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(54) **Heat transfer process.**

(57) A heat transfer process in which vapour condensing in a tube bundle transfers heat to a fluid in contact with the exterior of the tubes. The tubes and the pattern of temperature and flow distribution in the external fluid are similar from each tube, but each tube is nevertheless provided with an internal fluid flow restrictor, preferably at its entrance.

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Heat Transfer Process

This invention relates to a heat transfer process of the kind in which a vapour is condensed within a series of tubes, and in so doing gives up heat to a fluid in contact with the outer surface of the tubes.

It is well known that in heat exchangers where heat is transferred from a fluid condensing in an array of tubes through which the fluid flows in parallel, to a fluid in contact with the exterior of the tubes, that for maximum thermal efficiency, the flow of vapour into each tube should be carefully balanced. There may be variation in the heat flux demanded of individual tubes for example resulting from differing tube lengths, and/or differences in the flow pattern or temperature distribution within the fluid exterior to the tubes. Various proposals for correcting the resulting maldistribution of the vapour flow within the tubes have been made in the past, including restrictions in selected tubes designed to limit the flow rate of vapour within tubes which are expected to sustain the lower heat flux on account of their shorter length, or in anticipation of the fluid external to those tubes being warmer, flowing with less velocity, or otherwise demanding lower heat flux. Also, in UK Patent No 1263254 there are described in-tube condensers in which the flow of vapour to all tubes is restricted. In this patent disclosure it is anticipated that a maldistribution of vapour to the tubes will occur either because of varying tube lengths, or because the external fluid flow pattern is uneven as regards temperature distribution, and the tubes are restricted to varying degrees to correct the anticipated imbalance resulting therefrom.

In many instances however, where the tubes are all similar, and the temperature distribution externally of each tube is similar, no reason would be seen for the inclusion of flow restrictors in the tubes, since it would be thought that these would needlessly hinder the flow of vapour therethrough. Thus, in a kettle reboiler, a vapour such as steam is condensed as it flows in parallel through a group of vapour tubes, and gives up heat to liquid in which the tubes are immersed, the liquid thus being caused to boil. Kettle reboilers are widely used in the chemical industry for distillation of liquids which must not be allowed to overheat. In particular, they find use in the petro-chemical industry.

In the case of a kettle reboiler in which the vapour tubes are all of substantially the same length and cross-sectional area, it has not in the past been foreseen that any maldistribution of the vapour flow will occur. The tubes are all immersed in a boiling liquid during use, and so the external temperature of the tubes is the same at all points. Equally, no variation resulting from uneven flow conditions externally of the tubes can be expected. If the tubes are of the same length and cross-sectional area, no maldistribution resulting from varying pipe friction can be anticipated.

Nevertheless, it has been found in practice that the heat transfer performance of kettle reboilers frequently falls far short of the design prediction. This has often been erroneously attributed to "dryout" - ie film boiling - occurring in the liquid on the exterior of some of the tubes, which would lead to much reduced heat transfer for these tubes. The only way of avoiding this problem has been considered to be to reduce the total steam flowrate, hence reducing the heat flux through individual tubes to the point where film boiling no longer occurs on any tube. The reboiler will then work at below its design heat transfer capacity.

As a further example, the invention is also concerned with a heat transfer process in shell and tube heat exchangers in which a vapour condensing within a set of tubes through which it flows in parallel, gives up heat to a fluid flowing longitudinally along the external surface of the tubes. The fluid and vapour most usually flow in countercurrent; arrangements are also common in which baffles within the shell cause the fluid to flow back and forth across the shell whilst its general progression is longitudinally along the tubes. In all of these shell and tube heat exhangers, if the tubes are of the same length and cross-sectional area, no reason would have been seen to expect any maldistribution of the vapour. Each tube offers the same restriction in the path of the vapour flow, and each tube is subject to the same external pattern of thermal distribution, and external fluid flow. Hence, as with the kettle re-boiler, the conditions are such that every tube would be expected to sustain the same thermal load, and hence to condense the same amount of vapour. This would not be regarded as a situation likely to lead to maldistribution of vapour among the tubes.

Nevertheless, it is frequently found in practice that such in-tube condensers operate at well below their design heat transfer capacity. Investigation has shown this to be because some tubes are running "cold". This is now recognised by the Applicant to be the result of maldistribution, causing vapour which passes right through some tubes re-entering others from the wrong end via the outlet header. Non-condensable gases thus gradually collect in these latter tubes, so as gradually to prevent vapour from reaching the thus occluded lengths of tube.

However this may be, no reason was seen in the past to explain any such maldistribution, and no possible cure has previously been proposed. One solution adopted has been simply to increase the vapour flow until all tubes remain hot throughout their length. As a consequence, excess vapour has passed through all tubes. This has led to wastage, or the complication of providing a downstream condenser.

The present invention seeks to provide an improved heat transfer process for use in heat exchangers comprising tubes through which a condensing vapour flows in parallel, particularly for those instances where no reason would previously have been foreseen to expect an imbalance of the vapour flow distribution among the tubes.

Accordingly the present invention provides a heat transfer process comprising the steps of

causing a relatively hot condensible vapour to flow through the interior of a plurality of tubes connected in parallel,

contacting a relatively cool fluid with the exterior of the tubes so that heat is transferred through the tube walls from the vapour to the fluid and the vapour thus condenses within the tubes,

the tubes being mutually similar one to another, and each being subjected to substantially the same velocity and temperature distribution in the external fluid, and the process comprising the further step of providing a fluid flow restrictor in each tube.

A balanced flow of fluid through the tubes can thus be obtained in which the quality of fluid leaving each tube has substantially the same value.

Preferably the arrangement is such that the quality of fluid leaving each tube is zero. The term "quality" is defined herein as the ratio m_v/m_t where mv is the mass flow rate of vapour in the fluid, and m_t is the mass flow rate of the total fluid comprising liquid and vapour. Thus a quality of 1 is respresentative of a fluid comprising only vapour, while a quality of 0 represents a fluid which is wholly liquid.

The inventor's have found that a particularly effective way of obtaining the desired balanced flow condition, is by the provision in each vapour tube of a fluid flow restrictor.

The invention thus resides primarily in the surprising discovery that the performance of in-tube condensing heat exchangers can be improved by providing a fluid flow restrictor in each vapour tube, irrespective of whether there is any apparent cause for maldistribution of vapour. Thus the invention finds application in those cases where the vapour tubes are all such as to offer the same flow resistance under the same conditions of fluid flow therein, and the arrangement is such that each tube is of the same length and subject to the same flow conditions and temperature in the external fluid. Without limiting the invention in any way thereby, a possible explanation is thought to be as follows. When vapour is condensing as it flows along a tube, the pressure drop along the tube may be very small indeed, because the frictional pressure loss is offset by a recovery produced by the deceleration of the flow. Hence the distribution of vapour within the tube bundle will be very sensitve to minor variations in pressure upstream or downstream of the bundle. Thus slight variations of pressure resulting from the upstream pipework, or from variations in the kinetic head of vapour within the inlet header to the tubes can possibly cause significant differences in the flowrates between different tubes. By providing even a mild restriction to the fluid flow in each tube, the total pressure drop in the tube is considerably increased. It is thought probable that the success of the invention results from the fact that the vapour flow distribution is thus rendered far less sensitive to the slight variations inevitably present.

The restrictors then advantageously each have the same cross-sectional area for fluid flow.

Very conveniently, the restrictors are provided in the form of removable inserts.

The restrictors are normally most advantageously positioned one at the entry to each vapour tube. Their design is thus simplified in that they will carry vapour only.

The invention will now be described by way of example only, with reference to the accompanying drawings in which

Fig 1 shows a simplified schematic view of a kettle reboiler,

Fig 2 is a detail view of part of the kettle reboiler shown in Fig 1, showing a restrictor in the form of a removable insert, positioned in the inlet end of a vapour tube, and

Fig 3 shows a simplified schematic view of a baffled shell and tube heat exchanger.

In Figure 1 there is shown a kettle reboiler comprising an array of vapour tubes 1 within a vessel 2 for containing a liquid to be boiled. A single row of vapour tubes 1 is shown in the plane of the drawing, but the reboiler can include several such rows, eg in parallel planes. All of the vapour tubes are of the same length and cross-sectional area. The vapour tubes can be supplied with vapour through common inlet header 3 having an inlet 4. Fluid leaving the tubes is collected in an outlet header 5 and can flow through an outlet 6. The vessel 2 is provided with an inlet 7 for liquid and an outlet 8 for vapour which can first collect in a vapour space 9.

Provided in the inlet end of every tube 1 is a flow restrictor 10, in the form of a removable insert.

In use, liquid to be evaporated is supplied to the vessel 2 _via_ the inlet 7, at an appropriate rate to keep all of the tubes 1 immersed therein. Vapour is supplied _via_ the inlet 4 and the header 5 so as to flow in parallel through the tubes 1. The vapour gives up heat to the liquid through the tube walls, so that the liquid boils in the vessel 2 and the vapour condenses in the tubes 1. In practice it is found that, because of the presence of the restrictors 10 at the entry to the tubes 1, the flow of vapour through each tube 1 is virtually the same. It can thus be arranged that the fluid issuing from the downstream ends of the tube consists almost entirely of condensate (quality of about zero), ie little or no vapour issues from the downstream ends of the tubes 1 but vapour is condensing along virtually their entire length so as to maximise the heat transfer to the boiling liquid. The heat transfer rate in a given kettle reboiler has thus been shown in practice to be capable of considerable improvement, resulting from the provision of restrictors 10.

The restrictors 10 are readily removed to allow cleaning of the tubes, and can subsequently be replaced without difficulty.

In Figure 3, there is shown a baffled shell-and-tube heat exchanger comprising an array of vapour tubes 11 within a shell 12. A single row of tubes 11 is shown in the plane of the drawing, but the heat exchanger can include several such rows, eg in parallel planes. Each tube is of the same length and cross-sectional area. The tubes 11 define a number of flow paths through which vapour can flow in parallel from an inlet header 13 having an inlet 14 to an outlet header 15 having an outlet 16.

All of the vapour tubes are of the same length and cross-sectional area. Each tube 11 is provided at its inlet with a removable restrictor 10 of the kind shown in Fig 2.

The shell is provided with an inlet 17 and an outlet 18. Spaced longitudinally of the shell 12 and extending alternately from its top and bottom are a number of baffles 20. Each baffle extends only partway across the shell, so as to define between inlet and outlet a tortuous flow path whose general direction is longitudinally along the length of the tubes 11.

In use, cool liquid to be heated enters the shell 12 via the inlet 17 and leaves via the outlet 18. Vapour such as steam flows via the inlet 14 and the header 15, through restrictors 10, to flow along the tubes 11 in parallel paths, countercurrent to the liquid in the shell. As the vapour flows along the tubes it gives up heat to the cooler liquid in the shell, and condenses. Although the liquid flows back and forth across the shell, its general progression is longitudinally along the tubes, and hence each tube is subject to substantially the same external flow conditions including velocity and temperature distribution.

In practice it is found that in the absence of the flow restrictors 10 the heat exchanger can only be operated either with an excess of vapour or with some tubes cold. In either case, the heat transfer rate attained in practice is substantially less than that theoretically attainable.

With a restrictor 10 in place in every tube, however, it is found that the flow of vapour through each tube is virtually the same, so that fluid condenses along the whole length of every tube and the fluid issuing from the downstream ends of the tubes is almost entirely condensate having a quality of approximately unity. The heat transfer performance is thus very considerably increased with a balanced flow condition achieved by the provision of a restrictor 10 in every tube.

Claims:

1. A heat transfer process comprising the steps of
causing a relatively hot condensible vapour to flow through the interior of a plurality of tubes connected in parallel,
contacting a relatively cool fluid with the exterior of the tubes so that heat is transferred through the tube walls from the vapour to the fluid and the vapour thus condenses within the tubes,
the tubes being mutually similar one to another, and each being subjected to substantially the same velocity and temperature distribution in the external fluid, and the being characterised by the further step of providing a fluid flow restrictor in each tube.

2. A heat transfer process according to claim 1 characterised in that the fluid leaving the tubes consists substantially wholly of liquid condensate.

3. A heat transfer process according to claim 1 or claim 2 characterised in that the fluid flow restrictors each have the same cross-sectional area for fluid flow.

4. A heat transfer process according to any one of claims 1 to 3, characterised in that the restrictors are provided in the form of removable inserts.

5. A heat transfer process according to any one preceding claim characterised in that the restrictors are positioned one at the entrance of each vapour tube.

6. A heat transfer process according to any one preceding claim characterised in that the tubes form part of a kettle reboiler or a baffled shell-and-tube heat exchanger.

Fig. 1.

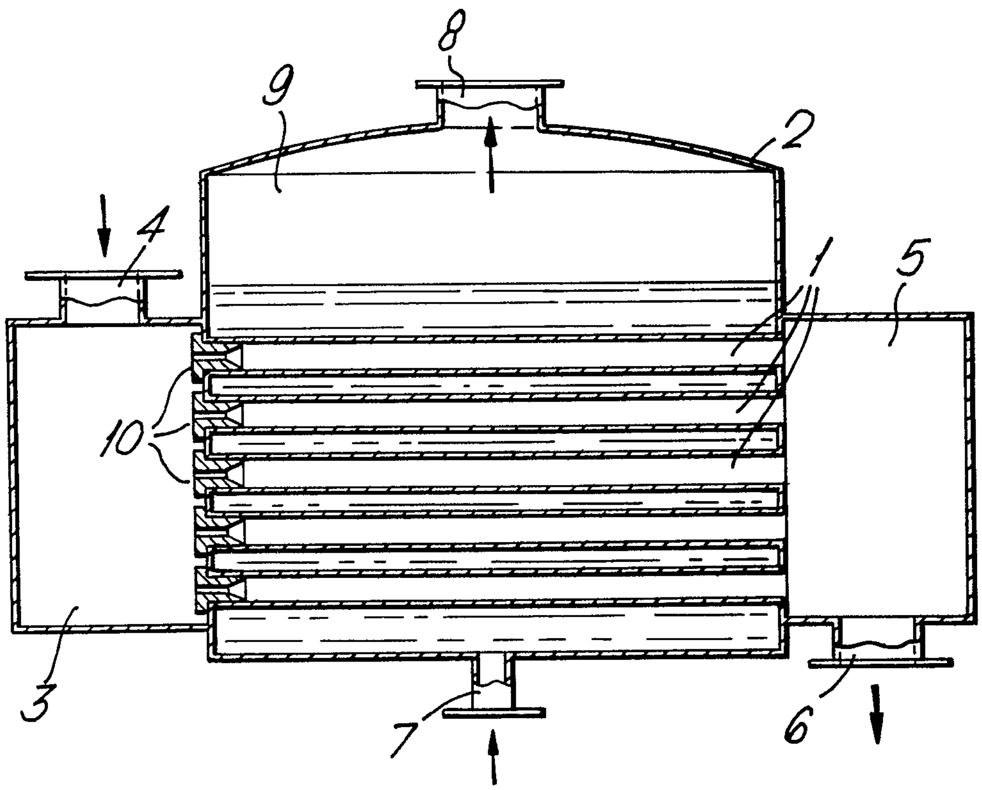


Fig. 2.

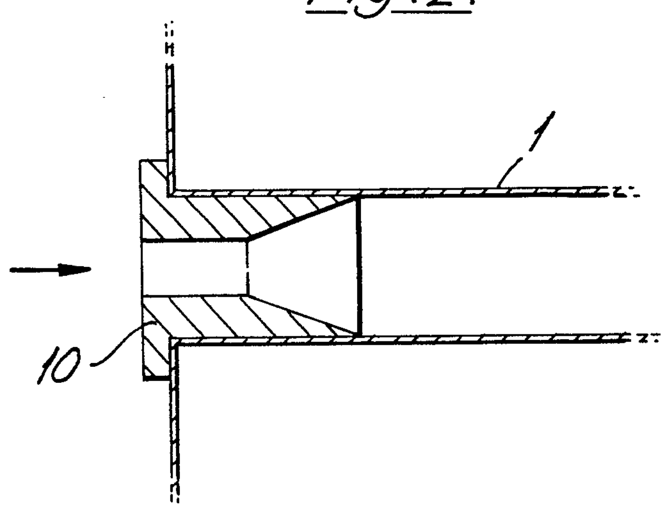
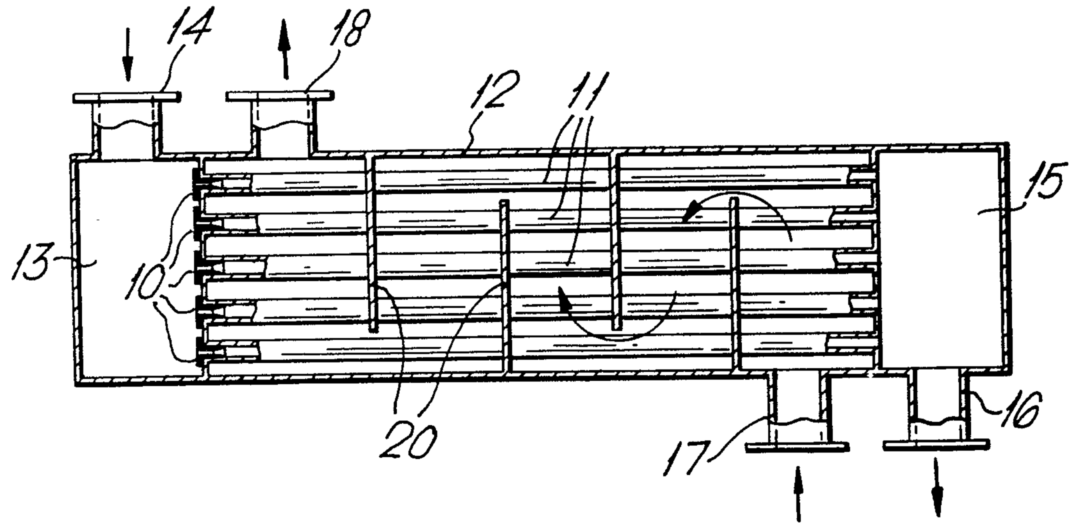


Fig. 3.



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EUROPEAN SEARCH REPORT

Application number

EP 83 30 6441

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
A	GB-A-2 051 596 (DEEG) * Abstract; page 2, lines 41-47; figure *	1	F 28 B 1/00 F 22 B 37/74 B 01 D 1/04
A	GB-A-1 344 812 (BANNER) * Page 2, lines 33-78; figures 1-3 *	3-5	
D,A	GB-A-1 263 254 (FOSTER WHEELER)	1	
A	US-A-3 229 761 (WARE)		
			TECHNICAL FIELDS SEARCHED (Int. Cl. 3)
			F 28 B F 22 B B 01 D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	31-01-1984	FILTRI G.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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