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[54] **TUBE AND SHELL HEAT EXCHANGERS**

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[51] **Int. Cl.** **F28f 13/08**

[58] **Field of Search** 165/106, 108, 134, 142, 165/143, 154, 155, 159, 173, 174, 158, 150, 151

[56] **References Cited**

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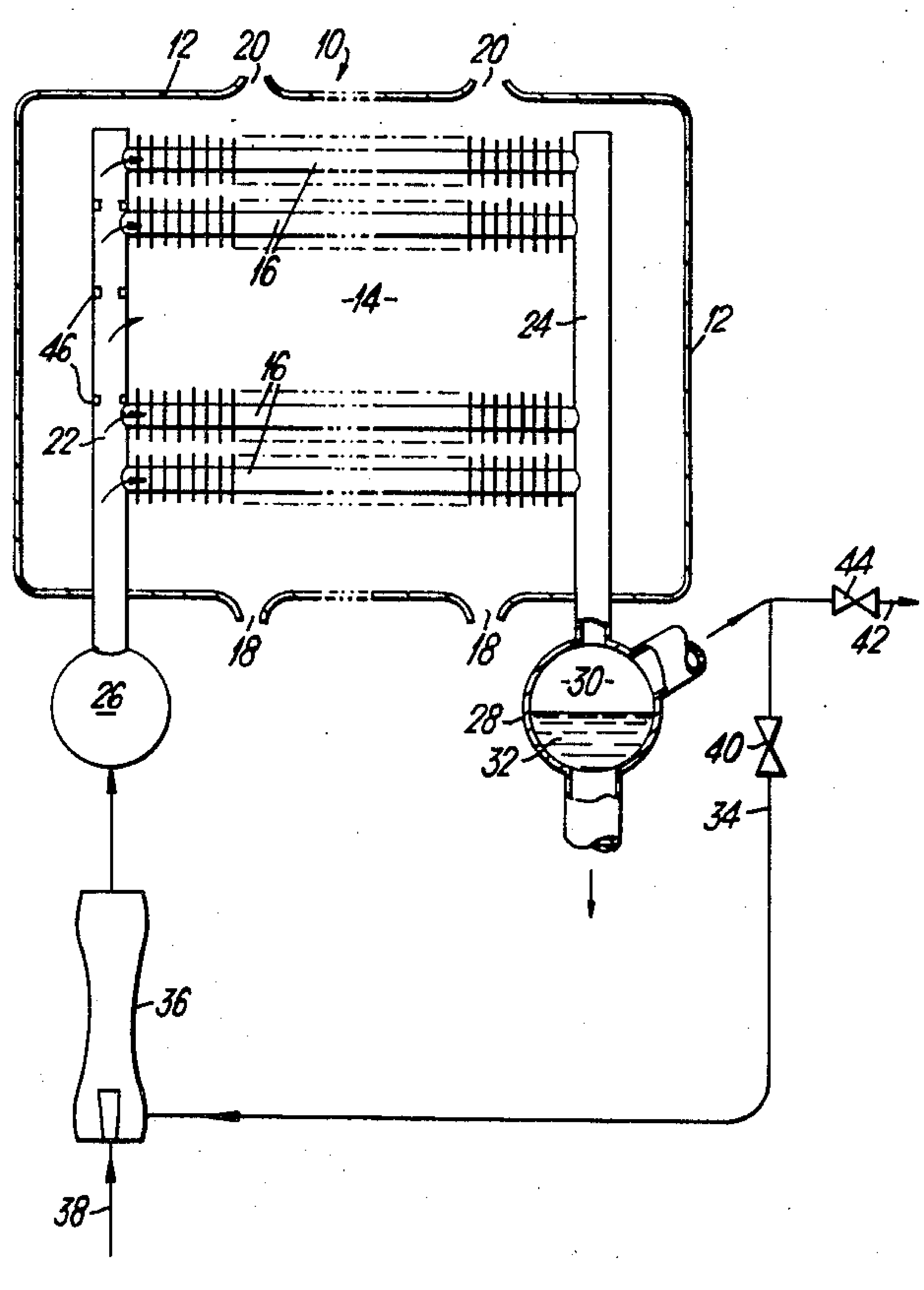
[57] **ABSTRACT**

This invention relates to tube and shell heat exchangers in which a vapour gives up it's latent heat and in so doing condenses in the tubes while a fluid passing through the shell over the tubes is heated. Flow restricting devices are arranged in the flow path for the vapour to the tubes and the number and effectiveness of these devices is arranged so that there is about the same amount of excess vapour flowing out of the outlet of each tube irrespective of how much vapour has been condensed in that tube, the excess vapour from the tubes being recirculated.

8 Claims, 3 Drawing Figures



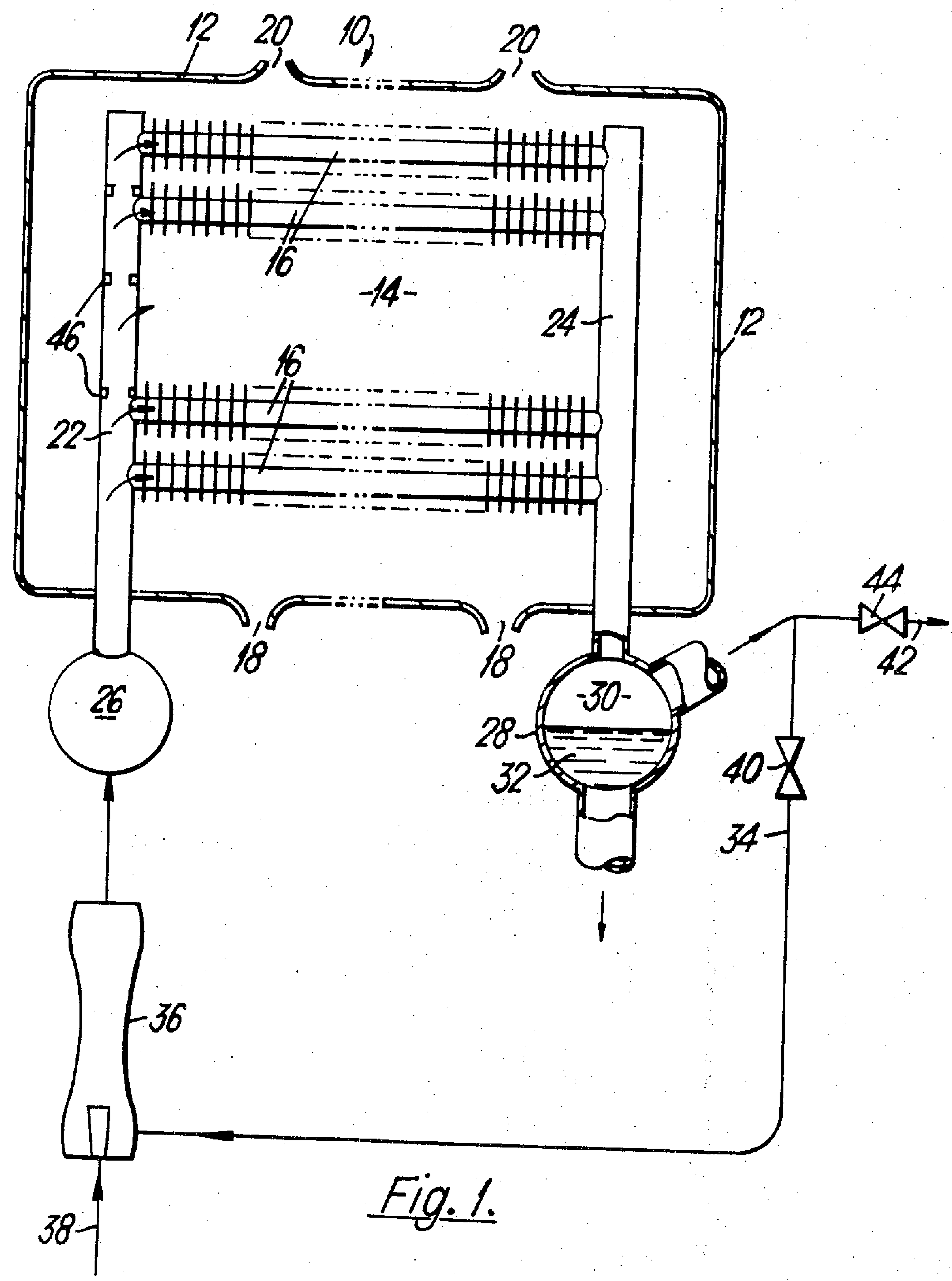


Fig. 1.

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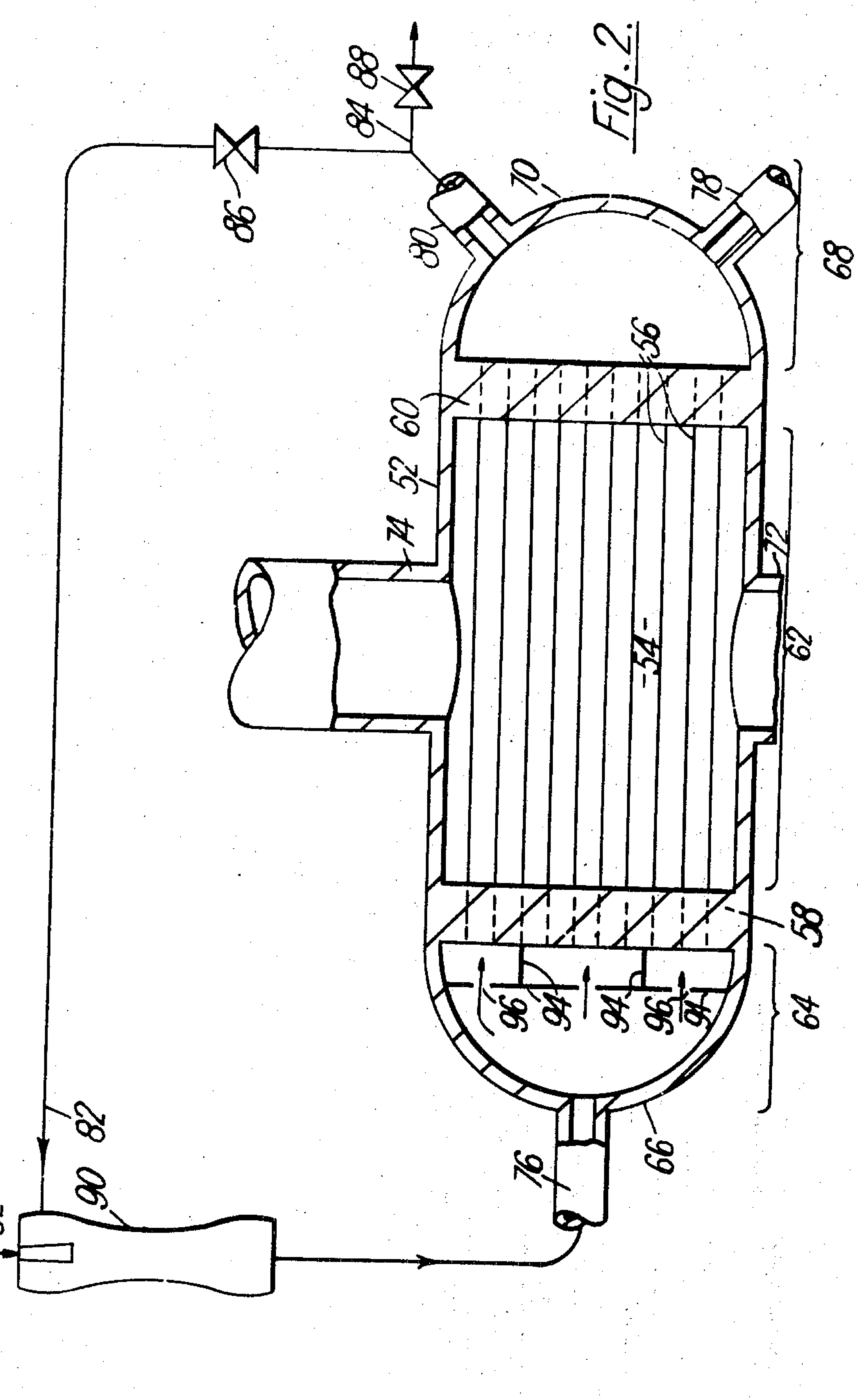

Fig. 2.

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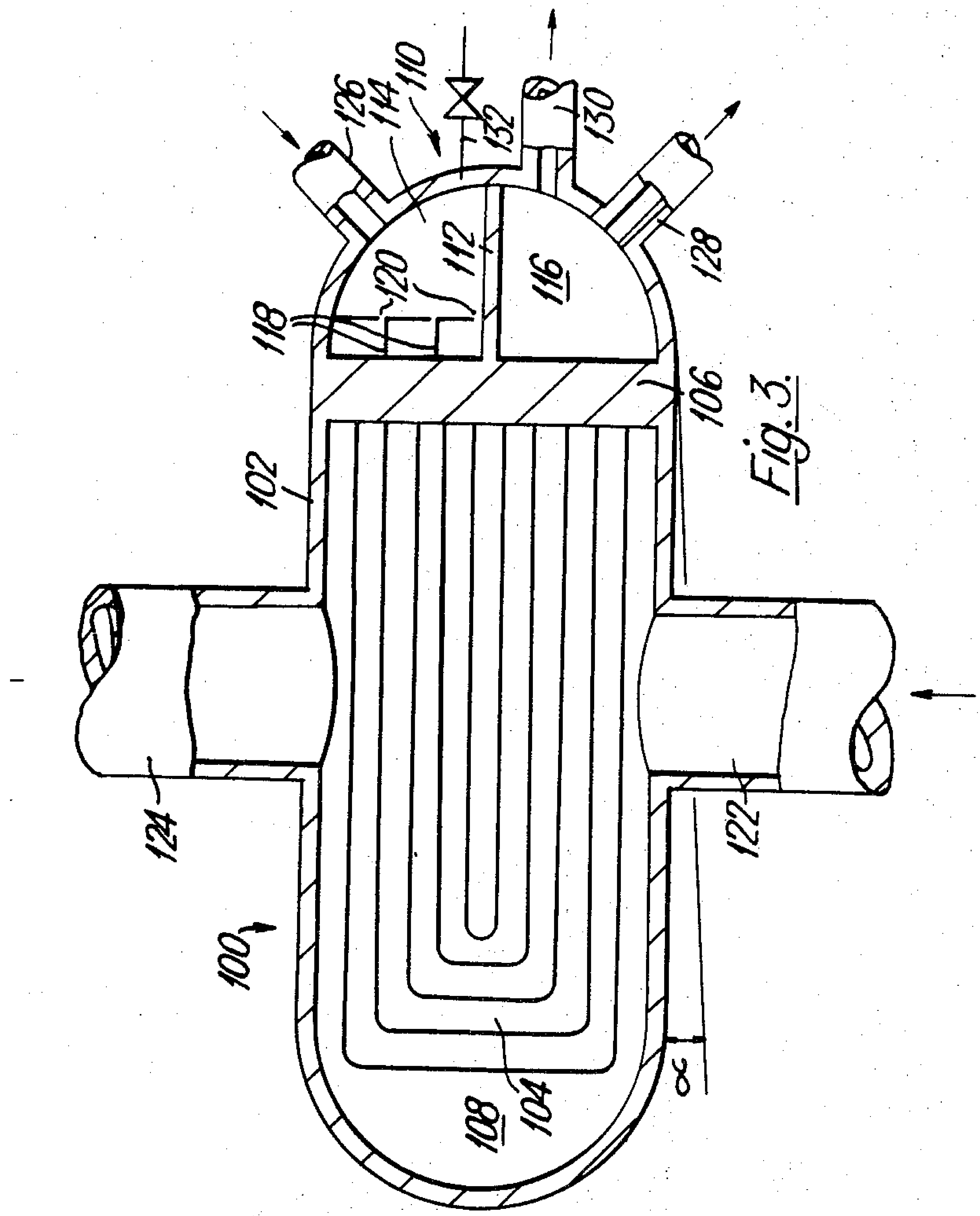

Fig. 3.

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TUBE AND SHELL HEAT EXCHANGERS

This invention relates to tube and shell heat exchangers and is especially concerned with heat exchangers in which a vapour gives up its latent heat and in so doing condenses in the tubes, while a fluid passing through the shell over the tubes is heated.

BACKGROUND OF THE INVENTION

In such heat exchangers where a vapour is condensed in the tubes flow, stagnation can occur because of accumulation of so called non-condensible gases which may initially be present in minor amounts in the vapour and which progressively inhibit condensation. By feeding an excess of the condensable vapour over that which will be condensed in the heat exchanger one can ensure that flow stagnation does not occur in any of the tubes. The excess condensable vapour and the non-condensable gases can be recirculated to the inlet of the tubes. In this way any accumulation of the non-condensible gases is avoided at any particular point although, of course, the concentration of non-condensable gases gradually builds up in the circulating vapour. A continuous small purge of the excess vapour and the gases can, however, be made and in this way concentration of the non-condensable gases can, at equilibrium conditions, easily be kept below an acceptable figure.

Because the temperature of the fluid in the shell being heated by the vapour in the tubes rises during its passage across the tube bank, the amount of heat given up by the tubes and consequently the amount of the vapour condensed in them varies with the position of the tube in the bank. Thus, in the earlier tubes over which the fluid to be heated flows, more vapour is condensed than in the later tubes.

This situation can mean that excess vapour leaves some tubes while no vapour at all leaves others and in fact one can have the result that the excess steam from same tubes flows in the reverse direction part-way back through other tubes where complete condensation has occurred at an intermediate point along their length. This in turn results in flow stagnation in some tubes which is the very situation one is trying to avoid by providing and recirculating excess vapour.

This flow stagnation can be avoided by providing sufficient recirculation to ensure that at least some vapour passes completely through each tube but this requires a large degree of recirculation and can increase the total cost of the equipment such that it becomes uneconomic.

It is therefore an object of the invention to overcome this problem in a simple fashion.

According to the invention one or more flow restricting devices are inserted in the flow path for the vapour to the tubes and their number and flow restricting effectiveness are arranged so that there is a small amount, preferably approximately the same amount, of excess non-condensed vapour flowing out of the outlet end of each tube irrespective of how much vapour has been condensed in that tube.

This solution has the advantage that only a minimum amount of recirculation is required and the flow restricting devices can be very simple and cheap. In fact they can be simple orifices positioned up the inlet conduit to the tubes.

The recirculation of excess vapour supplied to the tubes can be made in any convenient way. Thus one can use a venturi vapour compressor positioned in the vapour inlet line to the tubes to draw the excess vapour from the outlet ends of the tubes so as to recirculate this.

This tube and shell heat exchanger can be one in which case the flow restricting devices can be one or more nozzles provided along the length of the inlet manifolds. In this case the vapour supply to the tubes connected further up the length of the inlet manifold can be progressively restricted in relation to the tubes connected lower down the length of the inlet manifold.

Other types of heat echangers are, however, possible. Thus the heat exchanger can comprise a tube plate of header from which the tubes extend, areas of the tube plate or header being screened with partitions through which orifices of a predetermined size are provided so that the tubes originating from a particular area are fed with an amount of vapour which is proportional to the heat duty of those tubes, the size of the orifices being chosen to ensure this. The advantage of this arrangement is that the size of the orifice for any particular area can be chosen quite independently of the other areas. Thus the proportion of the vapour supplied need not be progressively more or less in a particular direction across the tube plate or header.

Alternatively the tubes may be U-tubes which have the advantage that the variation in duty per tube is considerably less than with a straight tube design, thereby considerably reducing the flow correction to be achieved by the orifices and consequently the pressure drop through them. A difficulty with the U-tube design is that if a drainage slope is provided, the condensation in one of the legs must flow against the direction of vapour flow. We have found, however, that by careful selection of the drainage angle in relation to the flow rates within the tubes and by having the reverse drainage slope in the inlet legs of the U-tubes, sufficient drag force may be provided by the steam flow on the condensate in the inlet leg to overcome the natural drainage force and carry it over into the outlet leg of the U-tube when the steam flow will then assist the natural drainage by gravity.

DESCRIPTION OF THE DRAWINGS

Examples of heat exchanger arrangements in accordance with the invention will not be illustrated with reference to the accompanying diagrammatic drawings, in which:

FIG. **1** is a view of one arrangement;

FIG. **2** is a similar view of another arrangement; and

FIG. **3** is a similar view of a further arrangement.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The heat exchanger **10** shown in FIG. **1** of the drawings comprises a shell **12** surrounding a tube bank **14** composed of a large number of individual tubes **16.**

The fluid material to be heated e.g., relatively low pressure steam, passes through the shell **12** from inlets **18** to outlets **20.**

The tubes **16** extend between upright inlet manifolds **22** and upright outlet manifolds **24.** An inlet manifold **22** and an outlet manifold **24** is provided for each set of tubes lying on one upright plane and the tube bank is composed of a large number of these sets of tubes. The inlet manifolds **22** originate from a common inlet header **26** while the outlet manifolds **24** lead to a common outlet drain **28.**

In the drain **28,** the excess steam and non-condensable gases separate out in a vapour phase **30** above the condensed water phase **32,** and a recirculation line **34** for excess vapour not condensed in the tubes **16** and the non-condensable gases leads from the vapour phase **30** of the drain **28** to a thermocompressor **36.** The latter is supplied with new vapor in the form of fresh relatively high pressure heating steam from a line **38** which draws the vapour from the drain **28** through the recirculation line **34.** This arrangement prevents flow stagnation occuring in the tubes **16** because of accumulation of the non-condensable gases. A valve **40** is provided in the line **34** to control the rate of recirculation. In addition a bleed line **42** provided with a valve **44** is provided from the recirculation line **34** so as to give continuous small purge of steam and non-condensable gases. This purge prevents build-up of concentration of the non-condensable gases in the system. As an alternative the line **42** can lead back through the shell **12** so that the latent heat of the bleed steam is not wasted.

We have found that more vapour is condensed in the lower tubes **16** since they are in contact with the inlet cooler fluid material in the shell than in the upper tubes **16** since they are in contact with partially warmed fluid material in the sheel.

Thus, although an overall excess of steam is supplied to the inlet manifold, there may be no excess steam at the outlet from the lower tubes whereas there may be plenty of excess steam from the upper tubes. Because of this some of the excess steam collecting in the outlet manifold may flow back in the reverse direction into part of the lower tubes and this can result in flow stagnation in those tubes and so reduce the efficiency of the heat exchanger quite substantially.

To avoid this, and in accordance with the invention, flow restricting orifices **46** are provided in the inlet manifolds **22.** These have the effect of progressively restricting the flow of steam up the inlet manifolds so causing some vapour to flow into the lower tubes and less into the upper tubes. By suitable choice of the number of these orifices and their flow restricting effect one can arrange for approximately the same amount of excess non-condensed vapour to pass from each tube **16** in the outlet manifolds **24** irrespective of the amount of vapour which is condensed in the tubes. Therefore one can prevent flow stagnation occuring in any tube without increasing to an undesirably large degree the amount of vapour recirculated through the line **34.**

In fact one can arrange for a minimum amount of vapour to recirculate through the line **34** and so its size, the size of the compressor **36,** and the size of the tubes **16** can be reduced, with a consequent saving in cost and increase in efficiency.

An important advantage of the invention is its simplicity.

The heat exchanger **10** is only shown diagrammatically in FIG. **1** the detailed construction can be similar to the heat exchanger described and shown in our copending Pat. application No: 5520/68.

Although the heat exchanger **10** has been described in connection with the use of the thermocompressor **36** to promote recirculation through the line **34,** this recirculation can be achieved in any convenient way. Thus for example, a pump can be included in the line **34** or recirculation can be effected or assisted by the drawing of condensate down the outlet manifolds **24** as described in our copending Patent Application No: **18002/68.**

The heat exchanger **50** shown in FIG. **2** comprises a substantially cylindrical shell **52** surrounding a bank **54** of tubes **56.** The tubes extend between tube plates **58** and **60** which extend across the shell and divide its interior into a central heat exchanger region **62,** an inlet manifold in the form of an inlet end region **64** defined additionally by a domed end cover **66,** and an outlet end region **68** defined additionally by a domed end cover **70.**

Fluid material to be heated, e.g., relatively low pressure steam, passes through the central region **62** of the shell across the tubes **56** from an inlet **72** to an outlet **74.**

Vapour which will condense in the tubes **56** and in so doing heat the fluid material passing through the shell, e.g., relatively high pressure steam is supplied to the end region **64** through an inlet **76** and from there passes into the tubes.

As explained in connection with FIG. **1,** excess vapour over that which will condense in the tubes **56** is supplied to the region **64** and the excess vapour and any non-condensable gases and condensate discharge from the tubes into the end region **68.** From there a lower condensate outlet down **78** and an upper vapour outlet **80** lead. The vapour outlet **80** leads to a recirculation line **82** through which the major portion of the vapour is recirculated and a bleed line **84** through which a continuous small purge of vapour is vented to the atmosphere. The lines **82** and **84** have valves **86** and **88** respectively to control flow through them.

The recirculation line **82** leads to a thermocompressor **90** which is fed with a fresh supply of vapour from a line **92** and this vapour together with the recirculation vapour leads to the inlet **76.** Naturally the thermocompressor **90** could if desired be replaced by a pump in the line **82.**

As explained in connection with the embodiment of FIG. **1** more vapour may be condensed in some tubes than in others. To ensure that approximately the same amount of excess vapour leaves each tube **56** irrespective of its position in the tube bank **54,** partitions **94** are provided as flow restrictors across the region **64** so as to divide the surface of the tube plate into distinct region; three regions are shown for the sake of simplicity in FIG. **2.** Orifices **96** are provided through the partitions and the size of each orifice is chosen so that the correct amount of vapour is supplied to each region of the tube plate so that the tubes originating from that region receive the correct flow of vapour.

The advantage of this embodiment over that of FIG. **1** is that the size of each orifice **96** can be chosen independently of other orifices and there is no need for the flow of vapour to be progressively restricted the higher the position of the tube up the tube bank, as is the case with the embodiment of FIG. **1.**

The embodiment of FIG. **2** is, however, simple and effective.

Another simple embodiment of a heat exchanger **100** is shown in FIG. **3.** This comprises a shell **102** in which are positioned U-tubes **104.** These are connected to a tube plate **106** which extends across the shell and divides it into a heat exchange region **108** and an end region **110.** The latter is again divided by a plate **112** into an inlet manifold region **114** and an outlet manifold or region **116.**

In the inlet region **114** are positioned partitions **118** which divide the surface of the tube plate into distinct regions to serve as flow restrictors. Orifices **120** are provided through each partition in exactly the same way as described in connection with the embodiment of FIG. **2.** The size of each orifice is chosen so that the correct amount of vapour is supplied to each region of the tube plate so that the tubes originating from that region receive the correct flow of vapour.

The shell **102** has an inlet **122** and an outlet **124** for the passage of a fluid to be heated.

Also the inlet region **114** has a vapour inlet **216** and the outlet region **116** has a condensate outlet **128** and an excess non-condensed vapour and non-condensable gases outlet **130.** This heat exchanger **100** is supplied with excess vapour in exactly the same way as the heat exchanger arrangements described in connection with FIGS. **1** and **2** and reference is made to those arrangements for a full description of how the present arrangement operates.

In order to ensure drainage of the U-tubes **104,** the whole heat exchanger is tilted slightly at the angle to the horizontal. By a suitable choice of the angle in relation to the steam and condensate flow rates, it is found that this tilting keeps the tubes drained because any condensate in the upper legs of the tubes can be entrained and in the lower legs, where the vapour velocity is lower, it drains by gravity to the outlet region **106.**

When the heat exchanger is shut down, the condensate in the upper legs of the tubes drains into the inlet region **114** and so a valved condensate outlet **132** is provided from this region for draining condensate after shut down.

This heat exchanger is simple and, because U tubes **104** are employed rather than straight tubes, there is a relatively smaller differential condensation between different tubes. The provision of a small amount of excess vapour in each tube may therefore be achieved by using the orifices **120** with a smaller pressure drop than with a straight tube design.

A latitude of modification, change and substitution is intended in the foregoing disclosure and in some instances some features of the invention will be employed without a corresponding use of other features. Accordingly it is appropriate that the appended claims be construed broadly and in a manner consistent with the spirit and scope of the invention.

I claim:

1. A condenser comprising:

a shell;

a cooling fluid inlet for allowing cooling fluid to flow into said shell;

a cooling fluid outlet for allowing said cooling fluid to flow out of said shell;

an inlet manifold positioned within said shell for receiving vapor;

an outlet manifold positioned within said shell;

a plurality of tubes connecting said inlet manifold with said outlet manifold for directing vapor from said inlet manifold to said outlet manifold, so that said vapor is cooled by indirect heat exchange with said cooling fluid and said vapor is partly condensed to liquid which flows to said outlet manifold; and

a number of flow restricters in said inlet manifold spaced to control the flow of vapor into said tubes so that the closer a tube is to the fluid inlet in the flow path of said cooling fluid the more vapor enters it and the more heat from said vapor will be absorbed each of said tubes receiving enough vapor to insure that vapor exits from each tube and enters said outlet manifold.

2. The condenser defined in claim **1** further comprising a conduit connecting said outlet manifold with said inlet manifold so that vapor which has flowed from said tubes into said outlet manifold is recirculated to said inlet manifold, and

means to remove a portion of said recirculating vapor from said conduit to limit the amount of uncondensable gases flowing through said conduit into said inlet manifold.

3. The condenser defined in claim **2** further comprising a pump in said conduit to induce said recirculation.

4. The condenser defined in claim **3** wherein said pump is connected with a vapor feed line to mix new vapor with said recirculated vapor for injection into said inlet manifold.

5. The condenser defined in claim **4,** wherein said means to remove a portion of said recirculating vapor is positioned upstream of said pump.

6. The condenser as defined in claim **1,** in which said inlet and outlet manifolds are substantially upright with said tubes extending substantially horizontally, said flow restrictors being nozzles positioned along the length of said inlet manifold to progressively restrict the flow of vapor upwardly through said inlet manifold to thereby control the amount of said vapor supplied to said tubes.

7. A condenser as defined in claim **1** wherein said flow restrictors comprise partitions which extend into said inlet manifold parallel to the direction of flow of said vapor and partitions connected with the ends of said first defined partitions and extending at an angle thereto with said last defined partitions being provided with orifices of predetermined definite sizes to regulate the flow of vapor between said first defined partitions and into said tubes.

8. The condensers defined in claim **7** wherein said tubes are U-shaped so that said inlet manifold and outlet manifold are positioned on the same side of said plurality of tubes.

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