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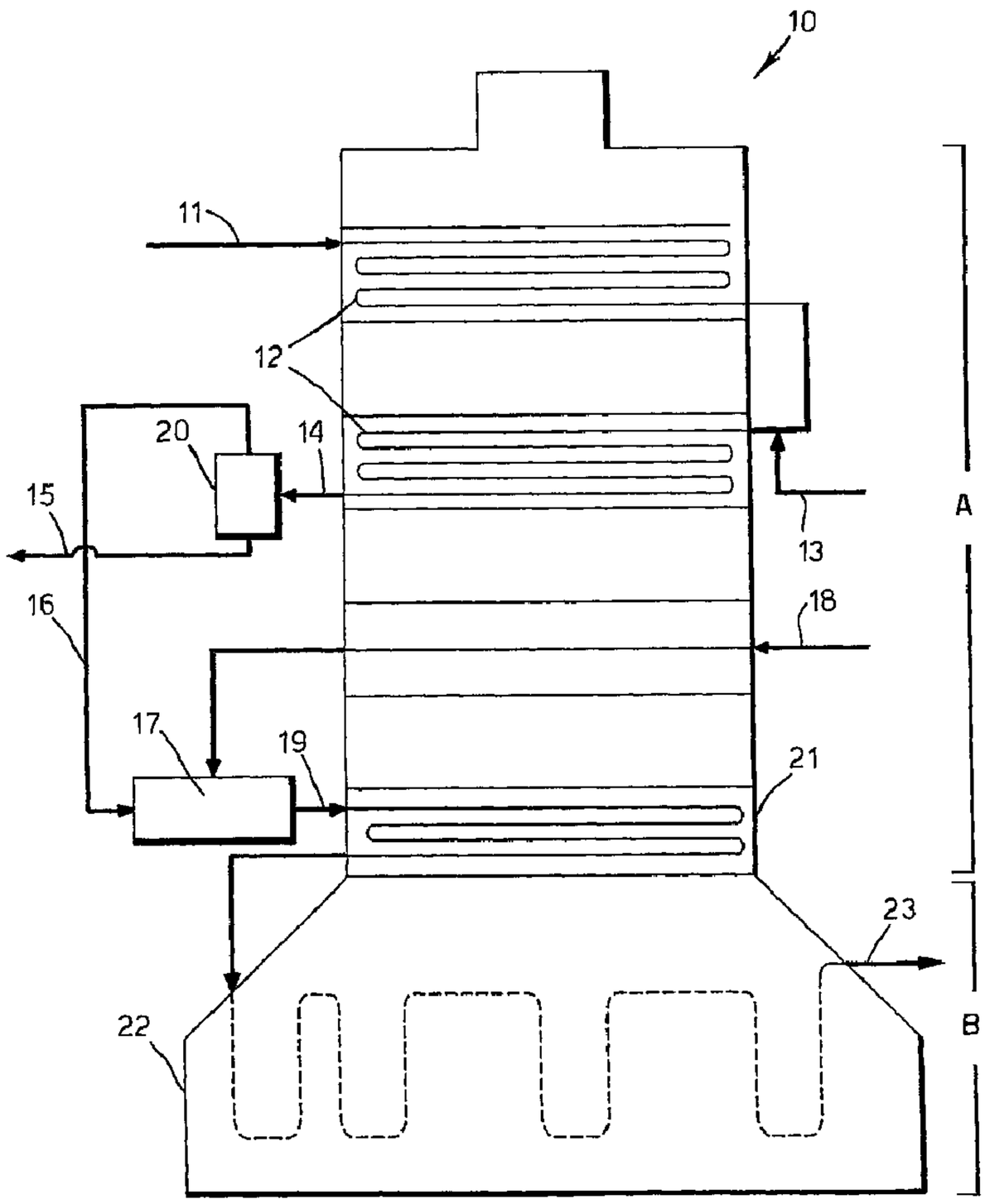

(57) Abrégé/Abstract:
A vapour/liquid separator comprising: a vessel having an inlet for receiving a vapour/liquid mixture; a hub located within the vessel at a position below the inlet wherein the hub supports a plurality of vane elements at its near end for centrifuging the mixture as the

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(57) Abrégé(suite)/Abstract(continued):
mixture proceeds through the vessel; a vapour outlet located at the distant end of the hub for withdrawing the vapour phase of the mixture from the vessel; and an outlet located below the vapour outlet for withdrawing the liquid phase of the mixture from the vessel. The invention further relates to a method for separating the vapour and liquid phases of a mixture of hydrocarbon and steam comprising the steps of: flowing the mixture through the inlet of a vessel; centrifuging the mixture by means of a centrifuge located at the head end of the vessel; controlling the recirculation and splashing of the mixture as the mixture falls on the centrifuge; flowing the liquid phase down the walls of the vessel; directing the vapour phase toward an outlet pipe for the vapours; directing the vapour phase from the vessel and to means for further processing; and directing the liquid phase from the vessel and to means for further processing.

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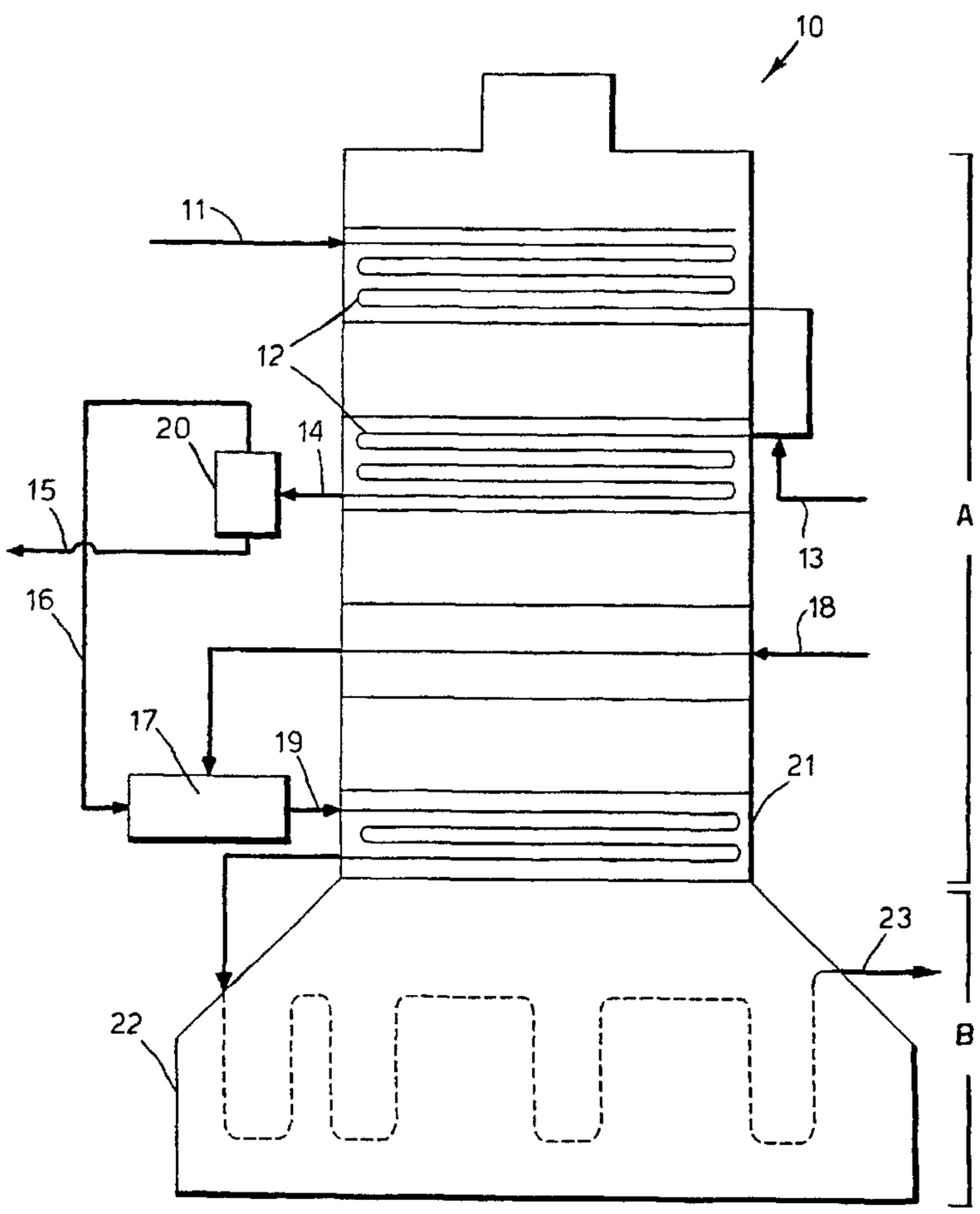

(57) Abstract: A vapour/liquid separator comprising: a vessel having an inlet for receiving a vapour/liquid mixture; a hub located within the vessel at a position below the inlet wherein the hub supports a plurality of vane elements at its near end for centrifuging the mixture as the mixture proceeds through the vessel; a vapour outlet located at the distant end of the hub for withdrawing the vapour phase of the mixture from the vessel; and an outlet located below the vapour outlet for withdrawing the liquid phase of the mixture from the vessel. The invention further relates to a method for separating the vapour and liquid phases of a mixture of hydrocarbon and steam comprising the steps of: flowing the mixture through the inlet of a vessel; centrifuging the mixture by means of a centrifuge located at the head end of the vessel; controlling the recirculation and splashing of the mixture as the mixture falls on the centrifuge; flowing the liquid phase down the walls of the vessel; directing the vapour phase toward an outlet pipe for the vapours; directing the vapour phase from the vessel and to means for further processing; and directing the liquid phase from the vessel and to means for further processing.

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A VAPOUR/LIQUID SEPARATOR

The invention relates to a vapour/liquid separator which can be used for separating a mixture of hydrocarbon and steam.

The concept of a flow-through cyclone, for separation of solids or liquids from a carrier gas, is well established in the literature.

The present invention relates to the use of a vapour/liquid separator for separating a mixture containing hydrocarbon and steam, which comprises:

a vessel having an inlet for receiving a vapour/liquid mixture;

a hub located within the vessel at a position below the inlet wherein the hub supports a plurality of vane elements at its near end for centrifuging the mixture as the mixture proceeds through the vessel thereby keeping the walls of the vapour/liquid separator completely wetted with a liquid;

a vapour outlet located at the distant end of the hub for withdrawing the vapour phase of the mixture from the vessel; and

an outlet located below the vapour outlet for withdrawing the liquid phase of the mixture from the vessel.

Further, the present invention relates to a method for separating the vapour and liquid phases of a mixture of hydrocarbon and steam comprising the steps of:

flowing the mixture through the inlet of a vessel;

centrifuging the mixture by means of a centrifuge located at the head end of the vessel;

flowing the liquid phase down the walls of the vessel;

directing the vapour phase toward an outlet pipe for the vapours;

directing the vapour phase from the vessel and to means for further processing; and

directing the liquid phase from the vessel and to means for further processing.

The vapour/liquid separator according to the present invention can separate the vapour and liquid phases of a hydrocarbon and steam mixture, such that only the vapour stream is fed and processed further downstream. The design of the separator can ensure that all partially wetted surfaces in the separator, except at the vapour outlet pipe, are well wetted and washed by the non-vapourized liquid portion of the feed. Surface wetting ensures that no coke deposition occurs which could eventually lead to plugging of the separator. With the surface-wetting preventing coking, the flash temperature in the separator can be increased beyond the typical limit (limited because of the coking concern), thus achieving a deeper cut into the feed and enabling the recovery of a larger fraction of the feed as vapour for further downstream processing.

One possible application of the present vapour/liquid separator is in pre-processing heavy olefins plant feed (crude or condensates), more specifically an olefins gas oil steam cracker plant, by flashing the hydrocarbon feed with steam at high temperature, then mechanically separating the non-vapourizable liquid fraction by this vapour/liquid separator so that only the vapourizable fraction of the feed is fed further downstream to be processed in the radiant tubes of a thermal pyrolysis furnace. The liquid, non-vapourizable portion contains heavy hydrocarbons such as pitch which are separated and can be sent to a coker, cat cracker, or other residue-processing units for further processing, or as fuel.

The uniformly wetted walls obtainable in the present invention furthermore increase the service life of the present vapour/liquid separator. The multiple-inlet type of vane design according to a specific embodiment of the present invention, is especially well suited for the creation and maintenance of a uniform film of irrigating liquid on the internal surfaces of the vapour/liquid separator.

The vane portion of the vapour/liquid separator according to the present provides a very smooth aerodynamic acceleration and spin to the incoming gas/liquid mixture necessary to achieve high separation efficiency and low pressure loss. The vane design is further distinguished by its lack of stagnant zones which would lead to areas of coke deposition. In addition, unlike conventional tangential entry type cyclone separators which typically feature a single, asymmetrical inlet slot or pipe opening, the vane itself is comprised of a series of vane elements or blades which are responsible for imparting a uniform centrifugal force to the incoming gas/liquid mixture along the entire circumference of the inlet section of the vapour/liquid separator.

Preferably, the apparatus separator according to the invention further comprises a skirt element at the distant end of the hub for directing any liquid phase of the mixture in an outward direction away from the hub and toward the walls of the vessel.

The separator according to the invention further preferably includes means located in the vessel between the inlet and the near end of the hub for controlling the recirculation and splashing of the mixture as the mixture enters through the inlet and falls on the hub.

The separator can further include a screen over the distant end of the hub for preventing any coke within the interior of the hub from falling therethrough.

Further, the separator can include a skirt located at the entrance of the vapour outlet for directing any liquid in an outward direction and away from the entrance.

Preferably, the hub of the separator according to the present invention, is located axially in the vessel. The vapour outlet is preferably located axially at the distant end of the hub. The vapour/liquid mixture used in the separator and method according to the present invention, is preferably a mixture containing hydrocarbon and steam.

FIG. 1 is a schematic of a flow diagram of the overall process in a pyrolysis furnace which may be used with the present invention.

FIG. 2 is an elevational view, partly in section, of a vapour/liquid separator according to the invention.

FIG. 3 is a plan view of FIG. 2.

FIG. 4 is a perspective drawing of the vane assembly of the vapour/liquid separator of Fig. 2.

The heavy ends of crude oils and heavy natural gas liquids cannot be vapourized under typical ethylene furnace convection section conditions. They are normally removed by distillation, and only the lighter, vapourizable fraction from the distillation is used as olefin plant feeds. The feed preparation step of distilling off the heavy ends from the olefins plant feed require additional capital and operating cost. The present apparatus and process allow to integrate the heavy end separation step with the feed pre-heater section of the modified olefins furnace, allowing only the vapourizable fraction of the heavy feed to enter the cracking zone of the furnace. Furthermore, the ability

to flash the hydrocarbon with dilution steam at a temperature higher than that typically achievable in a vacuum column (400 °C), results in a higher fraction of the crude oil being recovered as olefins plant feed than that recovered through the atmospheric/ vacuum distillation columns, thus reducing the yields of the lower value heavy end pitch. This is achieved through a non-coking vapour/liquid separator design according to the present invention. The vapour/liquid separator can be operated over a wide range of temperatures, e.g. 260-482 °C (500-900 °F). Optimal conditions are determined by acceptable coking over a desired temperature range.

The convection section of a typical olefin pyrolysis furnace can be modified such that heavy hydrocarbon feeds can be fed directly to the cracking furnace. Heavy hydrocarbon feeds include desalted crude oils, heavy natural gas liquids, long and short residues which contain heavy tail-end hydrocarbons that cannot be completely vapourized under normal operating conditions in the convection section of an olefins pyrolysis furnace.

Referring now to FIG. 1 which is a schematic view of an ethylene furnace 10, the heavy hydrocarbon feed 11 enters through first stage preheater 12 of the convection section A of ethylene furnace 10 at a temperature of 140 °C (285 °F) and at a pressure of 21 bar (300 psig). A small amount of dilution steam 13 (saturated steam at 8 bar (100 psig)) is fed into the convection section preheater tubes until it is heated to a temperature ranging from 343-482 °C (650-900 °F) at a pressure of 6-7 bar (70-80 psig), at which point the mixed hydrocarbon and steam 14 is fed into a vapour/liquid separator 20. The vapour/liquid separator 20 removes the non-vapourized portion 15 of the mixed hydrocarbon feed and steam 14, the non-vapourized liquid 15 being

withdrawn and separated from the fully vapourized hydrocarbon 16. Depending on the heavy hydrocarbon feed 11, different processing schemes may be employed.

The vapourized portion 16 is subsequently fed through a vapourizer/mixer 17, in which the hydrocarbon vapour 16 mixes with superheated steam 18 to heat the mixture 19 to a temperature of 510-566 °C (950-1050 °F), external to the furnace 10. The mixture 19 is then heated further in the second stage preheater portion 21 of the convection section A of the olefins pyrolysis furnace 10 and is subsequently fed into the radiant section B, 22 of the pyrolysis furnace 10 where the hydrocarbon mixture 19 is thermally cracked.

The conditions of the hydrocarbon/steam mixture 14 at the entrance of the vapour/liquid separator 20 are dependent on the heavy hydrocarbon feed 11 properties, with the preference that non-vapourized liquids 15 are present (between 2-40 vol% of feed, preferably 2-5 vol%) to wet the internal surfaces of the vapour/liquid separator 20. The wetted wall prevents coke formation and deposition on the surface of the separator 20. The degree of vapourization (or vol% of non-vapourizable liquid 15) can be controlled by adjusting the dilution steam/feed ratio and flash temperature of the hydrocarbon/steam mixture 14.

The vapour/liquid separator 20 described herein permits separation of the liquid 15 and vapour 16 phases of the flash mixture in such a manner that coke solids tend not to form and subsequently foul either the separator 20 or the downstream equipment (not shown). On account of its relatively compact construction, the wetted-wall vapour/liquid separator 20 design can achieve a higher temperature flash than that in a typical vacuum crude column, thus effecting the recovery of a higher vapourized fraction 16 of the feed 11 for further

downstream processing. This increases the fraction of hydrocarbon feed 11 which can be used for producing higher valued products 23, and reduces the fraction of heavy hydrocarbon liquid fraction 15 having a lower value.

Referring now to Figs. 2 and 3, the vapour/liquid separator 20 is shown in a vertical, partly sectional view in Fig. 2 and in a sectional plan view in Fig. 3. The vapour/liquid separator 20 comprises a vessel having walls 20a, an inlet 14a for receiving the incoming hydrocarbon/steam mixture 14, a vapour outlet 16a for directing the vapour phase 16 and a liquid outlet 15a for directing the liquid phase 15. Close to the inlet 14a is a hub 25 having a plurality of vanes 25a spaced around the circumference of the hub 25, preferably close to the end nearest the inlet 14a. The vane assembly is shown more clearly in the perspective view of Fig. 4. The incoming hydrocarbon/steam mixture 14 is dispersed by splashing on the near end of the hub 25 and, in particular, by the vanes 25a forcing a portion of the liquid phase 15 of the mixture 14 outwardly toward the walls 20a of the vapour/liquid separator 20 thereby keeping the walls 20a completely wetted with liquid and preventing any coking of the interior of the walls 20a. Likewise, the outer surface of the hub 25 is maintained in a completely wetted condition by a liquid layer that flows down the outer surface of hub 25 due to insufficient forces to transport the liquid 15 in contact with the surface of hub 25 to the interior of the walls 20a. A skirt 25b surrounds the far end of the hub 25 and aids in forcing any liquid transported down the outer surface of the hub 25 to the interior of the walls 20a by depositing the liquid into the swirling vapour. The upper portion of the vapour/liquid separator 20 is filled in at 20b between the inlet 14a

and hub 25 to aid wetting of the interior of walls 20a as the vapour/liquid mixture 14 enters the vapour/liquid separator 20. As the liquid 15 is transported downward, it keeps the walls 20a and the hub 25 washed and prevents the formation of coke on their surfaces. The liquid 15 continues to fall and exits the vapour/liquid separator 20 through the liquid outlet 15a. A pair of inlet nozzles 26 is provided below the vapour outlet tube 16a to provide quench oil for cooling collected liquid 15 and reduce downstream coke formation The vapour phase 16 enters the vapour outlet duct 16a at its highest point 16c, exits at outlet 16a and proceeds to a vapourizer 17 for further treatment prior to entering the radiant section B 22 of the pyrolysis furnace 10 as shown in FIG. 1. A skirt 16b surrounds the entrance 16c to the vapour duct 16 and aids in deflecting any liquid 15 outwardly toward the separator walls 20a.

EXAMPLE 1

A 70% scale, cold-flow clear plastic and metal model using water and air was tested and refined in the laboratory. In the cold-flow test model, the vapour/liquid separation was so effective that no liquid phase was detected at the vapour outlet, and visual observation showed that the internal surfaces of the model vapour/liquid separator remained well-irrigated by an active flow of the incoming liquid phase over these surfaces. Such liquid coverage is required to prevent run-limiting coke formation.

The important data for sizing include vapour rate, density and viscosity. Liquid rate, density and surface tension are also checked as a comparison with the performance of the air/water model and to estimate the drop sizes reporting to the separator.

The inlet pipe size recommended (20 cm diameter) was chosen to provide a calculated liquid drop size.

The vane assembly sizing was determined and sized to give a velocity through the vanes of 24-30 m/s. In the current design, containing twelve vanes attached to a 25 cm diameter pipe, the estimated velocity is 27 m/s through the 30° flat section of the vanes. This vane assembly is shown in Fig. 4.

Position of the vane assembly 25a relative to the entrance 14a and 'filling' in of the top head 20b of separator 20 was guided by computational fluid dynamics modeling. The intent was to remove areas of potential recirculation to reduce coking tendencies. The internal shape of the head 20b was formed to follow the stream lines of the gas so the walls 20a would remain washed by liquid that was pushed into the main body of the separator 20.

The distance of the hub 25 extension below the vanes 25a was picked based on estimation of the liquid drop size that would be captured before the drop had moved more than half way past the hub 25. Significant liquid 15 will be streaming down the hub 25 (based on observations with the air/water model) and the presence of a 'skirt' 25b on the hub 25 will introduce liquid droplets into the vapour phase well below the vanes 25a, and collection will continue below the skirt 25b of hub 25 due to the continued swirl of the vapour 16 as it moves to the outlet tube 16a.

The hub skirt 25b was sized to move liquid from the hub 25 as close as possible to the outer wall 20a without reducing the area for vapour 16 flow below that available in the vanes 25a. As a practical matter, about 20% more area for flow has been provided than is present at the vanes 25a.

The distance between the bottom of the hub 25 and the highest point 16c of vapour outlet tube 16a was sized as four times the vapour outlet tube 16a diameter. This was

consistent with the air/water model. The intent is to provide area for the vapour to migrate to the outlet 16a without having extremely high radial velocities.

The distance from the entrance 16c of the vapour outlet tube 16a to the centerline of the horizontal portion of vapour outlet pipe 16a, has been chosen as roughly three times the pipe diameter. The intent is to provide distance to keep the vortex vertical above the outlet tube 16a - not have it disturbed by the proximity of the horizontal flow path of the vapour 16 leaving outlet tube 16a. The position and size of the anti-creep ring 16b on the vapour outlet tube 16a are somewhat arbitrary. It is positioned close to, but below, the lip and is relatively small to allow room for coke to fall between the outer wall 20a and the ring 16b.

Details of the separator 20 below the outlet tube 16a have been dictated by concerns outside the bounds of this separator. As long as nothing is done to cause liquid to jet above the inlet 16c to the outlet tube 16a, there should be no impact to separation efficiency.

Chief areas of coking concern involve sections with vapour recirculation, or metal not well washed with liquid. The area 20b inside the top head may be shaped or filled with material to approximate the expected recirculation zone. The inside of the hub 25 is another potential trouble point. If coke were to grow and fall over the inlet 16c to vapour outlet tube 16a, a significant flow obstruction could occur (such as a closed check valve). For this reason, a cage or screen 25c of either rods or a pipe cap may be used. This would not prevent the coke from growing, but would hold most of it in place so that a large chunk is not likely to fall. Areas under the vane skirts and the skirts 16b on the vapour outlet tube 16a are also 'unwashed' and coke growth in these areas is possible.

The lab model on which these design rules have been tried has been tested over a wide range of flow conditions as shown in TABLE 1 below. Air rates ranged from 15-45 m/s at the inlet and water was tested at 0.06-0.28 l/s. Over all these conditions, losses were below the measurable range. At water flows less than 0.06 l/s (estimated at 0.03-0.05 l/s) the wetting of the separator outer wall 20a was less than complete. Streamers of water ran down the plexiglass, with 'dry' areas between. In terms of l/s water per cm of circumference, at 0.06 l/s water the separator walls 20a were washed at a rate of 0.0008 l/cm.s. The design data oil rate, 519 g/s at 0.2 bar, or 0.8 l/s would give a wash rate of 0.006 l/cm.s.

TABLE 1

	Low Air/ High Water	High Air/ Low Water	Plant Design Case
Vapour Inlet Velocity, m/s	15	45	25
Vapour Vane Velocity, m/s	18	45	27
Vapour Rate, g/s	183	550	5780
Vapour Rate, m^3/s	0.14	0.42	0.82
Liquid Rate, g/s	283	63	519
Liquid Rate, l/s	0.28	0.06	0.79
g Liquid/g Vapour	1.55	0.11	0.090
dm^3/s Liquid / m^3/s Vapour	2	0.14	0.96
l/s Liquid / cm Separator Circumference	0.003	0.0008	0.006

If the coking tendency of the separator walls 20a is controlled by the wash rate (liquid volumetric flow rate per circumferential inch), the plant design conditions should provide better washing than the lab model. Assuming the plant wash properties track those of the lab, opportunity will exist to operate with feeds having lower liquid volumes. The design data indicate a liquid flow that is 'low' on a weight basis and 'high' on a volume basis, when compared to the lab. However, the lab model showed no visual problems with separation at liquid rates below 0.06 l/s or above the 0.28 l/s at which data was taken.

CLAIMS:

1. Use of a vapour/liquid separator for separating a mixture containing hydrocarbon and steam, which comprises:

a vessel having an inlet for receiving a vapour/liquid mixture;

a hub located within the vessel at a position below the inlet wherein the hub supports a plurality of vane elements at its near end for centrifuging the mixture as the mixture proceeds through the vessel thereby keeping the walls of the vapour/liquid separator completely wetted with a liquid;

a vapour outlet located at the distant end of the hub for withdrawing the vapour phase of the mixture from the vessel; and

an outlet located below the vapour outlet for withdrawing the liquid phase of the mixture from the vessel.

2. Use of a separator according to claim 1, further including a skirt element at the distant end of the hub for directing any liquid phase of the mixture in an outward direction away from the hub and toward the walls of the vessel.

3. Use of a separator according to claim 1 or 2, further including a screen over the distant end of the hub for preventing any coke within the interior of the hub from falling therethrough.

4. Use of a separator according to any one of claims 1 to 3, further including a skirt located at the entrance of the vapour outlet for directing any liquid in an outward direction and away from the entrance.

5. Use of a separator according to any one of claims 1 to 4, wherein the hub is axially located in the vessel.

6. Use of a separator according to any one of claims 1 to 5, wherein the vapour outlet is axially located at the distant end of the hub.

7. A method for separating the vapour and liquid phases of a mixture of hydrocarbon and steam comprising the steps of:

flowing the mixture through the inlet of a vessel;

centrifuging the mixture by means of a centrifuge located at the head end of the vessel;

flowing the liquid phase down the walls of the vessel;

directing the vapour phase toward an outlet pipe for the vapours;

directing the vapour phase from the vessel and to means for further processing; and

directing the liquid phase from the vessel and to means for further processing.

Fig.1.

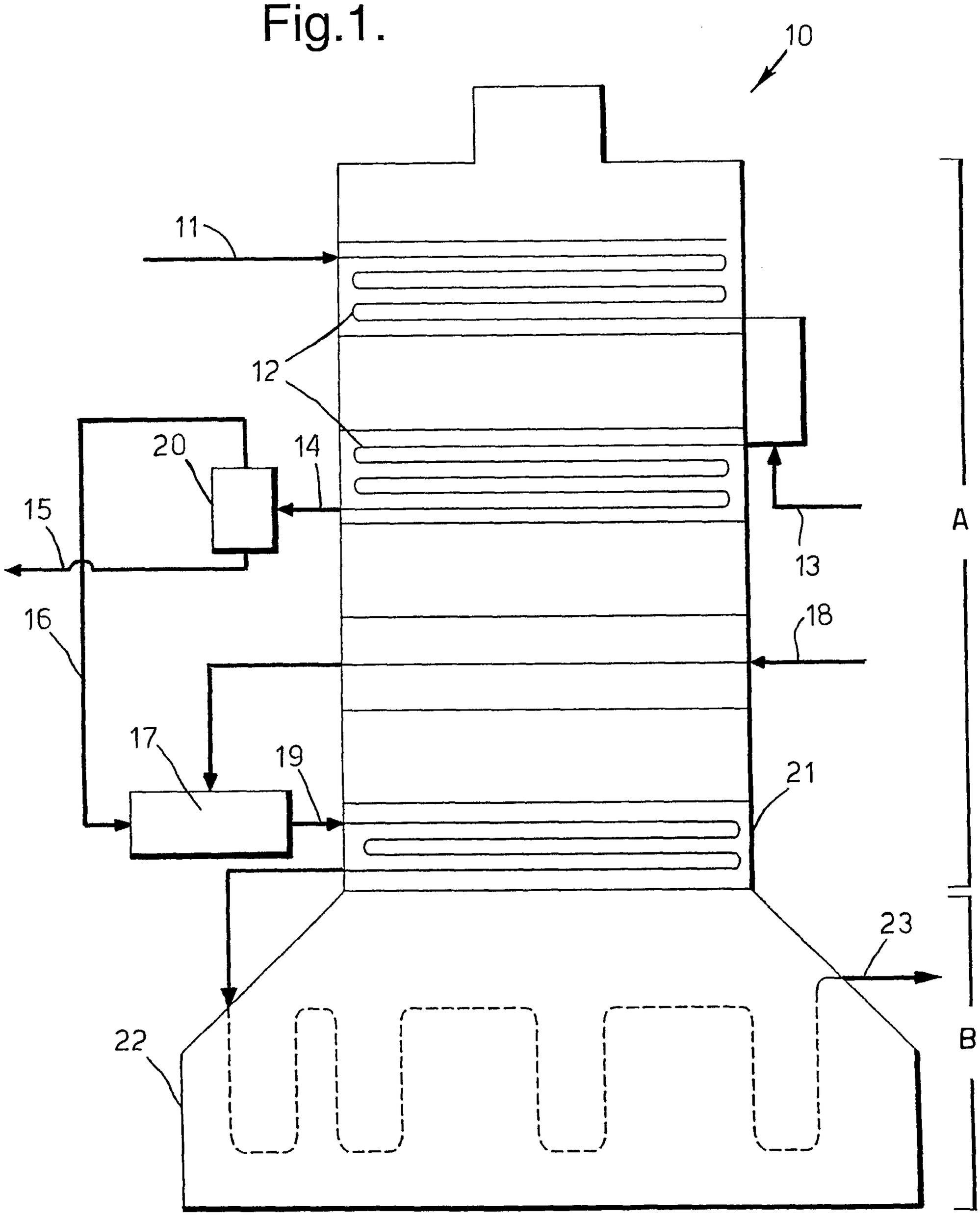


Fig.2.

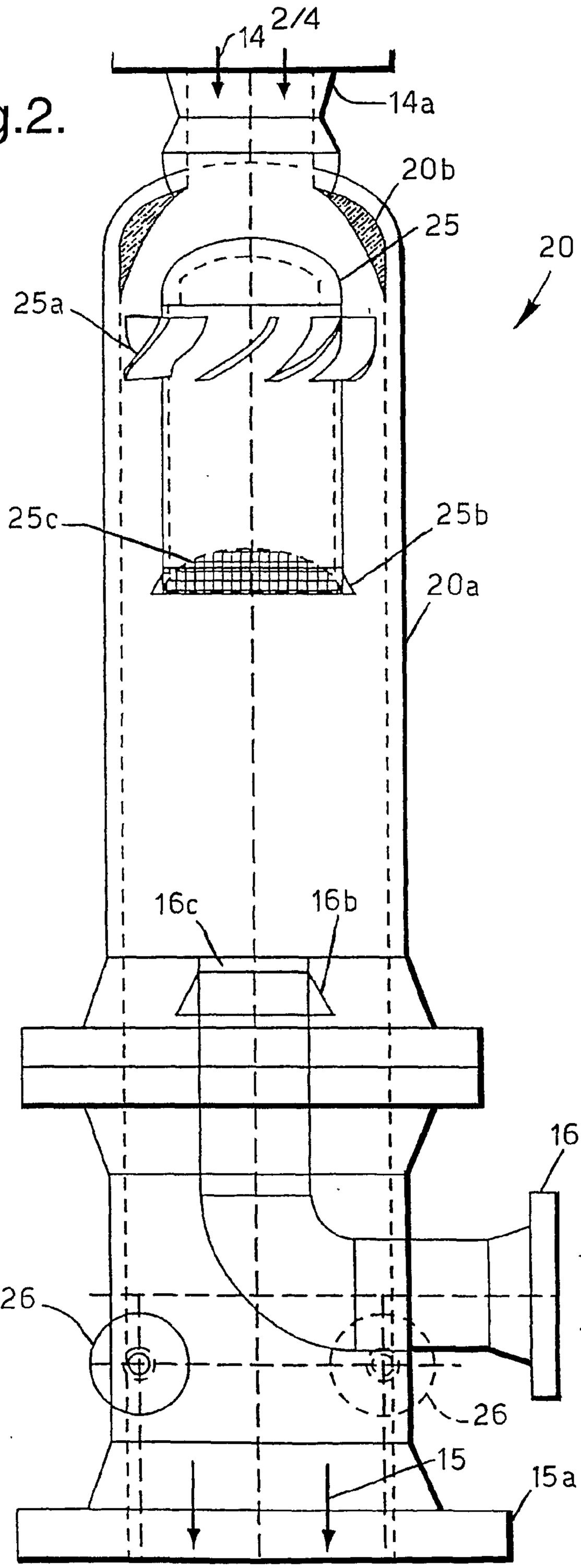


Fig.3.

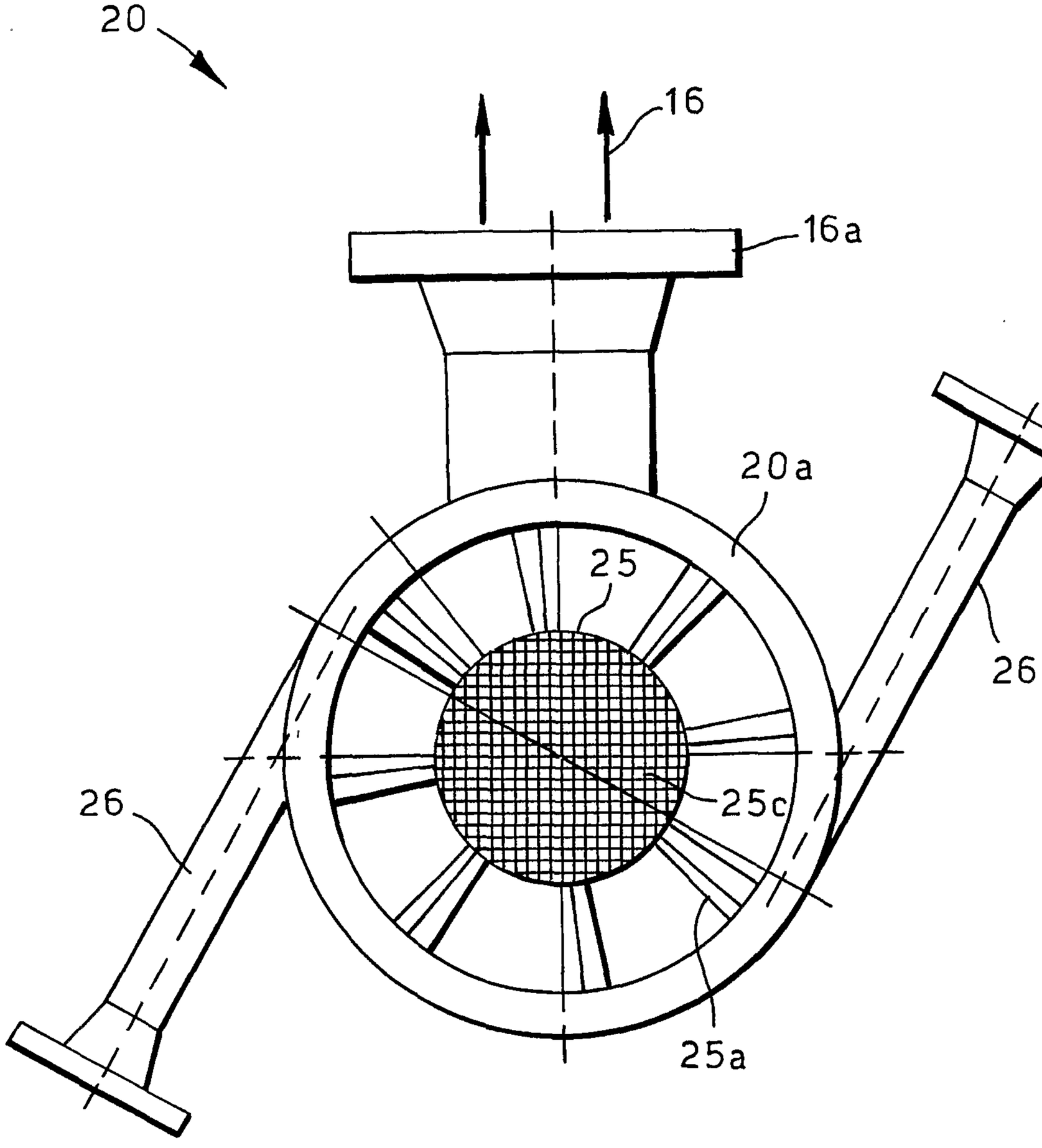
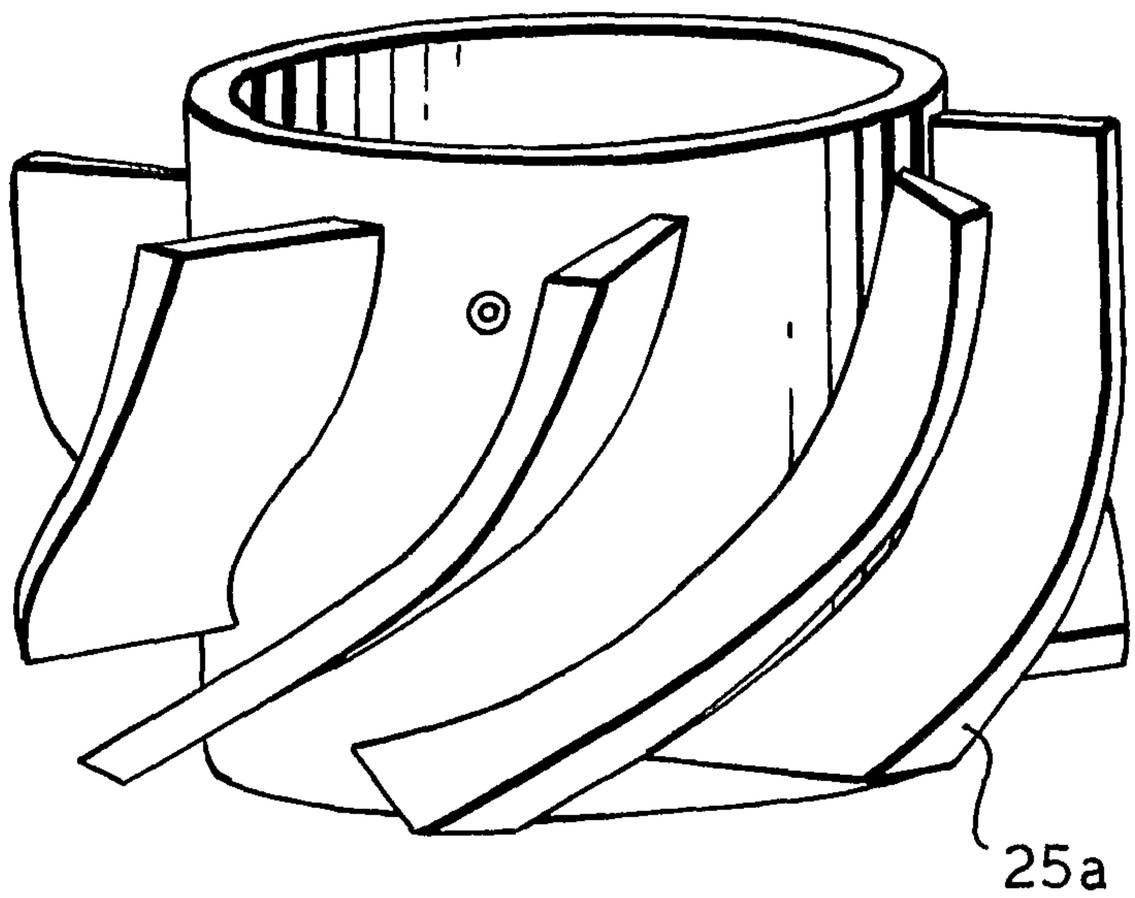
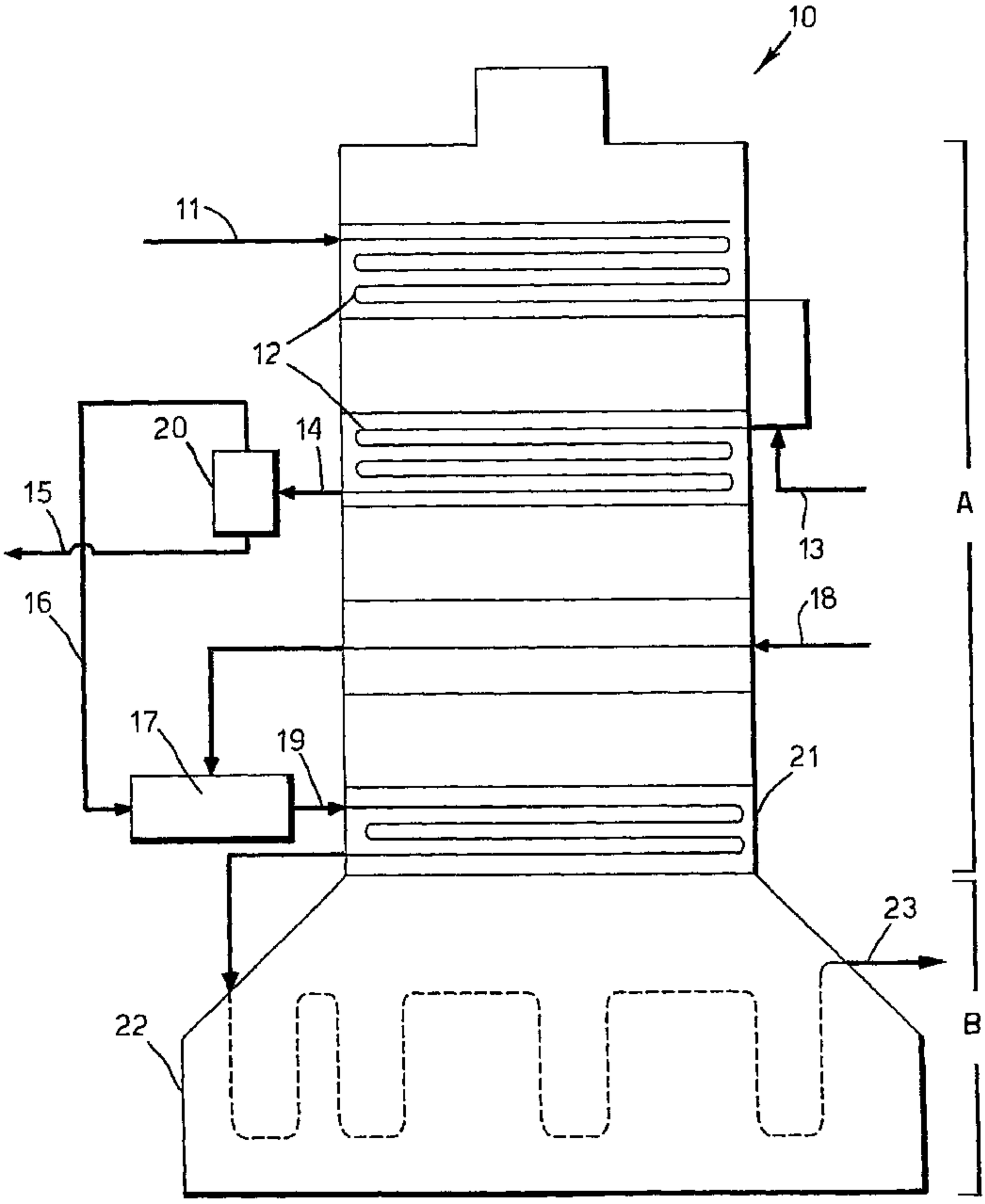


Fig.4.

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