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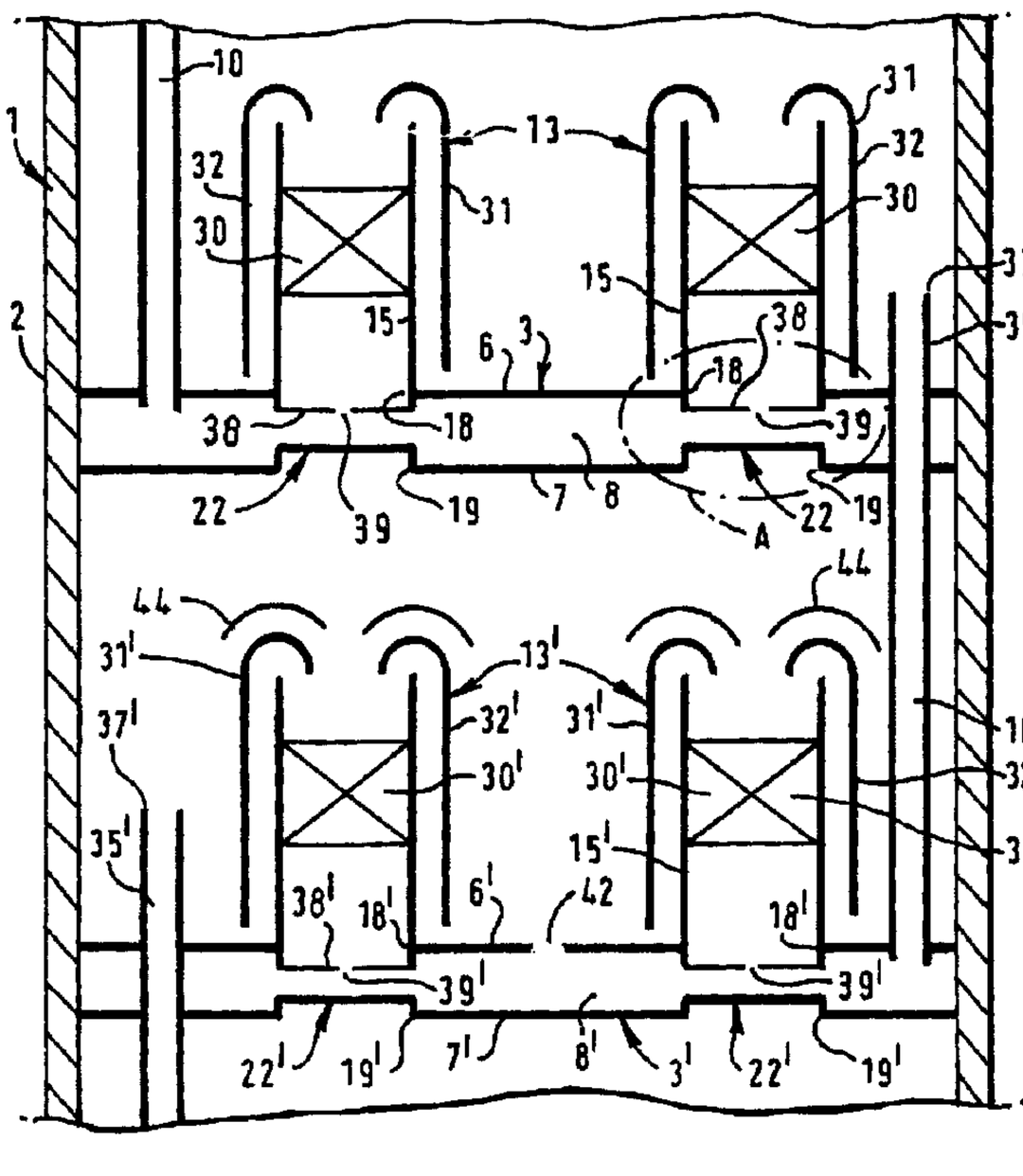
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(54) Titre : PLATEAU HORIZONTAL ET COLONNE DE MISE EN CONTACT DE GAZ ET DE LIQUIDE
(54) Title: HORIZONTAL TRAY AND COLUMN FOR CONTACTING GAS AND LIQUID



(57) Abrégé/Abstract:
Horizontal tray (3) for use in a normally vertical column (1) for counter-currently contacting gas and liquid, which horizontal tray (3) comprises an upper horizontal plate (6), a lower horizontal plate (7), a liquid supply space (8), a liquid feed pipe (10) opening into the liquid supply space (8), and a vertical tubular contact and separation device (13), which comprises an open-ended tube (15) extending through the horizontal plates (6, 7), a liquid delivery device (22) comprising an upwardly directed liquid delivery opening (24, 39) which is in fluid communication with the liquid supply space (8), swirl imparting means (30) arranged in the open-ended tube (15) above the liquid delivery opening (24), and guide means (31) to direct liquid from the upper end of the open-ended tube (15) onto the upper horizontal plate (6), which horizontal tray further comprises an open-ended downcomer (35) having an inlet arranged above the upper horizontal plate (6) and an outlet arranged below the lower horizontal plate (7).

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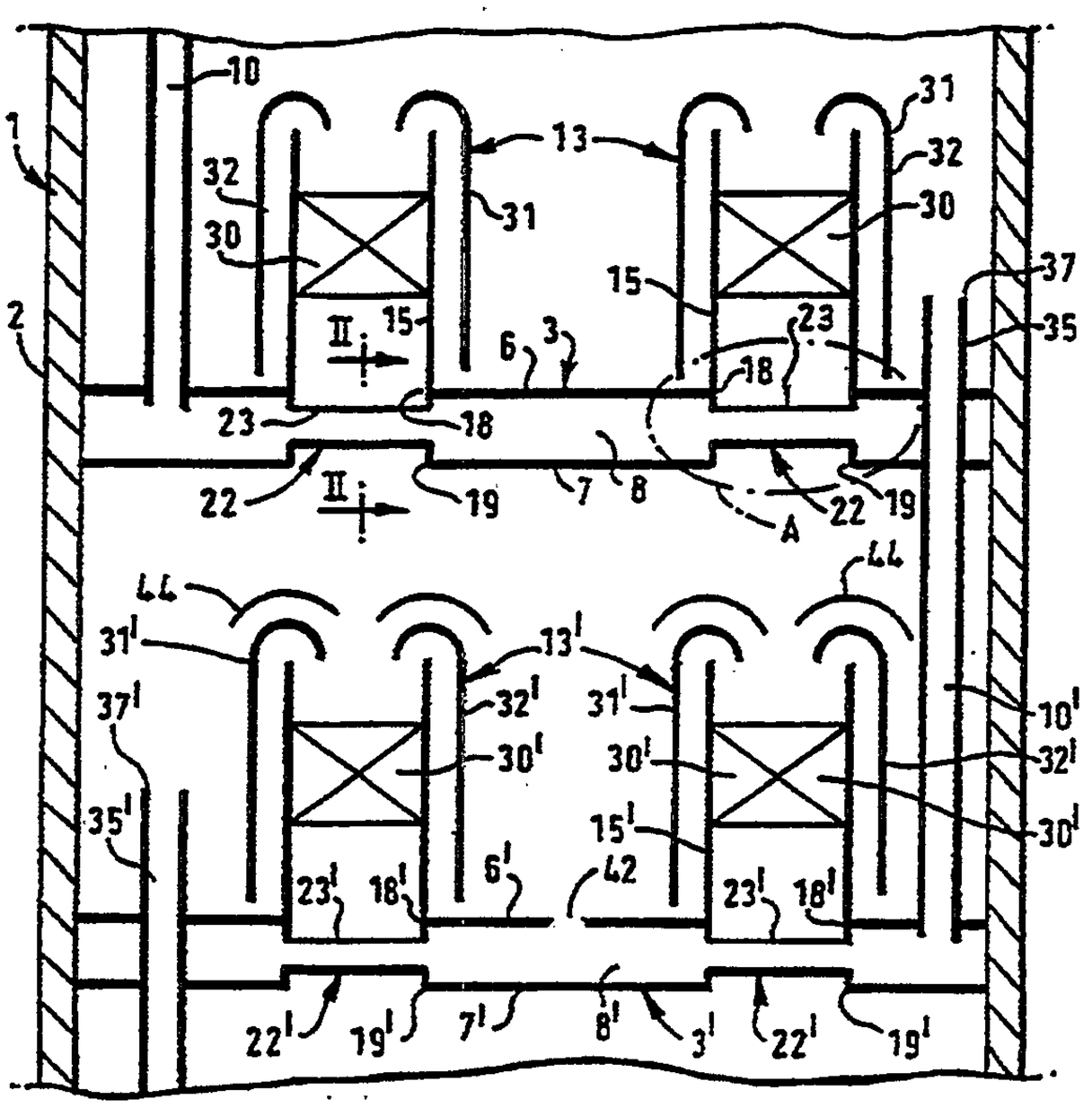
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(54) **Title:** HORIZONTAL TRAY AND COLUMN FOR CONTACTING GAS AND LIQUID

(57) **Abstract**

Horizontal tray (3) for use in a normally vertical column (1) for counter-currently contacting gas and liquid, which horizontal tray (3) comprises an upper horizontal plate (6), a lower horizontal plate (7), a liquid supply space (8), a liquid feed pipe (10) opening into the liquid supply space (8), and a vertical tubular contact and separation device (13), which comprises an open-ended tube (15) extending through the horizontal plates (6, 7), a liquid delivery device (22) comprising an upwardly directed liquid delivery opening (24, 39) which is in fluid communication with the liquid supply space (8), swirl imparting means (30) arranged in the open-ended tube (15) above the liquid delivery opening (24), and guide means (31) to direct liquid from the upper end of the open-ended tube (15) onto the upper horizontal plate (6), which horizontal tray further comprises an open-ended downcomer (35) having an inlet arranged above the upper horizontal plate (6) and an outlet arranged below the lower horizontal plate (7).



HORIZONTAL TRAY AND COLUMN FOR CONTACTING GAS AND LIQUID

The present invention relates to a horizontal tray for use in a normally vertical column for counter-currently contacting gas and liquid. Such a column comprises a housing provided with an inlet for gas and an inlet for liquid which is arranged above the inlet for gas, and an outlet for gas arranged in the upper end of the column and an outlet for liquid arranged in the lower end of the column.

The horizontal tray is arranged in the housing between the inlet for gas and the inlet for liquid. During normal operation gas is supplied through the inlet for gas and liquid through the inlet for liquid, and on the horizontal tray gas and liquid are brought in contact with each other to exchange heat and/or matter. After contacting, gas separated from the liquid is withdrawn from the column through the outlet for gas which is located above the horizontal tray, and liquid is withdrawn from the column through the outlet for liquid which is located below the horizontal tray.

Such a horizontal tray is known from UK patent specification No. 1 070 777. The known horizontal tray comprises a horizontal plate and a vertical tubular contact and separation device, which contact and separation device comprises an open-ended tube extending through an opening in the horizontal plate, a liquid feed pipe which opens near the inner surface of the open-ended tube, swirl imparting means arranged in the open-ended tube above the opening of the liquid feed pipe, and guide means to direct liquid from the upper end of the open-ended tube onto the horizontal plate,

which horizontal tray further comprises a tube for removing separated liquid.

A disadvantage of the known horizontal tray is that when such a horizontal tray contains more than one tubular contact and separation device, a liquid feed pipe has to be provided for each of the contact and separation devices. In such a case it will be difficult, if not impossible to supply liquid to each contact and separation device in such a way that the amount of liquid is evenly distributed over the contact and separation device.

It is an object of the present invention to provide a horizontal tray for use in a normally vertical column for counter-currently contacting gas and liquid wherein liquid is evenly distributed over the contact and separation devices.

To this end the horizontal tray according to the present invention for use in a normally vertical column for counter-currently contacting gas and liquid is characterized in that the liquid delivery device comprises a liquid delivery opening which is centrally arranged in an open-ended tube, which open-ended tube is in fluid communication with the liquid supply space.

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Reference is made to the abstract of Soviet patent publication No. 1 535 563, which publication relates to a horizontal tray for use in a normally vertical column for counter-currently contacting gas and liquid, which horizontal tray is provided with a vertical tubular contact device in the form of an open-ended tube including a gutter for delivering liquid into the lower part of the contact device and a vertical sheet resting in the gutter. During normal operation liquid is supplied to the gutter, and gas flowing upwards through the contact device will entrain the liquid so that films are formed on both sides of the sheet. Thus gas-liquid contacting is not done by dispersing the liquid in the gas, as is done in the present invention, but by forming a film of liquid along which gas flows. Moreover, this publication does not disclose that the contact device contains swirl imparting means so that the contact device can also serve as a separation device, nor does this publication disclose that there are guide means to direct liquid from the upper end of the contact device.

A further disadvantage of the known tray is that at relatively low liquid flow rates, the contact efficiency is not very large. One reason is that the opening of the liquid pipe is near the inner surface of the open-ended tube so that liquid is collected on the inner surface. Consequently contacting between liquid and gas has to take place in the film of liquid on the inner surface. A more efficient way of contacting is obtained when the liquid is dispersed in the gas, and this can only be partly achieved with the known device.

To overcome this problem, the liquid delivery device comprises a liquid delivery opening which is centrally arranged in an open-ended tube, which open-ended tube is in fluid communication with the liquid supply tube.

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The horizontal tray according to the present invention can be used for low flow parameters, even for flow parameters which are less than 0.01. The flow parameter is defined as $(L/G)*(\rho_l/\rho_g)^{1/2}$, wherein L is the liquid flow rate in m^3/s, G is the gas flow rate in m^3/s, ρ_l is the liquid density in kg/m^3, and ρ_g is the gas density in kg/m^3.

The invention also relates to a normally vertical column for counter-currently contacting gas and liquid comprising at least one horizontal tray according to the present invention, which horizontal tray is arranged in the column between an inlet for gas and an inlet for liquid.

The invention further relates to a normally vertical column provided with two or more horizontal trays according to the invention, wherein the liquid feed pipe of one horizontal tray is in fluid communication with

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the downcomer of the above horizontal tray.

The invention will now be described by way of example in more detail with reference to the accompanying drawings, wherein

Figure 1 shows schematically a cross-section of part of a normally vertical column for counter-currently contacting gas and liquid provided with horizontal trays according to the present invention; and

Figure 2 shows schematically part A of the tubular contact and separation device of Figure 1 drawn to a scale larger than the scale of Figure 1.

Reference is now made to Figures 1 and 2 showing a cross-sectional view of part of a vertical column 1 for counter-currently contacting gas and liquid comprising a housing 2 provided with the horizontal trays 3 and 3'. The upper horizontal tray 3 is arranged above the lower horizontal tray 3'. The lower horizontal tray 3' is similar to the upper horizontal tray 3 and corresponding parts of the lower horizontal tray 3' have got corresponding reference numerals provided with a bar.

The upper horizontal tray 3 comprises an upper horizontal plate 6 and a lower horizontal plate 7. Between the upper and lower horizontal plates 6 and 7 is defined a liquid supply space 8. To supply during normal operation liquid into the liquid supply space 8, the upper horizontal tray is provided with a liquid feed pipe 10 opening into the liquid supply space 8.

The upper horizontal tray 3 is furthermore provided with a vertical tubular contact and separation device 13. This contact and separation device 13 comprises an open-ended tube 15 extending through openings 18 and 19 in the horizontal plates 6 and 7. The contact and

separation device 13 comprises a liquid delivery device 22. The liquid delivery device 22 comprises an open-ended conduit 38 provided with an upwardly directed liquid delivery opening 39, wherein the open ends of the open-ended conduit 38 open into the liquid supply space 8. The liquid delivery opening 39 is centrally arranged in the open-ended tube 38.

The contact and separation device 13 further comprises swirl imparting means 30 arranged in the open-ended tube 15 above the liquid delivery device 22, and guide means 31 to direct liquid from the upper end of the open-ended tube 15 onto the upper horizontal plate 6. The guide means 31 include an outer tube 32 having an inwardly deflecting upper end, which outer tube 32 extends around the open-ended tube 15 to above the upper horizontal plate 6.

The upper horizontal tray 3 further comprises an open-ended downcomer 35 having an inlet 37 arranged above the upper horizontal plate 6 and an outlet arranged below the lower horizontal plate 7. In the embodiment shown, the downcomer 35 opens into the liquid feed pipe 10' of the lower horizontal tray 3'. The distance between the upper horizontal plate 6 and the lower end of the outer tube 32 is less than the distance between the upper horizontal plate 6 and the inlet 37 of the downcomer 35.

During normal operation liquid supplied through liquid feed pipe 10 into the liquid supply space 8 of the upper horizontal tray 3 is brought into contact on the upper horizontal tray 3 with gas from the lower horizontal tray 3' passing upwardly into the lower end of the open-ended conduits 15. The gas flows past the liquid delivery devices 22, and liquid from the liquid delivery devices 22 is dispersed in the gas streams. The mixture of liquid dispersed in gas passes upwardly

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through the open-ended tubes 15 and gets a swirling motion from passing along the swirl imparting means 30. Liquid is thrown outward and a liquid-rich stream passes near the inner surface of the upper parts of the open-ended tubes 15. Liquid separated from the gas stream is directed by guide means 31 from the upper end of the open-ended tubes 15 onto the upper horizontal plate 6. A substantially liquid-free gas stream passes upwardly to the outlet for gas (not shown) arranged in the upper end of the housing 2. Liquid collected on the upper horizontal plate 6 is passed through the downcomer 35 and the liquid feed pipe 10' into the liquid supply space 8' of the below horizontal tray 3'.

On this horizontal tray 3' liquid is brought in contact with gas coming from below the horizontal tray 3', and the way in which liquid is brought in contact with gas is the same as described above. After contacting, liquid separated from the gas is passed through downcomer 35' to the next lower horizontal tray (not shown) or to the outlet for liquid (not shown) arranged in the lower end of the housing 2.

Contact between liquid and gas takes place when the liquid is dispersed in the gas.

To further improve the dispersion of gas in the liquid stream a deflector 40 (see Figure 2) is arranged directly above the liquid delivery opening 39. Suitably the deflector

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40 is a plate which has a diameter up to 0.5 times the internal diameter of the open-ended tube 15, and suitably in the range of from 0.1 to 0.5 times the internal diameter of the open-ended tube 15.

To allow operation of the column 1 at very low liquid flow rates it is beneficial to recirculate liquid collected on the upper horizontal plate. To this end the upper horizontal plate is provided with a recirculation opening. To illustrate this embodiment one recirculation opening 42 is shown in the upper plate 6' of the lower horizontal tray 3', however, the upper plate may be provided with more than one recirculation opening. The number and the size of the recirculation openings is suitably so selected that the mass flow rate through the recirculation openings can be up to five times the mass flow rate through the downcomer 35'.

In the embodiment as shown in the drawing the guide means 31, 31' to direct liquid from the upper end of the open-ended tubes 15, 15' include outer tubes 32, 32'. Each guide means 31, 31' suitably further includes a beaker-shaped gas outlet arranged in the upper end of the outer tube. To illustrate this embodiment a beaker-shaped gas outlet 44 is shown in the guide means 31' pertaining to the contact and separation devices 13' of the lowermost horizontal tray 3'.

In the embodiment shown in Figure 1 the open-ended downcomer 35 passes into the liquid feed pipe 10' of the lower horizontal tray 3'. In an alternative design (not shown), the liquid feed pipe has a larger diameter than the downcomer, and the downcomer extends through the open end of liquid feed pipe into the liquid feed pipe. At least part of the annular space between the liquid feed pipe and the downcomer is then filled with liquid which provides a seal.

The invention will now be illustrated with the aid

of the following example.

A single horizontal tray was used to determine the transfer of heat between gas and liquid. This tray was provided with a tubular contact and separation device including an open-ended tube having an inner diameter of 110 mm. Three different liquid delivery devices were tested: (1) a liquid delivery device provided with an opening at the inner surface of the open-ended tube (not the according to the invention); and (2) the liquid delivery device of Figures 1 and 2 wherein the diameter of the upwardly directed opening was 17 mm, the diameter of the deflector 35 mm and the height of the deflector above the opening 20 mm. The liquid delivery devices will be designated with LDD1 and LDD2.

In the experiments, water and air were contacted, the water had a temperature of 20 °C, and the flow parameter φ, the load factor λ and the gas temperatures are included in the below Table. The flow parameter has been defined herein above, and the load factor is $(V_g)*(\rho_g/\Delta\rho)^{1/2}$, wherein V_g is the gas velocity in the open-ended tube in m/s, and ρ_g is the gas density in kg/m^3, wherein $\Delta\rho$ is the difference between ρ_l and ρ_g and wherein ρ_l is the liquid density in kg/m^3. T_{gin} is the gas temperature at the gas inlet, T_{gout} is the gas temperature at the gas outlet, and ΔT_g is the difference between the two temperatures.

Table. Results of the tests of the three liquid supply devices.

	φ (-)	λ (m/s)	$T_{gin} - T_{gout}$ (°C)	ΔT_g (°C)
LDD1	0.09	0.61	35.8-28	7.8
LDD2	0.11	0.60	40.6-27.5	13.1

From the results shown in the above Table it can be concluded that under substantially the same conditions the ΔT_g obtained with the liquid delivery device not according to the invention (LDD1) is smaller than the ΔT_g obtained with the liquid delivery device according to the invention (LDD2). The larger the ΔT_g the more heat is transferred, and the results show the advantageous effect of the use of the horizontal tray of the present invention.

The horizontal tray of the present invention is suitably used in a column for drying natural gas, wherein the natural gas is counter-currently contacted with a solvent for water vapour such a glycol.

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AMENDED CLAIMS

1. Horizontal tray (3) for use in a normally vertical column (1) for counter-currently contacting gas and liquid, which horizontal tray (3) comprises an upper horizontal plate (6), a lower horizontal plate (7), a liquid supply space (8) defined between the plates (6, 7), a liquid feed pipe (10) opening into the liquid supply space (8), and a vertical tubular contact and separation device (13), which contact and separation device (13) comprises an open-ended tube (15) extending through openings (18, 19) in the horizontal plates (6, 7), a liquid delivery device (22) comprising an upwardly directed liquid delivery opening (39) which is in fluid communication with the liquid supply space (8), swirl imparting means (30) arranged in the open-ended tube (15) above the liquid delivery device (22), and guide means (31) to direct liquid from the upper end of the open-ended tube (15) onto the upper horizontal plate (6), which horizontal tray (3) further comprises an open-ended downcomer (35) having an inlet (37) arranged above the upper horizontal plate (6) and an outlet arranged below the lower horizontal plate (7), characterized in that the liquid delivery device (22) comprises a liquid delivery opening (39) which is centrally arranged in an open-ended tube (38), which open-ended tube (38) is in fluid communication with the liquid supply space (8).

2. Horizontal tray according to claim 1, wherein the vertical tubular contact and separation device (13) further includes a deflector (40) arranged directly above the liquid delivery opening (39).

3. Horizontal tray according to claim 2, wherein the deflector (40) is a plate having a diameter up to

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0.5 times the internal diameter of the open-ended tube (15).

4. Horizontal tray according to any one of the claims 1-3, wherein the upper horizontal plate (6) is provided with a recirculation opening (42).

5. Horizontal tray according to any one of the claims 1-4, wherein the guide means (31) to direct liquid from the upper end of the open-ended tube (15) include an outer tube (32) having an inwardly deflecting upper end, which outer tube (32) extends around the open-ended tube (15) to above the upper horizontal plate (6).

6. Horizontal tray according to claim 5, wherein the distance between the upper horizontal plate (6) and the lower end of the outer tube (32) is less than the distance between the upper horizontal plate (6) and the inlet (37) of the downcomer (35).

7. Horizontal tray according to claim 5 or 6, wherein the guide means (31) to direct liquid from the upper end of the open-ended tube (15) further include a beaker-shaped gas outlet (44) arranged in the upper end of the outer tube (32).

8. Normally vertical column for counter-currently contacting gas and liquid comprising at least one horizontal tray according to any one of the claims 1-7 arranged in the column between an inlet for gas and an inlet for liquid.

9. Normally vertical column according to claim 8 provided with two or more horizontal trays according to any one of the claims 1-7, wherein the liquid feed pipe (10') of one horizontal tray (3') is in fluid communication with the downcomer (35) of the above horizontal tray (3).

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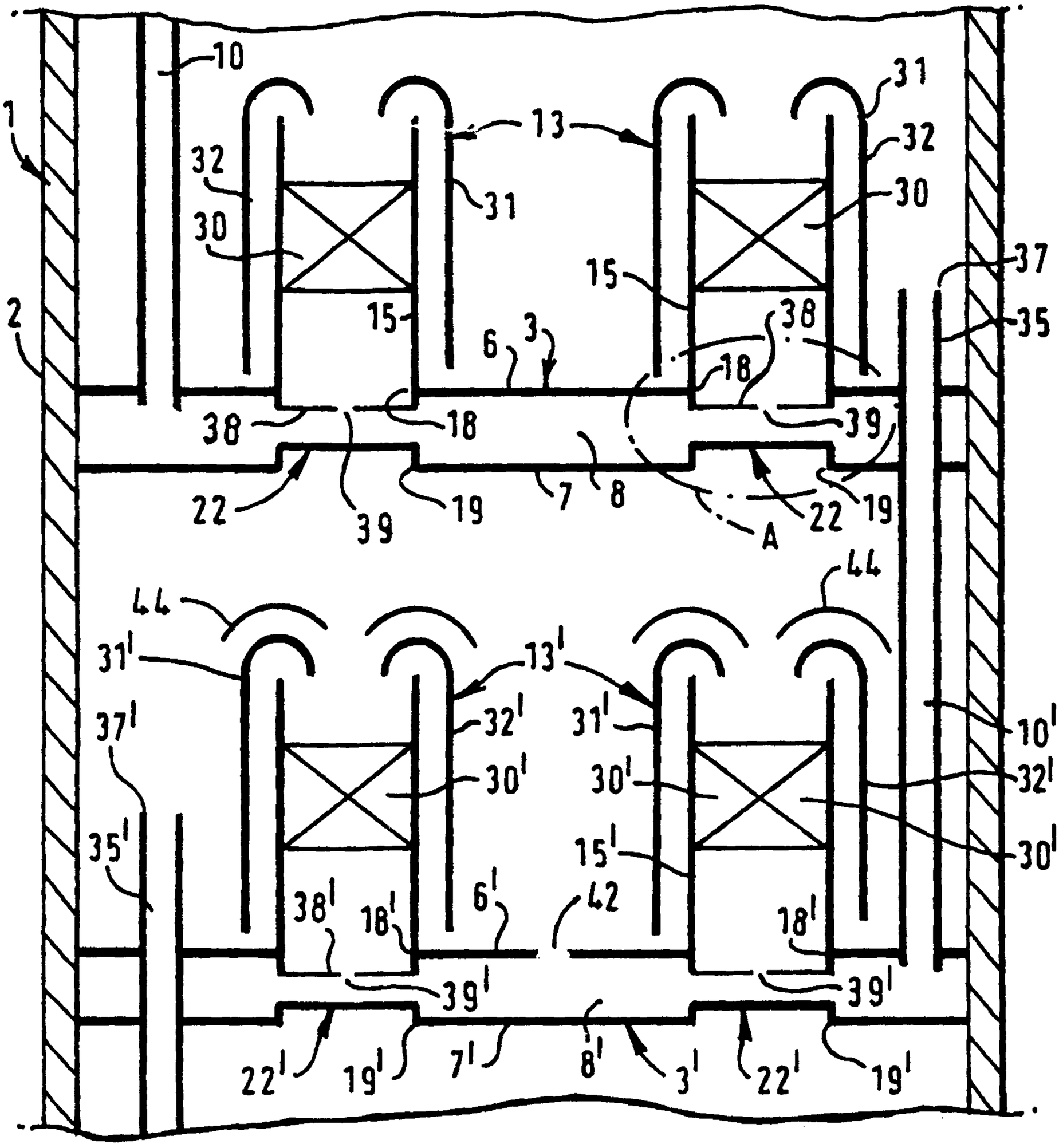

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FIG.1

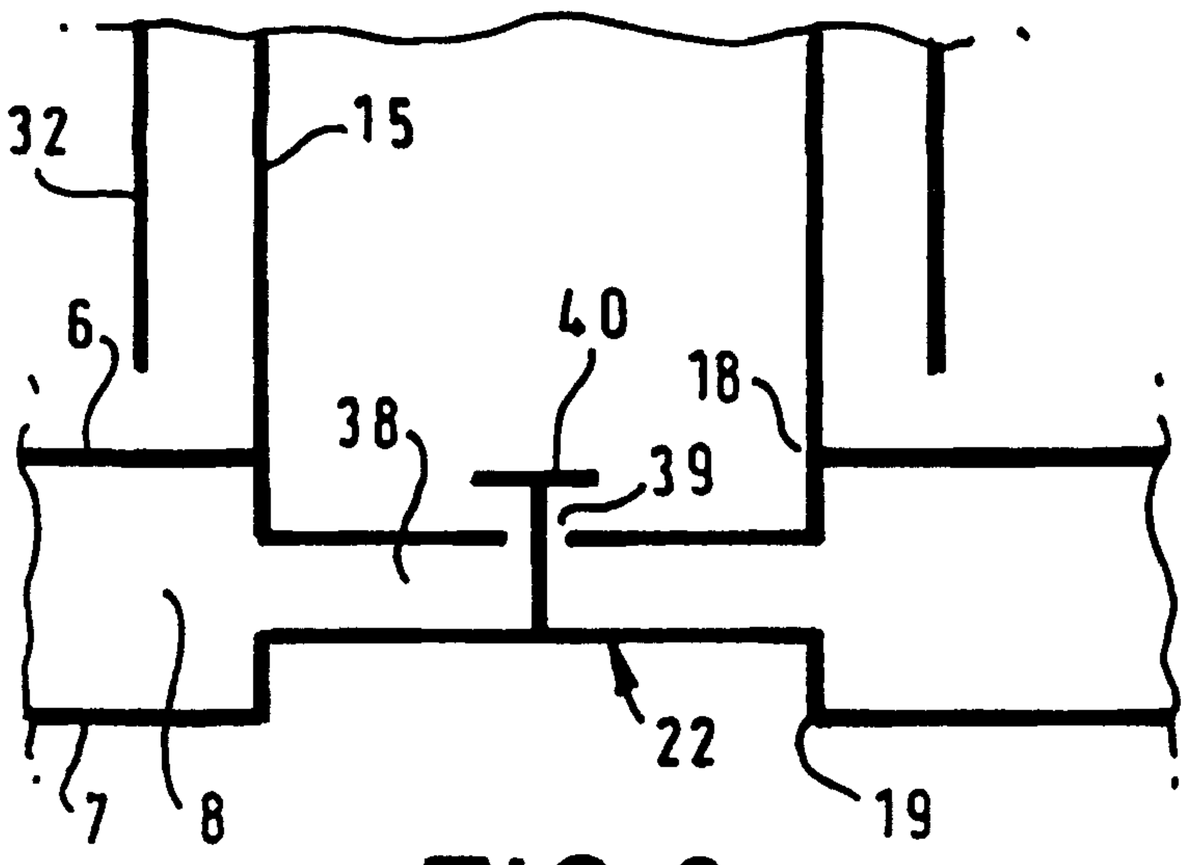
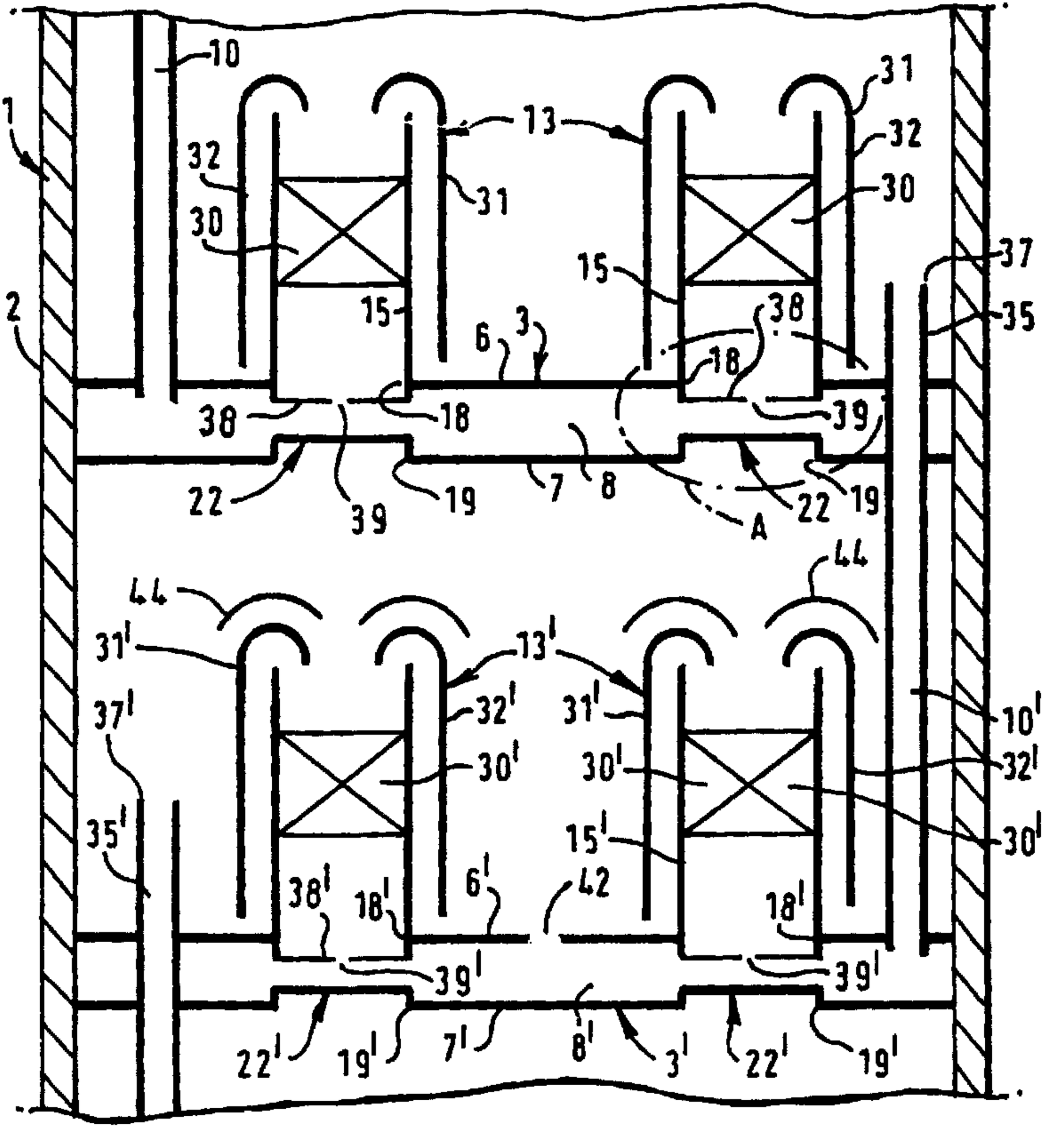


FIG. 2


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