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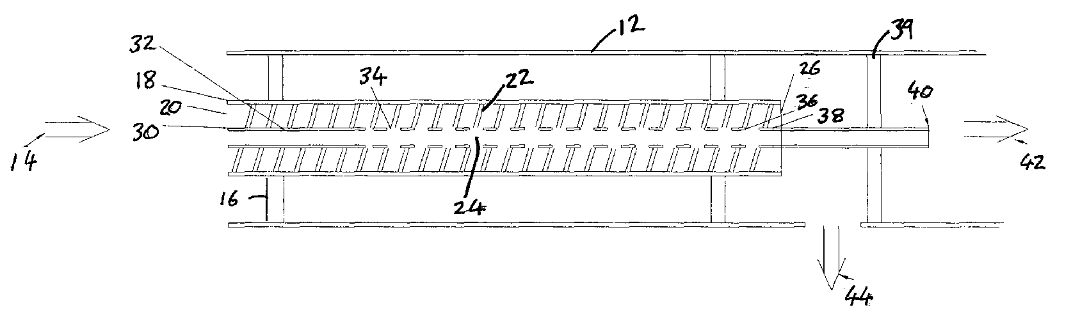

(57) Abstract: The invention provides an apparatus and method for treatment of fluids. A flow passage (18) comprises centrifugal means (22) for providing a radial acceleration to a fluid mixture as it flows through the flow passage. A fluid collecting arrangement (24) extends through a substantial part of the flow passage, the fluid collecting arrangement removing a portion of the fluid flowing through the flow passage. Aspects of the invention provide an apparatus comprising a plurality of treatment stages. Aspects of the invention also include a method for constructing the apparatus.

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Fluid Treatment

The present invention relates to apparatus and methods for treating of fluids and to methods used in the construction of the apparatus. More particularly, but not exclusively, the invention relates to apparatus and methods suitable for use in coalescing and/or segregating one or more fluid phases in a mixed-phase fluid.

Coalescers are used in many industrial fields, for example in oil and gas production, where fluid streams are produced, which contain more than one fluid phase. For example, the fluid stream may contain one or more fluids in a liquid phase mixed with one or more other fluids in a gas phase. Alternatively, the stream may contain two or more fluids, each in a liquid phase. In many circumstances the mixture will contain a distributed phase within a continuous phase. The distributed phase will usually comprise droplets which are carried by the continuous phase fluid.

In oil production a typical process flow would contain a mixture of oil droplets in a water continuous phase. In some circumstances, depending on relative proportions of the phases and the conditions of temperature and pressure, the mixture may contain water droplets in an oil continuous phase. Another common mixed phase flow in oil and gas production processes has water droplets carried by a hydrocarbon gas.

There is often a need to extract a fluid phase from the mixture, requiring a separation process. A variety of methods exist for separating phases. One example of is described in WO2005/035995, and referred to hereafter as a CTC (centrifugal tube coalescer). In the CTC, a radial acceleration is provided to the fluid flowing through a tube so as to cause rotation of the fluid and promote movement of at least one fluid phase towards or away from a wall of the tube. In doing so, droplets of one fluid phase coalesce to form larger droplets, which are subsequently more easily separated. Another reason for wanting to coalesce droplets is that when the droplet size is small, there is a risk that the small droplets will pass straight through a separation device (e.g a settling vessel) without being separated. A CTC is a useful device because increasing the droplet size reduces the number of very small droplets.

Another common requirement in industrial processes is to produce a mixture of two or more fluid phases from separate single phase sources. Again the CTC can be used as an effective mixer by introducing the two phases to be mixed at the inlet to the tubes. The radial acceleration imparted to the fluids as they pass through the tubes mixes the two phases together.

Although the CTC is an effective device for coalescing or mixing, it does no more than that. When, for example, the coalesced droplets of water carried in oil exit from the CTC, the two phases still need to be separated from each other. This requires additional equipment, for example a settling vessel in which the two fluid phases are held for a certain residence time. While in the settling vessel the water phase, being more dense, settles below the less dense oil phase and the two can be extracted through separate vessel outlets. To achieve separation, settling vessels rely on a certain residence time of the fluids in the vessel. This means that separation vessels are bulky and heavy, a particularly severe handicap for their use on off-shore oil and gas installations.

It is an aim of the present invention to provide an improved fluid treatment apparatus, and method of construction thereof. An additional aim is to provide an apparatus that may be used to separate and/or coalesce more than two fluids.

According to a first aspect of the present invention there is provided an apparatus for treatment of fluids comprising: a flow passage that comprises centrifugal means for providing a radial acceleration to the fluid mixture as it flows through the flow passage; and a fluid collecting arrangement extending through a substantial part of the flow passage, the fluid collecting arrangement removing a portion of the fluid flowing through the flow passage.

Preferably, the fluid collecting arrangement is configured to convey the portion of fluid removed to an outlet. More preferably, a remaining portion of fluid, not removed by the fluid collecting arrangement is conveyed to a separate outlet.

In one embodiment the fluid collecting arrangement comprises a longitudinal passage through the flow passage. The longitudinal passage may have a closed end adjacent an inlet of the flow passage.

In one embodiment, the fluid collecting arrangement is a pipe having openings along its length. The openings may have a variety of shapes and sizes. In one embodiment, the pipe has a portion of its length without openings.

In embodiments of the invention, the fluid collecting arrangement may vary in shape (34) and size along its length.

The apparatus may comprise a plurality of substantially parallel flow passages through a housing whereby a fraction of the fluid passes through each flow passage, each flow passage including a centrifugal means and a flow collecting arrangement for removing a portion of the fluid fraction therein. Preferably the flow collecting arrangements are configured to convey the removed portions of each fluid fraction to an outlet separate from an outlet to which fluid not removed by the collecting arrangements is conveyed.

In embodiments of the invention, the apparatus may comprise a staged configuration including a first stage having a first flow passage that comprises centrifugal means for providing a radial acceleration to the fluid as it flows through the first flow passage, a first fluid collecting arrangement extending through at least a substantial part of the first flow passage, the first fluid collecting arrangement removing a first portion of the fluid flowing through the first flow passage into a second stage having a second flow passage that comprises centrifugal means for providing a radial acceleration to the first portion of fluid as it flows through the second flow passage, a second fluid collecting arrangement extending through a substantial part of the second flow passage, the second fluid collecting arrangement removing a second portion of the fluid flowing through the second flow passage.

The staged configuration may comprise more than two stages. In one embodiment each stage is provided with a separate outlet for fluid passing through the stage, but not removed by the fluid collecting arrangement in that stage.

In embodiments of the invention, the flow passage(s) have a tubular form and the centrifugal means comprises one or more vanes or baffles arranged in a spiral or helical form around the inside bore of the tube. The centrifugal means may comprise a plurality of inter-wound vanes or baffles. The vanes or baffles may have a curved or stepped profile.

The centrifugal means may be continuous along substantially the length of the flow passage. Alternatively, the centrifugal means may comprise one or more short sections for imparting rotation to the fluid. The short section may comprise a length of vane or baffle wound helically around the inside of a short length of the flow passage. In one embodiment, a plurality of short sections are provided, spaced at intervals along the flow passage. In this arrangement, a first section initiates rotation of the fluids, and the remaining sections sustain or augment further rotation of the fluids further down the flow passage.

In one embodiment, the flow passage has an inlet configured to provide a tangential inlet flow. The tangential inlet flow may form part of the centrifugal means.

In embodiments of invention, the housing and/or the flow passage are curved.

According to a second aspect of the invention there is provided an apparatus for treatment of fluids comprising a plurality of treatment stages, wherein each treatment stage comprises: a flow passage that comprises centrifugal means for providing a radial acceleration to the fluid as it flows through the flow passage, and a fluid collecting arrangement extending through a substantial part of the flow passage, the fluid collecting arrangement removing a portion of the fluid flowing through the flow passage.

The treatment stages may be arranged to treat parallel flows of fluid. Alternatively, the treatment stages may be arranged in series to treat a flow of fluid in one stage after treatment in another stage. The apparatus may comprise a combination of series and parallel treatment stages.

The apparatus may comprise or be used in combination with further sequences of fluid treatment. The further sequences of fluid treatment may comprise deoilers/degassers, gravitational separation, electrostatic coalescers etc.

According to another aspect of the present invention there is provided a method for the treatment of a fluid comprising: providing a flow of said fluid into a flow passage; imparting a radial acceleration to the fluid as it flows through the flow passage; and removing a portion of the fluid flowing through the flow passage by means of a fluid collecting arrangement extending through a substantial part of the flow passage.

Preferably, the method further comprises conveying the portion of fluid removed to an outlet. More preferably, the method also comprises conveying a remaining portion of fluid, not removed by the fluid collecting arrangement, to a separate outlet.

The method may comprise providing said flow of fluid to a plurality of flow passages whereby a fraction of the fluid passes through each flow passage, imparting a radial acceleration to the fluid fraction in each flow passage and removing a portion of the fluid fraction flowing through the flow passage by means of a fluid collecting arrangement therein. Preferably the method further comprises conveying the removed portions of each fluid fraction to an outlet separate from an outlet to which fluid not removed by the collecting arrangements is conveyed.

The method may further comprise one or more additional stages wherein the portion of fluid removed by the fluid collecting arrangement is provided to a second stage having a second flow passage, providing a radial acceleration to the portion of fluid as it flows through the second flow passage, and removing a second portion of the fluid flowing through the second flow passage by means of a second fluid collecting arrangement extending through a substantial part of the second flow passage.

The method may comprise more than two stages. In one embodiment fluid passing through each stage, but not removed by the fluid collecting arrangement in that stage, is conveyed to a separate outlet.

According to another aspect of the present invention there is provided a method for constructing an apparatus for the treatment of a fluid, wherein the apparatus comprises a flow passage having centrifugal means for providing a radial acceleration to the fluid mixture as it flows through the flow passage, and a fluid collecting arrangement extending through a substantial part of the flow passage, the method comprising: constructing the centrifugal means in the form of a spiral vane from a sheet of material, the spiral vane having an annular form so as to provide an axial passageway extending throughout the spiral vane for the fluid collecting arrangement; securing the spiral vane to a longitudinal member; and forming an enclosure around the vane to define the flow passage.

In one embodiment, the longitudinal member comprises a pipe forming at least part of the fluid collecting arrangement and inserted through the axial passageway. Preferably, openings are provided in the wall of the pipe for collecting fluid. The step of forming an enclosure around the vane may comprise inserting the vane, secured to the longitudinal member, into a pipe. The step of inserting the vane, secured to the longitudinal member, into a pipe may comprise heating the pipe to expand its diameter, inserting the spiral vane assembly while the pipe is hot, and allowing the pipe to cool so that it shrinks to firmly grip the vane.

In another embodiment the longitudinal member comprises a strip of material wound around and secured to outer edges of the helical vane. In this embodiment, the width of the strip of material may be selected to correspond to a pitch distance of the helical vane, the strip being wound in a close-coiled arrangement such that one edge of the strip abuts the other and whereby the strip also forms the enclosure around the vane.

In another embodiment, the longitudinal member comprises a narrow strip or rod. The narrow strip or rod may be inserted through the axial passageway and secured to points on an inner edge of the vane. Alternatively, the narrow strip or rod may be secured to points on an outer edge of the vane. A plurality of longitudinal members in the form of narrow strips or rods may be used.

Preferably, where one or more narrow strips or rods is secured to the outer edge of the vane, the enclosure is formed by inserting the vane, secured to the narrow strip or rod, into a pipe, wherein the pipe has a longitudinal groove formed along its bore for receiving the narrow strip or rod.

In one embodiment, where the longitudinal member is secured to an inner edge of the vane, the enclosure is formed by providing a spiral groove in the bore of a pipe, and inserting the vane using a screwing action such that an outer edge of the vane is threaded into the spiral groove.

In embodiments the vane may be secured to the longitudinal member by welding or soldering.

Embodiments of the invention will now be described with reference to the following drawings.

Figure 1 is a sectional elevation of a fluid treatment apparatus embodying the principles on which the present invention is based.

Figures 2 and 3 are sectional elevations of embodiments of a fluid treatment apparatus based on the apparatus of Figure 1.

Figure 3a is an enlarged view of a single short spiral vane section of Figure 3.

Figure 4 is a sectional elevation of another embodiment of a fluid treatment apparatus based on the apparatus of Figure 1.

Figure 4a is a view on an end of a pipe forming part of the apparatus of Figure 4.

Figure 5 is a sectional elevation of another embodiment of a fluid treatment apparatus based on the apparatus of Figure 1.

Figure 5a is an enlarged view of an inlet arrangement forming part of the apparatus of Figure 5.

Figure 6 is a sectional elevation of another embodiment of a fluid treatment apparatus based on the apparatus of Figure 1.

Figure 7 is a sectional elevation of another embodiment of a fluid treatment apparatus based on the apparatus of Figure 1, having a curved flow passage.

Figures 8 and 8a are sectional side elevation and end views of another embodiment of a fluid treatment apparatus.

Figure 9 is a sectional elevation of another embodiment of a fluid treatment apparatus.

Figure 10 is a schematic presentation of an arrangement of fluid treatment vessels of the type shown in Figure 6.

Figure 11 is a schematic presentation of an arrangement of fluid treatment vessels of the type shown in Figure 8.

Figure 12 is another schematic presentation of an arrangement of fluid treatment vessels of the type shown in Figure 6.

Figure 13 is another schematic presentation of an arrangement of fluid treatment vessels of the type shown in Figure 8.

Figure 14 illustrates stages in one embodiment of the construction of a spiral vane apparatus forming part of the apparatus of the invention.

Figure 15 illustrates stages in another embodiment of the construction of a spiral vane apparatus forming part of the apparatus of the invention.

Figure 16 illustrates stages in yet another embodiment of the construction of a spiral vane apparatus forming part of the apparatus of the invention.

Figure 17 illustrates stages in still another embodiment of the construction of a spiral vane apparatus forming part of the apparatus of the invention.

Figure 18 illustrates stages in a further embodiment of the construction of a spiral vane apparatus forming part of the apparatus of the invention.

Referring to Figure 1, a fluid treatment apparatus 10 includes a vessel 12. A fluid to be treated enters the vessel 12 in the direction of arrow 14. Inside the vessel 12 is a support structure 16 supporting a pipe 18, which defines a flow passage for the fluid. The fluid enters the flow passage through an inlet 20. Inside the flow passage is a centrifugal means for imparting a radial acceleration to the fluid. In Figure 1, the centrifugal means consists of a helically wound spiral vane or baffle 22. The spiral vane 22 abuts and may be secured to the bore of the pipe 18, but extends only part of the way radially inwards towards the axis of the pipe 18. This means that there is an axial passageway 24 extending along the pipe 18. Fluid exits the pipe at an outlet end

26 and flows away in the direction of arrow 28. The support structure 16 preferably extends across the entire cross-section of the vessel 12 such that all the fluid passes through the pipe 18.

When the fluid enters the pipe 18 it undergoes an acceleration. The spiral vane 22 imparts rotation (i.e. a radial acceleration) to the flowing fluid. This is the principle of the CTC. As described in WO2005/035995, the radial acceleration provides beneficial effects on the fluid. If the fluid is a mixture of fluid phases, such as oil and water, where one phase (referred to as the continuous phase) carries droplets of the other phase, the radial acceleration has the effect of coalescing droplets to form larger droplets. In addition, the radial acceleration has the effect of increasing fluid turbulence, which can also enhance droplet coalescing.

Alternatively, if the fluid entering the vessel 12 comprises two different un-mixed fluids (for example entering through two separate inlets), then the radial acceleration and turbulence are effective mixers of the two fluids.

In the apparatus 10, the vane 22 does not extend across the entire diameter of the pipe 18. When used as a coalescer, for example, the radial acceleration will cause the droplets to move either towards or away from the wall of the pipe 18, depending on the relative densities of the two phases. This means that the droplets will either tend to accumulate closer to the pipe wall in the annular region between the walls of the vane 22, or in the axial passageway 24. With the configuration shown in Figure 1, this makes little difference, because when the fluid emerges from the pipe outlet 26 it merges back into a single stream. Nevertheless, the apparatus still has a beneficial effect because the larger coalesced droplets will allow the fluids to separate much more quickly in a separation process such as a settling vessel, as well as reducing the number of very small droplets that could pass straight through the separation process.

In the apparatus shown in Figure 2, where equivalent features have the same reference numerals as used in Figure 1, a fluid collecting arrangement in the form of a central pipe 30 extends through the flow passage along the axial passageway 24. The central pipe 30 has an inlet section 32 adjacent the inlet 20 of the pipe 18, and a fluid collecting section extending along the remainder of the length of the pipe 18. In the fluid collecting section the central pipe 30 has openings 34 formed in the pipe walls. The openings 34 may be of any shape or size to suit (for example, round holes, oval holes, slots etc.), and may vary in shape and or/size along the length of the central pipe 30. For example the openings 34 may get larger further along the central pipe 30 where there are more larger coalesced droplets to collect. The central pipe 30 has a section 38 without openings extending beyond the outlet 26 of the pipe 18, leading past a dividing wall 39 to an outlet 40. The dividing wall 39 extends across the vessel 12 and separates two outlet flow streams 42, 44.

In use, a fluid enters the flow passage through the inlet 20 to pipe 18 and encounters the helical vane 20, which imparts a radial acceleration (i.e. a centrifugal force causing the fluid to rotate). Initially, the rotating fluid is constrained to flow in the annular region between the central pipe 30 and the pipe 18. But when the fluid has passed beyond the inlet region 32 of the central pipe 30, fluid close to the axis will be able to enter the central pipe 30 through the openings 34. For example, if the fluid contained a mixture of water droplets in a continuous oil phase, the water droplets would start to coalesce due to the radial acceleration and turbulence effects such that, water being heavier than oil, the water droplets would move towards the wall of the pipe 18, while the oil near the axis would become relatively free of water droplets. As a consequence, when the fluid reaches the outlet 26 of the pipe 18, the fluid inside the central pipe 30 will contain relatively less water, while the fluid exiting from the annular space between the central pipe 30 and the pipe 18 will have a higher concentration of larger water droplets. Now the oil-rich fluid is removed through the extended central pipe section 38 to the outlet 40 and on as outlet flow stream 42. The water-rich fluid exits the pipe 18 through the outlet 26 and forms the outlet flow stream 44.

It is important to realize that the fluids in the central pipe 30 fluid collecting arrangement still can be a mixture, but that the ratio of the phases (oil/water content) changes.

Subsequently, the two flow streams can be taken to separate downstream processes, where, for example, further separation may be undertaken. However, it will be appreciated that, by collecting and removing the fluid through the central pipe

30 in a separate flow stream, the subsequent separation will be much faster than where the two flow streams are merged.

In the embodiment shown in Figure 2, the central pipe 30 has an open end adjacent the inlet 20. Some fluid will enter the central pipe through the open end and may pass all the way through the central pipe 30 to the outlet 40 without being subjected to significant radial acceleration. To avoid this, in an alternative embodiment, the end of the pipe 30 is closed off.

Referring to Figures 3 and 3a, where equivalent features have the same reference numerals as used in Figures 1 and 2, a similar arrangement to that of Figure 2 is shown, except that in this case the centrifugal means for imparting radial acceleration does not extend all the way along the pipe 18. Instead the apparatus employs a few relatively short spiral vane sections 46, 47, 48, 49, spaced at intervals along the pipe 18. As shown in Figure 3a, which is an enlarged view of a single short spiral vane section 47, each short spiral vane section includes a short vane 50 wound in a helical spiral inside a section of pipe 52. The first short spiral vane section 46 imparts an initial rotation (radial acceleration) to the fluid as it enters the pipe 18. Thereafter the subsequent short spiral vane sections 47, 48, 49 each sustains or imparts further rotation of the fluids further down the pipe 18.

One advantage of the arrangement shown in Figure 3 is that less material is used for the vanes, and less vane surface area is presented to the flowing fluid, thereby reducing the pressure drop of the fluid flowing through the apparatus. Another advantage is that the short spiral vane sections 46-49 are simpler to manufacture than a continuous vane. For example each vane section may be assembled in a separate short section of pipe 52 (as in Figure 3a), and the short spiral vane sections 46-49 sandwiched between longer un-vaned pipe sections 54 to make up the complete pipe 18.

Also shown in Figures 3 and 3a, the vanes 50 have a curved or stepped profile in cross-section. This type of cross-section can be advantageous in improving the radial acceleration and droplet coalescing or mixing effects, by varying the amount of radial acceleration imparted at different radii.

Figures 4 and 4a show another embodiment, similar to that shown in Figure 2, except that the centrifugal means used to impart a radial acceleration to the fluid includes two helical vanes 56, 58 arranged in a double spiral along the inside of the pipe 18. As shown in Figure 4a, which is an end view on the pipe 18, the two spiral vanes 56, 58 are disposed at 180 degrees to each other inside the circumference of the bore of the pipe 18.

Another feature of the embodiment shown in Figure 4 is that much of the central pipe 30 used for the fluid collecting arrangement has been dispensed with leaving an axial passageway 60 inside the helical vanes 56, 58. The double spiral vane arrangement increases the amount of vane surface area that imparts a radial acceleration and helps to reduce the amount of any re-mixing of separated phases flowing in the annular region or the axial region of the pipe 18. As a consequence, only the short end portion 38 of the central pipe 30 is required to remove fluid to beyond the bulkhead 39. Thus, in this embodiment, the fluid collecting arrangement comprises the axial passageway 60 and the section of pipe 38. In some circumstances a fluid collecting arrangement of this type could be used satisfactorily with other forms of centrifugal means, for example those shown in Figures 1 to 3.

In the embodiments described above, the centrifugal means used to impart a radial acceleration to the fluid consists of one or more vanes. However, other means may be used either alone or in conjunction with spiral vanes. For example, surfaces may be provided inside the flow passage, which have a similar effect to a helical or spiral vane, and include surfaces angled to the axis of flow, but not strictly arranged in a helix or spiral. Figure 5 depicts another example in an apparatus similar to that of Figure 2 (equivalent features having the same reference numerals). A tangential inlet 62 is provided to impart a rotational flow in the pipe 18. Figure 5a is an enlarged view of a cross-section A-A through the pipe 18 and tangential inlet 62. A similar effect may be obtained with more than one tangential inlet.

Figure 6 shows an embodiment operating on the same principle as described above with reference to Figure 2, but in which the entire apparatus is enclosed within a pipe 64, the pipe 64 forming the flow passage inside which a spiral vane 66 and central tube fluid collecting arrangement 68 are mounted. The pipe 64 is provided with an inlet end flange 70 and an outlet end flange 72. A bulkhead 74 is mounted to the outlet end flange 72, through which extends the pipe 30 of the fluid collecting arrangement to the outlet 40. A branch pipe 76, terminating in another flange 78 is provided for a second stream outlet 44.

Figure 7 depicts another embodiment in which the apparatus is enclosed within a pipe 80. Here the pipe 80 is curved, with a spiral vane 82 inside the pipe 80. The fluid collecting means includes a short obstruction in the form of a closed-ended section of pipe 84 mounted in the axial passage at the inlet end of the pipe, and a section of pipe (not shown) axially aligned with the axial passage at the outlet end of the pipe. Although it would be possible to include a curved central pipe with openings (to perform the same function as the central pipe 30 of Figure 2), in many circumstances this is not necessary. The closed-ended section of pipe 84 extends far enough into the flow passage for the rotational flow of the fluids to be maintained through the rest of the pipe with very little re-mixing between fluid collected in the axial region and the fluid in the annular region bounded by the vane 82 and the inner wall of the pipe 80.

Figures 8 and 8a show a sectional elevation and end view respectively of a fluid treatment apparatus that includes a multi-array of flow passages 102. Each flow passage 102 has a construction similar to that described above with reference to Figure 2. The flow passages 102 are arranged inside a vessel 100 that has an inlet 104 and two separate outlets 106, 108. Each flow passage 102 is provided with a spiral vane and a central fluid-collecting tube 110. The flow passages 102 are supported in baffle walls 112, 114 and the fluid collecting tubes 110 extend through a dividing wall 116.

Fluid enters the apparatus through the inlet 104 and passes through the flow passages 102. The baffle walls ensure that fluid cannot bypass the flow passages 102. Fluid in the annular regions of each flow passage 102 passes into a volume 118 in front of the dividing wall 116 and out through a first of the outlets 106. Fluid in the fluid collecting tubes 110 is conveyed to beyond the dividing wall 116 and out through a second of the outlets 108.

Figure 9 illustrates an embodiment employing a three-staged treatment process. Each stage operates in accordance with the same principles as described for the embodiments above. The apparatus includes a vessel 120 housing a series of concentrically arranged pipes having progressively smaller diameters. An outermost, first pipe 122 extends from an inlet end 123 for a first length inside the vessel 120 to a first pipe outlet end 124. A first annular spiral vane 125 is arranged along the inside wall of the first pipe 122 and extends radially inwards as far as the outer surface of a second pipe 126, having a smaller diameter than the first pipe 122. The second pipe 126 extends a second length from a closed end 127 adjacent the inlet end 123 of the first pipe 122, to a second pipe outlet end 128 beyond the outlet end 124 of the first pipe 122. The second pipe 126 has openings 129 formed in the pipe wall along part of its length that resides inside the first pipe 122.

A second annular spiral vane 130 is arranged along the inside wall of the second pipe 126 and extends radially inwards as far as the outer surface of a third pipe 131, having a smaller diameter than the second pipe 126. The third pipe 131 extends a third length from a closed end 132 adjacent the closed end 127 of the second pipe 126, to a third pipe outlet end 133 beyond the outlet end 128 of the second pipe 126. The third pipe 131 has openings 134 formed in the pipe wall along part of its length that resides inside the second pipe 126.

A third annular spiral vane 135 is arranged along the inside wall of the third pipe 131 and extends radially inwards as far as the outer surface of a fourth pipe 136, having a smaller diameter than the third pipe 131. The fourth pipe 136 extends a fourth length from a closed end 137 adjacent the closed end 132 of the third pipe 131, to a fourth pipe outlet end 138 beyond the outlet end 133 of the third pipe 131. The fourth pipe 136 has openings 139 formed in the pipe wall along part of its length that resides inside the third pipe 131.

The first pipe 122 is supported inside the vessel 120 on baffle walls 140, 141. The second pipe 126 is supported inside the first pipe 122 on the first spiral vane 125, and adjacent its outlet end 128 on a first dividing wall 142. The third pipe 131 is supported inside the second pipe 126 on the second spiral vane 130, and adjacent its outlet end 133 on a second dividing wall 143. The fourth pipe 136 is supported inside the third pipe 131 on the third spiral vane 135, and adjacent its outlet end 138 on a third dividing wall 144. The vessel 120 has a first outlet 145 from a volume between the baffle wall 141 and the first dividing wall 142; a second outlet 146 from a volume between the first dividing wall 142 and the second dividing wall 143; a third outlet 147 from a volume between the second dividing wall 143 and the third dividing wall 144; and a fourth outlet 148 from a volume beyond the third dividing wall 144;

Fluid entering the vessel, as indicated by arrows 150, passes into the inlet end 123 of the first pipe 122, in the annular space between the first pipe 122 and the second pipe 126. In the first stage, the fluid encounters the first spiral vane 125, which imparts rotation (radial acceleration) to the fluid. Denser phases of fluid, such as coalesced droplets of water, are forced towards the pipe wall, while lighter phases, such as oil, migrate inwards. The denser phases remain near the wall of the first pipe and exit through the first pipe outlet end 124, into the volume between the baffle wall 141 and the first dividing wall 142, and out through the first outlet 145. The lighter phases pass through the openings 129 in the second pipe 126, to commence the second stage, where they encounter the second spiral vane 130. A similar process occurs in the second stage for the fluid inside the second pipe 126 with denser phases exiting through the second pipe outlet end 128 and second outlet 146, while lighter phases pass through the openings 134 in the third pipe 131 to commence the third stage. Denser phases form the third stage exit through the third pipe outlet end 133 and third outlet 147. Lighter phases from the third stage pass through the openings 139 in the fourth pipe and are conveyed via the fourth pipe outlet end 138 to the fourth outlet 148.

The apparatus of Figure 9 provides a staged process within a single vessel. However, it will be appreciated that staging may be achieved by use of apparatus such as that shown in Figures 6 or 8, by arranging two or more vessels in stages. Figures 10 to 13 illustrate some examples.

Referring to Figure 10, a first stage treatment vessel 200, which is similar to the vessel 64 shown in Figure 6, is mounted in-line with a second stage vessel 202, of similar design. The second stage vessel is, in turn mounted in-line with a third stage vessel 204, of similar design. The stage vessels 200, 202, 204 are arranged such that, in the first stage, a lighter phase fluid collected from the fluid collecting arrangement 206 in the first stage vessel 200 is conveyed to an inlet end 208 of the second stage vessel 202. Similarly, in the second stage, lighter phase fluid collected from the fluid collecting arrangement 210 in the second stage vessel 202 is conveyed to an inlet end 212 of the third stage vessel 204. Denser phase fluids from each stage vessel 200, 202, 204 exit through respective outlets 214, 216, 218 and are conveyed to an inlet 220 of a fourth vessel 222, where a further fourth processing stage is conducted.

Figure 11 illustrates a staged arrangement, equivalent to that of Figure 10, but wherein the vessels at each stage 230, 232, 234, 236 are of the type shown in Figure 8, having multiple flow passages.

Figure 12 illustrates another arrangement, in which a fluid stream in a pipe 240 is split into three parallel fluid streams 241, 242, 243. Each stream 241, 242, 243 enters the inlet of a respective first stage fluid treatment apparatus 244, 245, 246 of the type shown in Figure 6. Denser phase fluid leaves each apparatus through a respective outlet 247, 248, 249 and is conveyed to a further treatment apparatus 250, which in this case is another apparatus of similar type. The lighter phase fluid removed by respective fluid collecting arrangements 251, 252, 253 in each first stage apparatus 244, 245, 246 is conveyed directly to a respective inlet 254, 255, 256 of respective second stage apparatus 257, 258, 259.

Figure 13 illustrates a similar parallel arrangement to that of Figure 12, in which three parallel flow streams 261, 262, 263 are conveyed into respective treatment apparatus 264, 265, 266 of the multi-flow passage type shown in Figure 8. In the arrangement of Figure 13 the lighter phase fluids are conveyed to a further treatment apparatus 267, while the denser phase fluids are conveyed to a separate common out-flow 268.

Embodiments of the invention described above make use of a spiral vane for imparting a radial acceleration so as to provide a rotation to the fluid flow through a flow passage in the form of a pipe or tube. However, the spiral vanes do not extend across the entire pipe diameter because an axial passageway is provided for the fluid collecting arrangement. Figure 14 illustrates one embodiment of a method for constructing such an arrangement. In step 1 of Figure 14 a spiral vane 301 is formed by twisting a strip of material (e.g. a suitable metal/alloy) around a central tube 302. the spiral vane 301 is then secured to the central tube 302 by suitable means, for example a weld or solder joint 304. The assembled spiral vane 301 has an outer diameter designated Dia 1. In some embodiments the assembly of the spiral vane 301 onto the central tube 302 may be performed to reproduce Dia 1 sufficiently accurately. Alternatively, if this is not possible, or if Dia 1 needs to be produced with high precision, the outer diameter of the assembly may be machined. The central tube 302 acts as a longitudinal stiffening member so that after the vane has been secured to it the assembly can be handled as a single component without the risk of the vane 301 moving. Securing the spiral vane to the central tube 302 also allows spiral vane 301 to be held rigidly in a lathe, for example, so that the outer diameter can be accurately machined.

In step 2 a pipe 306 is provided, having an internal diameter Dia 2. In step 3 the spiral vane 301 and tube 302 assembly is inserted into the pipe 306. In one embodiment this is done by first heating the pipe 306 to expand its diameter Dia 2 and inserting the spiral vane assembly while the pipe 306 is hot. Cooling of the pipe 306 causes the Dia 2 to shrink and firmly grip the spiral vane 301.

As can be seen in Figure 14, the central tube 302 forms part of the fluid collecting arrangement and has openings 303 along its length for collecting fluid.

Figure 15 illustrates another way that a spiral vane and tube assembly can be constructed. In some cases it may not be desirable to have a longitudinal member extending through the vane along the axial passageway. Thus, in this embodiment, after forming the spiral vane 310 from a strip of material (step 1), in step 2 the wall of a pipe or flow passage is constructed from a strip 312 of sheet material. The strip 312 has a width that corresponds to the longitudinal pitch, H of the spiral vane 310. In step 3, the strip 312 is then wound around the spiral vane 310 in a close-coiled arrangement such that one edge of the strip abuts the other. The strip 312, wound in this way, is then secured (e.g. by a welded connection 314) to the outer edges of the vane 310. Thus, the strip 312 not only acts as a longitudinal stiffening member, but also forms an enclosure around the vane 310 to define the flow passage.

The methods shown in Figures 14 and 15 may be combined, such that the vane is secured to a central tube first, as shown in Figure 14, step 1, and then an outer enclosure is formed around the vane using a strip, as shown in Figure 15.

Figure 16 illustrates another embodiment, in which an assembly 320 is constructed in step 1, from a spiral vane 322 and central tube 324 (as described above for step 1 of Figure 14). In step 2 a spiral groove 326 is formed in the bore of a pipe 328. In step 3, the assembly 320 is inserted into the pipe 328 using a screwing action, such that an outer edge of the vane 322 is threaded into the helical groove 326.

Figure 17 illustrates another embodiment of the construction method. In step 1 a longitudinal member in the form of a narrow strip or rod 330 is inserted through the axial passageway in a spiral vane 332 and secured to points 334 on an inner edge of the vane (e.g. by welding). The assembled spiral vane 332 and rod 330 assembly can then be inserted into a pipe 336 as shown in steps 2 and 3, using any of the methods described above.

Figure 18 illustrates an alternative method to that of Figure 17. In step 1, a longitudinal member in the form of narrow strip or rod 340 is secured to points on an outer edge of a spiral vane 342. Further longitudinal members in the form of narrow strips or rods 343-345 are secured to the outer edge of the vane at other circumferential locations. As shown in step 2, a pipe 346 has longitudinal grooves 348 formed in its bore. In step 3, the spiral vane 342, secured to the rods 342-345, is inserted into the pipe 348, such that the longitudinal grooves 348 receive the rods 343-345.

Claims

1. An apparatus for treatment of a fluid comprising:

a flow passage that comprises centrifugal means for providing a radial acceleration to the fluid as it flows through the flow passage; and

a fluid collecting arrangement extending through a substantial part of the flow passage, the fluid collecting arrangement removing a portion of the fluid flowing through the flow passage.

2. The apparatus of claim 1 wherein the fluid collecting arrangement is configured to convey the portion of fluid removed to an outlet.

3. The apparatus of claim 2 wherein a remaining portion of fluid, not removed by the fluid collecting arrangement is conveyed to a separate outlet.

4. The apparatus of any preceding claim wherein the fluid collecting arrangement comprises a longitudinal passage through the flow passage.

5. The apparatus of claim 4 wherein the longitudinal passage has a closed end adjacent an inlet of the flow passage.

6. The apparatus of claim 4 or claim 5 wherein the fluid collecting arrangement is a pipe having openings along its length.

7. The apparatus of claim 6 wherein the openings have a variety of shapes and sizes.

8. The apparatus of claim 6 or claim 7 wherein the pipe has a portion of its length without openings.

9. The apparatus of any preceding claim wherein the fluid collecting arrangement varies in shape and/or size along its length.

10. The apparatus of any preceding claim comprising a plurality of substantially parallel flow passages through a housing whereby a fraction of the fluid passes through each flow passage, each flow passage including a centrifugal means and a flow collecting arrangement for removing a portion of the fluid fraction therein.

11. The apparatus of claim 10 wherein the flow collecting arrangements are configured to convey the removed portions of each fluid fraction to an outlet separate from an outlet to which fluid not removed by the collecting arrangements is conveyed.

12. The apparatus of any preceding claim comprising a staged configuration including a first stage having a first flow passage that comprises centrifugal means for providing a radial acceleration to the fluid as it flows through the first flow passage, a first fluid collecting arrangement extending through at least a substantial part of the first flow passage, the first fluid collecting arrangement removing a first portion of the fluid flowing through the first flow passage into a second stage having a second flow passage that comprises centrifugal means for providing a radial acceleration to the first portion of fluid as it flows through the second flow passage, a second fluid collecting arrangement extending through a substantial part of the second flow passage, the second fluid collecting arrangement removing a second portion of the fluid flowing through the second flow passage.

13. The apparatus of claim ~~13~~ 12 wherein the staged configuration comprises more than two stages.

14. The apparatus of claim 12 or 13 wherein each stage is provided with a separate outlet for fluid passing through the stage, but not removed by the fluid collecting arrangement in that stage.

15. The apparatus of any preceding claim wherein the flow passage has a tubular form and the centrifugal means comprises one or more vanes or baffles arranged in a spiral or helical form around the inside bore of the tube.

16. The apparatus of claim 15 wherein the centrifugal means comprises a plurality of inter-wound vanes or baffles.

17. The apparatus of claim 16 wherein the vanes or baffles have a curved or stepped profile.

18. The apparatus of any preceding claim wherein the centrifugal means is continuous along substantially the length of the flow passage.

19. The apparatus of any of claims 1 to 17 wherein the centrifugal means comprises one or more short sections for imparting rotation to the fluid.

20. The apparatus of claim 19 wherein the short section comprises a length of vane or baffle wound helically around the inside of a short length of the flow passage.

21. The apparatus of claim 20 comprising a plurality of short sections spaced at intervals along the flow passage.

22. The apparatus of any preceding claim wherein the flow passage has an inlet configured to provide a tangential inlet flow.

23. The apparatus of claim 22 wherein the tangential inlet flow forms part of the centrifugal means.

24. The apparatus of any preceding claim wherein the housing and/or the flow passage is curved.

25. An apparatus for treatment of a fluid comprising a plurality of treatment stages, wherein each treatment stage comprises:

a flow passage that comprises centrifugal means for providing a radial acceleration to the fluid as it flows through the flow passage; and

a fluid collecting arrangement extending through a substantial part of the flow passage, the fluid collecting arrangement removing a portion of the fluid flowing through the flow passage.

26. The apparatus of claim 25 wherein the treatment stages are arranged to treat parallel flows of fluid.

27. The apparatus of claim 25 wherein the treatment stages are arranged in series to treat a flow of fluid in one stage after treatment in another stage.

28. The apparatus of claim 25 comprising a combination of series and parallel treatment stages.

29. The apparatus of any of claims 25 to 28 comprising, or arranged in combination with, further sequences of fluid treatment.

30. The apparatus of claim 29 wherein the further sequences of fluid treatment comprise one or more of deoilers/degassers, gravitational separation, electrostatic coalescers.

31. A method for the treatment of a fluid comprising:

providing a flow of said fluid into a flow passage;

imparting a radial acceleration to the fluid as it flows through the flow passage; and

removing a portion of the fluid flowing through the flow passage by means of a fluid collecting arrangement extending through a substantial part of the flow passage.

32. The method of claim 31 further comprising conveying the portion of fluid removed to an outlet.

33. The method of claim 31 or claim 32 comprising conveying a remaining portion of fluid, not removed by the fluid collecting arrangement, to a separate outlet.

34. The method of any of claims 31 to 33 comprising providing said flow of fluid mixture to a plurality of substantially parallel flow passages whereby a fraction of the fluid passes through each flow passage, imparting a radial acceleration to the fluid

fraction in each flow passage and removing a portion of the fluid fraction flowing through the flow passage by means of a fluid collecting arrangement therein.

35. The method of claim 34 further comprising conveying the removed portions of each fluid fraction to an outlet separate from an outlet to which fluid not removed by the collecting arrangements is conveyed.

36. The method of any of claims 31 to 35 further comprising one or more additional stages wherein the portion of fluid removed by the fluid collecting arrangement is provided to a second stage having a second flow passage, providing a radial acceleration to the portion of fluid as it flows through the second flow passage, and removing a second portion of the fluid flowing through the second flow passage by means of a second fluid collecting arrangement extending through a substantial part of the second flow passage.

37. The method of claim 36 comprising more than two stages.

38. The method of claim 36 or claim 37 wherein fluid passing through each stage, but not removed by the fluid collecting arrangement in that stage, is conveyed to a separate outlet.

39. A method for constructing an apparatus for the treatment of a fluid, wherein the apparatus comprises a flow passage having centrifugal means for providing a radial acceleration to the fluid as it flows through the flow passage, and a fluid collecting arrangement extending through a substantial part of the flow passage, the method comprising:

constructing the centrifugal means in the form of a helical vane from a sheet of material, the helical vane having an annular form so as to provide an axial passageway extending throughout the vane for the fluid collecting arrangement;

securing the helical vane to a longitudinal member; and

forming an enclosure around the vane to define the flow passage.

40. The method of claim 39 wherein the longitudinal member comprises a pipe forming at least part of the fluid collecting arrangement and inserted through the axial passageway.

41. The method of claim 40 wherein openings are provided in the wall of the pipe for collecting fluid.

42. The method of any of claims 39 to 41 wherein step of forming an enclosure around the vane may comprise inserting the vane, secured to the longitudinal member, into a pipe.

43. The method of claim 39 wherein the longitudinal member comprises a strip of material, the method including winding the strip around the helical vane and securing it to outer edges of the helical vane.

44. The method of claim 43, wherein the width of the strip of material is selected to correspond to a pitch distance of the helical vane, the strip being wound in a close-coiled arrangement such that one edge of the strip abuts the other and whereby the strip also forms the enclosure around the vane.

45. The method of claim 39, wherein the longitudinal member comprises a narrow strip or rod.

46. The method of claim 45, wherein the narrow strip or rod is inserted through the axial passageway and secured to points on an inner edge of the vane.

47. The method of claim 45, wherein the narrow strip or rod is secured to points on an outer edge of the vane.

48. The method of any of claims 45 to 47 wherein a plurality of longitudinal members in the form of narrow strips or rods are used.

49. The method of claim 47 wherein the enclosure is formed by inserting the vane, secured to the narrow strip or rod, into a pipe, wherein the pipe has a longitudinal groove formed along its bore for receiving the narrow strip or rod.

50. The method of any of claims 39 to 42, 45 or 46, where the longitudinal member is secured to an inner edge of the vane, the enclosure is formed by providing a helical groove in the bore of a pipe, and inserting the vane using a screwing action such that an outer edge of the vane is threaded into the helical groove.

51. The method of any of claims 39 to 50, wherein the vane is secured to the longitudinal member by welding or soldering.

52. The method of claim 42, wherein the step of inserting the vane, secured to the longitudinal member, into a pipe comprises heating the pipe to expand its diameter, inserting the spiral vane assembly while the pipe is hot, and allowing the pipe to cool so that it shrinks to firmly grip the vane.

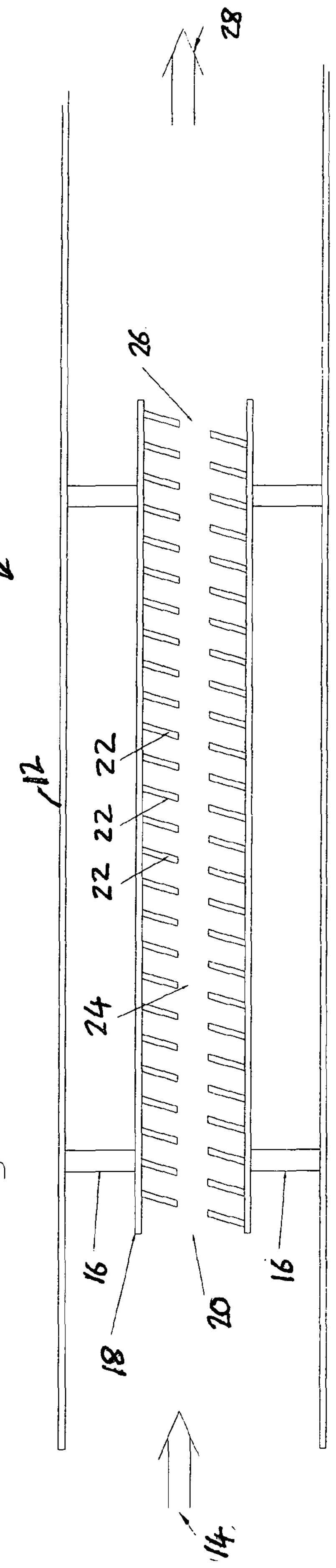


Figure 1

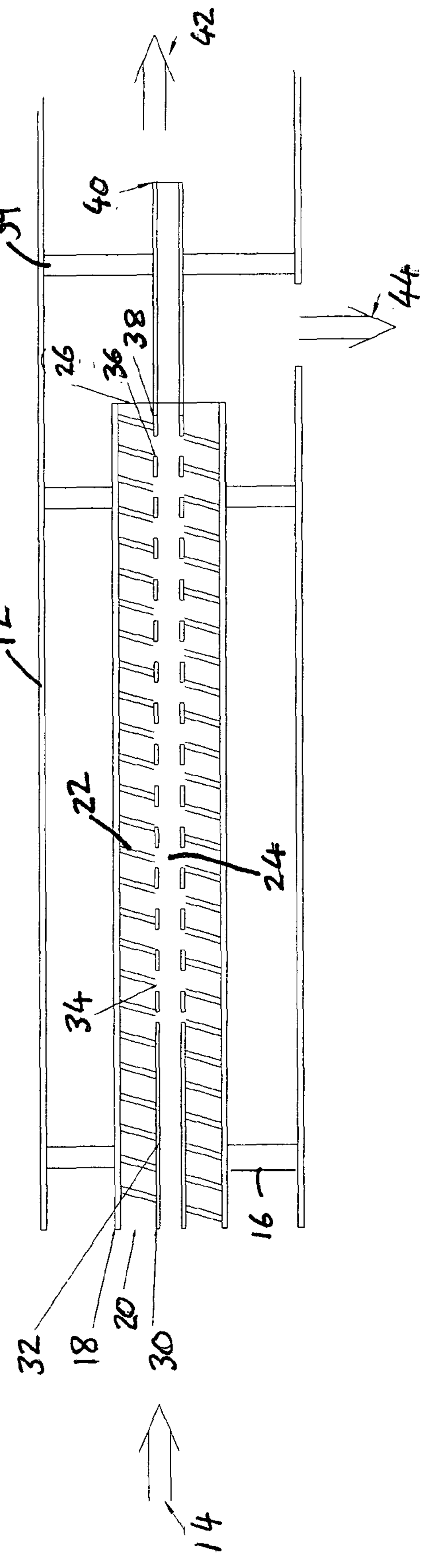


Figure 2

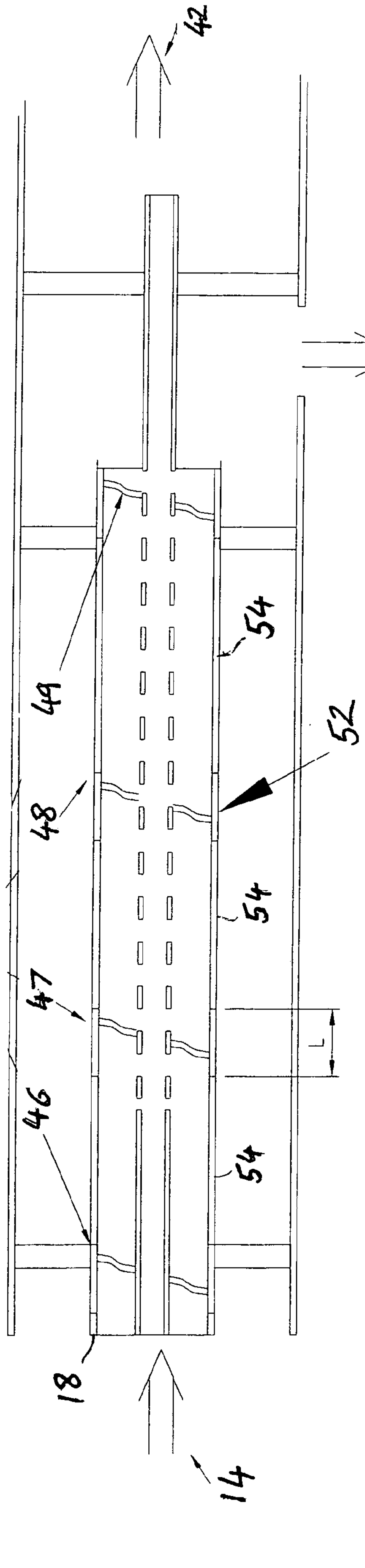


Figure 3

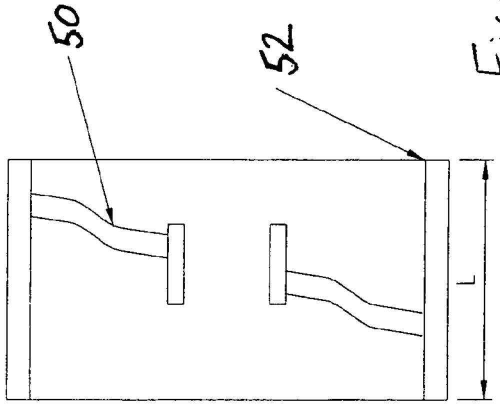


Figure 3a

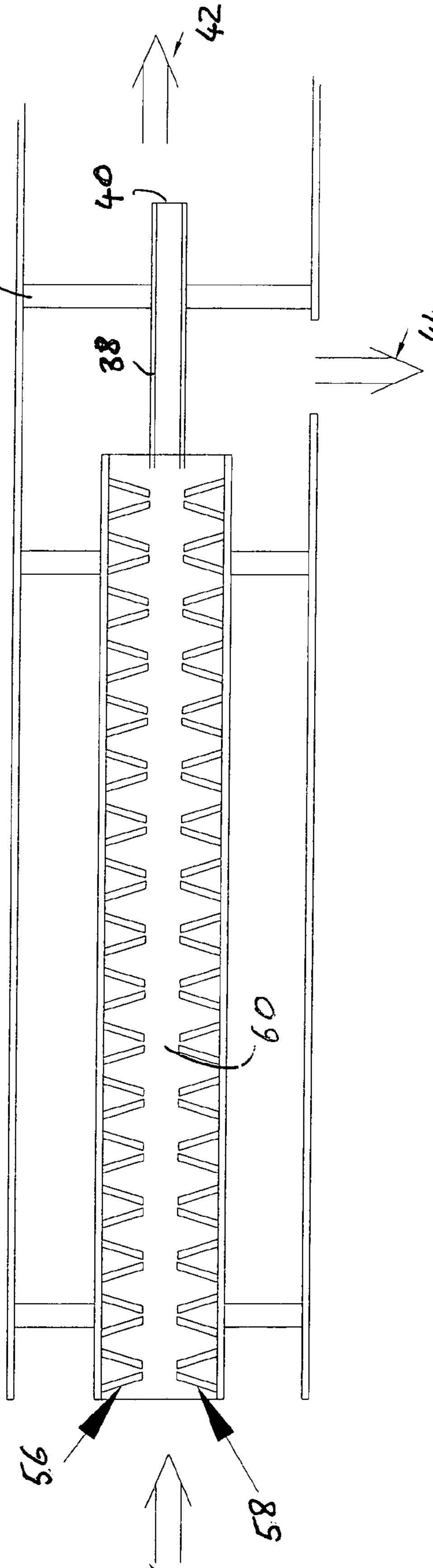


Figure 4

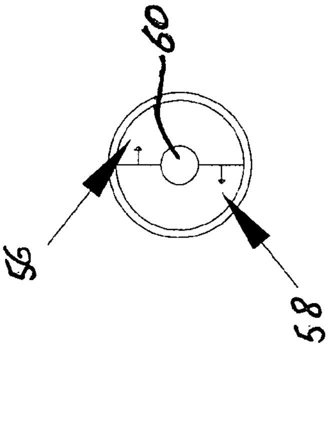
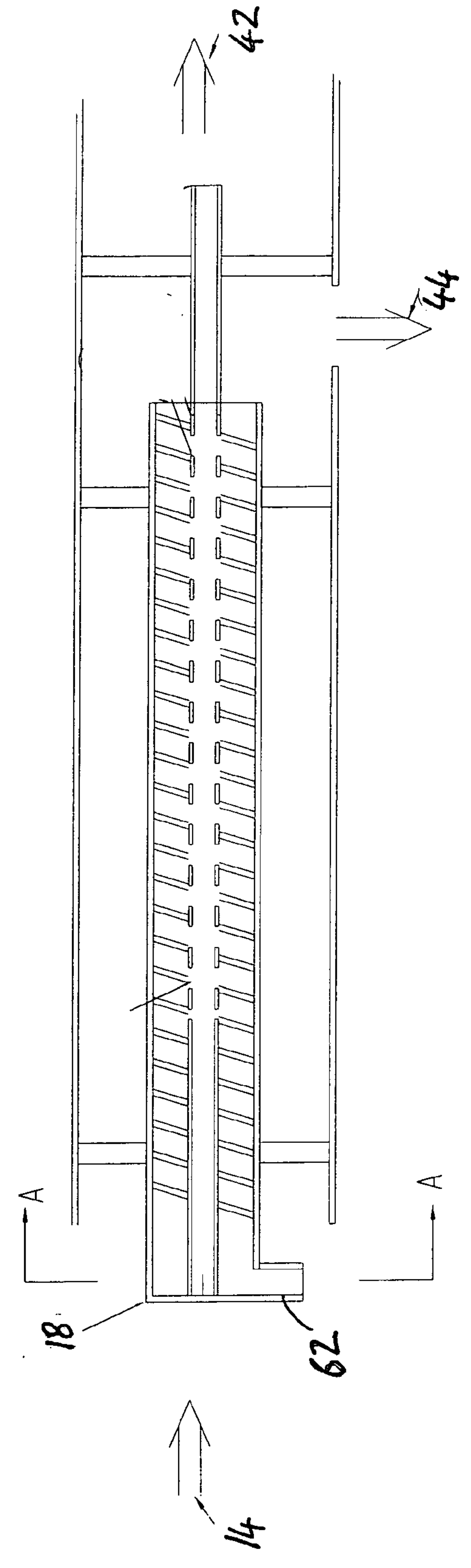


Figure 4a

Figure 5



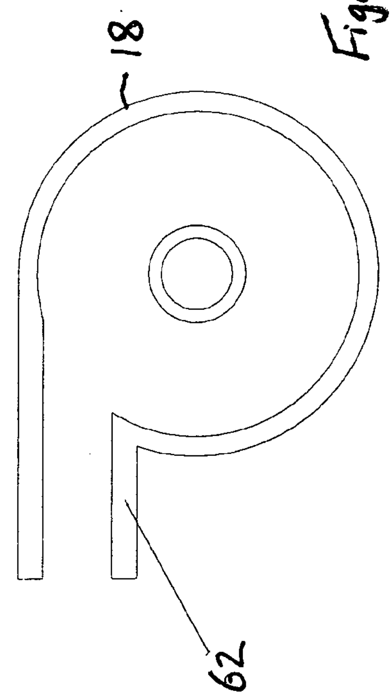


Figure 5a

SECTION A-A

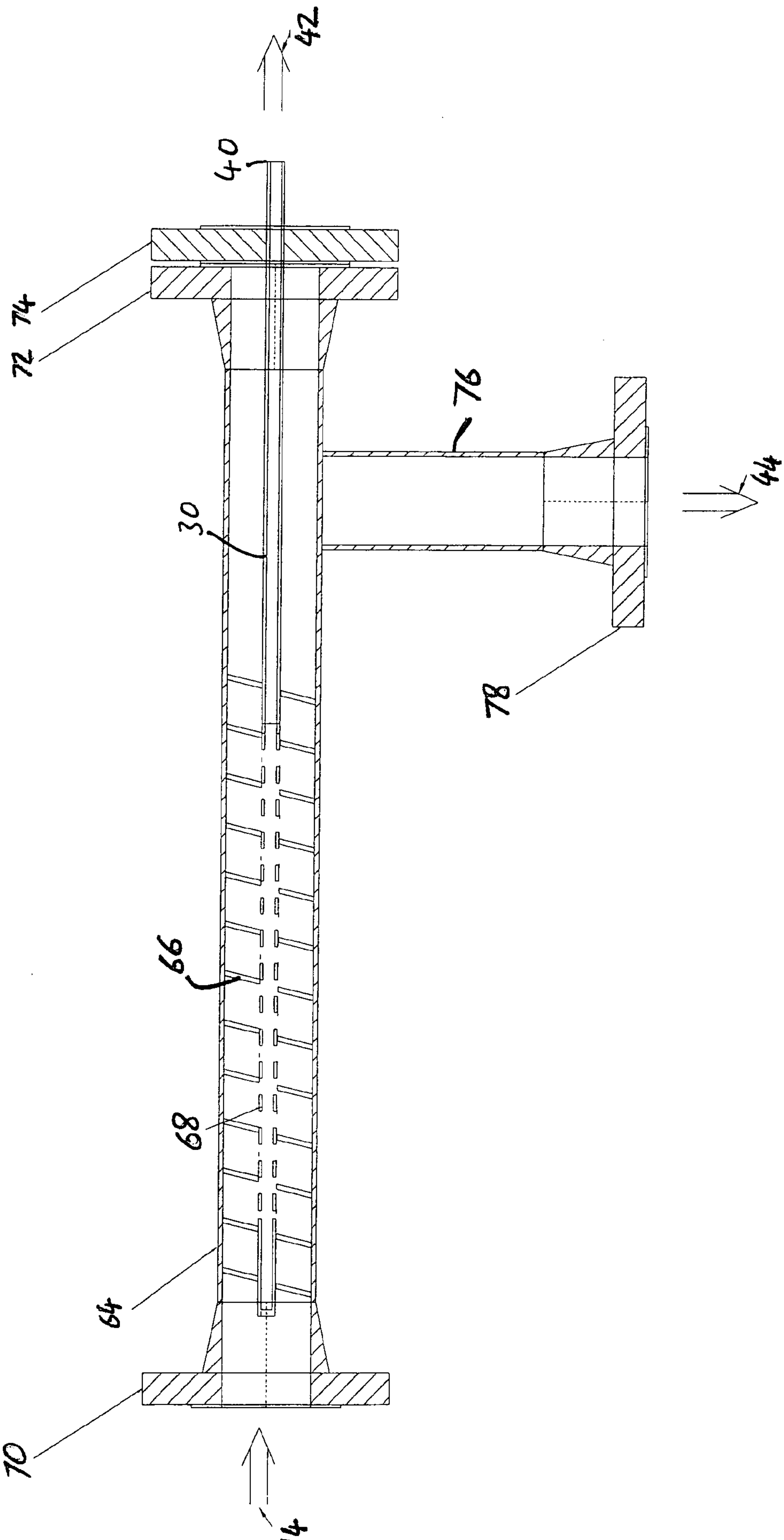


Figure 6

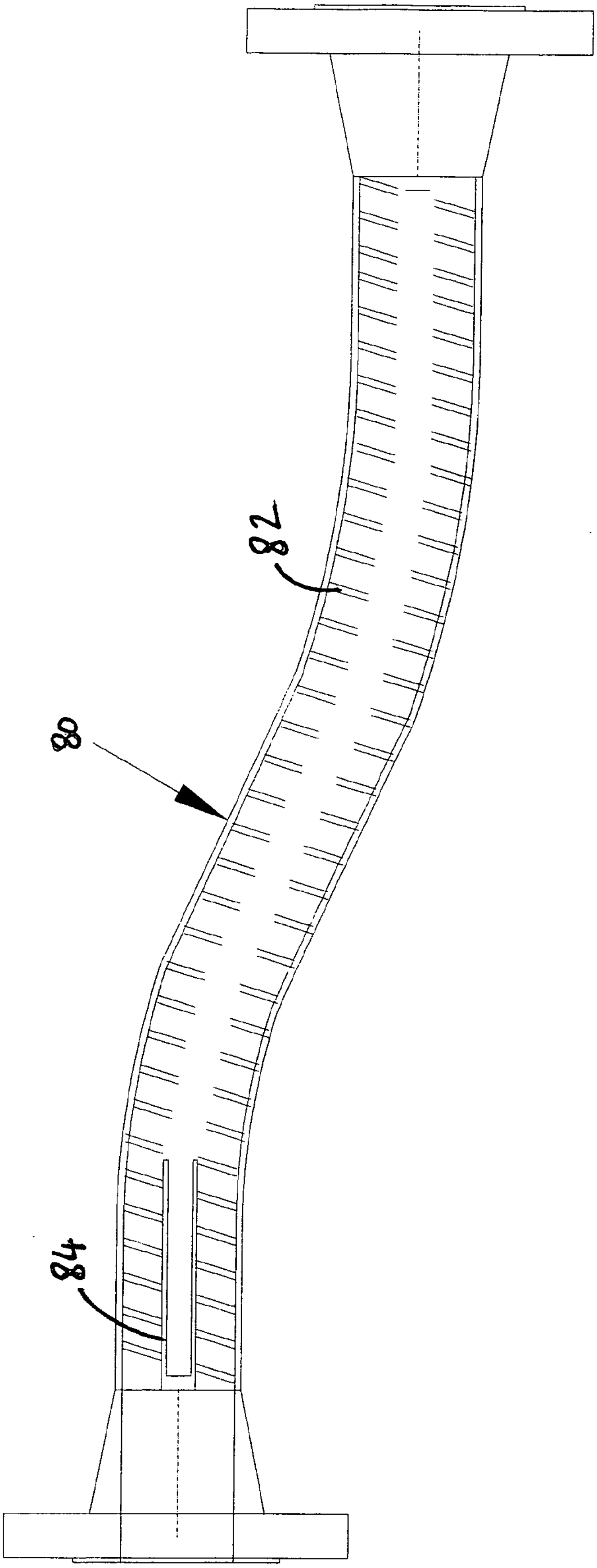


Figure 7

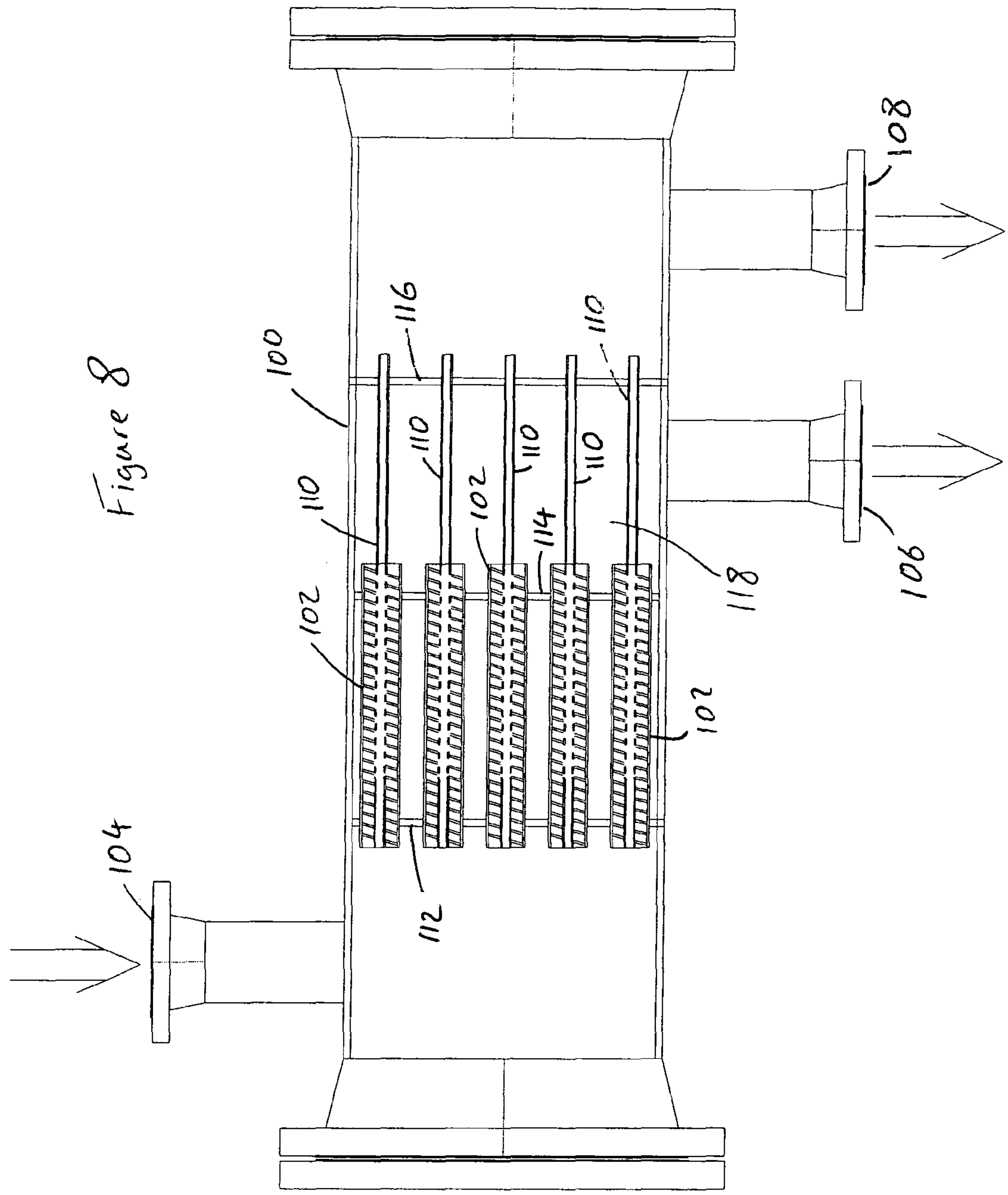


Figure 8

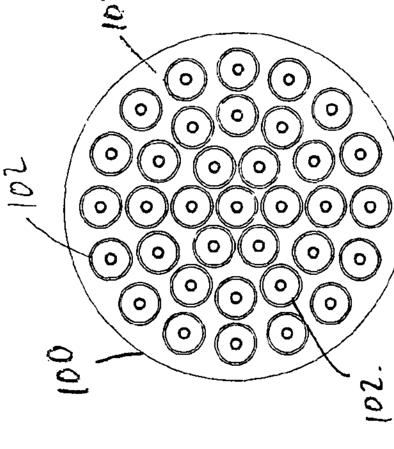


Figure 8a

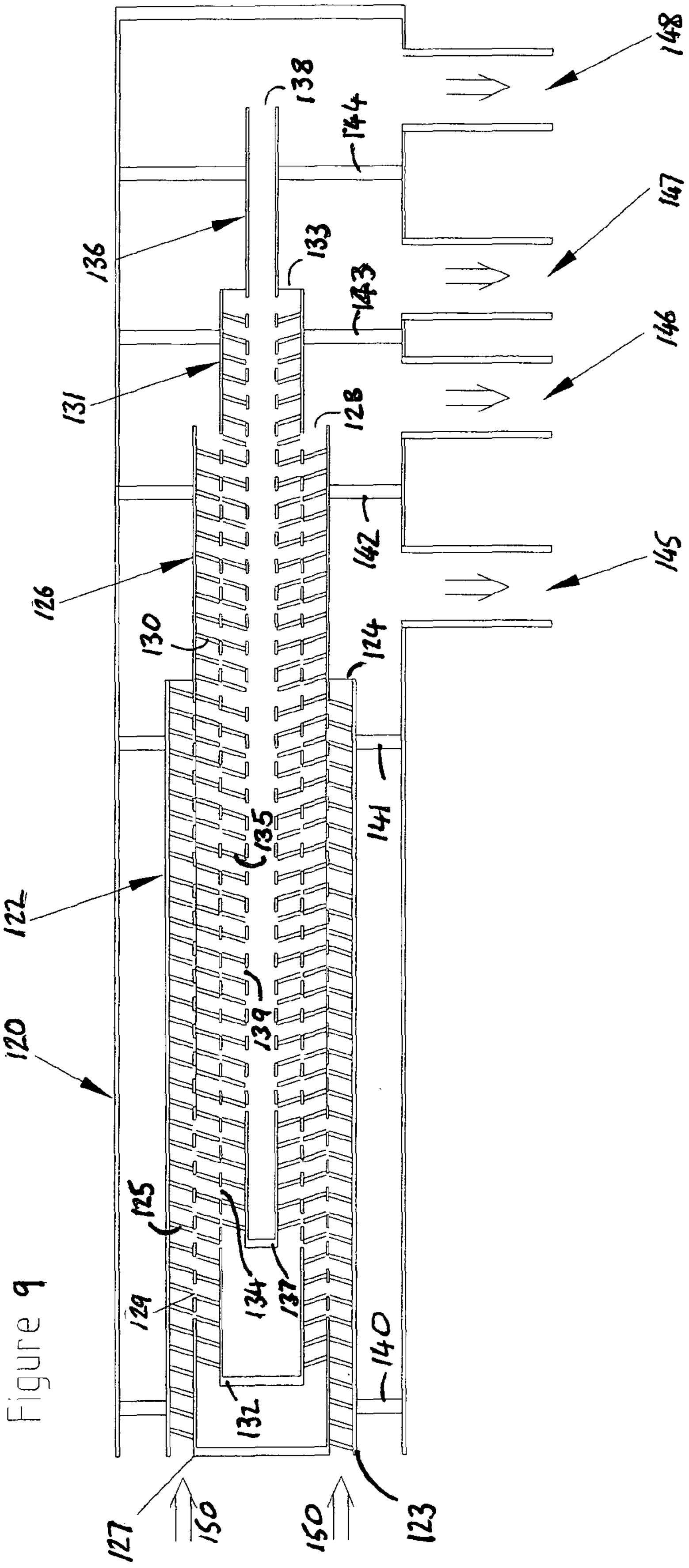

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Figure 9

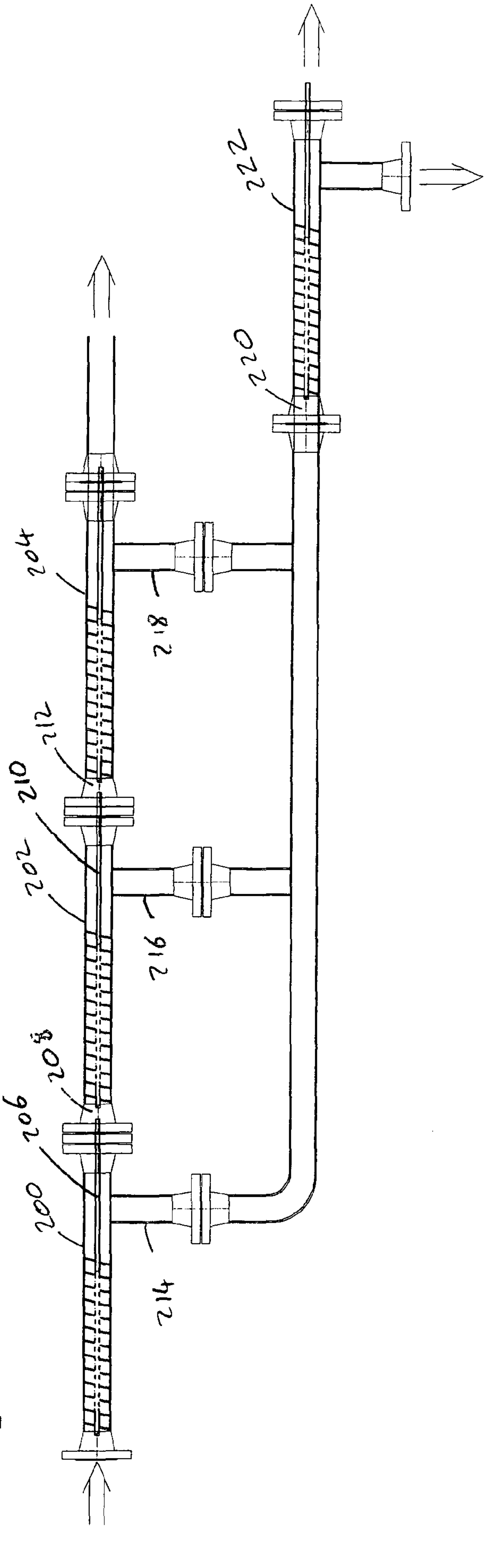


Figure 10

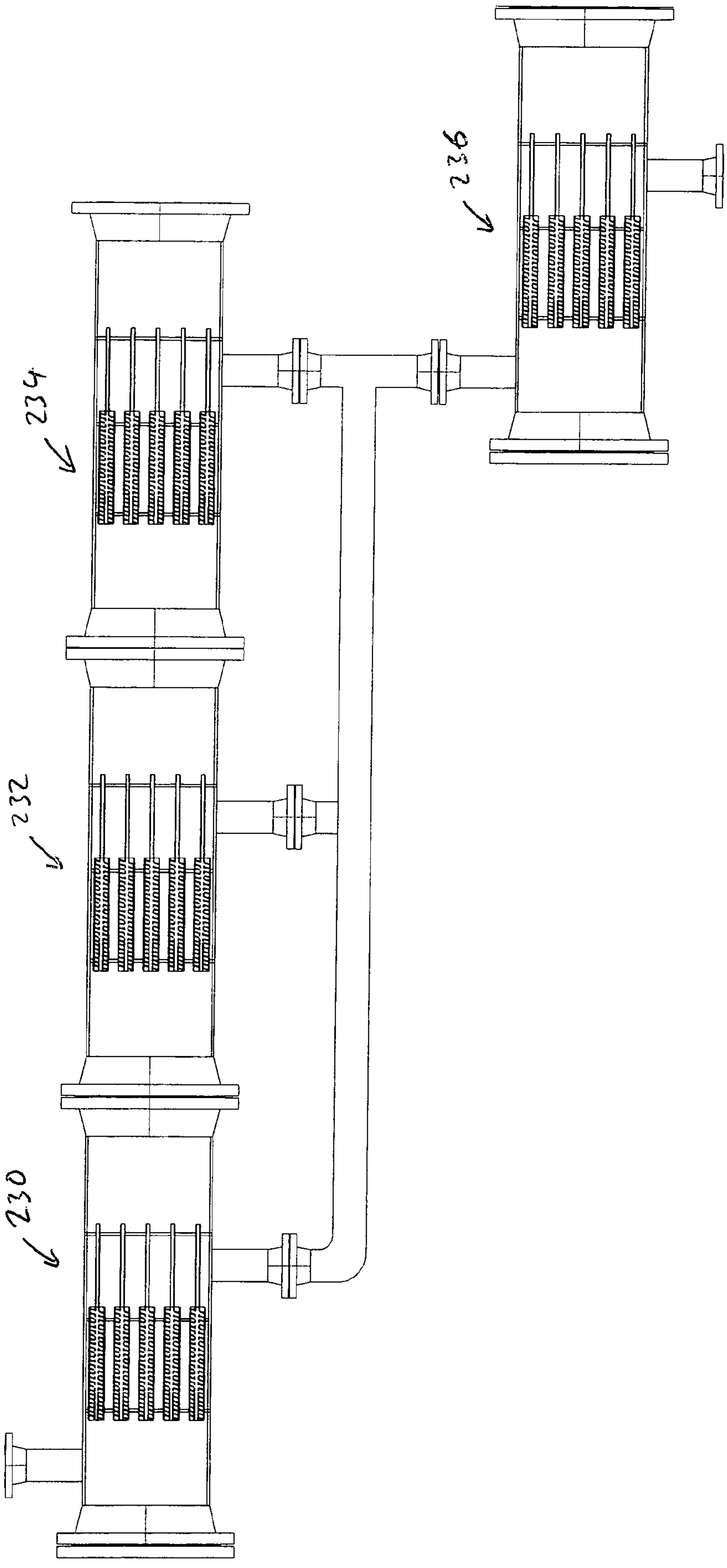
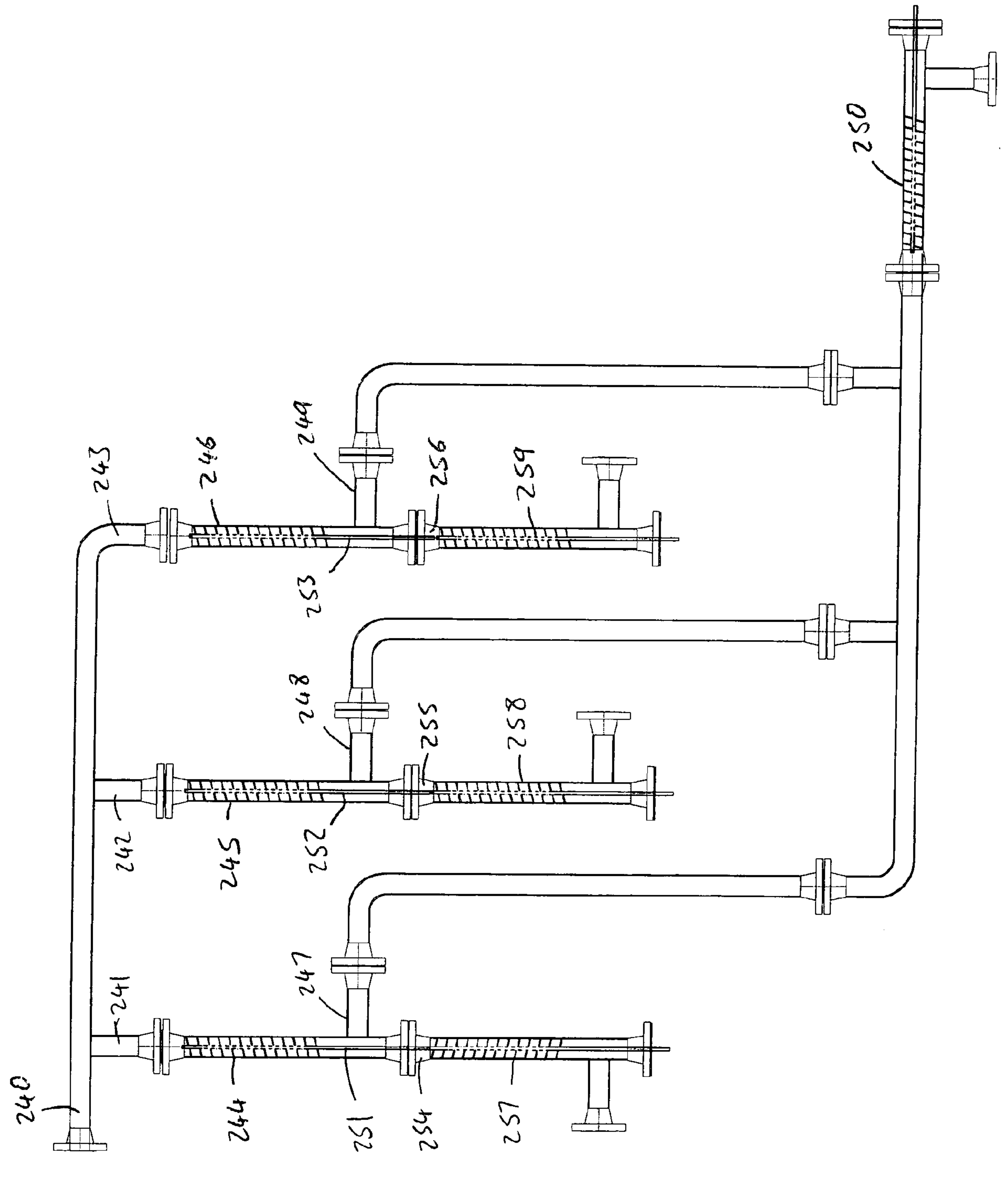


Figure 11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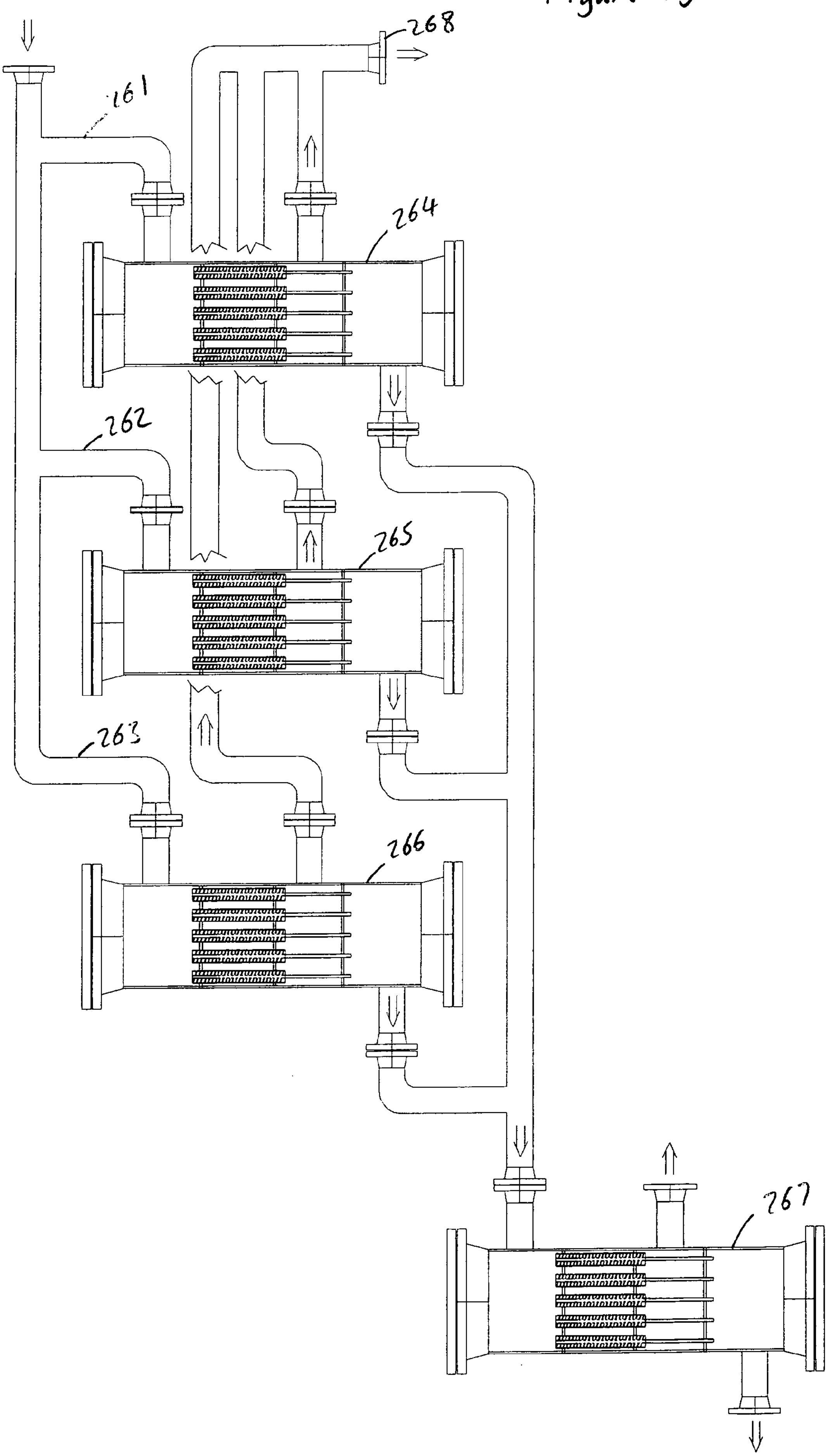
259

Figure 12

Figure 13



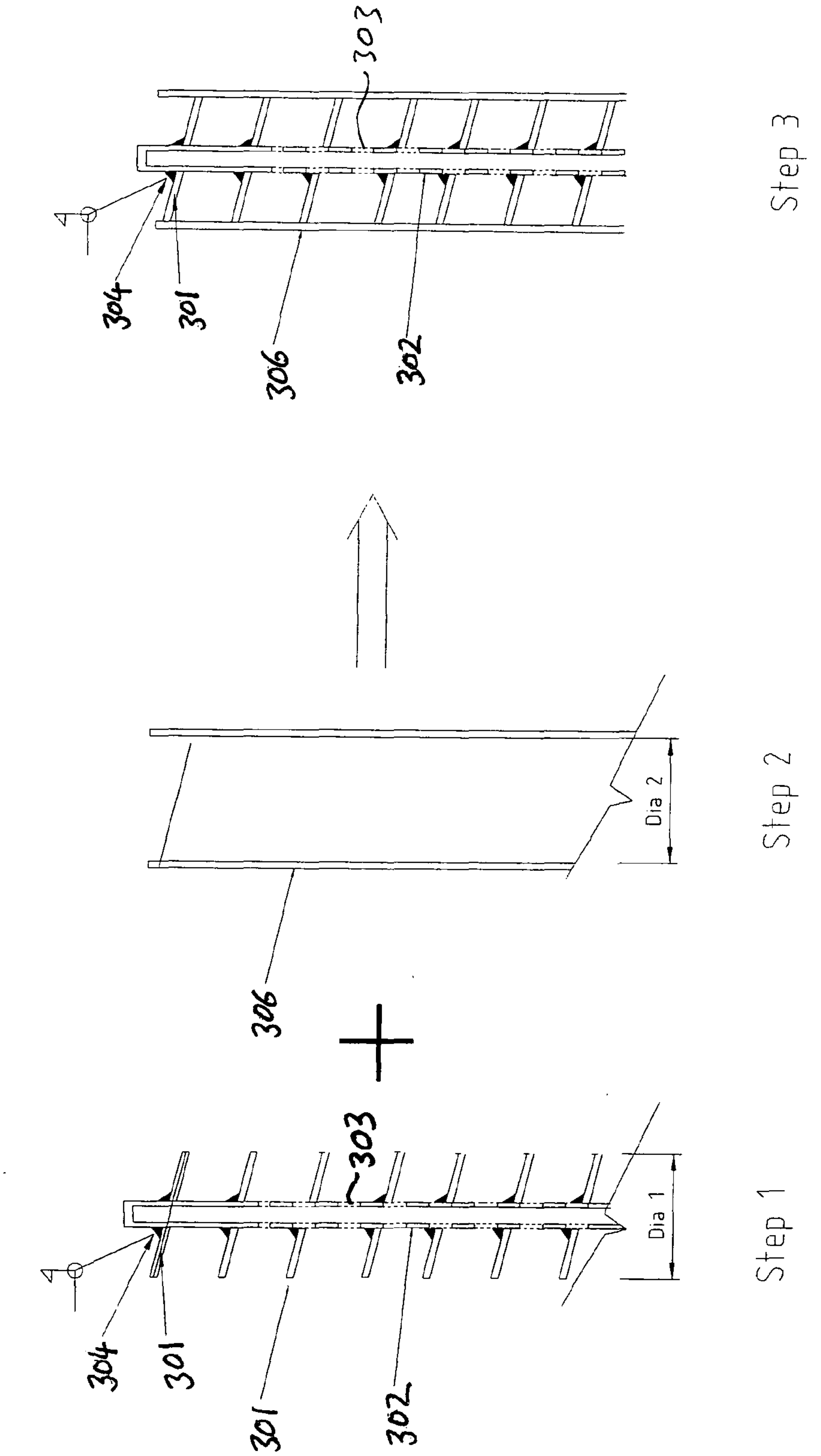
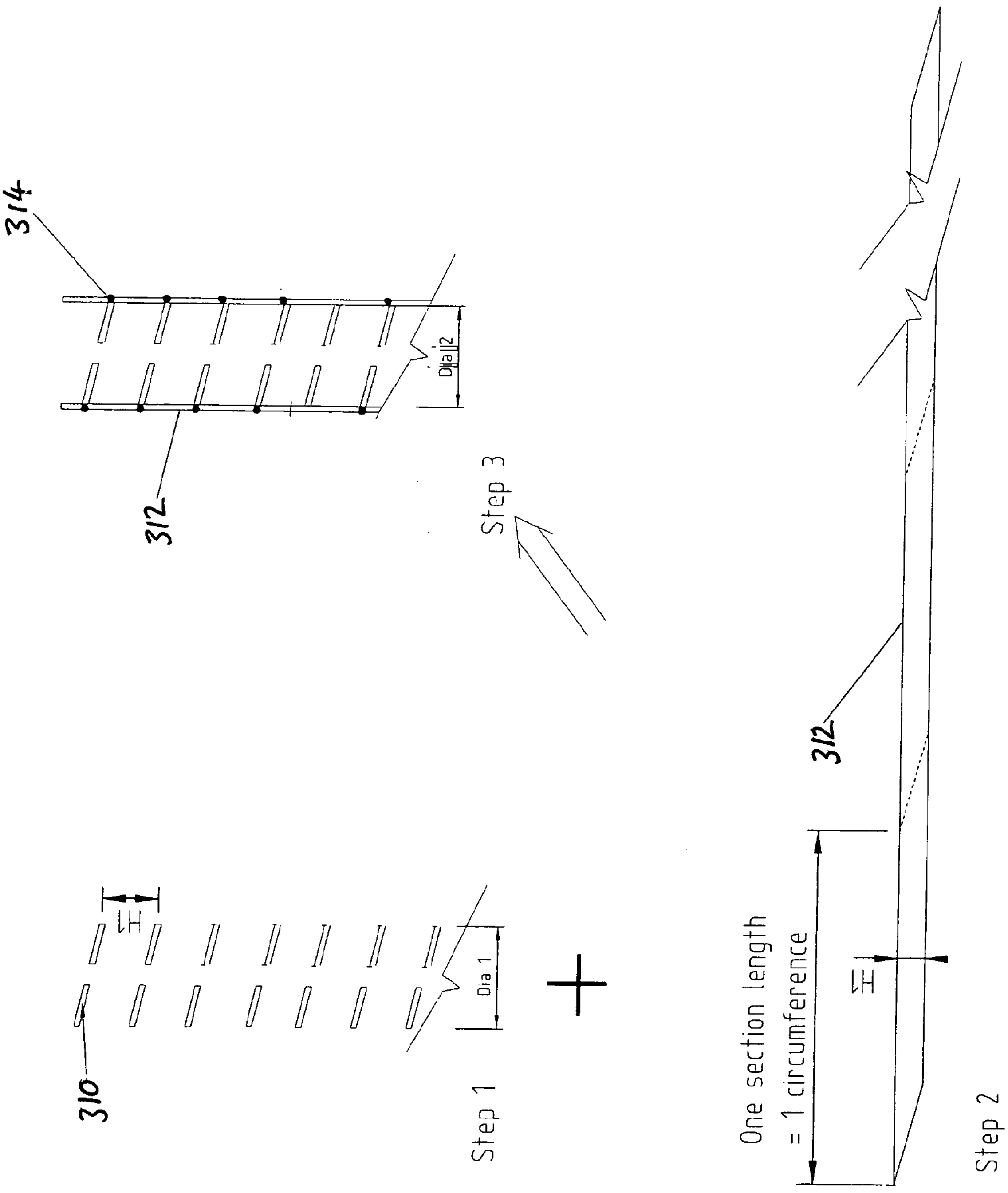

303
304
301
306
302
Step 3
Dia 2
306
Step 2
303
Dia 1
304
301
301
302
Step 1

Figure 14

Figure 15


314
312
Step 3
310
Dia 1
Step 1
One section length
= 1 circumference
312
Step 2

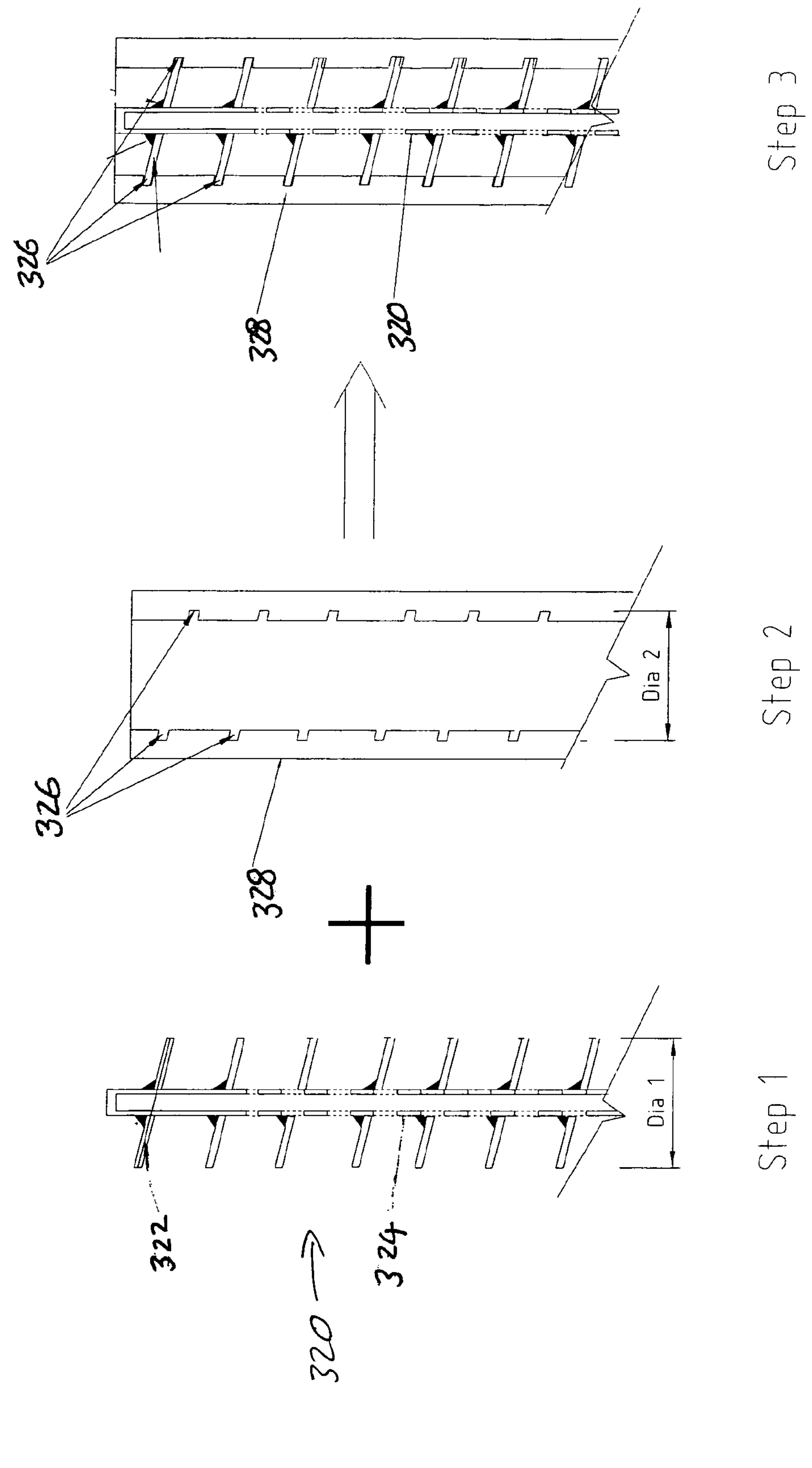
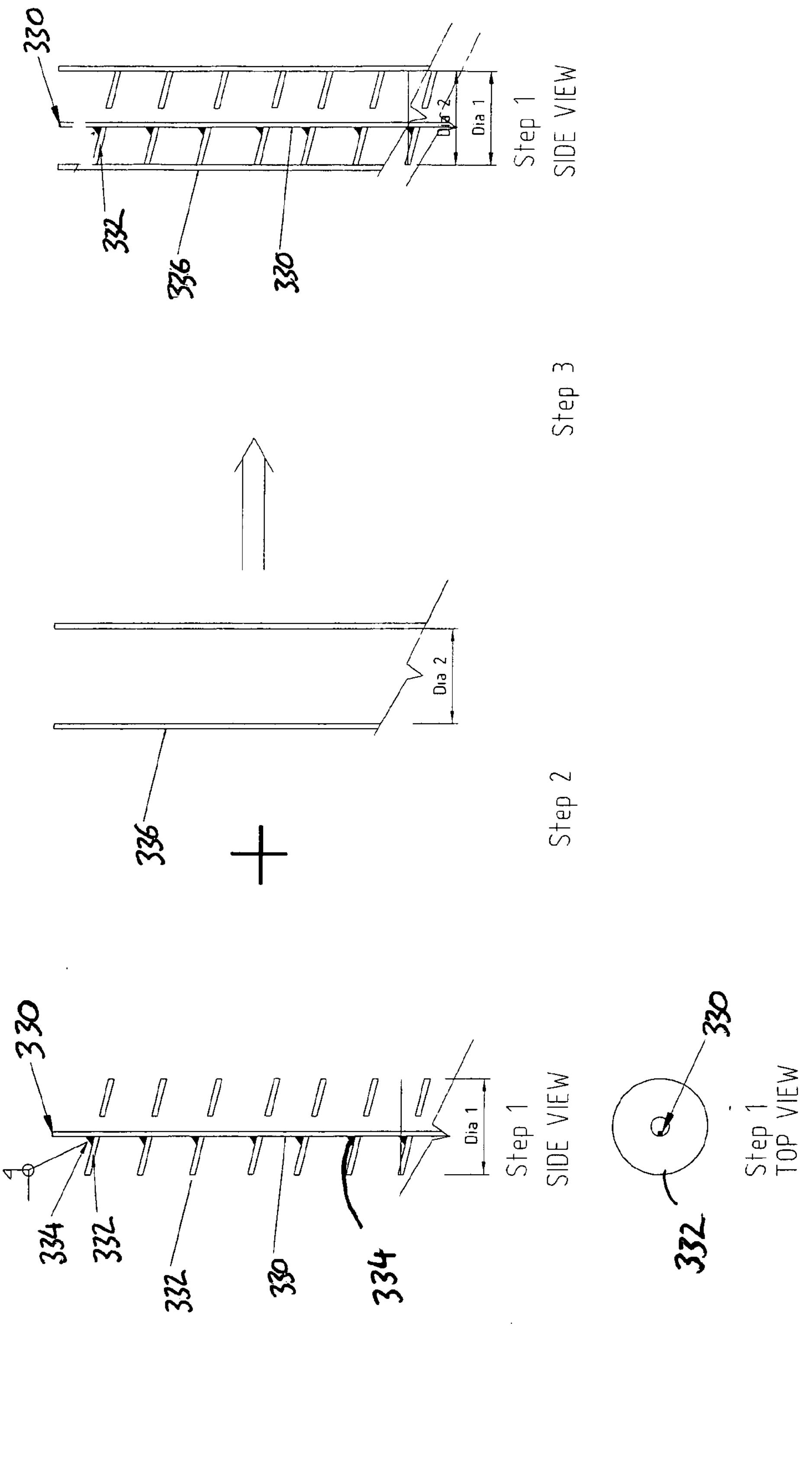


Figure 16

Manufaucturing example 4

Figure 17

Manufaucturing example 5



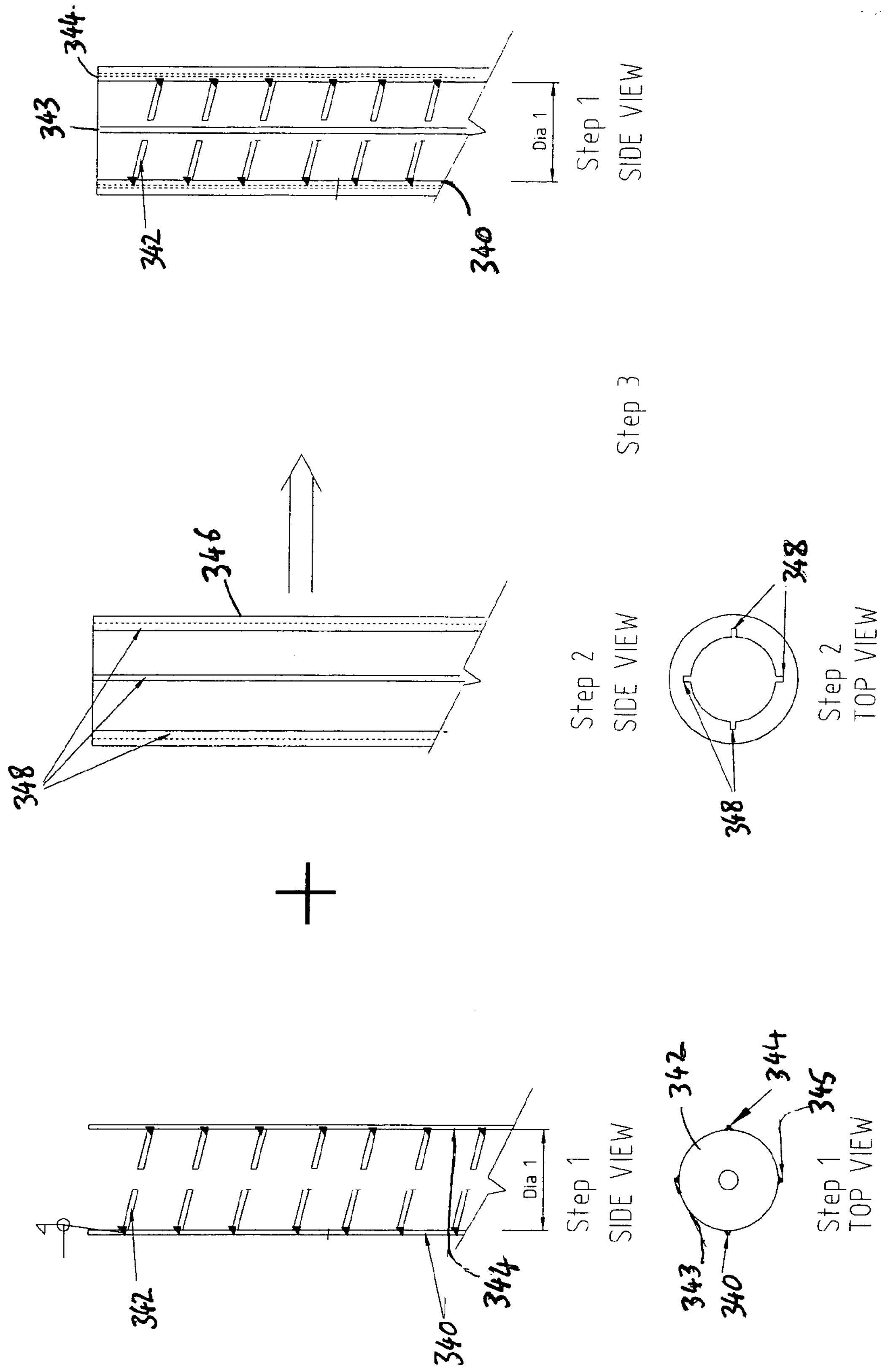

344
343
342
340
Dia 1
Step 1
SIDE VIEW
346
348
Step 2
SIDE VIEW
Step 2
TOP VIEW
Step 3
345
Step 1
TOP VIEW

Figure 18