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(54) Gas-fired boiler

(57) A gas-fired boiler (10) provided with: a burner (16) arranged in a firebox (18); a gas/water heat exchanger (20) arranged around the firebox and provided with a system of flat pipes (22) for the conveyance of the burnt gases (14) arranged in a radial pattern and provided with lateral recesses (106; 24) for noise reduction; a mixer (28) for supplying a gas-air mix to the burner, structured so that the pressure of the gas-air mix is constant regardless of the amount of mix supplied.

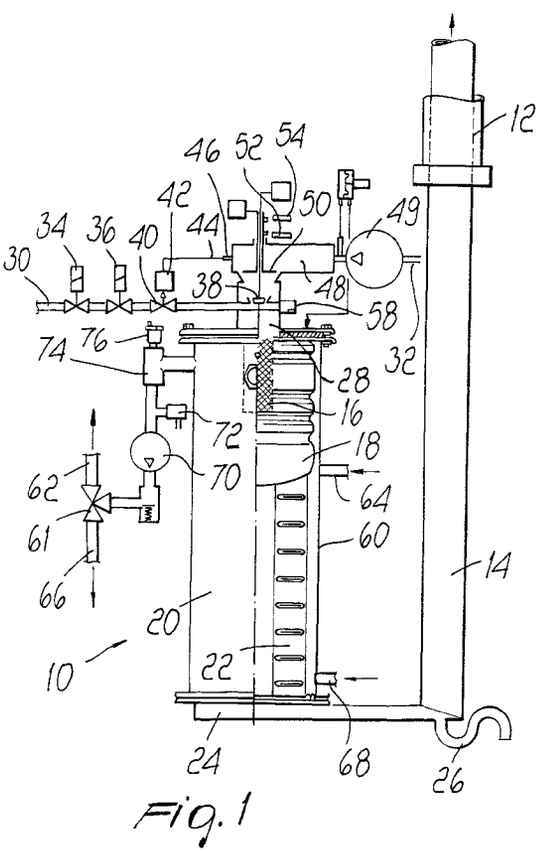

Fig. 1

EP 0 926 439 A2

Description

[0001] The present invention relates to a gas-fired boiler which allows to meet the demand for sanitary hot water and for hot water for heating.

[0002] With respect to fuel oil-fired boilers, gas-fired boilers have the advantage that they do not require a gasometer which can be compared to a tank for the fuel oil or a boiler room and can instead be installed also in living spaces such as the kitchen.

[0003] Gas-fired boilers normally used in houses have a power range between approximately 9 and 25 kW. The width of the modulation band is therefore only 1:3. In homes, the energy demand for heating is usually much lower than 9 kW/h, while the energy demand for dispensing hot water is much higher and requires a power of approximately 20-25 kW/h. High efficiency of the heat exchange between the hot combustion gases and the water is decisive for the good yield of a gas-fired boiler, in order to cope with the dispensing of hot water at its maximum power level. In order to adapt to the reduced energy demand for heating, conventional gas-fired boilers with a 1:3 modulation range turn on and off very often and can reach as many as approximately 3000 burner ignitions per year. Every burner ignition, in addition to constituting an energy loss, also produces much higher emissions of noxious substances than during continuous operation. These emissions of noxious substances which form during ignition are not taken into account during the monitoring of the noxious substances of gas-fired boilers. Due to environmental and energy-loss reasons, therefore, the number of burner ignitions should be minimized.

[0004] Starting from this state of the art, the aim of the invention is to provide an improved gas-fired boiler.

[0005] According to a first aspect of the present invention, a gas-fired boiler is provided which has: a firebox; a burner arranged at least partially in the firebox; a mixer located upstream of the burner and meant to supply a controlled gas-air mix; a flue gas-water heat exchanger arranged around the firebox; and a system of pipes for discharging the burnt gases or flue gas, characterized in that said mixer is adapted to ensure that the pressure of the gas-air mix remains constant regardless of the amount of mix supplied to the burner.

[0006] Since the pressure of the gas-air mix is always kept constant, regardless of the respective amount of mix supplied and therefore regardless of the instantaneous power level of the boiler, it is possible to increase the modulation range considerably. The gas-fired boiler according to the invention can therefore operate over a power range between 3.1 and 24.8 kW/h and therefore with a complete modulation within a modulation range of 1:8. Accordingly, instead of the 3000 ignitions that a burner must perform on the average in a year according to the state of the art, only approximately 300 burner ignitions per year are required. A modulation range of 1:8 cannot be achieved with conventional gas boilers.

[0007] Such a wide modulation range allows ignition at very low power levels of approximately 5 kW, at which the typical noise of ignition is also reduced drastically.

[0008] With conventional gas burners, ignition occurs at 50% power. Apart from the corresponding great annoyance caused by the noise, this is also uneconomical if a lower heating power is subsequently required.

[0009] According to a preferred embodiment of the gas-fired boiler according to the invention, the pressure of the gas and the pressure of the air are both kept constant. The amount of gas and the amount of air are then changed synchronously with respect to each other depending on the required heating power.

[0010] The burner that is present in the gas-fired boiler according to the invention can have a cylindrical sleeve with a plurality of openings. The cylindrical sleeve is preferably fitted in a suspended configuration. By virtue of said suspended mounting, the stresses caused by the heating of the sleeve are better absorbed. In an exemplifying case shown in greater detail in the drawings, the cylindrical sleeve can be fixed from the outside and from below by screwing onto the annular part which tapers downward.

[0011] The openings provided in the sleeve can be slots with a length of approximately 6 mm and a width of approximately 0.4 mm. Said slots can be formed advantageously in a groove-shaped recess of the skirt. In this case the recesses are directed outward.

[0012] For the practical operation of such a gas-fired boiler, it has been found that it is advantageous for the entire transverse cross-section of the openings of the slots to be equal to approximately 6-7% of the surface of the sleeve of the burner. For example, in the case of a sleeve surface of approximately 36,000 square mm, the transverse cross-section of the openings of the slots can be as little as approximately 2,500 square mm. The cylindrical sleeve, in this embodiment, has a height of approximately 164 mm.

[0013] According to another aspect of the present invention, a hot flue gas/water heat exchanger with high thermal efficiency is provided which comprises:

- a water vessel or boiler;
- a furnace which is at least partially immersed in the vessel;
- a plurality of flat pipes in said water vessel, each pipe having two opposite larger surfaces affected by a sequence of closely spaced inward indents and two lateral edges, each flat pipe having an end which is connected to said furnace and another end which is connected to a flue during use;
- at least one lower endplate and an upper endplate for supporting and fixing said pipes, which has a corresponding plurality of through openings, each of which is suitable to receive an end of a respective portion of pipe;

and is characterized in that each one of said pipes

has, on at least one its larger surfaces and, at at least one of its longitudinal edges, a sequence of mutually spaced recesses or hollows.

[0014] Advantageously, said upper endplate is convex, while said lower endplate is concave with respect to the inside of the water vessel or boiler.

[0015] The heat exchanger provided in the gas-fired boiler according to the invention advantageously has burnt-gas pipes which are arranged in a radial pattern. The burnt-gas pipes have mutually opposite recesses which produce narrower regions of the transverse cross-section of said pipes but give the pipes sufficient stability. The burnt-gas pipes in the present embodiment are arranged parallel to each other. The transverse cross-section of the pipes in the region that is not constricted by recesses resembles a very flat ellipse.

[0016] The burnt-gas pipes of the heat exchanger end with a common lower manifold. Said manifold is to be connected to a system of burnt-gas discharge pipes or ducts by means of which the burnt gases are discharged externally. Starting from a manifold, the condensate formed therein can be made to exit preferably through a siphon which is meant to avoid bad odors.

[0017] Further characteristics and advantages of the invention will become apparent from the following detailed description of some currently preferred embodiments thereof, given by way of non-limitative example with reference to the accompanying drawings, wherein:

Figure 1 is a schematic sectional view of a gas-fired boiler according to the invention;
Figure 2 is a view of the burner of the gas-fired boiler of Figure 1, with parts shown in cross-section in its coupling region;
Figure 3 is a top view of the burner of Figure 2;
Figure 4 is a view of a detail of the sleeve of the burner of Figure 2;
Figure 5 is an enlarged-scale sectional view, taken along a transverse plane, of the heat exchanger of the gas-fired boiler according to Figure 1;
Figure 6 is a sectional view, taken along a transverse plane, of a first type of burnt-gas pipe in the exchanger of Figure 5, at a narrower region thereof;
Figure 7 is an elevation view of the detail of the burnt-gas pipe of Figure 6;
Figure 8 is a sectional view, taken along a transverse plane, of a second type of burnt-gas pipe which can be used in the exchanger of Figure 5 at a narrower region thereof;
Figure 9 is an elevation view of the detail of the burnt-gas pipe of Figure 8;
Figure 10 is a sectional front elevation view, taken along an axial longitudinal plane, of another embodiment of a heat exchanger according to the invention;
Figure 11 is a partially sectional bottom view of the exchanger assembly of Figure 10;
Figure 12 is an enlarged-scale view of a detail of a flue gas pipe contained in the exchanger of Figure 10;
Figure 13 is a sectional view, taken along the plane IV-IV of Figure 12;
Figure 14 is a partial sectional view, taken along the plane XIV-XIV of Figure 12;
Figure 15 is a front view of a flue gas pipe or burnt-gas pipe;
Figure 16 is a side view, with a portion shown in cross-section, of the pipe of Figure 15;
Figure 17 is a rear view of the pipe of Figure 6; and
Figures 18 to 21 are, respectively, views which are similar to Figures 15, 16, 12 and 13 but show another embodiment of the burnt-gas pipe.

[0018] In the accompanying drawings, identical or similar parts or components have been designated by the same reference numerals.

[0019] Figure 1 illustrates a gas-fired boiler 10 which is connected to a burnt-gas exhaust system 12 which comprises a pipe 14, made for example of aluminum, which is integrated in a flue (not shown). The burnt gases generated in the gas-fired boiler 10 are discharged through the burnt-gas pipe 14.

[0020] In the gas-fired boiler 10, a burner 16 is kept suspended in a firebox 18 which is provided inside a heat exchanger 20. A plurality of burnt-gas pipes or flue gas pipes 22, arranged in a radial pattern inside the heat exchanger 20, run from the firebox 18 to a common manifold 24 arranged at the lower end of the exchanger. The condensate that forms during the operation of the boiler 10 also accumulates in the manifold 24 and can be drained by means of a siphon 26 provided at the outlet of the manifold 24 to avoid bad odors. The manifold 24 is connected to the pipe 14. The burnt gases or flue gas formed in the firebox 18 thus flow through the various pipes 22 into the heat exchanger 20, collect in the manifold 24 and are discharged into the pipe 14.

[0021] A mixer 28 is provided above the firebox 18 and therefore above the burner 16; the gas supplied by means of a feeder pipe 30 and the air supplied by means of a feeder pipe 32 are mixed in said mixer. The gas that is present in the mixer 28 has a constant pressure regardless of the amount of gas-air mix that is present in said device in each instance.

[0022] In the gas feeder pipe 30 there are provided two adjustable valves 34 and 36, by means of which the pressure in the pipe 30 is kept constant between an upper limit value and a lower limit value. The amount of gas released by means of a valve 38, inserted in the mixer 28, accordingly always has a high constant pressure. The amount of incoming gas is instead variable according to the heating power of the device 10 required in each instance.

[0023] A third valve 40 is inserted downstream of the two valves 34 and 36 with respect to the direction of the gas stream. By means of the valve 40 it is possible to adjust the gas/air ratio. The valve 40 is correspondingly

adjusted by means of a regulator 42 which is connected by means of a pipe 44 to a nipple 46 for measuring the air pressure which measures the air pressure in an air chamber 48. The air that arrives from the feeder pipe 32 is sent to the chamber 48 by means of a blower 49. A high constant pressure is present in the chamber 48 as well, regardless of the position of the valve 50 arranged between the chamber 48 and the mixer 28. By means of the valve 50, it is possible to feed into the mixer 28 a variable amount of air which arrives from the air chamber 48. The two valves 50 and 38 accordingly adjust the amount of air and gas that enters the mixer 28. In the mixer 28, the pressure of the mix has a constant value regardless of the setting of the two valves 38 and 50.

[0024] The two extreme positions of the two valves 38 and 50 can be set by means of two limit switches 52 and 54 as a function of the minimum and maximum power of the boiler 10. The constant gas pressure in the mixer 28 is monitored by a measurement nipple 58.

[0025] The firebox 18 and the burnt-gas pipes 22 are part of the heat exchanger 20 and are arranged in a seat or container 60 which is filled with water. If required, in the seat 60 a delivery pipe 62 leads to an external water heater by means of a three-way valve 61. In the central region of the seat 60 there is provided a return pipe 64 which is connected to the water heater. A delivery pipe 66 from the three-way valve 61 is directed to the heating bodies of a heating system, which are connected to the boiler 10. A return pipe 68 returns from the heating bodies and leads into the lower region of the seat 60. The amount of water directed to the three-way valve 61 is conveyed by means of a pump 70. A safety valve 72 and an air manifold 74 are connected upstream of the pump 70 with respect to the flow direction. From the air manifold 74, the air that is present in the pipe system can discharge externally through a quick vent 76.

[0026] The hot water preparation circuit, arranged in the upper region of the seat 60, is used to take into account the need to usually give priority to the production of sanitary hot water with respect to the production of the amount of hot water required for the heating system.

[0027] The burner 16 can have a sleeve 80 which is closed in a downward region and delimits a cylindrical internal space. The sleeve 80 is fixed, at its upper end, to a peripheral flange 82 which rests by means of a sealing ring 84 on the outer edge of a cone 86. The cone 86, with its internal opening 88, which tapers downward in a transverse cross-section, protrudes into the region of the sleeve 80. The outer upper edge 93 of the cone 86, which contains the screw holes 90 by means of which the flange 82 is anchored to the cone 86 with the gasket 84 interposed, is fixed to the upper edge of the seat 60.

[0028] In the sleeve 80 there are provided vertically orientated slots 92. Each slot has, for example, a width 94 of 0.4 mm and a length (slot height) 96 of 6 mm. The slots are parallel to each other and are provided in each instance in a groove 98 which cambers outward. In the illustrated example, the sleeve 80 has a vertical extension 100 of 164 mm. In this region, in the sleeve 80 there are provided 1,020 slots with a total transverse open cross-section of 2,448 square mm. The surface of the sleeve 80 measures 36,080 square mm with a height of the sleeve 80 of 164 mm and a circumference of the sleeve 80 of 220 mm.

[0029] The sleeve 80 is kept suspended from the flange 82. In practice there are no cambering stresses in the sleeve 80 caused by different heating conditions of the sleeve 80. Below the flange 82 there is provided a ceramic gasket 102 which seals the firebox 18 in an upward region.

[0030] The burnt-gas pipes 22 that are present in the heat exchanger 20, lead out of the firebox 18 and end in the manifold 24, are arranged in a radial pattern, as shown in Figure 5. The burnt-gas pipes 22 can comprise pipes 22.1 and 22.2 which are smaller and larger in a transverse cross-section. Each one of said pipes has a transverse cross-section shaped like a flat ellipse. On the longer side 104 of the transverse cross-section of the smaller exhaust pipe 21.1 there are provided recesses 106 which lie transversely on this side 104. The recesses 106 are mutually spaced and parallel to each other and are arranged vertically one above the other along the pipe 22.1, as shown in Figure 1.

[0031] In front of the recesses 106, on the other longer side of the transverse cross-section 108, there are provided smaller recesses 110. The recesses 106, 110 are arranged in the pipe 22.1 in front of each other and reinforce the pipe. Correspondingly, recesses 112 are also provided in the larger burnt-gas pipe 22.2 on a longer side of the transverse cross-section 114 and correspondingly smaller recesses 116 are present in the other longer side wall 118 located in front of the side wall 114. The recesses 112, 116 act, like the recesses 106, 110, as reinforcements for the pipes 22.2 and 22.1. In the illustrated example, the pipe 22.2 has maximum transverse sectional dimensions of approximately 63 x 11 mm. The smaller burnt-gas pipe 22.1 has maximum dimensions of approximately 50 x 11 mm.

[0032] With reference to Figures 10 and 11 of the drawings, the heat exchanger unit 20 meant to receive flue gas or burnt hot gases arriving from the burner 16 or from another adapted source comprises a water vessel or boiler 60, having for example a cylindrical plan shape, which contains a plurality of pipes 203 which can be immersed in the water present in the vessel or boiler 60, are arranged in a radial pattern and are preferably alternated; one pipe 204 has a larger transverse cross-section and the other pipe 205 has a smaller transverse cross-section. For example, the pipes 204 and the pipes 205 are arranged so as to be angularly equidistant at 45° to each other and together they cover substantially all the circular transverse cross-section of the boiler 60.

[0033] The pipes 203 are supported by, and fixed to, a lower endplate 206 and an upper endplate 207 which have a corresponding plurality of through openings 208, each of which is suitable to receive an end of a respec-

tive pipe 203 of which they reproduce the external configuration, which is preferably ellipsoidal.

[0034] The upper plate 207 is convex, while the lower plate 206 is concave with respect to the inside of the boiler 60.

[0035] The upper plate 207 constitutes the bottom of a vertical furnace 209 which is formed by a tubular body 210 which has a preferably corrugated side wall and is meant to accommodate the nozzle of a burner of any suitable type not shown in the drawings. Said furnace 209 is entirely contained in the boiler 60 and is closed in an upward region by a cover 212 which has a central opening 213 for the passage of the nozzle. The cover 212 comprises thermally insulating material 214 around the central opening 213 and a flanged upper portion 216 which abuts against a free edge 217 of the wall of the vessel or boiler 60. The flanged portion 216 has through holes 218 which are angularly spaced and are meant to accommodate means, for example screws, for securing the heat exchanger unit 20 to a frame or supporting structure (not shown).

[0036] The lower plate 206 has a perimetric recess 219 which is concave toward the outside of the boiler 60 in order to form a seat 220 for abutment with the lower edge of the container 60 and on which at least one opening 221 is formed for the intake of cold water to be heated as well as an opening for the discharge of the water heated by the heat released by the hot flue gas. The plate 206 has a flanged peripheral edge 222 which is meant to protrude with respect to the boiler 60 and is provided with slots 223 for fixing, by means of screws, to a lower flue gas manifold (not shown) which can be connected to a flue.

[0037] As shown in Figures 12 to 17, the pipes 203 have two opposite larger surfaces 224 and 225 which are affected by a sequence of closely spaced inward indents 226 at the larger surfaces 224 and 225, so as to delimit a convoluted internal path 229 for the hot combustion gases or flue gas. Proximate to each one of its longitudinal edges 227, each pipe 203 has a sequence of recesses or studs 228 which preferably have a circular perimeter and are arranged with the same spacing as the recesses 226 but are staggered with respect to them. As shown in Figure 14, the recesses 228 increase the heat exchange surface with an equal space occupation and delimit an uneven internal opening 229 for the hot gases or flue gas.

[0038] The concave internal part 233 of each recess 228 helps to greatly attenuate resonances due to the passage of the pressurized flue gas inside the pipe 203, considerably reducing their noise.

[0039] With reference to Figures 15 to 17, it is noted that the ends 34 of the pipes 203 are oblique in order to adapt to the convexity of the upper plate 207 and to the concavity of the lower plate 206 in which they are meant to be inserted.

[0040] The convexity of the upper plate 207 is adapted to facilitate a natural circulation of the hot water and in particular of the steam bubbles that may have formed or transferred in the vicinity of the plate which, by being inclined or convex, makes said bubbles flow toward the upper part of the boiler 60 around the furnace 210, thus reducing any cavitation.

[0041] The concavity of the lower plate 206 is particularly adapted to collect and convey any condensate rich in corrosive compounds in order to drain it adequately by dripping at the external central protrusion 231 provided in the plate, in order to increase the life of said plate 206 and of the pipes 203 inside the boiler 60.

[0042] The radial arrangement of the pipes 203 allows to use a smaller number of pipes with an equal heat exchange, at the same time simplifying the production of the exchanger unit 20, which is also lighter.

[0043] In the example illustrated in Figures 18 to 21, all or some of the recesses 228 are replaced with notch-shaped crimps 240 which have been found to have a significantly better effect in reducing noise or hissing of the burnt gases that flow through the pipes 204 and 205.

[0044] The materials and the dimensions may be various according to requirements.

[0045] Where technical features mentioned in any claim are followed by reference signs, those reference signs have been included for the sole purpose of increasing the intelligibility of the claims and accordingly such reference signs do not have any limiting effect on the interpretation of each element identified by way of example by such reference signs.

Claims

1. A gas-fired boiler (10) provided with:

   -- a burner (16) arranged in a firebox (18);
   -- a gas/water heat exchanger (20) arranged around said firebox and provided with a system of conveyance pipes for the burnt gases (14) produced in the firebox;
   -- a mixer (28) to supply a gas-air mix to said burner;

   characterized in that said mixer (28) is structured so that the pressure of the gas-air mix is constant regardless of the amount of mix supplied.

2. The gas-fired boiler according to claim 1, characterized in that the pressure of the gas and the pressure of the air are always constant in each instance, while the amount of gas and the amount of air can vary synchronously.

3. The gas-fired boiler according to claim 2, characterized in that the amount of gas and the amount of air can vary with the same ratio.

4. The gas-fired boiler according to any one of the pre-

ceding claims, characterized in that said burner (16) has a peripheral sleeve (80) which has a plurality of openings (92).

5. The gas-fired boiler according to claim 4, characterized in that said sleeve (80) is fixed in a suspended arrangement.

6. The gas-fired boiler according to claim 5, characterized in that said sleeve (80) is fixed from the outside and from below onto a conical part (86) which tapers downward.

7. The gas-fired boiler according to any one of claims 4 to 6, characterized in that said openings (92) in the sleeve are slots which have a height of approximately 6 mm and a width of approximately 0.4 mm.

8. The gas-fired boiler according to any one of claims 4 to 7, characterized in that said slots (92) are provided as a groove (98) of the sleeve (80).

9. The gas-fired boiler according to any one of claims 4 to 8, characterized in that the overall transverse cross-section of the openings or slots (92) is approximately equal to 6.5 to 7.0% of the total surface of the sleeve.

10. The gas-fired boiler according to claim 9, characterized in that the overall transverse cross-section of the openings (92) is approximately 2,488 square mm on a total sleeve surface of approximately 36,080 square mm.

11. The gas-fired boiler according to any one of claims 4 to 10, characterized in that the sleeve (80) has a height of approximately 164 mm.

12. The gas-fired boiler according to any one of the preceding claims, characterized in that said heat exchanger (20) has burnt-gas pipes (22) arranged in a radial pattern, each burnt-gas pipe (22) having opposite recesses (106, 110; 112, 116, 240) which reduce the transverse cross-section of said pipe by regions.

13. The gas-fired boiler according to claim 12, characterized in that said burnt-gas pipes (22) are parallel to each other.

14. The gas-fired boiler according to claim 10 or 11, characterized in that said burnt-gas pipes (22) have, in their transverse cross-section that has no recesses, a rectangular transverse cross-section with shorter rounded corners and longer sides of the rectangle which are slightly cambered outward.

15. The gas-fired boiler according to one of claims 12 to 14, characterized in that said burnt-gas pipes (22) end with a common manifold (24) which is connected to a discharge or flue and is provided with a condensate discharge (26).

16. The gas-fired boiler according to claim 5, characterized in that said discharge (26) comprises a siphon.

17. A hot gas or flue gas/water heat exchanger with high thermal efficiency, comprising:

- a water vessel or boiler (60);
- a furnace (209) which is at least partially immersed in the vessel (60);
- a plurality of flat pipes (203) in said vessel (60), each pipe having two opposite larger surfaces (224, 225) affected by a sequence of closely spaced inward indents (226) and two lateral edges, each pipe (203) having an end which is connected to said furnace (209) and another end which is connected to a flue during use;
- at least one lower endplate (206) and an upper endplate (207) for supporting and fixing the pipes (203), which has a corresponding plurality of through openings, each of which is adapted to receive an end of a respective pipe (203);

and is characterized in that each one of said pipes (203) has, on at least one its larger surfaces (224, 225) and, at at least one of its longitudinal edges, a sequence of mutually spaced indents or hollows (228, 240).

18. A unit according to claim 17, characterized in that said recesses (228, 240) are uniformly spaced and staggered with respect to said indents (228).

19. A unit according to claim 17 or 18, characterized in that said pipes (203) are arranged in a radial pattern with respect to the longitudinal axis of said vessel or boiler (20).

20. A unit according to claim 19, characterized in that said radial arrangement comprises alternately, in an angular sequence, a pipe (203) which has a larger transverse cross-section and a pipe which has a smaller transverse cross-section.

21. A unit according to any one of the preceding claims 17 to 20, characterized in that said pipes (203) have a substantially ellipsoidal transverse cross-section.

22. A unit according to any one of the preceding claims 17 to 21, characterized in that said upper endplate (207) is convex with respect to the inside of said water vessel or boiler (60).

23. A unit according to any one of the preceding claims

17 to 22, characterized in that said lower endplate (206) is concave with respect to the inside of said water vessel or boiler (60).

24. A unit according to claims 22 and 23, characterized in that the ends of said pipes are oblique in order to adapt, during use, to the convexity and concavity, respectively, of said upper endplate (207) and of said lower endplate (206).

25. A unit according to any one of the preceding claims, characterized in that said lower endplate (206) has a perimetric raised portion (219) which is concave toward the outside of the boiler and on which openings (221) are formed for the intake and discharge of the water and against which the wall of said vessel (60) abuts.

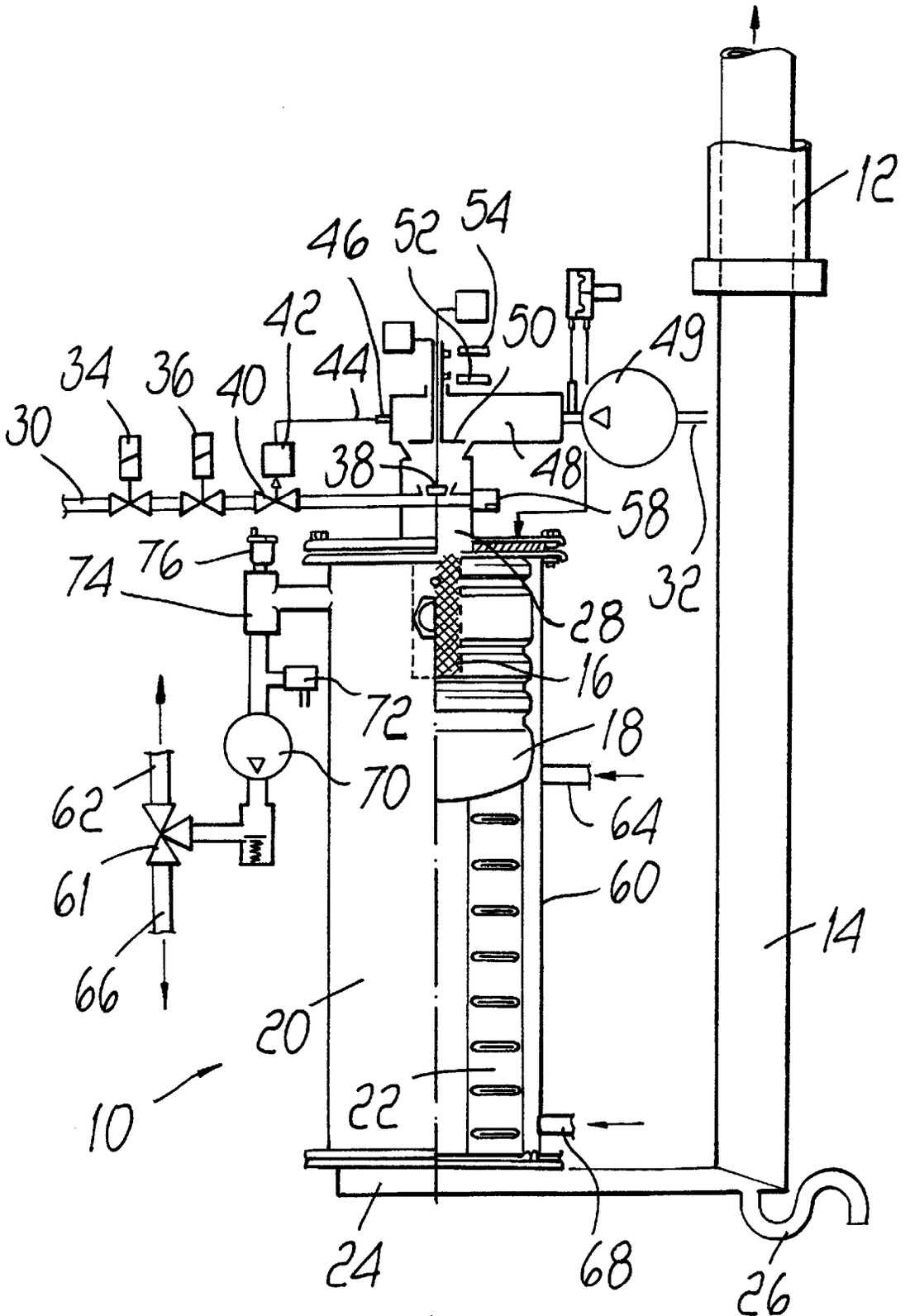
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Fig. 1

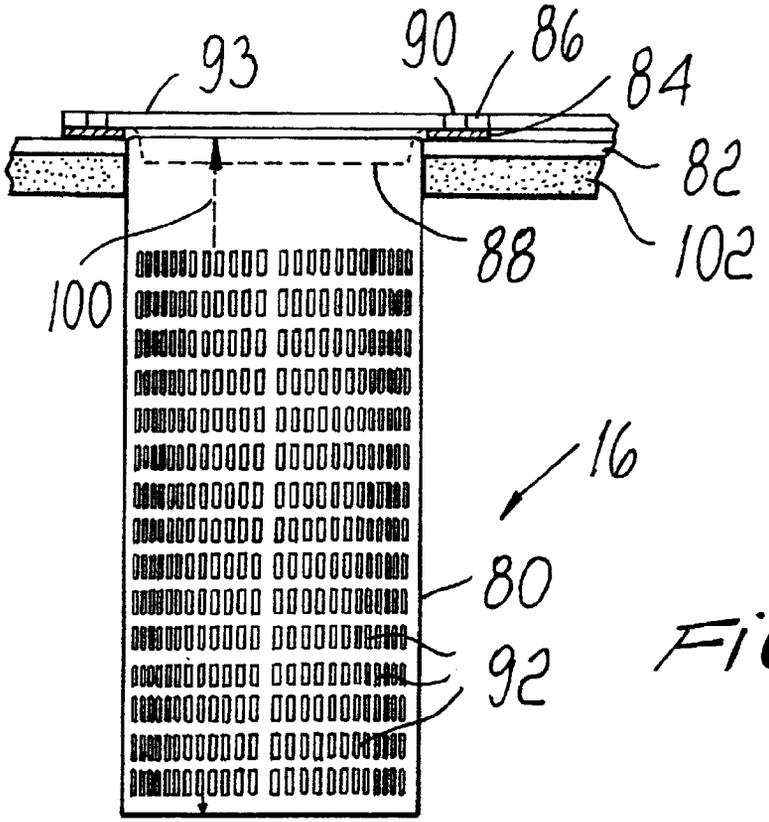

Fig. 2

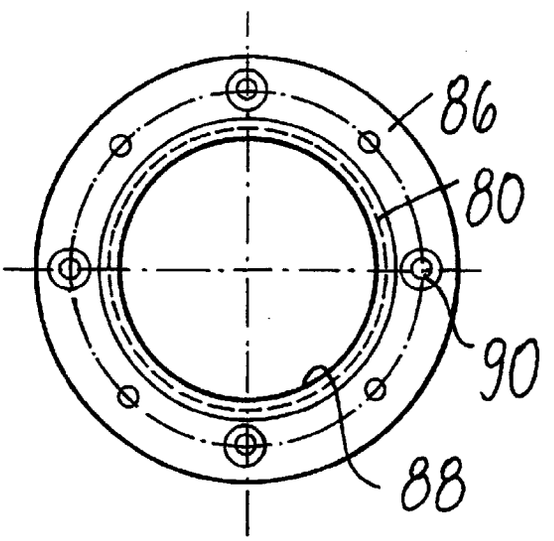

Fig. 3

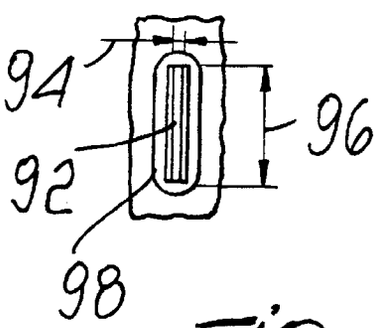

Fig. 4

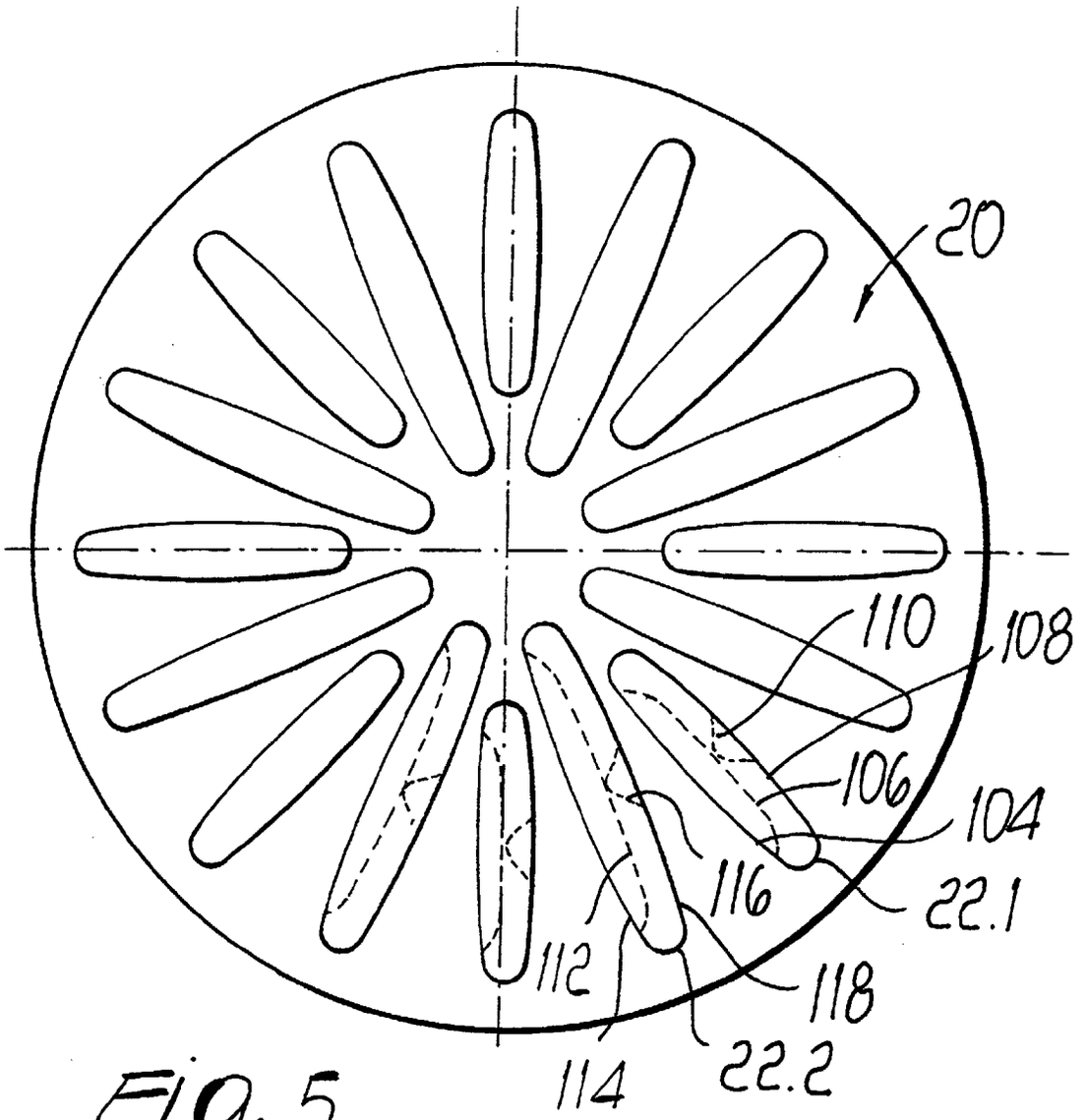

Fig. 5

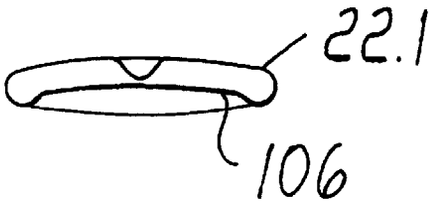

Fig. 6

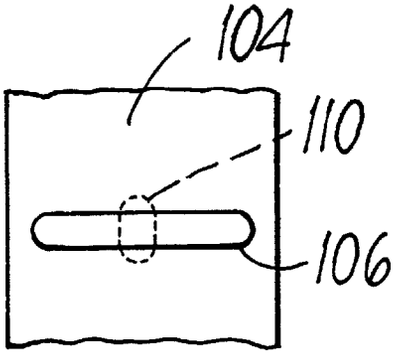

Fig. 7

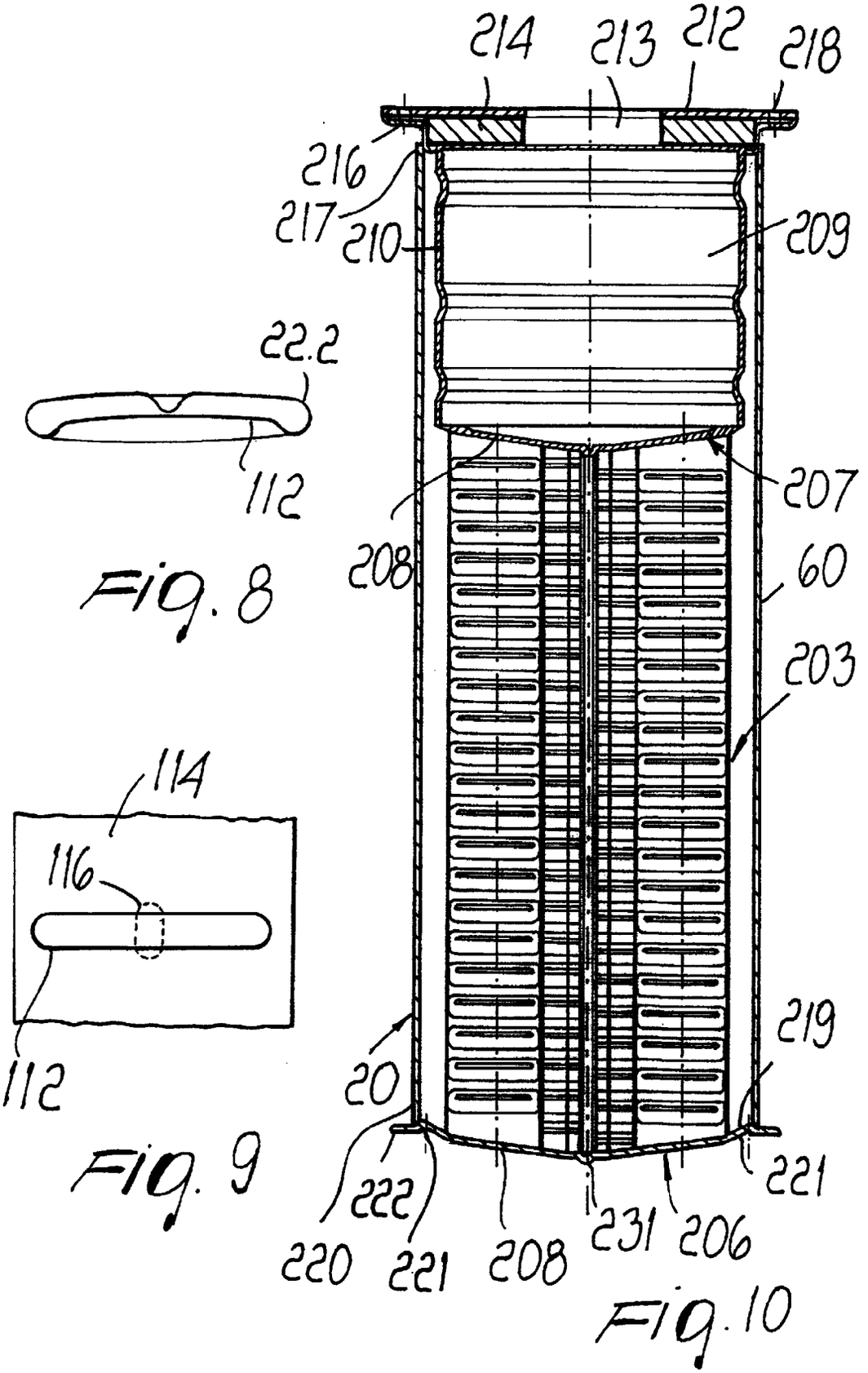

Fig. 8

Fig. 9

Fig. 10

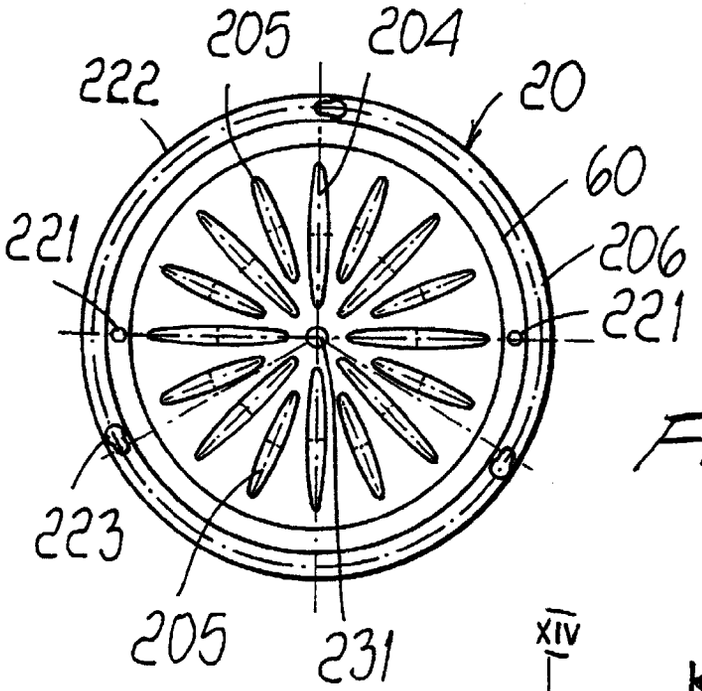

Fig. 11

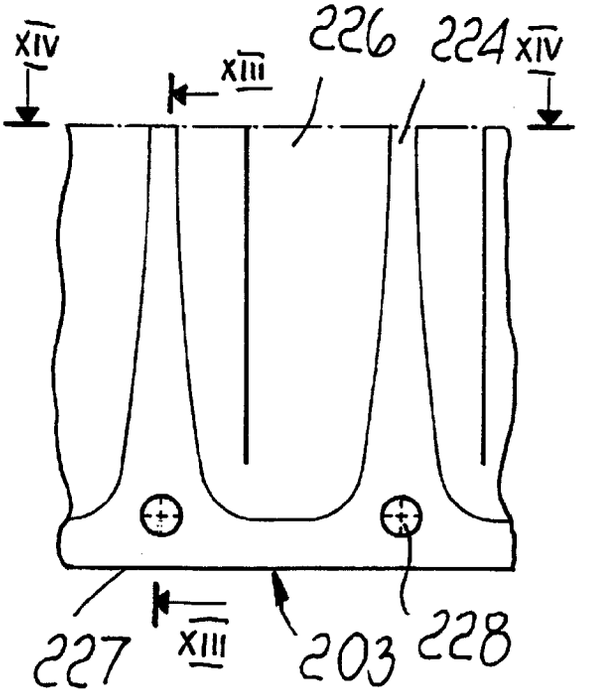

Fig. 12

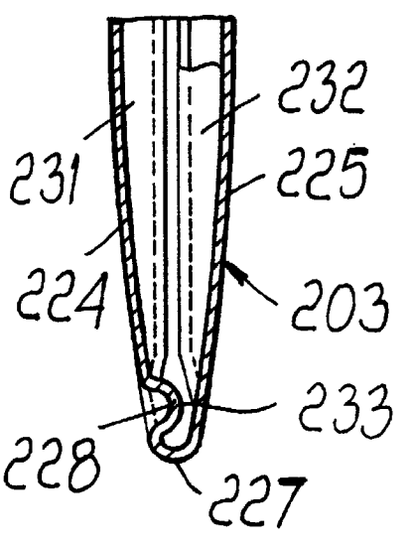

Fig. 13

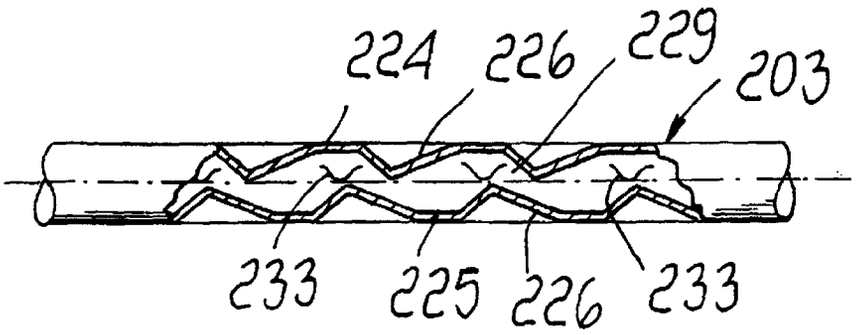

Fig. 14

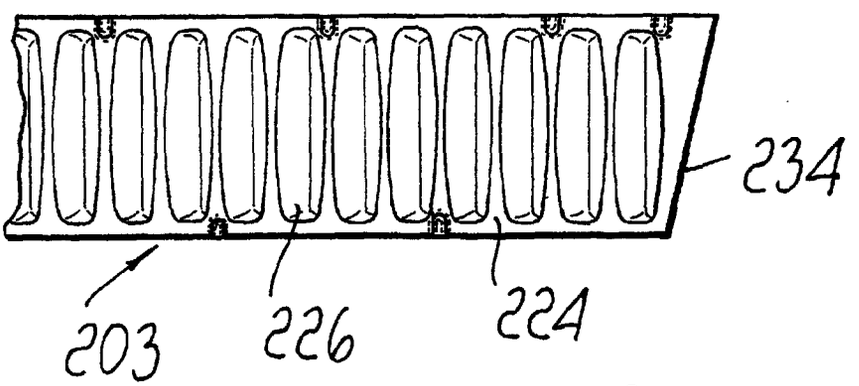

Fig. 18

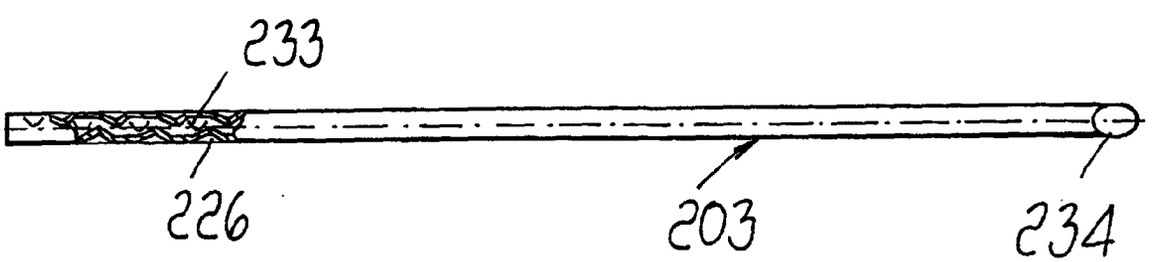

Fig. 19

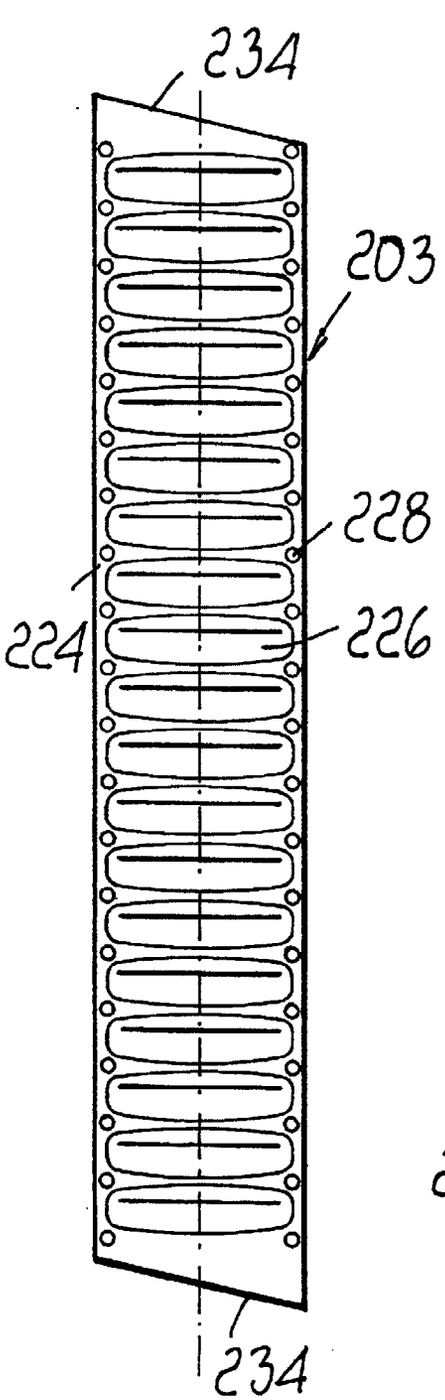

FIG. 15

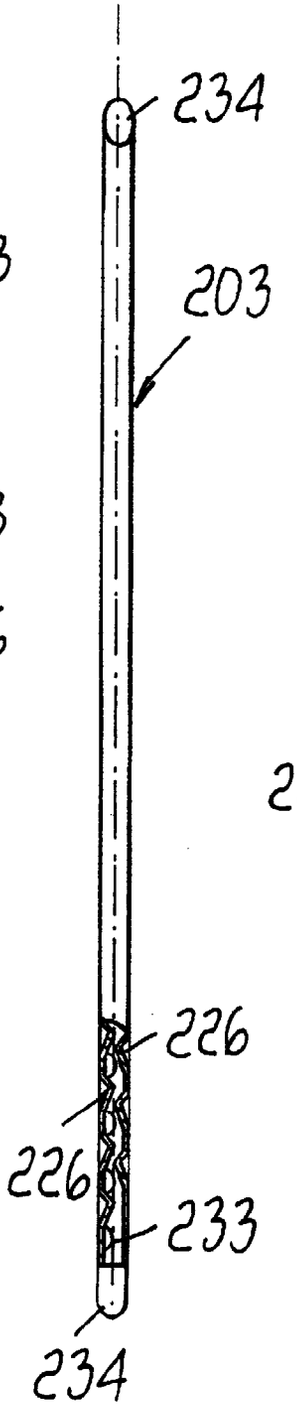

FIG. 16

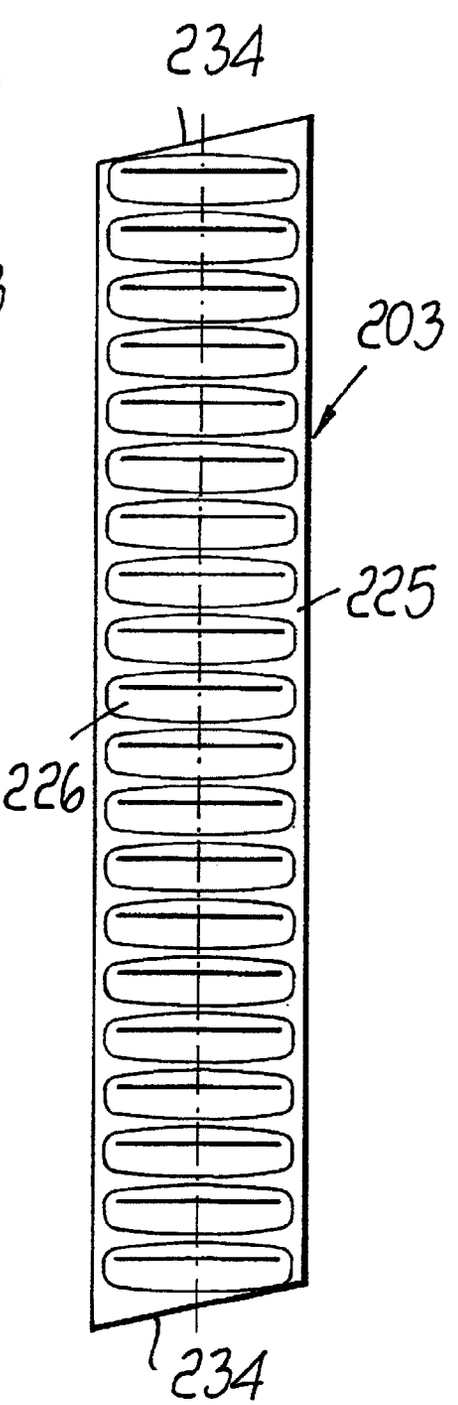

FIG. 17

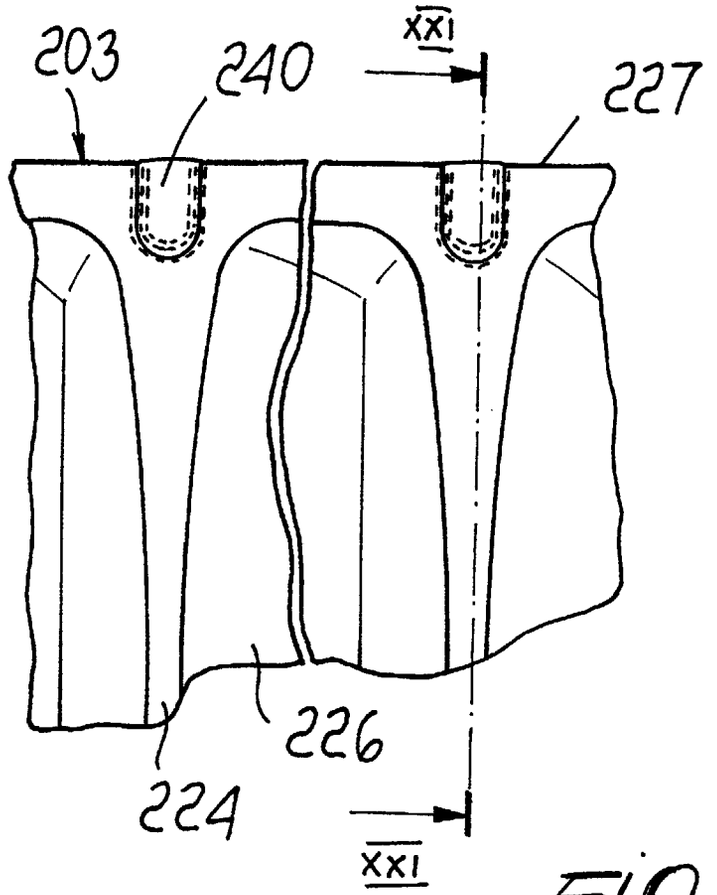

Fig. 20

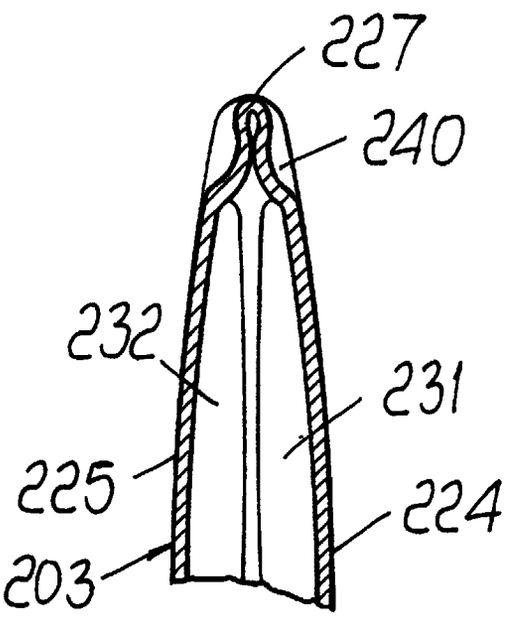

Fig. 21