIN/HEFTRICH , (DE)

(74) Asiamies - Ombud - Agent

BERGGREN OY , P.O. Box 16 (Eteläinen Rautatiekatu 10 A) , 00101 HELSINKI

(54) Keksinnön nimitys - Uppfinningens benämning - Title of the invention

Putkinippulämmönsiirrin, jossa on peräkkäin järjestetyt putkinippukomponentit

Värmeväxlare med rörknippen med sekventiellt anordnade rörknippekomponenter

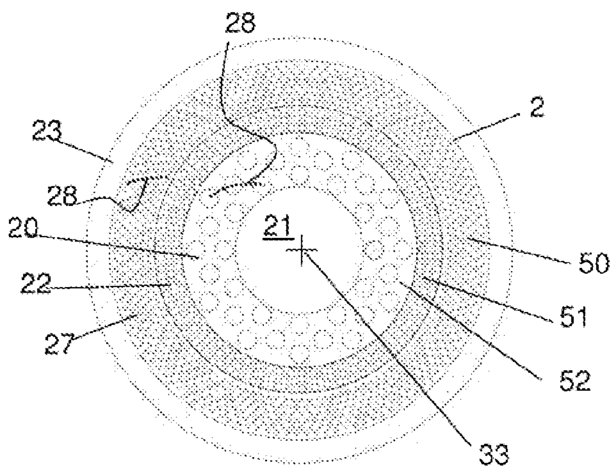
A shell and tube heat exchanger with sequentially arranged tube bundle components

(56) Viitejulkaisut - Anförda publikationer - References cited
US 2004194932 A1, US 5291944 A, US 4357991 A

(57) Tiivistelmä - Sammandrag - Abstract

Lämmönsiirtopinnan lisäämiseksi ilman että putkinippulämmönvaihtimen kokonaishalkaisijaa pitää kasvattaa, keksintö luo putkinippulämmönsiirtimen (1), jossa yhteen vaippatilaan (3) on järjestetty useista putkista (20, 22, 27) ja ainakin yhdestä putkipohjasta (25; 26) koostuva putkinippu (2), jolloin putkinippulämmönsiirrin (1) rajoittuu ulkoa päin vaippapintaan (31) ja sillä on keskellä vaippatilassa kulkeva pituusakseli (33), jonka ympärille on
muodostettu putketon sisempi kanava (21) ja jolloin sisäpuolelle vaippapinnan (31) viereen on muodostettu putketon ulompi kanava (23), jolloin putkinippu (2) sisemmän kanavan (21) ja ulomman kanavan (23) välissä sisältää ainakin kaksi putkinippukomponenttia (50, 51, 2, 53, 54), jotka eroavat toisistaan putkien lukumäärässä pintaa kohti ja/tai putkien ulkohalkaisijan suhteen ja/tai putkien keskinäisen etäisyyden suhteen.

The invention relates to a shell and tube heat exchanger (I) in which a tube bundle (2) consisting of a plurality of tubes (20, 22, 27) having at least one tube bottom (25; 26) is arranged in a shell space (3), in order to be able to increase the heat exchanger area without having to enlarge the total diameter of a shell and tube heat exchanger. The shell and tube heat exchanger (I) is delimited to the outside by a shell surface (31) and has a longitudinal axis (33) extending centrally in the shell space, around which an inner channel (21), which is free of tubes, is designed, and wherein an outer channel (23), which is free of tubes, is designed on the inside, adjacent to the shell surface (31), wherein the tube bundle (2) comprises at least two tube bundle components (50, 51, 2, 53, 54) between the inner channel (21) and the outer channel (23), which differ in the number of tubes per area and/or in the outside diameter of the tubes and/or in the spacing of the tubes.



A Shell and tube heat exchanger

with sequentially arranged tube bundle components

The invention relates to a shell and tube heat exchanger according to claim 1.

Shell and tube heat exchangers are also referred to as heat transfer apparatus and are the heat exchangers most frequently used in industry.

In the shell and tube heat exchangers, the heat transfer surface separates a hot fluid space from a cold fluid space. One fluid flows through the tubes (tube-side), while the other fluid flows around the tubes (shell-side). Tube bundles are placed into a shell and held within a tube sheet in such a manner that this tube sheet acts as a barrier in order to prevent the mixing of the two fluids having different temperatures. In order to produce a higher velocity within the shell space or to increase the contact frequency of the medium in the shell space with the heat transfer area, baffles, deflection segments, are used. The fluid in the shell space is thereby forced to travel a longer distance between the inlet and outlet nozzles.

A heat exchanger of this type according to the prior art is shown in FIG. 1.

In this figure, the top illustration is a longitudinal section through a cross-flow operated shell and tube heat exchanger. The bottom illustration shows an open perspective representation of the shell space with tube bundle and deflection segments, baffles.

On the shell-side, the tube pitch has a strong influence on the fluid velocity and thus on the heat transfer and on the pressure loss. Conventional cross-flow heat exchangers have non-uniform flow lines on the shell-side and, as a result, a higher mechanical load. In addition, the pressure losses in these heat exchangers are very high.

The next step in the development of shell and tube heat exchangers were so-called radial flow heat exchangers. A longitudinal section of this type of heat exchanger is shown in FIG. 2. The top illustration shows a longitudinal section of a cross-flow operated shell and tube heat exchanger. An open perspective representation of the shell space with tube bundle and baffles is shown in the bottom illustration in the figure, wherein the respective heads for the supply and discharge of the tube-side and shell-side fluids are not shown. Radial flow heat exchangers are also disclosed by US 2004/0194932 A1, US 4,357,991 A and US 5,291,944 A.

The weaknesses encountered in conventional shell-and-tube heat exchangers can be reduced by means of a shell and tube heat exchanger with radial through-flow. As a result of uniform flow from the central channel outward in the radial direction or from the space between the shell of the heat exchanger around the tube bundles to the central channel respectively, both, lower mechanical loads and lower pressure losses in the shell space of the heat exchanger are achieved. This results not only in freedom in the selection of the shell-side orientation of the supply and discharge nozzles, but also in a more compact design of the tube bundle.

The radial arrangement of the tubes has the disadvantage, in that the number of tube rows is limited.

The tubes are referred to here as “tube rows”, which are arranged next to one another substantially on a circular path around the longitudinal axis of the tube bundle. The tube bundle has a plurality of such tube rows having different radii. The mutual distances between the tubes in each tube row and the distance between adjacent tube rows are selected in such a way that a through-flow of the tube bundle which is as uniform as possible is given in the radial direction by the shell space fluid in order for the intended heat transfer to be carried out reliably.

Problems can arise in shell and tube heat exchangers in particular if large heat transfer surfaces are to be realised. As the illustration in figure 3A shows, the predetermined dimensions of the shell and tube heat exchanger, after a small number of tube rows, lead to the tube rows getting so close that this type of construction becomes uneconomical and practically impossible. In the example shown, an increase from three to four rows of tubes can no longer be possible. Furthermore, the poor through-flow of bottle necks between the tubes results in an effective reduction of the effective heat exchange surface. Due to the tubes colliding, the accommodation of the required area for the heat exchange is reduced, which shows the limitations of the heat exchanger design.

As a counter measure, a larger diameter of the central space of the bundle is selected. This solution is shown in figure 3B. By the selection of larger dimensions, now four tube rows can be accommodated compared with the tube layout shown in Fig, 3A, which again however results in a larger total diameter of the heat exchanger.

It is therefore an object of the invention to provide a shell and tube heat exchanger which overcomes the disadvantages of known shell and tube heat exchangers. In particular it is an object of the invention to create a possibility to increase the heat exchange area without having to increase the overall size of the heat exchanger. It is the aim to increase the heat exchange area, while at the same time retaining constant dimensions of the shell and tube heat exchanger.

These tasks are solved in a surprisingly simple manner by the shell and tube heat exchanger according to Claim 1. Advantageous further developments are described in the dependent claims.

The invention provides a shell and tube heat exchanger, wherein a tube bundle consisting of a plurality of tubes, having at least one tube sheet, is arranged in a shell space, wherein the shell and tube heat exchanger is delimited to the outside by a shell surface and has, extending centrally in the shell space, a longitudinal axis around which an inner channel free of tubes is formed and wherein, on the inside adjacent to the shell surface, an outer channel free of tubes is formed, wherein the tube bundle between the inner channel and outer channel comprises at least two tube bundle components, which differ from each other with respect to the number of tubes per area or the outer diameter of the tubes and/or in the distance between the tubes.

20175826 PRH 23-10-2023

Thus, the invention offers the advantage that the heat exchanger area of the shell and tube heat exchanger whilst having constant dimensions of the shell can be flexibly adjusted to a variety of different requirements. The shell and tube heat exchange can therefore be described as a multi-bundle radial heat exchanger.

Such a multi-bundle radial heat exchanger offers flexibility to select initially the smallest possible tube bundle diameter and, if required, change over to a newly conceived tube bundle later. This is possible for heat exchanger bundles which have tubes arranged around the entire area of each tube row, as well as for so called semi radial heat exchangers, reference to which will be made in greater detail below in connection with the further development of the invention regarding a connection zone.

The number of tubes per area of the tube bundle component perpendicular to the longitudinal extension of the tubes defines the tube pitch.

The spacing of the tubes, one from the other is the shortest distance between the outer wall of a tube to the outer wall of the nearest, adjacent tube.

In operation, the at least two ring shaped tube bundle components are sequentially flowed through by the shell space fluid. In particular, they are arranged concentrically to the longitudinal axis. Thus, the invention creates a shell and tube heat exchanger with tube bundle components sequentially arranged in the shell space in a direction perpendicular to the longitudinal axis.

In an advantageous embodiment of the shell and tube heat exchanger according to the invention, the at least two tube bundle components, viewed perpendicularly to the longitudinal axis, each have a substantially annular cross-section. In this way, a structurally particularly simple option is provided for stacking tube bundle components radially to form a tube bundle. In particular, the shell and tube heat exchanger can comprise a tube bundle having between two and ten tube bundle components.

In order to obtain tube bundles that are adjusted to particular requirements of individual applications, the invention further provides that at least two tube bundle components are detachably connected to one another. In particular, the tube bundle is formed in a modular manner from at least two tube bundle components.

In a preferred embodiment of the invention, a first tube bundle component adjoins the inner channel as viewed radially outwardly from the longitudinal axis and this is then joined by a second tube bundle component, wherein the radius of the inner boundary of the second tube bundle component pointing towards the longitudinal axis is formed corresponding to the radius of the outer boundary of the first tube bundle component.

Conveniently, the radius of the inner boundary of the second tube bundle component pointing to the longitudinal axis can be larger than the radius of the outer boundary of the first tube bundle component, at least so much larger, that the second tube bundle component can be mounted over the first tube bundle component.

In this manner, further tube bundle components can be adjoined to the second tube bundle component. Such arrangements facilitate that, also within a tube bundle component, zones of different numbers of tubes per area and/or different outer diameters of the tubes and/or different spacing of tubes can be formed, so that one tube bundle component can comprise a plurality of tube bundle stages.

The arrangement of the tubes in the tube bundle and/or the tube bundle component defines the so-called tube layout. The tube layout can, in principle, have a radially arranged form or can assume a radial form with the help of a plurality of segments. The number of segments is optional. In practice the segments are embodied as tube bundle modules.

If at least one tube bundle component consists of at least two, preferably three or four or five, tube bundle modules, the construction of a desired tube bundle when realising the connection zone according to the invention is facilitated according to the modular principle with prefabricated modules.

The tube bundle modules can be identical in this case.

In particular, n -1 (for example three) tube bundle modules having a cross-section – seen perpendicular to the longitudinal axis – which is a substantially 1/n-circle (for example quarter-circle) tube field layout, are connected to one another, wherein the connection zone is produced by the nth (for example fourth) module which is absent in relation to the full circle. The tube bundle modules are preferably connected in a simple manner by insertion into the at least one tube sheet. In a further embodiment the at least one tube bundle is formed non-identical from the at least one other tube bundle module.

According to an advantageous development of the invention, the shell and tube heat exchanger has a single chamber.

In particular, the shell and tube heat exchanger having one chamber is designed as a module for a multi-part shell and tube heat exchanger in that the outlet from the discharge chamber is designed to connect to the inlet into the entry chamber. This allows a plurality of shell and tube heat exchangers to be connected to form a type of tower or stack inside which, during operation, the shell-space fluid after leaving one heat exchanger module enters the next module.

In order to be able to realise longer flow paths with the highest possible driving gradient for the heat transfer, in one development of the invention, the shell and tube heat exchanger has two or more, preferably up to twenty, chambers around a single tube bundle, wherein at least one deflection segment for the shell space fluid is arranged between adjacent chambers.

During operation of the shell and tube heat exchanger, the shell-space fluid enters into the first chamber which, apart from the shell surface and the edge of the connection zone between the inner and outer channel of the tube field layout, is delimited by a tube sheet and a deflection segment, baffle.

The baffle consists of a plate with a surface perpendicular to the longitudinal axis, which corresponds inversely to the tube field layout, wherein an inner region is cut out of this surface or an outer region is cut off.

In particular, the cross section of the inner region practically corresponds to that of the inner channel, and the cross section of the outer region is practically identical to that of the outer channel.

According to an advantageous development of the invention, the arrangement of the tubes in the tube bundle defines a tube field layout which has at least one connection zone via which the fluid enters or exits the shell space during operation of the shell and tube heat exchanger. In this arrangement the number of tubes per cross sectional area perpendicular to the longitudinal axis can be smaller inside the connection zone than outside the connection zone, so that the connection zone is free of tubes. By virtue of a heat exchanger with connection zone, the conventional practice of a bonnet following the tube sheet in the longitudinal direction of the heat exchanger can in principle be dispensed with. In this way, the invention allows for a more compact and thus also smaller size to be achieved.

The shell and tube heat exchanger according to the invention may be summed up as achieving a ”semi-radial flow”. A heat exchanger according to the invention is therefore also referred to as a “semi-RF heat exchanger”. The term “semi” should be understood to mean that only a part — not necessarily half — of the tube field layout is equipped with tubes.

If at least one tube bundle component is assembled of tube bundle modules and if at least one tube bundle module is designed to be non- identical to the at least one other tube bundle module, it is possible in an easy manner to construct the connection zone. For example, one tube bundle module can then comprise a section of the tube layout which includes the connection zone and adjacent tubes, while the one further tube bundle module contributes or the further tube bundle modules contribute the remaining tubes to the overall tube field layout.

The entry and/or exit gap created by the connection zone for the shell space fluid can assume any geometry. In an advantageous simple embodiment, the connection zone has a first and a second passage surface as well as two lateral boundaries ,wherein the first passage surface is the transition between the outer channel and the connection zone , the second passage surface is the transition between the connection zone and the inner channel, the first lateral boundary extends from an edge of the first passage surface −which edge runs in the longitudinal direction of the shell space − to the corresponding edge of the second passage surface – which edge (46) runs in the longitudinal direction of the shell space − and the second lateral boundary extends from the other edge of the first passage surface −which edge runs in the longitudinal direction of the shell space − to the corresponding edge (46) of the second passage surface −which edge runs in the longitudinal direction of the shell space .

The two lateral boundaries of the connection zone run substantially parallel to each other, when the connection zone is intended to realise the shortest path between the inner and the outer channel. Within the scope of the invention, in a direction perpendicular to the longitudinal axis or to a parallel of the longitudinal axis, the lateral boundaries of the connection zone can, in sections, create different cross-sectional shapes of the connection zone. The cross section of the connection zone is the area through which the shell space fluid passes when it flows between the inner and the outer channel.

The invention offers a multitude of options for designing the geometry of the connection zone in such a manner that it is adjusted to achieve the desired flow profile of the shell-space fluid and thus also the kinetics of the heat transfer during operation. The lateral boundaries of the connection zone can for instance extend substantially parallel to each other, at least in sections.

The two lateral boundaries of the connection zone can, at least in sections, enclose an angle α in the range of approximately 180° to approximately 10° with each other when viewed from the longitudinal axis. A further option within the scope of the invention is that both lateral boundaries, in the direction from the outer channel to the inner channel, enclose an angle α in the range of approximately 180° to approximately 10° with each other, at least in sections.

Furthermore, the invention provides the option, that the first or the second lateral boundary or both lateral boundaries of the connection zone extend radially, at least in sections, as viewed from the longitudinal axis. An additional option is that the first or the second lateral boundary or both lateral boundaries of the connection zone, viewed in cross section perpendicularly to the longitudinal axis, extend substantially tangentially to the edge of the inner channel, at least in sections.

A further embodiment of the invention provides that the first or the second lateral boundary or both lateral boundaries of the connection zone viewed in cross section perpendicularly to the longitudinal axis, run at least in sections, along a curved path, wherein the first or the second lateral boundary or both lateral boundaries, at least in sections, defines or define in particular a circular arc segment or a section of a spiral.

With regard to a more detailed description of the connection zone in a variety of design options, reference is herewith made to the German patent application of the present applicant of the same date with the title "A shell and tube heat exchanger", and in particular figures 12 to 30 and their description, which by reference is included as forming part of the present application.

The invention also provides a tube bundle for a shell and tube heat exchanger described above. Such a tube bundle can be manufactured and marketed separately. The final assembly of the entire heat exchanger can then be carried out, for example, at the site of use by installation in the shell and attaching the inlets and outlets to the connections for the connection zone.

Furthermore, the invention provides additional options by way of further parameters to target and influence aspects of the flow, in particular that of the space fluid, and adjust them to individual practical requirements. For example, it is provided that the arrangement of the tubes within the tube bundle defines a tube layout wherein the tubes, at least in sections, are arranged aligned with each other and/or at least in sections be arranged offset to each other. Furthermore, the tube bundle may be arranged in the shell space eccentrically to the longitudinal axis.

The shell and tube heat exchanger according to the invention can, in principle, be used for liquid and gaseous media as well as for fluids containing liquid and gaseous media components such as aerosols or wet steam. By virtue of its relatively high heat exchange surface the shell and tube heat exchanger is particularly advantageous for use as a gas to gas heat exchanger, that is to say for heat exchange between two substantially gaseous media. For example, the shell and tube heat exchanger according to the invention can be used for heat recovery from hot exhaust gas streams. A particular area of application is their use in the context of methods for synthesizing sulphuric acid (H2S04).

The invention is explained in more detail below, with reference to the attached drawings, on the basis of exemplary embodiments. Identical and similar components are provided with the same reference symbols, wherein the features of the different exemplary embodiments can be combined with one another.

FIG. 1 shows a schematic representation of a longitudinal section of a tube bundle heat exchanger operated in cross flow mode according to the prior art technology (top) and a schematic open perspective representation of the corresponding shell space with tube bundle and deflection segments (bottom);

FIG. 2 shows a schematic representation of a longitudinal section of a radial shell and tube heat exchanger operated in cross-flow mode according to the prior art technology (top) and a schematic open perspective representation of the corresponding shell space with tube bundle and deflection segments (bottom), wherein the respective heads for the supply and discharge of the tube-side and shell-side fluids are not shown;

FIG. 3 shows a schematic representation of a cross section through a tube bundle in the shell with colliding tubes (FIG. 3A) and with enlarged dimensions (FIG. 3B) for accommodating four rows of tubes instead of three rows of tubes;

FIG. 4 shows a schematic representation of a cross section through a tube bundle in the shell according to a first embodiment of the invention;

FIG. 5 shows a schematic representation of aligned and offset tube arrangements (FIG. 5A) and a schematic representation of a cross section through a tube bundle (FIG. 5B) in the shell (left) and without shell (right) with offset tube arrangement;

FIG. 6 shows a schematic open perspective representation of a shell and tube heat exchanger with two chambers and a tube bundle according to a further embodiment of the invention;

FIG. 7 shows a schematic representation of a cross section through a tube bundle in the shell according to a further embodiment of the invention;

FIG; 8 shows a schematic representation of a cross section through a tube bundle in the shell according to a further embodiment of the invention;

Figure 9 shows a schematic open perspective representation of a shell and tube heat exchanger according to the invention with two chambers and a tube bundle according with a further embodiment of the invention;

Figure 10 shows a schematic representation of a cross section of a tube bundle in the shell according to a further embodiment of the invention;

FIG. 11 shows a schematic representation of a cross section through a tube bundle in the shell according to a further embodiment of the invention;

FIG. 12 shows a schematic representation of a cross section through a tube bundle in the shell according to a further embodiment of the invention;

In the figures, for the sake of clarity, the direction of flow of the shell-space fluid and of the tube-space fluid is indicated by arrows, as can be seen in the operation of the tube-bundle heat exchanger according to the invention in principle. Furthermore, dotted lines are partially drawn in, which serves to illustrate the subdivision of the tube bundle into tube bundle components (FIGS. 4 and 8) or of the tube bundle and of the connection zone (FIG, 10).

The fluid inlet and outlet nozzles 13, 14 for the shell space fluid can, within the scope of the invention, in principle, assume any shape, for example a rectangular, oval or circular cross section. The operating temperature range of the shell and tube heat exchanger according to the invention can, in principle, be between – 270°c and 2000° C, in particular between -80°C and 2000°C, more preferred between -50°C and 1300°C. Most preferred is an operating range of between 0 and 600°C.

In order to vary the heat exchanger surface of a shell and tube heat exchanger without changing the outer dimensions of the tube bundle or of the heat exchanger, the invention provides a tube bundle 2 having a plurality of tube bundle components, which are combined with one another and the tubes of which together determine the entire heat transfer surface.

In FIG. 4, a tube bundle 2 according to the invention is shown in cross-section. It extends along the longitudinal axis 33 and has an inner channel 21.

The outer channel 23 extends between the outermost tube row of the tube bundle 2 and the inner side of the shell surface. In the exemplary embodiment shown, the tube bundle 2 comprises three tube bundle components 50, 51, 52. These are positioned concentrically with respect to one another about the longitudinal axis 33.

The tube bundle components 50, 51, 52 each have a circular cross-sectional area. Perpendicularly to this cross-sectional area, in the outer tube bundle component 50, tubes 27 run in six concentric tube rows about the longitudinal axis 33.

The middle tube bundle component 51 extends in the radial dimension with respect to the longitudinal axis 33, which is approximately half of the corresponding extension of the outer tube bundle component 51. The tubes 22 of the central tube bundle component 51 have a larger diameter than the tubes 27 of the outer tube bundle component 50.

The tubes extend in three concentric tube rows to the longitudinal axis 33.

The inner tube bundle component 52 has tubes 20 which are likewise arranged in three concentric tube rows to the longitudinal axis 33. The tubes 20 have a larger diameter than the tubes 22 of the middle tube bundle component 51. The tubes 22 have a diameter which is also larger than the diameter of the tubes 27 of the outer tube bundle component 52. Depending on the process requirement, this diameter relation can be realised precisely in the reverse order or viewed in the radial direction, being a mixture of successive increasing and decreasing diameters of the tube bundle components.

The tubes 20, 22, 27 are arranged in the tube bundle components 50, 51, 52 In the manner of a masonry wall, that is to say, arranged offset with respect to one another. The spacing between two adjacent tubes 20, 22, 27 in a tube bundle component 52, 51, 50 is a minimum distance of 1.05 times the tube diameter from the centre of a tube to the centre of the adjacent tube. Depending on the process and on the particular design, the minimum spacing can be increased.

The spacing between the tubes 20 of the inner tube bundle component 52 is approximately 1.8 to 2.0 times the tube diameter. The spacing between the tubes 22 of the central tube bundle component 51 is approximately 1.1 to 1.3 times the tube diameter. The spacing between the tubes 27 of the outer tube bundle component 50 is approximately 1.8 to 2 times the tube diameter.

A tube bundle consisting of tube bundle components has been described above, wherein each tube bundle component has an offset arrangement of the tubes with a tube-free centre and a tube-free tube outer ring (masonry wall). A further alternative for arranging the tubes relative to one another within the scope of the invention is a special variant of the offset arrangement, namely tube rows positioned one behind the other in that the tubes are arranged on a curved path. This arrangement is achieved when a wall is built up of tubes the centre points of which are positioned on concentric circles about the longitudinal axis. Figure 4 shows such curved paths 28 for the inner and outer tube bundle component as dotted lines.

In a preferred corresponding embodiment, the tube bundle component according to the invention has at least one tube bundle component in which tubes with their centre points on at least three of the concentric circles are arranged to the longitudinal axis in such a way that the connecting line of the centre points of a tube of a circle to a tube of the circle with the next larger diameter, a curved path 28 is obtained when the connecting line is continued on to an adjacent tube of a next circle having a larger diameter. The invention thus provides the possibility of packing the tubes in a particularly tight manner on mutually adjacent circles, since the spacing between the circles, on which the centre points of the tubes are arranged, can also be selected to be smaller than the tube radius when the tube spacing is suitably dimensioned. Such tube arrangements realised in tube bundles shown in Figs. 7 and 12.

Within the scope of the invention, the tubes in a tube bundle component can also, however, be arranged in alignment with one another. It is likewise within the scope of the invention to combine aligned and offset tube arrangements with one another. Such a combination can be used within a single tube bundle component. Furthermore, tube bundle components with offset tube arrangement can be combined with those having an aligned tube arrangement in one tube bundle component. In such case, the tube spacings in each tube bundle component can differ from one another.

Examples of aligned and offset tube arrangements are shown in FIG. 5. In FIG. 5A, an arrangement of tubes 20 is shown on the left-hand side, in which the centre points of adjacent tubes lie in a row of tubes on a straight line. Likewise, the centre points of adjacent tubes of directly successive tube rows lie in each case on a straight line. Each tube is thus the centre point of a cross with orthogonal arms, on the arms of which the adjacent tubes lie.

In the case of the offset tube arrangement illustrated on the right-hand side in FIG. 5A, two mutually adjacent tubes of a row of tubes define a spacing wherein, in the following row of tubes, the tubes are arranged at the point, which is positioned at a half spacing from a tube of the preceding and of the subsequent tube row. The tubes are thus arranged in the manner of a masonry wall.

FIG. 6 shows an open perspective illustration of a chamber of a shell and tube heat exchanger with a tube bundle, which comprises three tube bundle components 50, 51, 52. The tubes thereof have the same tube diameter, but the number of tubes per cross-sectional area of the inner tube bundle component 52 is smaller.

During operation, the shell-space fluid passes through the central channel 21 and flows around the tubes of the inner tube bundle component 52, the middle tube bundle component 51 and the outer tube bundle component 50. The shell space fluid then passes the deflection plate 32 in the outer channel 23 and on its way back passes into central channel 21 and flows around the tubes of said tube bundle components in the reverse order before it exits from the inner channel 21.

FIG. 7 shows a further embodiment of the tube bundle 2 according to the invention in cross section. It extends along the longitudinal axis 33 and has an inner channel 21. The outer channel 23 extends between the outermost tube row of the tube bundle 2 and the inner side of the shell surface. The tube bundle 2 comprises two tube bundle components 50, 51. These are positioned concentrically with respect to one another about the longitudinal axis 33.

The tube bundle components 50, 51 each have a circular cross-sectional area. Tubes 20 run perpendicularly to this cross-sectional area.

The tubes 20 of the inner tube bundle component 51 run in three concentric tube rows to the longitudinal axis 33. The distance of the tubes 20 of the inner tube bundle component 51 is about 0.95 to 1.05 times the tube diameter.

Following the third row of tubes of the inner tube bundle component radially in the direction towards the outside of the tube bundle component, there is a region free of tubes. This region corresponds in its radial dimension to approximately one row of tubes. In the case of a modular design of the tube bundle assembled of detachably connected tube bundle components, a free space of this type can be used as assembly area, where for instance fastening means such as flange connections can be attached (not shown in the figures). Adjacent to the free space, the outer tube bundle component 50 is arranged. In the latter, the tubes 20 are more densely packed than in the inner tube bundle component 51. The distance between tubes 20 in the outer tube bundle component 50 are about 0.05 to 0.1 times the tube diameter.

FIG. 8 shows a further embodiment of the tube bundle 2 according to the invention in cross-section, which comprises five radially, sequentially arranged tube bundle components 50, 51, 52, 53, 54, with each having a circular cross-sectional area. The distance of the tube rows from one another is equal in the outer, middle and inner tube bundle components 50, 52, 54. However, the number of tubes 20 per row in the middle tube bundle component 54 is significantly smaller than that in the outer tube bundle component 50.

In the embodiment of the tube bundles 2 shown in Figure 8, curved and non-curved zones radially alternate viewed from the longitudinal axis 33. As a result, between the outer and the middle tube bundle component 50, 52 and between the middle and the inner tube bundle component 52, 54, which can likewise be referred to as a tube bundle component 51, 53, a tube free area is created, which could also be described as tube bundle component 51, 53.

These have a tube density of zero. These zones are useful in modular constructions and assembly of the heat exchangers and assist in better maintenance and subsequent replacement of the system.

FIG. 9 shows an open perspective illustration of a chamber of a shell and tube heat exchanger having tube sheets 25, 26 for a tube bundle 2 according to the invention shown in FIG. 6 with two tube bundle components 50, 51. However, tubes are not inserted into all of the openings; rather, a region is kept free of tubes. Said region represents a connection zone 4 by means of which, during operation, the shell space fluid can be supplied and discharged into the inner channel around the longitudinal axis via corresponding supply and discharge nozzles (not shown).

During operation, the shell-space fluid passes through the connection zone 4 into the central channel 21, and subsequently flows across the tubes of the inner tube bundle component 51 and then the outer tube bundle component 50. The shell-space fluid then passes the baffle plate 32 in the outer channel and flows around the tubes of said tube bundle components in the reverse order on its way back into the central channel 21, before it exits again from the inner channel through the connection zone 4.

FIG. 10 shows a further embodiment of the tube bundle 2 according to the invention in cross-section, which tube bundle comprises four tube bundle components 51, 52, 53, 54 each occupying a ring shaped cross-sectional area of a three-quarter circle. The region which is cut out from the full circle forms the connection zone 4, connects the inner channel and the outer channel directly to one another. The spacing of the tubes from one another decreases from the inside to the outside from one tube bundle component to the next. The outer tube bundle component 51 has the largest tube density.

The tube bundle components of the embodiments described above allow a structure of the tube bundle according to the modular principle in the radial direction with respect to the longitudinal axis. In the context of the invention, this is also made possible in the direction parallel to the longitudinal axis, which allows a particularly simple construction in particular with regard to embodiments having a connection zone. In addition, the configuration of a tube bundle according to the invention having a plurality of tube bundle modules offers a further degree of freedom in the selection of the structure and the tube pitch of the tube bundle.

FIG. 11 shows a cross section of a tube bundle 2 in a shell space 3 of a further embodiment of the heat exchanger according to the invention. With regard to the radial subdivision into tube bundle components this tube bundle corresponds to the tube bundle shown in FIG. 6. The tube bundle is composed of four tube bundle modules 200 which extend parallel to the longitudinal axis 33.

The four tube bundle modules are mounted in the tube sheet in such a way, that they complement one another to form a tube bundle which is closed in the circumferential direction. In the example shown, each of the four tube bundle modules have a substantially quarter-circle cross-section. Within the scope of the invention, tube bundle modules with cross-sectional areas, which in each case cover different portions of a full circle ring in the circumferential direction when viewed in relation to the longitudinal axis, can be combined to form one tube bundle.

Within the scope of the invention, for example, three tube bundle modules 200 of the embodiment shown in FIG. 11 can also be used to form a tube bundle 2, which then has a connection zone instead of the fourth tube bundle module. This design corresponds, in principle, to the embodiment shown in FIG. 10. The subdivision into four tube bundle modules 200 or the embodiment with a connection zone of a quarter circle cross section only serves as an example. Within the scope of the invention, larger and smaller subdivisions of the full-circle cross-sectional area of the tube bundle can be selected and/or a plurality of connection zones can also be arranged in the tube bundle.

It is further possible, within the scope of the invention, to influence the flow of the shell-space fluid in that the tube bundle 2 is arranged with its longitudinal axis offset with respect to the longitudinal axis of the shell space 3. Such an eccentric arrangement of the tube bundle 2 in the shell space is shown in FIG. 12.

The spacing of the outer edge 24 of the tube bundle – in the embodiment shown in Fig. 12 seen in a centre top view – to the inner side of the shell surface 31, when viewed in the clockwise direction, initially increases until it reaches its maximum at the bottom in the middle and correspondingly decreases again to the minimum at the top in the middle. The fluid distribution can be optimised with an eccentric arrangement of the tube bundle relative to the central axis 33, particularly when gas as a shell space fluid does not flow through the central channel, but flows directly through the shell into the tube bundle. The invention thus provides the possibility of also taking into account any particular structural features that may be desirable.

It will be clear to the person skilled in the art that the invention is not restricted to the examples described above, but rather can be varied in many ways. In particular, the features of the individual illustrated examples can also be combined with one another or exchanged for each other. This applies in particular to the tube density, the outer diameter of the tubes and the spacing of the tubes from one another in tube bundle components which are illustrated in combination with one another.

In particular, with regard to these parameters, within the scope of the invention, there is freedom in the design of a tube bundle composed of a plurality of tube bundle components so that, in practice, for each particular application, the optimum tube pitch can be selected. This applies both to embodiments with and without a connection zone.

20175826 PRH 23 -10- 2023

LIST OF REFERENCE NUMERALS

1 Shell and tube heat exchanger 11 Chamber, first chamber 12 Last chamber 13 Supply for shell space fluid, supply device 14 Discharge for shell space fluid, discharge device 2 Tube bundle 20, 22, 27 Tube 21 Inner channel 23 Outer channel 24 Outer edge of the tube bundle 200 Tube bundle module 25 First tube sheet 26 Second tube sheet	28 Curved path 250 Supply chamber 260 Discharge chamber R tube space medium M shell-space medium 3 Shell space 31 Shell surface 32 Guide plate, deflection segment for the shell space fluid 33 longitudinal axis 4 Connection zone 50 to 54 Tube bundle component

CLAIMS

1. A shell and tube heat exchanger (1), wherein a tube bundle (2) consisting of a plurality of tubes (20, 22, 27) with at least one tube sheet (25; 26) is arranged in a shell space (3), wherein the shell and tube heat exchanger (1) is delimited to the outside by a shell surface (31) and has extending centrally in the shell space a longitudinal axis (33), around which an inner channel (21), free of tubes, is formed and where on the inside adjacent to the shell surface (31) an outer channel (23), free of tubes, is formed,
wherein the tube bundle (2) between inner channel (21) and outer channel (23) is comprised of at least two tube bundle components (50, 51, 52, 53, 54)
which differ from each other with respect to the number of tubes per area and/or the outer diameter of the tubes and/or in the spacing between the tubes,
characterised in that
the tube bundle components seen perpendicularly to the longitudinal axis (33) each have a substantially annular cross section and are sequentially arranged in the shell space in a direction perpendicular to the longitudinal axis, with
at least two tube bundle components (50, 51, 52, 53,54) being detachably connected with each other.

2. The shell and tube heat exchanger (1) according to claim 1,
characterised in that the tube bundle (2) is comprised of between two and ten tube bundle components (50, 51, 52, 53, 54).

3. The shell and tube heat exchanger (1) according to any one of the preceding claims, **characterised** in that in at least one tube bundle component (50, 51, 52, 53, 54) the tubes (20, 22, 27) are arranged with their centre points on at least three concentric circles to the longitudinal axis (33), in such a way that the connecting line of the centre points of a tube of a circle to a tube of the circle with the next larger diameter when being continued on to an adjacent tube of the next circle with a larger diameter, results in a curved path (28).

4. The shell and tube heat exchanger (1) according to any one of the preceding claims, **characterised** in that the tube bundle is assembled from at least two tube bundle components (50, 51, 52, 53, 54) in a modular manner.

5. The shell and tube heat exchanger (1) according to any one of the preceding claims, **characterised** in that at least one tube bundle component (50, 51, 52,53, 54) is assembled from at least two, preferably three or four or five, tube bundle modules (200).

6. The shell and tube heat exchanger (1) according to claim 5, **characterised** in that the tube bundle modules (200) are identical or that at least one tube bundle module is non-identical to the at least one other tube bundle module.

7. The shell and tube heat exchanger (1) according to any one of the preceding claims, **characterised** in that the shell and tube heat exchanger is comprised of a single chamber (11).

8. The shell and tube heat exchanger according to any one of the preceding claims,

characterised in that the shell and tube heat exchanger has two or more, preferably up to twenty chambers (11, 12) and at least one single tube bundle (2), wherein between adjacent chambers a deflection segment (32) for the shell space fluid (M) is arranged.

9. The shell and tube heat exchanger (1) according to any one of the preceding claims, **characterised** in that the arrangement of the tubes (20) in the tube bundle (2) defines a tube layout which has at least one connection zone (4) through which during the operation of the shell and tube heat exchanger (1) fluid (M) enters the shell space (3) and/or exits from the shell space (3).

10. The shell and tube heat exchanger (1) according to claim 9, **characterised** in that the number of the tubes (20) per cross section perpendicular to the longitudinal axis (33) is lower in the connection zone (4) than that outside of the connection zone or that the connection zone is free of tubes.

11. The shell and tube heat exchanger (1) according to any one of the preceding claims, **characterised** in that the arrangement of the tubes (20) in the tube bundle (2) defines a tube layout wherein the tubes (20) are, at least in sections, arranged aligned with one another and/or at least in sections, offset to one another.

12. The shell and tube heat exchanger (1) according to any one of the preceding claims, **characterised** in that the tube bundle (2) is arranged eccentrically to the longitudinal axis (33) in the shell space (3)

13. The tube bundle (2) for a shell and tube heat exchanger (1) according to any one of claims 1 to 12, which is arranged as a tube bundle (2) consisting of a plurality of tubes (20, 22, 27) with at least one tube sheet (25; 26) is arranged in a shell space (3) in an assembled state,

wherein the shell and tube heat exchanger (1) is delimited to the outside by a shell surface (31) and has extending centrally in the shell space a longitudinal axis (33), around which an inner channel (21), free of tubes, is formed and where on the inside adjacent to the shell surface (31) an outer channel (23), free of tubes, is formed,

wherein the tube bundle (2) between inner channel (21) and outer channel (23) is comprised of at least two tube bundle components (50, 51, 52, 53, 54), which differ from each other with respect to the number of tubes per area and/or the outer diameter of the tubes and/or in the spacing between the tubes,

characterised in that the tube bundle components perpendicularly to the longitudinal axis (33) each have a substantially annular cross section and are sequentially arranged in the shell space in a direction perpendicular to the longitudinal axis,

wherein at least two tube bundle components (50, 51, 52, 53, 54) are detachably connected with each other.

14. The use of a shell and tube heat exchanger (1) according to any one of claims 1 to 12 as gas to gas heat transfer apparatus, in particular for heat recovery.

15. The use of a shell and tube heat exchanger (1) according to any one of claims 1 to 12 as gas to gas heat transfer apparatus, in particular for heat recovery,

wherein the gas to gas heat transfer apparatus is used in a process for synthesis of sulphuric acid.

Patenttivaatimukset

1. Putkinippulämmönsiirrin (1), jossa vaippatilaan (3) on järjestetty useista putkista (20, 22, 27) muodostettu putkinippu (2), jossa on ainakin yksi putkipohja (25; 26),

jolloin putkinippulämmönsiirrin (1) rajoittuu ulospäin vaippapintaan (31) ja sillä on keskisesti vaippatilassa kulkeva pituusakseli (33), jonka ympärille on muodostettu sisempi kanava (21), jossa ei ole putkia, ja jolloin sisäpuolelle vaippapinnan (31) viereen on muodostettu ulompi kanava (23), jossa ei ole putkia,

jolloin putkinippu (2) sisemmän kanavan (21) ja ulomman kanavan (23) välissä sisältää ainakin kaksi putkinippukomponenttia (50, 51, 52, 53, 54), jotka eroavat toisistaan putkien lukumäärässä pinta-alaa kohti ja/tai putkien ulkohalkaisijan suhteen ja/tai putkien etäisyydessä,

tunnettu siitä, että putkinippukomponenteilla on kohtisuorassa pituusakseliin (33) nähden kulloinkin olennaisesti ympyrärenkaan muotoinen poikkileikkaus ja ne on vaippatilaan järjestetty kohtisuoraan pituusakseliin nähden olevassa suunnassa peräkkäin, ainakin kahden putkinippukomponentin (50, 51, 52, 53, 54) ollessa yhdistetty toisiinsa irrotettavasti.

2. Patenttivaatimuksen 1 mukainen putkinippulämmönsiirrin (1),

tunnettu siitä, että putkinippu käsittää 2–10 putkinippukomponenttia (50, 51, 52, 53, 54).

3. Jonkin edellä olevista patenttivaatimuksista mukainen putkinippulämmönsiirrin (1),

tunnettu siitä, että ainakin yhdessä putkinippukomponentissa (50, 51, 52, 53, 54) putket (20, 22, 27) ovat keskipisteiltään järjestetty siten ainakin kolmeen pituusakseliin (33) nähden samankeskiseen kehään, että yhdysviiva kehän yhden putken keskipisteestä seuraavaksi suuremman halkaisijan omaavan kehän putken keskipisteeseen johdettaessa se edelleen seuraavan kehän viereiseen, suuremman halkaisijan omaavaan putkeen muodostaa kaarevan radan (28).

4. Jonkin edellä olevista patenttivaatimuksista mukainen putkinippulämmönsiirrin (1),

tunnettu siitä, että putkinippu on moduulimaisesti koottu ainakin kahdesta putkinippukomponentista (50, 51, 52, 53, 54).

5. Jonkin edellä olevista patenttivaatimuksista mukainen putkinippulämmönsiirrin (1),

tunnettu siitä, että ainakin yksi putkinippukomponentti (50, 51, 52, 53, 54) on yhdistetty ainakin kahdesta, edullisesti kolmesta tai neljästä tai viidestä putkinippumoduulista (200).

6. Patenttivaatimuksen 5 mukainen putkinippulämmönsiirrin (1),

tunnettu siitä, että putkinippumoduulit (200) ovat samanlaisia tai että ainakin yksi putkinippumoduuli on muodostettu eri tavalla kuin ainakin yksi toinen putkinippumoduuli.

7. Jonkin edellä olevista patenttivaatimuksista mukainen putkinippulämmönsiirrin (1),

tunnettu siitä, että putkinippulämmönsiirtimessä on yksi ainoa kammio (11).

8. Jonkin edellä olevista patenttivaatimuksista mukainen putkinippulämmönsiirrin,

tunnettu siitä, että putkinippulämmönsiirtimessä on kaksi tai useampia, edullisesti aina 20:een saakka, kammiota (11, 12) ja ainakin yksi yksittäinen putkinippu (2), jolloin kahden vierekkäisen kammion väliin on järjestetty ohjaussegmentti (32) vaippatilafluidia (M) varten.

9. Jonkin edellä olevista patenttivaatimuksista mukainen putkinippulämmönsiirrin (1),

tunnettu siitä, että putkien (20) järjestys putkinipussa (2) määrittää putkiasetelman, jossa on ainakin yksi liitosalue (4), jonka kautta putkinippulämmönsiirtimen (1) käytön aikana fluidi (M) tulee vaippatilaan (3) ja/tai poistuu vaippatilasta (3).

10. Patenttivaatimuksen 9 mukainen putkinippulämmönsiirrin (1),

tunnettu siitä, että putkien (20) lukumäärä kohtisuorassa pituusakseliin (33) nähden olevaa poikittaispintaa kohti liitosalueella (4) on pienempi kuin liitosalueen ulkopuolella tai että liitosalueella ei ole putkia.

11. Jonkin edellä olevista patenttivaatimuksista mukainen putkinippulämmönsiirrin (1),

tunnettu siitä, että putkien (20) järjestys putkinipussa (2) määrittää putkiasetelman, johon putket (20) on järjestetty ainakin alueittaisesti linjaan toisiinsa nähden ja/tai ainakin alueittaisesti toistensa kanssa vuorottelevasti.

12. Jonkin edellä olevista patenttivaatimuksista mukainen putkinippulämmönsiirrin (1),

tunnettu siitä, että putkinippu (2) on järjestetty vaippatilaan (3) epäkeskisesti pituusakseliin (33) nähden.

13. Putkinippu (2) jonkin patenttivaatimuksista 1–12 mukaista putkinippulämmönsiirrintä (1) varten, joka on asennetussa tilassa järjestetty vaippatilaan (3) useista putkista (20, 22, 27) koostuvana putkinippuna (2), jossa on ainakin yksi putkipohja (25; 26), jolloin putkinippulämmönsiirrin (1) rajoittuu ulospäin vaippapintaan (31) ja sillä on keskisesti vaippatilassa kulkeva pituusakseli (33), jonka ympärille on muodostettu sisempi kanava (21), jossa ei ole putkia, ja jolloin sisäpuolelle vaippapinnan (31) viereen on muodostettu ulompi kanava (23), jossa ei ole putkia,

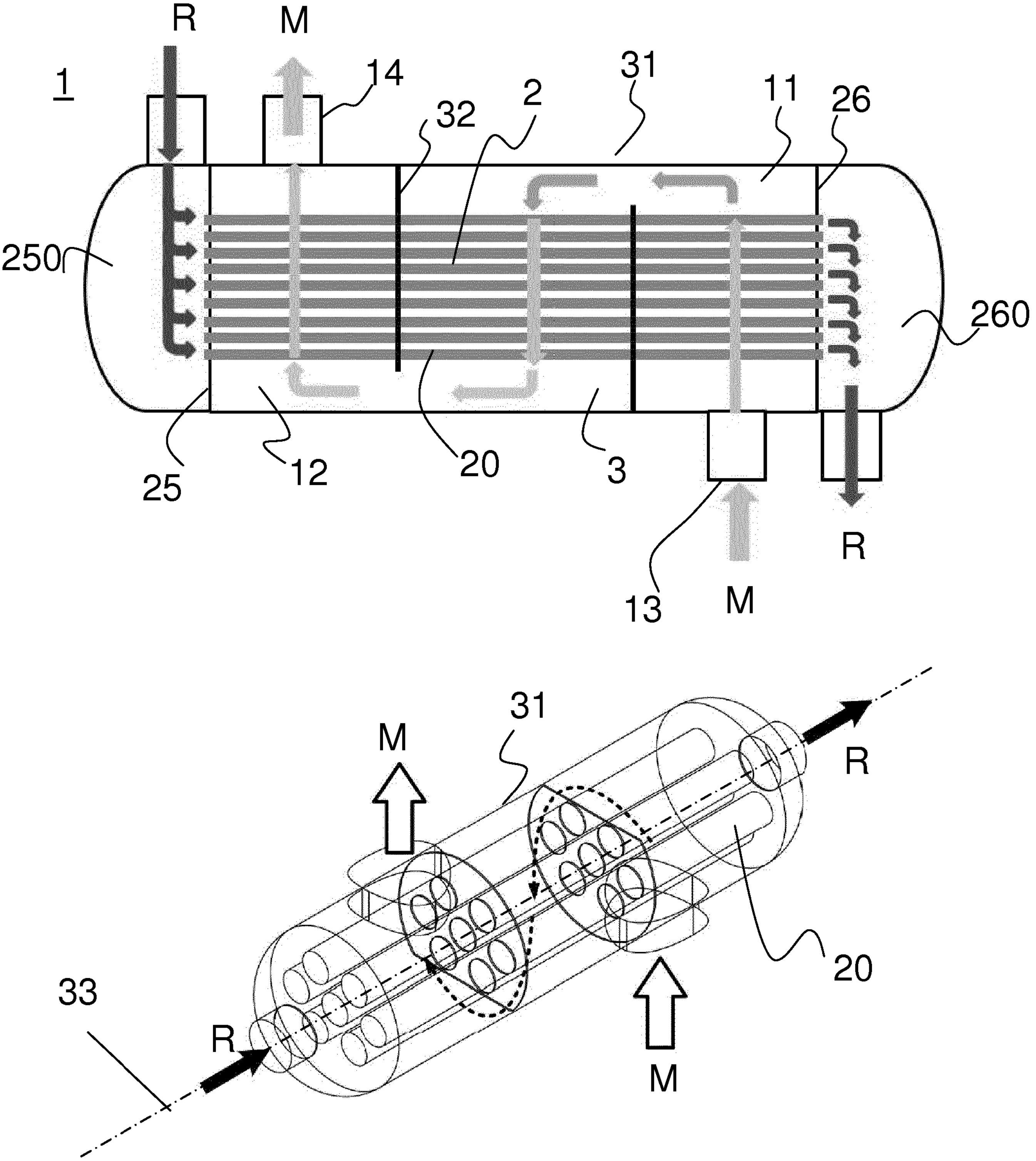
jolloin putkinippu (2) sisemmän kanavan (21) ja ulomman kanavan (23) välissä sisältää ainakin kaksi putkinippukomponenttia (50, 51, 52, 53, 54), jotka eroavat toisistaan putkien lukumäärässä pintaa kohti ja/tai putkien ulkohalkaisijan suhteen ja/tai putkien etäisyydessä,

tunnettu siitä, että putkinippukomponenteilla on kohtisuorassa pituusakseliin (33) nähden kulloinkin olennaisesti ympyrärenkaan muotoinen poikkileikkaus ja että ne on vaippatilassa järjestetty kohtisuoraan pituusakseliin nähden olevassa suunnassa peräkkäin, jolloin ainakin kaksi putkinippukomponenttia (50, 51, 52, 53, 54) on yhdistetty toisiinsa irrotettavasti.

14. Jonkin patenttivaatimuksista 1–12 mukaisen putkinippulämmönsiirtimen (1) käyttö kaasu-kaasu-lämmönsiirtimenä erityisesti lämmön takaisinsaamiseksi.

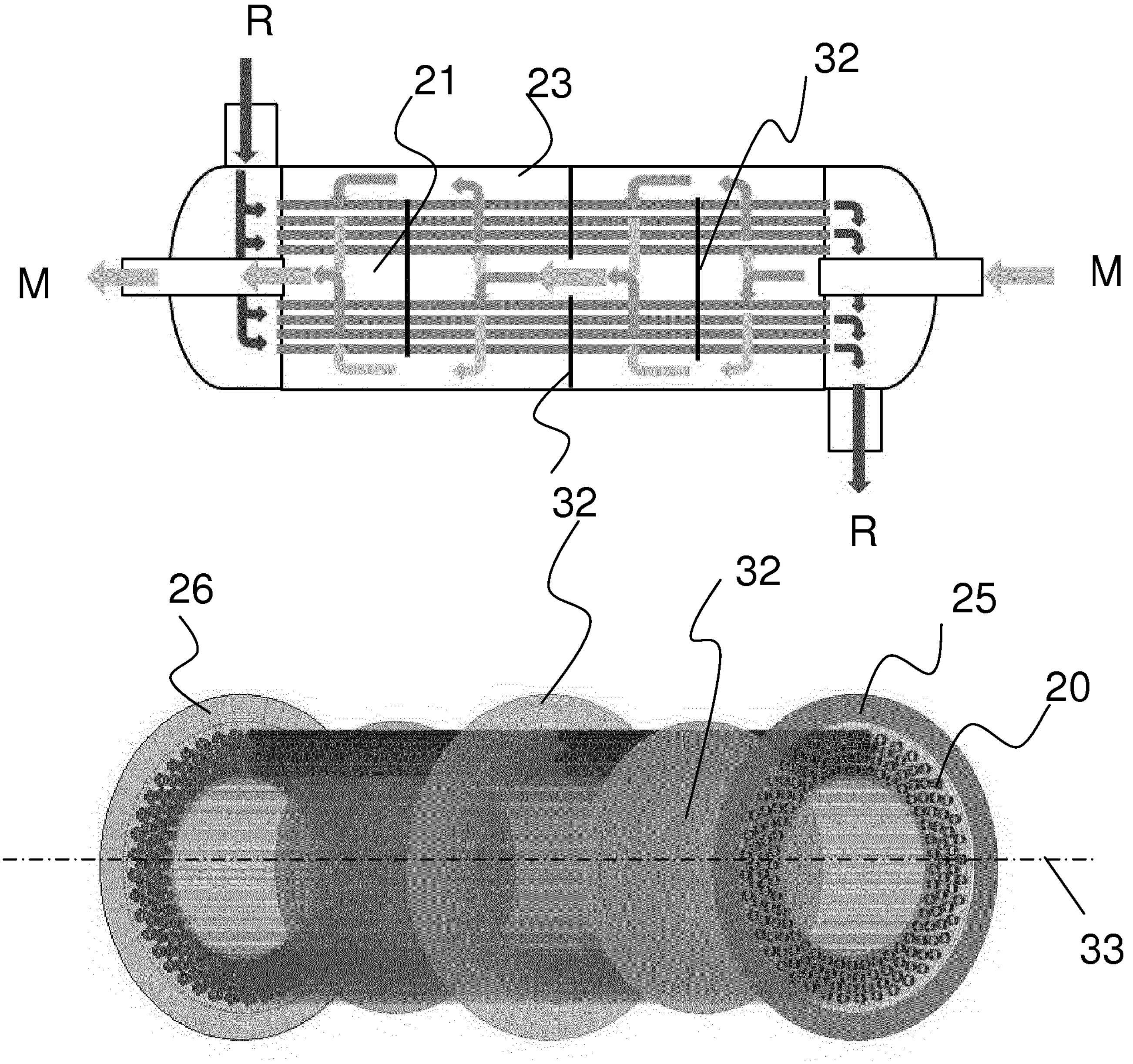
15. Jonkin patenttivaatimuksista 1–12 mukaisen putkinippulämmönsiirtimen (1) käyttö kaasu-kaasu-lämmönsiirtimenä, erityisesti lämmön takaisinsaamiseksi,

jolloin kaasu-kaasu-lämmönsiirrintä käytetään menetelmässä rikkihapon synteesiä varten.



State of the art

Fig. 1



State of the art

Fig. 2

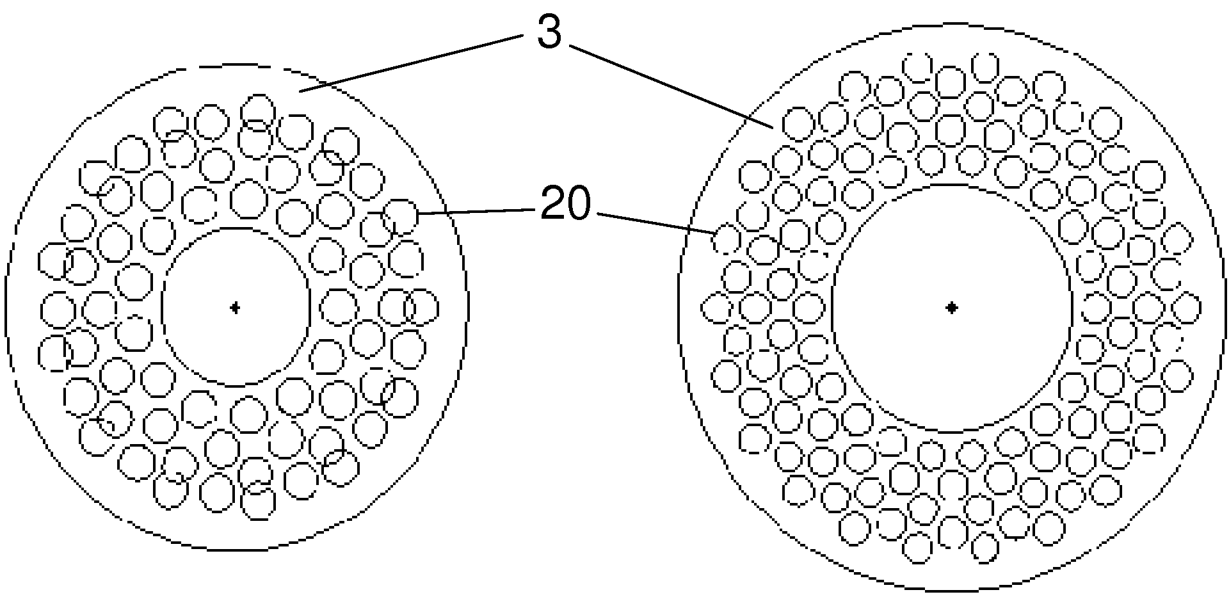


Fig. 3A

Fig. 3B

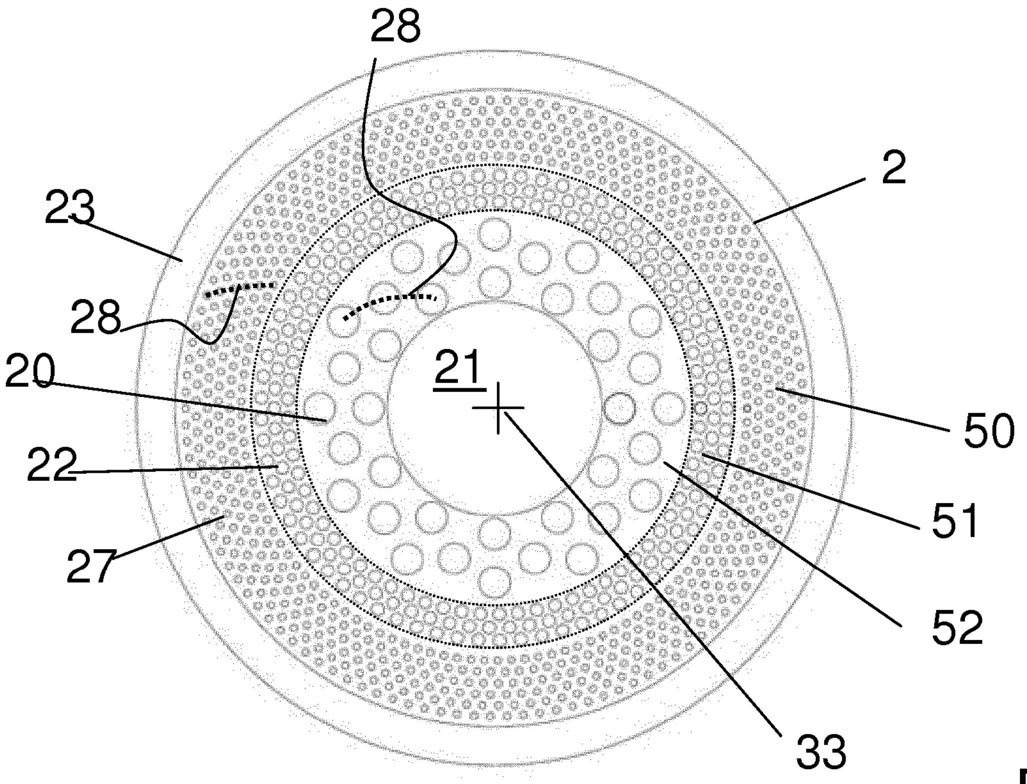


Fig. 4

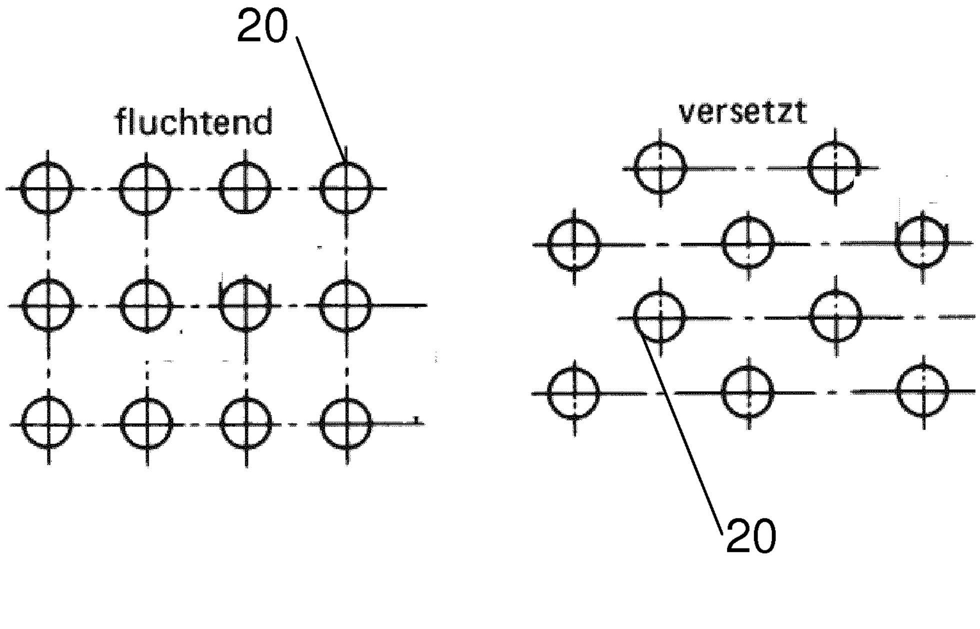


Fig. 5A

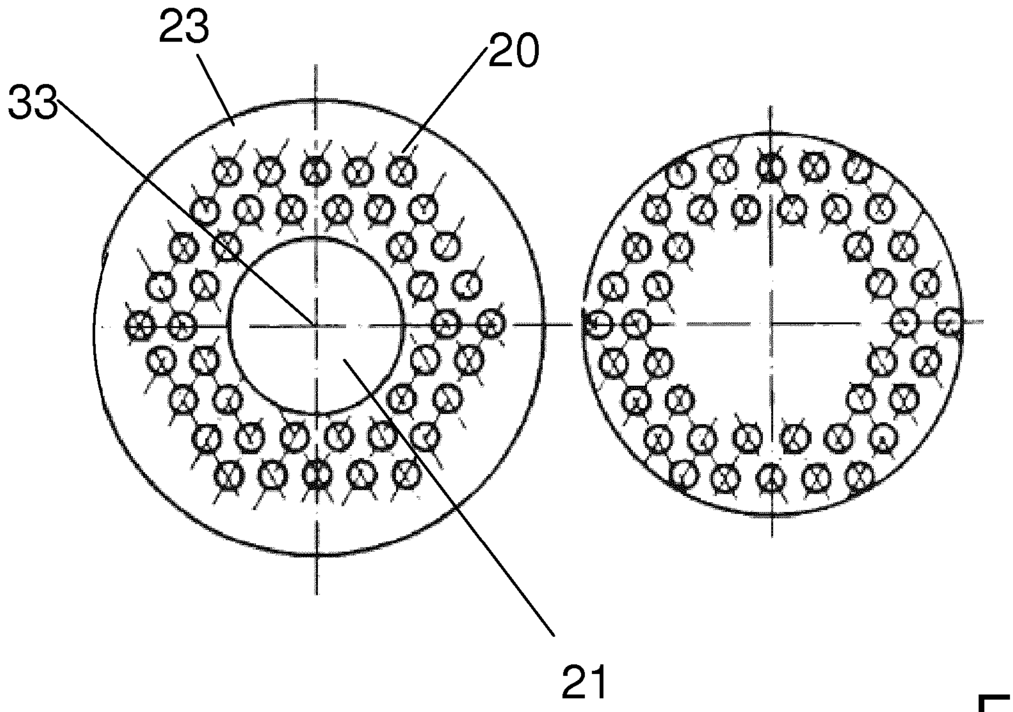


Fig. 5B

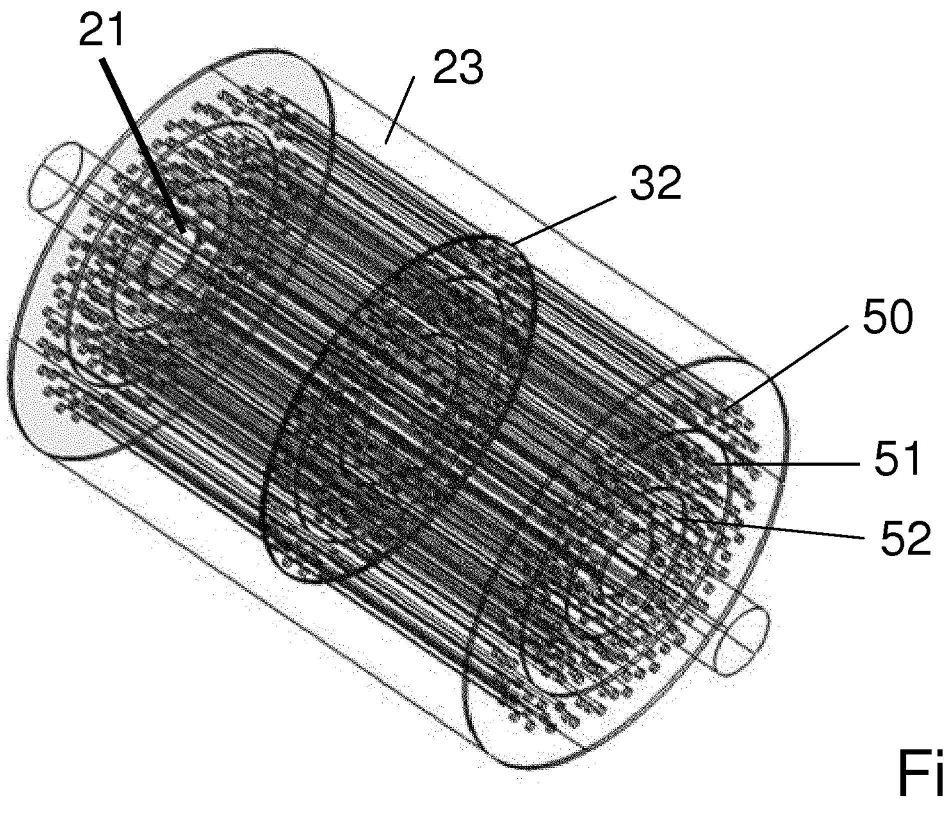


Fig. 6

20175826 PRH 18-09-2017

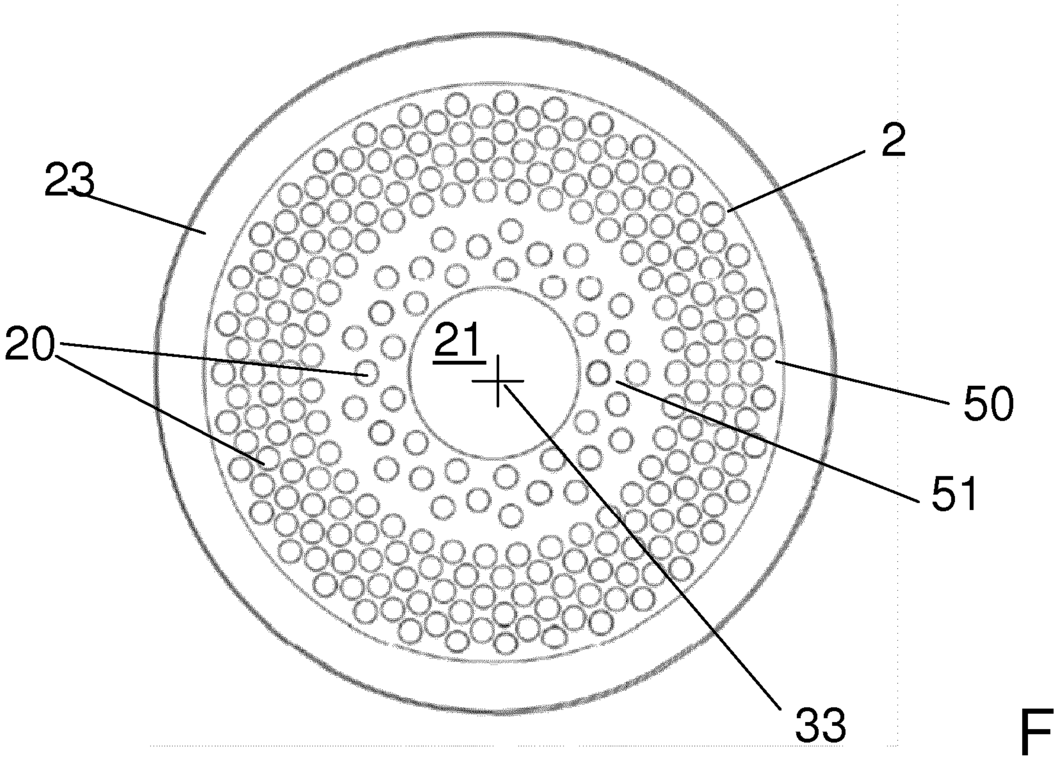


Fig. 7

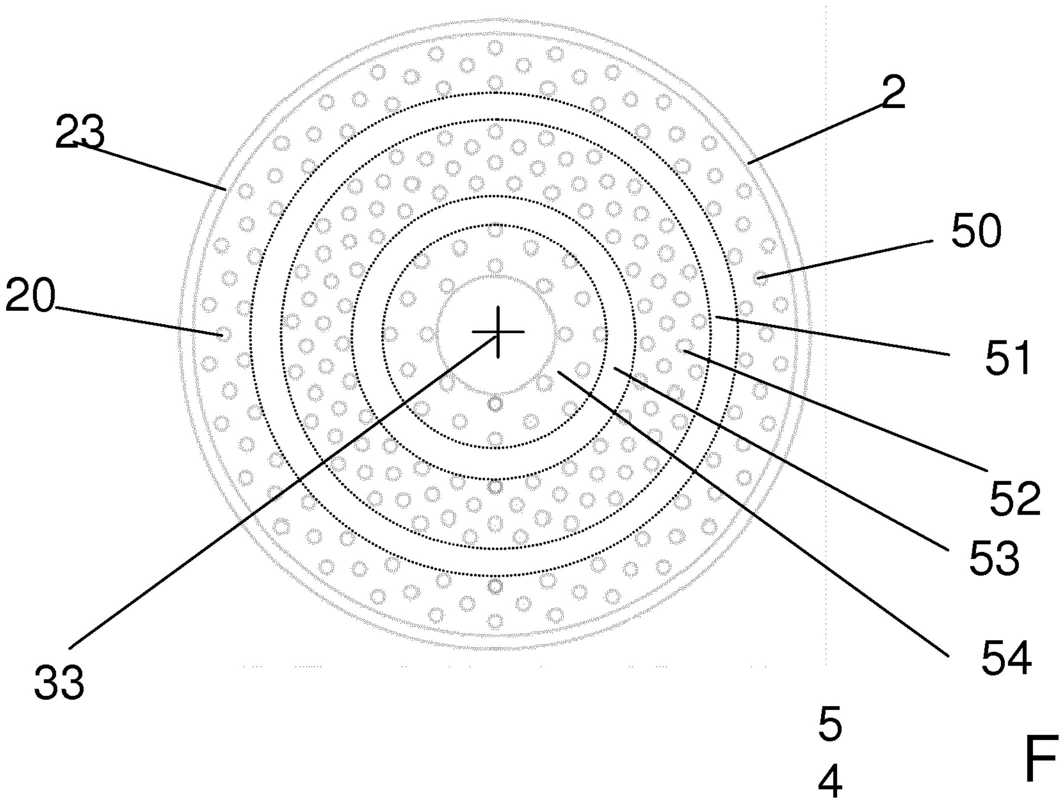


Fig. 8

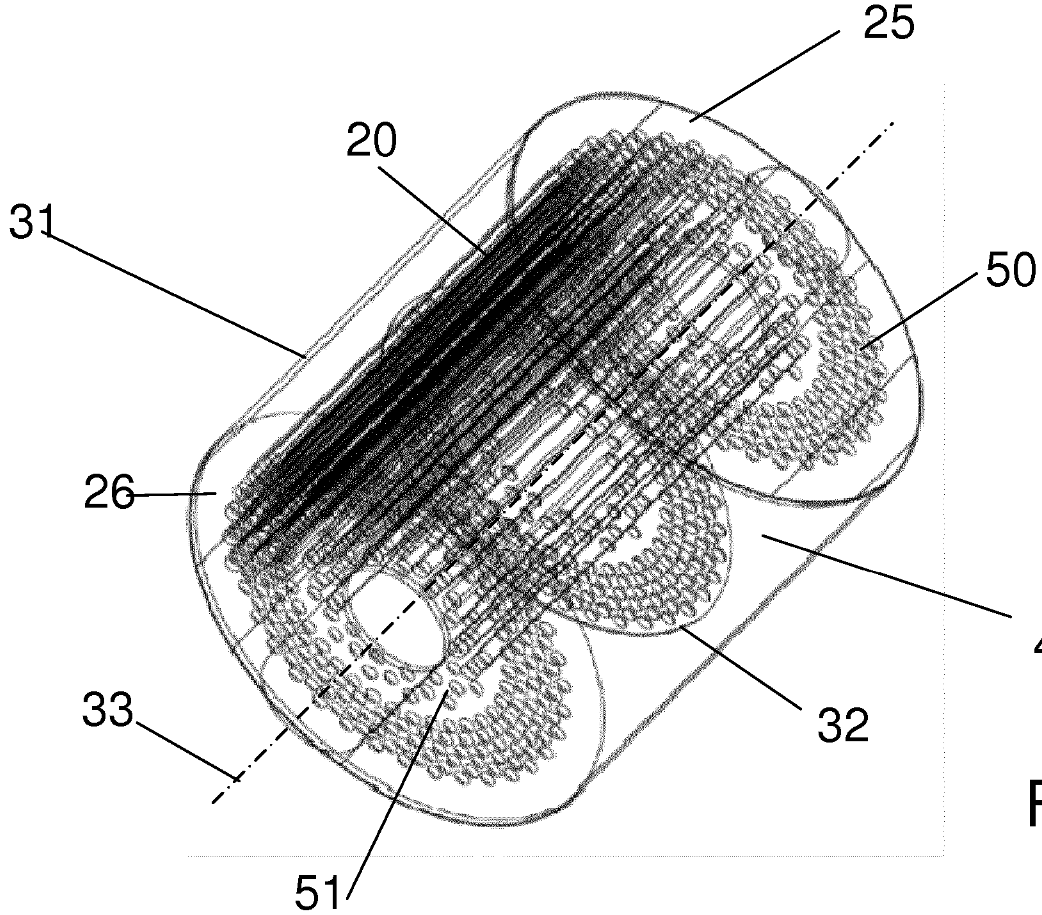


Fig. 9

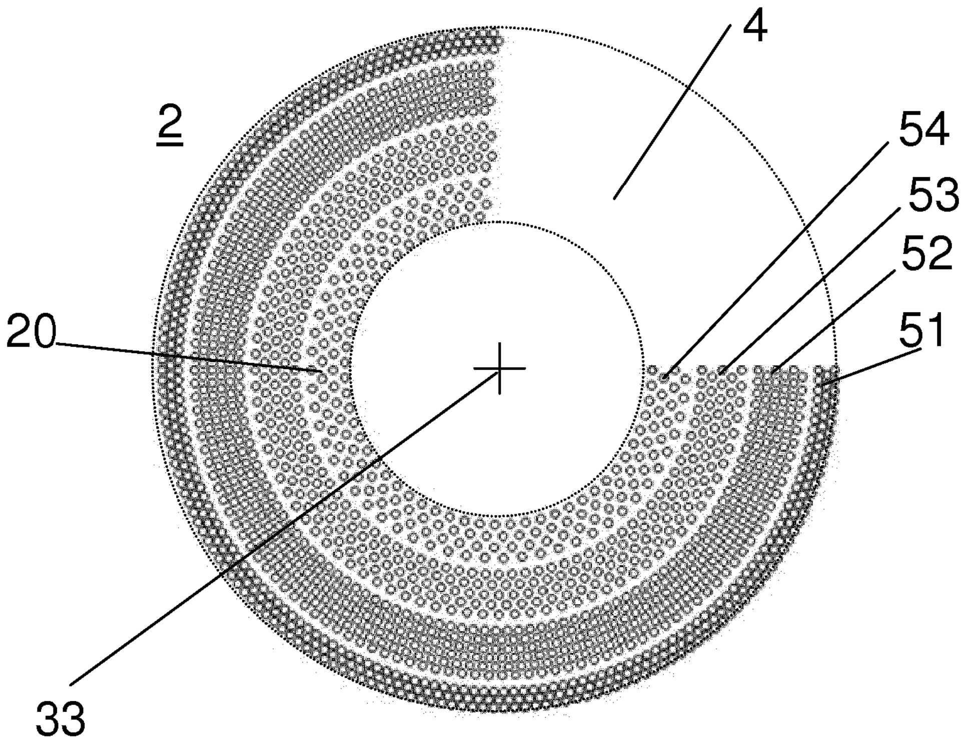


Fig. 10

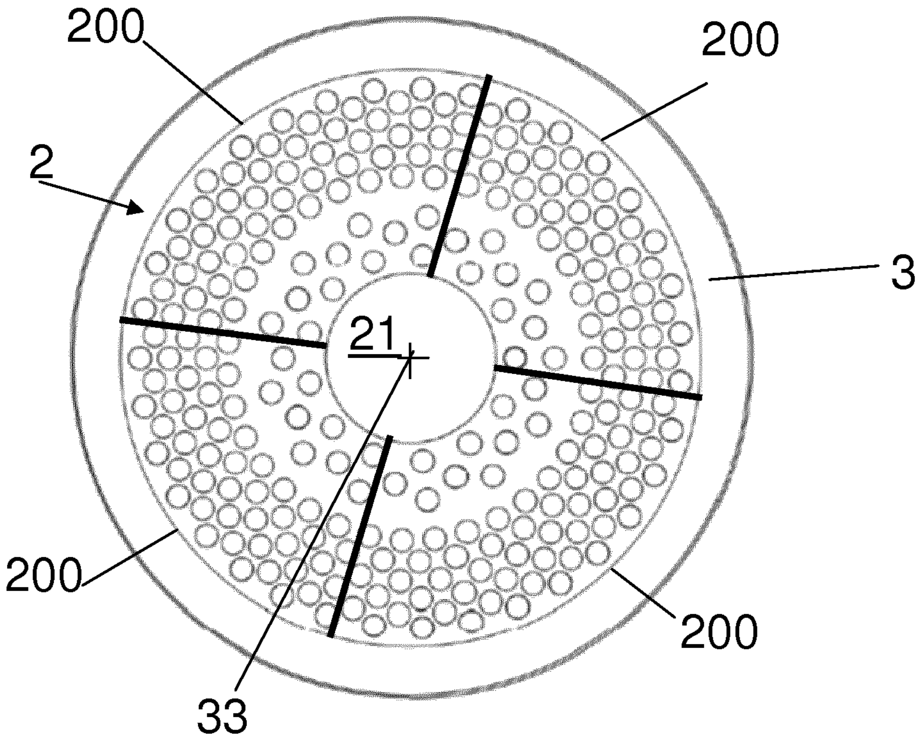


Fig. 11

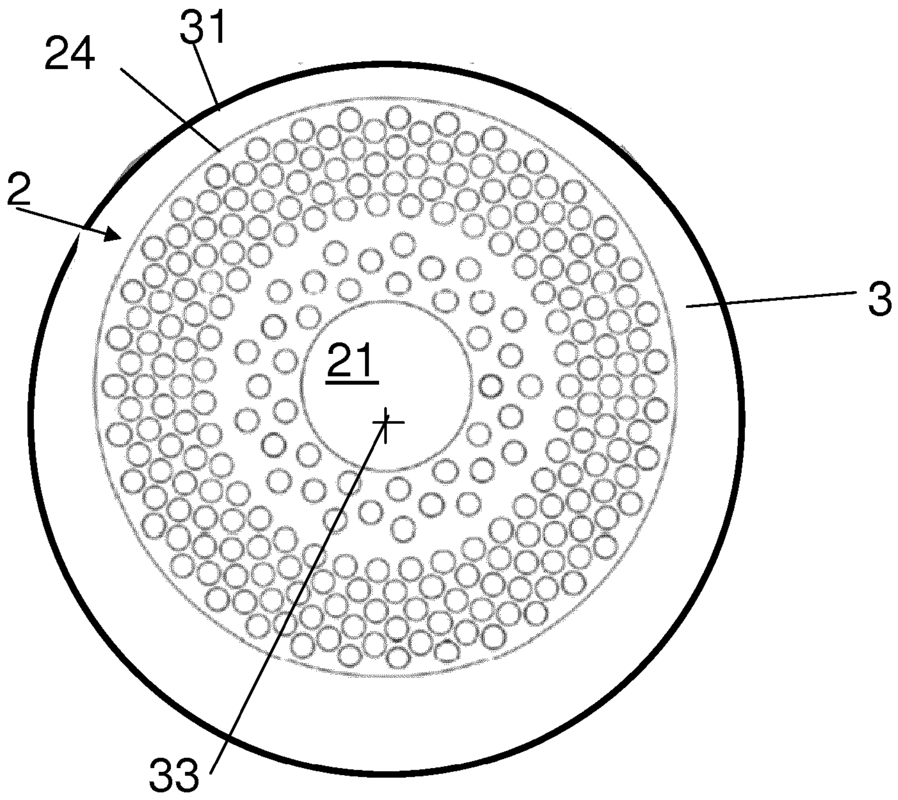


Fig. 12