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⑫ # EUROPEAN PATENT APPLICATION

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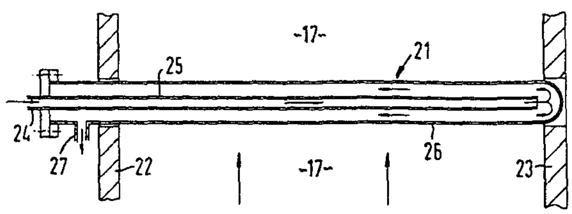
⑤④ **Method and apparatus for heating a fluid employing a gas containing sulfur oxides and water.**

⑤⑦ A fluid which is to be heated by a gas (in 17) containing sulfur oxides and water vapour is passed through the inner tube(s) (25) of a multi-pipe heat exchanger (21) and recovered from the outermost tube (26) thereof at such a temperature that the outer surface temperture of the outermost tube (26) is always above the acid dew point, thereby avoiding acid corrosion of the outermost tube (26) of the heat exchanger (21).

In an embodiment, the heat exchanger (21) is of the double pipe type, but whichever type is employed, the heat transfer characteristics and/or sizes of the tubes of the heat exchanger (21) are selected to provide an outer surface temperature exceeding the acid dew point for reasonable and/or acceptable ranges of fluid flow rates and pressure drops therethrough.

FIG. 2



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"Method and Apparatus for Heating a Fluid Employing a Gas containing Sulfur Oxides and Water"

The present invention relates to a method and apparatus for heating a fluid employing a gas containing sulfur oxides and water.

Hot gases containing sulfur oxides and water are commonly employed for heating in industry and are derived by burning fuels containing sulfur. Among such fuels are solid fuels such as coals and lignites and fluid fuels such as fuel oils and hydrocarbon gases. A well-known problem arising from the use of such hot gases is that of acid corrosion which occurs when the temperature of the hot gases falls to the dew point and an acidic liquid condenses on metal parts such as the low temperature heat recovery tubes of a furnace or boiler.

The usual method of avoiding acid corrosion is to ensure that the hot gases never contact surfaces which are at such temperatures as to cause condensation of acidic liquid. In the case of boilers or process stream heaters, the water or process stream feed is preheated to a temperature exceeding the dew point of the hot gases from which heat is to be extracted, and this practice has obvious drawbacks in that an additional heat exchanger and an additional source of heat therefor are required, and moreover, the heat which can be recovered from the hot gases is not as fully exploited as it might be.

An alternative approach which has been suggested is to form the surfaces of the heat recovery tubes from materials which are capable of resisting acid corrosion. This alternative approach has practical limitations since it is not usually economic to form the surfaces of heat recovery tubes wholly from acid-resistant material, and in practice, only those sections of the tubes which are vulnerable to acid corrosion are formed of acid-resistant materials. However, even this approach is not free from difficulties because the strength of the acid formed on the exposed surface of a heat recovery tube depends on the temperature of the exposed surface, and the temperature unavoidably varies along the length of the tube. The vulnerable sections of the tubes must therefore be formed from different materials each capable of resisting corrosion by the acid deposited locally thereon. Besides adding to the cost of the heat recovery tubes, the approach is not reliable because a change in the operating conditions of the furnace can change the strength of the acid deposited at each location so that materials which previously would not have been corroded become exposed to an acid strength which they may not be able to resist.

The present invention, in one aspect, provides a method of heating a fluid employing a heating gas containing SO_x and H_2O which passes in heat exchange relationship with the outer surface of a heat exchanger through which the fluid is passed, wherein the heat exchanger comprises a multi-pipe heat exchanger, and unheated fluid is passed into an inlet of one pipe of the multi-pipe heat exchanger at a temperature below the acid dew point of the heating gas and discharged from an outlet of another pipe of the said multi-pipe heat exchanger at a temperature exceeding the acid dew point of the heating gas, and maintaining the flow of fluid through the multi-pipe heat exchanger at a rate such that the temperature of the outer surface of the multi-pipe heat exchanger is above the acid dew point of the heating gas.

Preferably, the said other pipe is the outermost pipe of the multi-pipe heat exchanger, and the said one pipe is inwards of the said other pipe.

The fluid discharged from the multi-pipe heat exchanger preferably is conducted to another heat exchange means and heated therein to a higher temperature.

The said other heat exchange means may be heated mainly by radiation from a flame in which a sulfur-containing fuel is burned to produce combustion gases.

The said combustion gases may form at least some of the said heating gas, and the multi-pipe heat exchanger may be heated mainly by convection from said combustion gases.

In another aspect, the invention provides apparatus for heating a fluid comprising at least one burner for burning a sulfur-containing fuel in a flame to produce combustion gases containing SO_x and H_2O, comprising heat exchange means through which the fluid can flow in indirect heat exchange relationship with combustion gases contacting the outer surface of the heat exchange means, wherein the heat exchange means comprises a multi-pipe heat exchanger having an inlet for unheated fluid at one end of one pipe and an outlet for heated fluid at one end of another pipe of the multi-pipe heat exchanger, and comprising means for supplying fluid to the multi-pipe heat exchanger at a rate within a predetermined range to avoid the deposition of acid dew on the outer surface of the multi-pipe heat exchanger.

The apparatus may comprise a second heat exchange means connected to receive heated fluid from the outlet of the said other pipe of the multi-pipe heat exchanger.

The second heat exchange means may be so disposed relative to the burner that, during operation, a major part of the heat received by the second heat exchange means is by radiation from the flame.

The multi-pipe heat exchanger may be so constructed and/or arranged in the apparatus that, during operation, a major part of the heat received by the multi-pipe heat exchanger is by convection from the combustion gases.

The apparatus may comprise walls defining a conduit for the passage of combustion gases, the multi-pipe heat exchanger extending across said conduit and being fixedly attached to the walls thereof at one end only.

The heat transfer properties of the multi-pipe heat exchanger may be improved by providing extended surfaces such as fins and/or protrusions on one or more heat transfer surfaces thereof.

The multi-pipe heat exchanger may comprise one or more passes.

The invention is now further described with reference to some non-limitative, examplary illustrative diagrammatic drawings in the accompanying Figures, wherein:-

Figure 1 is a diagrammatic vertical cross-sectional elevation of the main features of a known furnace employed for heating a process fluid;

Figure 2 shows diagrammatically a part of the furnace of Figure 1 incorporating apparatus in accordance with the invention but not showing pumps and/or valves or other flow-influencing equipment; and

Figure 3 shows an alternative modification to that depicted in Figure 2.

Referring first to Figure 1, the furnace 10 comprises vertical walls 11 lined with refractory which define a number of sections of reduced horizontal cross-sectional area at the higher levels and which sections are connected by, e.g., sloping sections. The top section 12 is connected to a stack (not shown) for the discharge of combustion gases from the top of the furnace 10.

Near the base of the furnace are provided a suitable number of burners (not shown) supported by furnace floor 13. The or each burner is supplied with fuel which is burned in a flame 14 above the furnace floor 13. In the vicinity of flame 14, there is intense radiation and at more remote locations above the flame, most of the heating effect of the flame is by convection through the medium of the combustion gases and hot excess air.

Most fuels contain sulfur and in consequence the combustion gases contain sulfur oxides in addition to the water vapour producedby the oxidation of the hydrogen-containing components of the fuel.

Generally speaking, the process fluid which is to be heated is passed more or less countercurrently relative to the combustion gases so that cool fluid is employed to recover heat from the combustion gases near the top of the furnace mainly by convective heat transfer, and heated fluid is finally heated mainly by radiant heat transfer in the vicinity of the flame 14. Thus, as will be seen from Figure 1, the process fluid enters the furnace 10 near the top via tube 15 and passes through one (or more) sets or banks of tubes 16 disposed in a convection section 17 of the furnace for recovery of heat from the hot combustion gases passing upwardly towards the top section 12 and stack from a lower section 18 comprising a firebox. The fluid passes through tubes 16 in a generally countercurrent path to the combustion gases and relatively hot fluid circulates from the tubes 16 to one or more banks of tubes 19 in the lower section 18 surrounding the flame wherein a major proportion of high temperature heat is recovered from the radiation in the lower section 18. The fluid leaves the tube bank(s) 19 via outlet(s) 20 at a relatively high temperature.

Reference is now made to Figure 2 which shows, in simplified form, an arrangement of heat recovery tubes for use in the convection section 17 in accordance with the invention. In this arrangement, the fluid is heated employing a double pipe heat exchanger 21 extending across the convection section 17 and being supported at its end regions by the walls 22, 23 of the furnace around the section 17. Double pipe heat exchangers are known per se, and in the illustrated arrangement, the cool fluid is passed into one end 24 of the central tube 25 of the heat exchanger 21 and circulates from the open opposite end of the central tube 25 into the surrounding annulus defined between the central tube 25 and an outer tube 26. Matters are so arranged that heat is recovered from the combustion gases at temperatures exceeding the acid dew point on the outer surface of the outer tube 26, thereby avoiding acid corrosion problems. Some of the heat thus recovered in the fluid passing between the tubes 25 and 26 is transferred to the fluid in the central tube 25 by heat transfer through the walls of tube 25, and the proportions of heat retained in the outer annulus of fluid and transferred to the innermost fluid can be varied or predetermined by appropriate dimensioning of the cross-sectional flow areas of the annulus and of the central tube, by employing appropriate materials of construction to provide the desired amount of heat transfer through tube 25, by the use of baffles (not shown), fins, studs or other extended surfaces (not shown) on appropriate parts of the fluid-contacting regions of the tubes 25 and 26 and/or gas-contacting regions of tube 26, by varying the flow rate of the fluid through the heat exchanger 21, inter alia. It is within the ordinary competence of the skilled technologist to determine which one or combination of the foregoing techniques should be employed, and to what extent.

The heated fluid is recovered from outlet 27 and may be passed to further convective heat recovery units and/or to a radiant heat recovery tube bank as described in relation to Figure 1.

It will be seen that the arrangement of Figure 2 enables cold fluid to be heated to a temperature exceeding the acid dew point without causing acid dew point corrosion of the heat exchanger 21. In one mode of construction, the heat exchanger 21 is fixed at one end only, preferably the end at which cold fluid enters and from where heated fluid is recovered. The other end is supported in such a manner that it is free to move to accommodate thermal expansion and contraction of the heat exchanger 21 and the furnace walls.

With reference now to Figure 3, there is depicted a double pipe heat exchanger 29 of the so-called "hairpin" type mounted in the convection section 17 of a heating furnace.

In this arrangement, the cold fluid feed is completely separated from the fluid which recovers heat from the upwardly passing hot combustion gases giving a greater range of variability of throughputs of the cold fluid feed than in the embodiment of Figure 2 since the flow rate and initial temperature of the feed have less influence on the temperature of the outer surface of the heat exchanger 29.

The cold fluid feed is circulated into the entrance 30 of the lowest section of the central tube 31 and is recovered via an outlet 32 from the highest section of the central tube 31.

The fluid feed is circulated through tube 31 generally countercurrently to a fluid in the annular space 34 defined between the central tube 31 and an outer tube 33. The flow rate and temperature of the fluid in the annular space 34 are so arranged that the lowest temperature on the outside of the outer tube 33 exceeds the acid dew point.

Preferably the fluid in the central tube 31 circulates countercurrently to the fluid in the annular space 34, and the latter enters the heat exchanger 29 via inlet 36 on or communicating with the upper, cooler pass of the heat exchanger 29 and is recovered at a higher temperature from an outlet 37 or communicating with the lower, hotter pass. The temperature of the fluid in the cooler pass must be such that the temperature of the outer surface of the wall thereof exceeds the acid dew point.

In this embodiment, it is possible to raise the temperature of the cold fluid feed by a greater amount, generally speaking, than in the embodiment of Figure 2.

In a variant (not shown) of the Figure 3 arrangement, at least some of the heated fluid recovered from the outlet 32 of the central tube 32 is employed as the fluid in annular space 34.

In Figure 3, it will be seen that the outer tube 33 has flanged ends 38, 39 to permit access for cleaning, maintenance and repair. The central tube 31 may also be furnished with flanges (not shown) or other means of attachment in the vicinity of the return bend 40 (e.g. where each end of the bend 40 is attached to the straight sections of the tube 33) for servicing and removal of the central tube 31.

As in the previous embodiment, the heat transfer surfaces contacted by one or both streams of fluid may be provided with fins or other extended heat transfer surfaces and/or furnished with baffles.

It is contemplated that a plurality of double pipe heat exchangers may be employed in series and/or parallel connection, and that they may be of the same type or different types. Moreover, in a further variant of the invention, it is contemplated that in place of double pipe heat exchangers, there may be employed heat exchangers having at least two pipes enclosed by the outermost pipe and that the thus said enclosed pipes may be arranged side-by-side within the enclosing pipe and/or one within another inside the enclosing pipe.

Any feasible combination of the foregoing arrangements may also be employed without departing from the invention.

Although the invention has been more particularly described with reference to avoiding acid corrosion when heating a fluid in the convection section of a furnace or similar heating apparatus, the invention may be employed alternatively or additionally for heating a fluid elsewhere in a furnace or other heating apparatus. For example, acid corrosion has been observed on heat exchange tubes within the radiant heating section of a furnace when the temperature of the fluid passing through such tubes is relatively low. The heat exchange tubes which are subject to acid corrosion in the radiant section may be tubes in which a fluid is heated from a temperature below the local acid dew point to a higher temperature and is then conducted either (a) to heat exchange tubes in the same furnace or apparatus, or (b) to another item of equipment for further heating and/or utilization, or in part to both (a) and (b).

It will be appreciated that whichever type of multi-pipe heat exchanger is employed to perform the invention, the heat transfer characteristics and/or sizes of the tubes are selected to provide an outer surface temperature exceeding the acid dew point for reasonable and/or acceptable ranges of flow rates and pressure drops.

In some circumstances, it may be convenient to form at least the outermost tube of the multi-pipe heat exchanger with a rectangular cross-section so that the multi-pipe heat exchanger can be more easily interfitted with other items of equipment.

CLAIMS

1. A method of heating a fluid employing a heating gas (e.g., in 17, Fig. 2) containing SO_x and H_2O which passes in heat exchange relationship with the outer surface of a heat exchanger (21) through which the fluid is passed, characterized in that the heat exchanger (21) comprises a multi-pipe heat exchanger, and unheated fluid is passed into an inlet (24) of one pipe (25) of the multi-pipe heat exchanger (21) at a temperature below the acid dew point of the heating gas and discharged from an outlet (27) of another pipe (26) of the said multi-pipe heat exchanger (21) at a temperature exceeding the acid dew point of the heating gas, and maintaining the flow of fluid through the multi-pipe heat exchanger at a rate such that the temperature of the outer surface of the multi-pipe heat exchanger (21) is above the acid dew point of the heating gas.

2. A method as in claim 1 in which the said other pipe is the outermost pipe (26) of the multi-pipe heat exchanger, and the said one pipe (25) is inwards of the said other pipe (26).

3. A method as in claim 1 or claim 2 in which the fluid discharged from the multi-pipe heat exchanger (21) is conducted to another heat exchange means (e.g. 19, Fig. 1) and heated therein to a higher temperature.

4. A method as in claim 3 in which the said other heat exchange means (19) is heated mainly by radiation from a flame (14, Fig. 1) in which a sulfur-containing fuel is burned to produce combustion gases.

5. A method as in claim 4 in which the combustion gases form at least some of the said heating gas, and in which the multi-pipe heat exchanger is heated mainly by convection (in 17, Fig. 1) from said combustion gases.

6. Apparatus for heating a fluid comprising at least one burner for burning a sulfur-containing fuel in a flame (e.g. 14, Fig. 1) to produce combustion gases containing SO_x and H_2O, comprising heat exchange means (16, 19, Fig. 1) through which the fluid can flow in indirect heat exchange relationship with combustion gases contacting the outer surface of the heat exchange means, characterized in that the heat exchange means comprises a multi-pipe heat exchanger (21, Fig. 2) having an inlet (24) for unheated fluid at one end of one pipe (25) and an outlet (27) for heated fluid at one end of another pipe (26) of the multi-pipe heat exchanger (21), and comprising means for supplying fluid to the multi-pipe heat exchanger at a rate within a predetermined range to avoid the deposition of acid dew on the outer surface of the multi-pipe heat exchanger.

7. Apparatus according to claim 6 comprising a second heat exchange means (e.g. 19, Fig. 1) connected to receive heated fluid from the outlet (27) of the said other pipe (26) of the multi-pipe heat exchanger (21).

8. Apparatus according to claim 7 in which the second heat exchange means (19) is so disposed relative to the burner that, during operation, a major part of the heat received by the second heat exchange means is by radiation from the flame (14).

9. Apparatus according to any one of claims 6, 7 or 8 in which the multi-pipe heat exchanger (21) is so constructed and/or arranged in the apparatus (10, Fig. 1) that, during operation, a major part of the heat received by the multi-pipe heat exchanger (21) is by convection from the combustion gases (e.g., in section 17, Fig. 1).

10. Apparatus according to any one of claims 6, 7, 8 or 9 comprising walls (22, 23, Fig. 2) defining a conduit for the passage of combustion gases, the multi-pipe heat exchanger (21) extending across said conduit and being fixedly attached to the walls thereof at one end only (at 22).

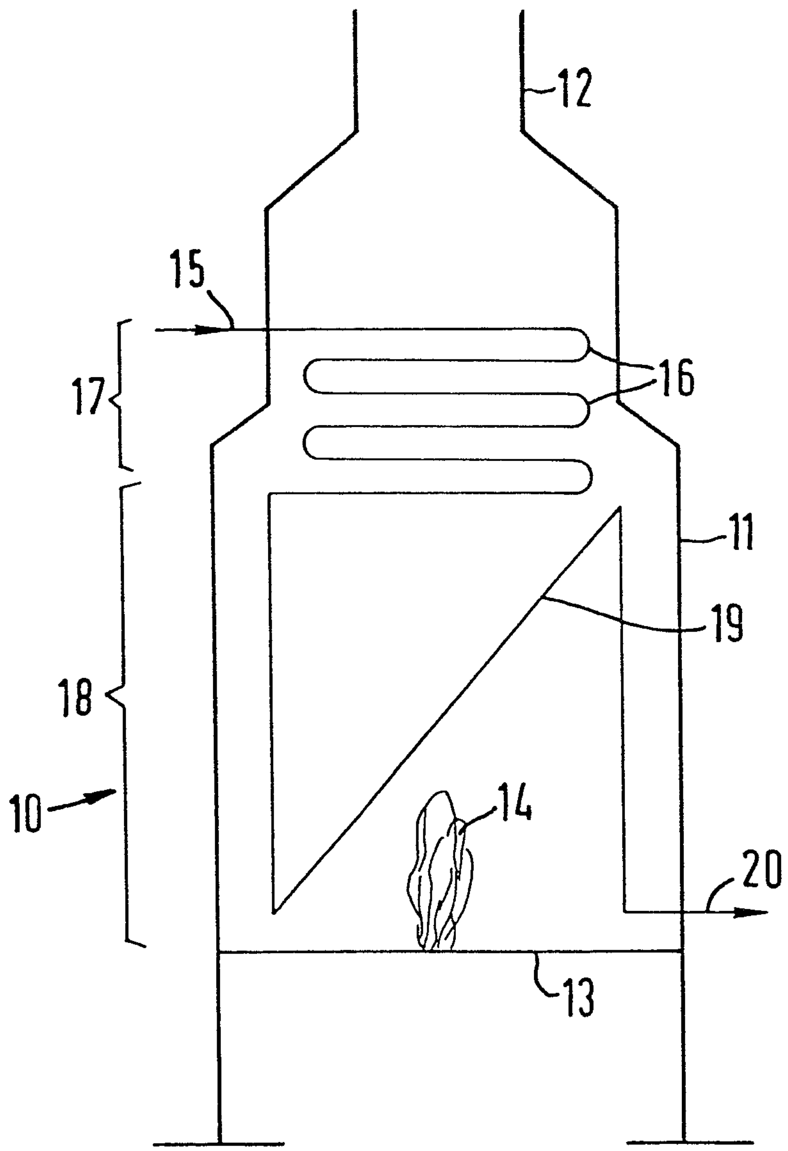

FIG. 1

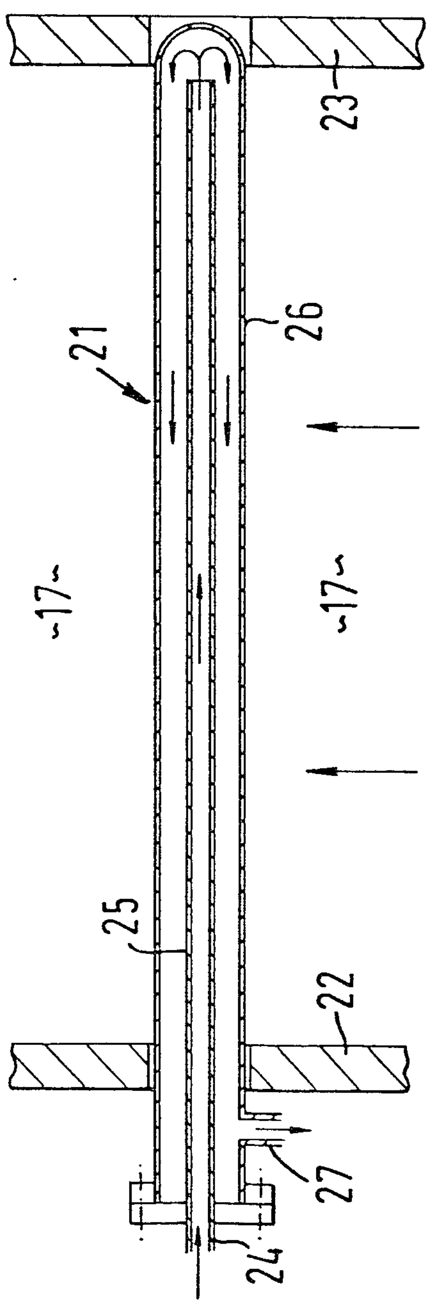
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FIG. 2

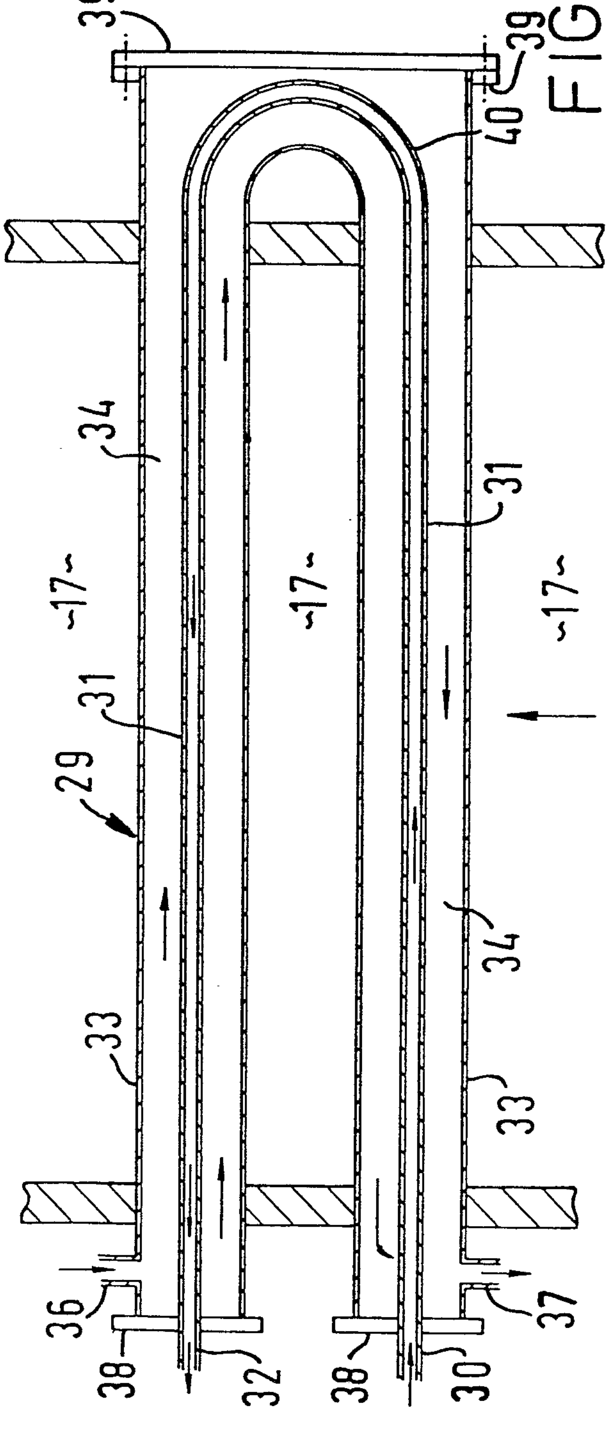
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FIG. 3