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(12) # EUROPEAN PATENT APPLICATION

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(54) **Improvements in or relating to tube heat exchangers.**

(57) Tube heat exchangers which can be used at temperatures much in excess of 230°C comprise a stack of tubes (1) held at their respective ends in plates (2,3) formed of fibrous refractory paste (4) set around the tubes.

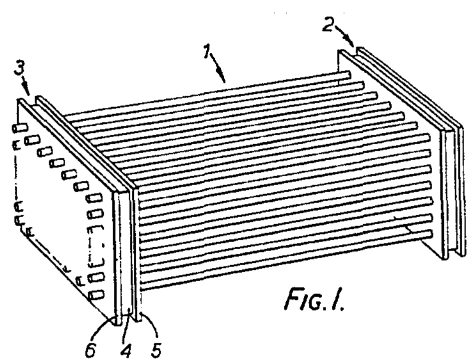

FIG. 1.

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"IMPROVEMENTS IN OR RELATING TO TUBE HEAT EXCHANGERS"

This invention relates to tube heat exchangers, by which is meant heat exchangers comprising a stack of tubes which are held at their respective ends in a plate, to form a unit which is seated in a housing having an inlet and an outlet for a fluid medium to travel across the stack of tubes and an inlet and an outlet for a fluid medium to pass through the tubes themselves.

Tube heat exchangers of the aforementioned type may either be gas/liquid heat exchangers in which liquid is passed through the tubes and a gas travels across the stack of tubes, i.e. externally of the tubes themselves, or a gas/gas heat exchanger in which a first gas passes through the tubes and a second gas travels across the stack of tubes. With gas/gas heat exchangers, it is common practice for the tubes to be formed of a borosilicate glass which is able to withstand temperatures of up to about 500°C. In practice, however, the gases employed generally have to exist at considerably lower temperatures, generally not more than about 230°C. This is because the glass tubes pass through openings in perforated metal plates positioned at their respective ends and are sealed at the plates by means of a resin layer on the metal plates cast around the tubes. This resin seal is usually formed of silicone resin and the casting resins employed generally do not withstand temperatures much above 230°C. An example of a tube heat exchanger of this type is disclosed in U.K. Patent Specification No.1,552,201.

Moreover the casting resins hitherto employed have a tendency to be attacked by many chemicals, such as sulphurous acids which may be present in the gases passed across the stack of tubes to give up their heat content to the gases flowing through the tubes. In an attempt to overcome this problem, U.K. Patent Specification No.2,009,914 proposes the provision of a layer of acid and heat resistant material such as mineral wool or glass wool to allow the resin to be protected from such harmful gases. Such measures complicate the construction of the head exchangers

The aforementioned temperature limitation has proved to be a serious handicap to the widespread adoption of gas/gas heat exchangers in industry where it is generally desired to be able to employ such heat exchangers at temperatures approaching the limits permitted by glass or at even higher temperatures if the tubes are formed of glass ceramic materials such as the material commercially available under the registered trade mark Vicor which are able to withstand temperatures of up to 1000^{o}C.

It is an object of this invention to provide a tube heat exchanger unit construction of such a type that can find use at higher temperatures than hitherto and under aggressive conditions.

According to the present invention, there is provided a tube heat exchanger unit which comprises a stack of tubes which are held at their respective ends in a plate, which unit is for seating in a housing having an inlet and an outlet for a fluid medium to travel across the stack of tubes and an inlet and an outlet for a fluid medium to pass through the tubes, the plates being formed of a fibrous refractory paste set around the tubes of said stack.

The tubes of the heat exchanger unit according to the invention will usually be formed of glass, more particularly borosilicate glass for which there are available appropriate fibre-containing refractory pastes which can be set therearound. Moreover, there are also available fibre-containing refractory pastes (and plates formed therefrom) which are capable of withstanding temperatures above 1000^{o}C and which therefore enable the use of glass ceramic tubes likewise capable of withstanding such temperatures to take place so that gas/gas heat exchange can take place at temperatures of up to about 1000°C. The fibre-containing refractory pastes which are commercially available are formed by mixing refractory fibres with an inorganic binder which is preferably air curing and have the ability to wet glass or glass ceramic material and the tubular heat exchanger may be produced in simple manner by holding the tubes in the required disposition in holes in preformed fibre-containing refractory boards. Pairs of these boards are disposed a suitable short distance from each other, together with removable non-wetting side walls preferably formed of or lined with polyethylene, to form a mould which may be filled with refractory paste which upon drying, and removal of the side walls, forms the respective end plates which will each be a sandwich of a composite fibre-containing refractory between a pair of fibre-containing refractory boards.

Refractory pastes employed in the practice of the present invention will generally contain ceramic fibres in a ceramic matrix. Such material is corrosion resistant to for example sulphurous gases such as may be present in waste gases from combustion plant. Moreover because of the composition thereof, the plates formed from the fibre-containing refractory paste will be relatively flexible about the tubes but perhaps less flexible than a silicone resin seal. Nevertheless thermal stressing is not generally a significant problem because the set paste, more especially its fibres, and the tubes which pass through the plates will have similar coefficients of expansion.

The operating temperature of a tube heat exchanger unit according to the invention, irrespective of the material of the tubes, will depend upon the constitution of the cast fibrous refractory paste and more particularly the refractory fibre content thereof. The refractory fibres contain alumina and silica as their major constituent and it is the proportion of these components which determines primarily the temperature range within which the cast pastes can be employed. In general, there will be employed 30 to 70 parts by weight of alumina, 70 to 30 parts by weight of silica and minor amounts of titania (up to about 2 parts by weight), iron oxide (up to about 1.3 parts by weight), calcium oxide/magnesium oxide (About 0.2 parts by weight), alkali metal oxides (up to about 0.6 parts by weight expressed as Na_2O) and trace quantities of boric oxide. The cement composition may be one of the air setting ceramic fibre and inert binder based compositions commercially available in the United Kingdom under the name "Mackechnie Pre-mix". A composition of such type which is commercially available has a maximum continuous working temperature of 1260°C and for this purpose contains ceramic fibres having the following composition:

Alumina	41% by weight
Silica	56% by weight
Titania	1.5% by weight
Iron oxide Fe_2O_3	0.9% by weight
Calcia/magnesia	0.2% by weight
Alkalis as Na_2O	0.4% by weight
Boric oxide	trace

This material is a homogeneous fibrous refractory paste which can be trowelled or hand moulded and will readily adhere to most surfaces with the exception of polyethylene film. Moulded bodies of this pre-mix will air dry to leave a product having low drying shrinkage and highly resistant to thermal shock.

For a better understanding of the invention and to show how the same can be carried into effect, reference will now be made by way of example only to the accompanying drawings, in which:

Figure 1 is a perspective view of a tube heat exchanger unit embodying this invention; and

Figure 2 is an elevational view of the heat exchanger as it undergoes manufacture.

Referring to Figure 1 of the drawings, a plurality of borosilicate glass tubes 1 arranged in a regular rectangular array are set in end tube plates 2 and 3 respectively. These tube plates are a composite formed of cast fibrous refractory paste 4, namely Mackechnie Pre-mix, and preformed inner and outer refractory boards 5 and 6 respectively, as aforementioned.

The aforementioned procedure for the manufacture of a tube heat exchanger of a type shown in Figure 1 will now be illustrated with reference to Figure 2 which shows in their assembled condition the structural components employed in the production of the tube heat exchanger. As will be apparent from the following description in practice, not all the parts shown are present at any one time.

In a first step, there is attached to each end of supporting bars 12 which are clamped to a central pivot 13 a steel frame work formed in situ from four non-wetting sidewalls 11. At this stage the assembly, which has been constructed is horizontally disposed as shown. Refractory boards 5 are inserted into each end frame 11 and held in place by means of grid frame support 14. An end plate 15A is attached to one end framework. Tubes 1 are passed through holes in the refractory boards 5 with their leading ends coming to terminate at or adjacent the end plate 15A. The assembly is then tilted to an angle of approximately 45^{o} to the horizontal with end plate 15A being at the lowermost position of the assembly. Refractory paste 4 is then applied to the upperface of the refractory board 5 remote from end plate 15A. Application of the refractory cement is by injection so as to cover the face of the refractory board 5 and occupy the spaces between tubes 1 completely. An outer refractory board 6 is then placed over the ends of the tubes 1 so as to make contact with the thick layer of refractory paste which has been formed to form as a sandwich out of the opposed faces of which the tubes 1 project. An outer grid frame 16 is fitted over the upper ends of the tubes 1, entering into engagement with recesses in the upper framework to keep the outer board 6 in position in contact with the refractory cement 4. An end plate 15B is then fitted to the end of the assembly to which the outer board 6 has just been applied.

The assembly is then tilted through 90° so that it is again inclined at 45° to the horizontal but with the end plate 15B representing the lowest part thereof. The end plate 15A is then removed to present the other end of the assembly uppermost for application of refractory cement to the other inner board 5 in a repetition of the aforementioned procedure followed by fitting of an outer refractory board and attachment of an outer grid frame.

The assembly is then returned to the horizontal position and is detached from the central pivot 13. Air curing of the refractory cement is then effected. This will generally take place by placing the assembly in a drying oven where it is maintained for three hours at a temperature of about $200^{\circ}C$. The assembly is then cooled, and all of the famework and the end plates are removed.

Claims:

1. A tube heat exchanger unit which comprises a stack of tubes (1) which are held at their respective ends in a plate (2,3), which unit is for seating in a housing having an inlet and an outlet for a fluid medium to travel across the stack of tubes and an inlet and an outlet for a fluid medium to pass through the tubes, characterised in that the plates (2,3) are formed of fibrous refractory paste (4) set around the tubes of said stack.

2. A tube heat exchanger unit according to claim 1, characterised in that the tubes (1) are formed of glass, in particular borosilicate glass.

3. A tube heat exchanger unit according to claim 1, characterised in that the tubes (1) are formed of glass ceramic and the fibrous refractory paste (4) has the capability of withstanding temperatures above 1000^{o}C without failure of the plates occurring.

4. A tube heat exchanger unit according to any one of the preceding claims, characterised in that the refractory paste contains refractory fibres composed of:

30 to 70 parts by weight alumina
70 to 30 parts by weight silica
up to 2 parts by weight titania
up to 1.3 parts by weight ferric oxide
about 0.2 part by weight CaO/MgO
up to 0.6 part by weight alkali metal oxides, and
trace amounts of boric oxide.

5. A tube heat exchanger unit according to claim 4, characterised in that the refractory fibres are composed of:

alumina	41% by weight
silica	56% by weight
titania	1.5% by weight
ferric oxide	0.9% by weight
calcia/magnesia	0.2% by weight
Na_2O	0.4% by weight
boric oxide	trace.

6. A tube heat exchanger unit according to any one of the preceding claims characterized in that each plate (2,3) is set between preformed refractory boards (5,6).

7. A method for the production of a tube heating exchanger unit according to any one of claims 1 to 5, characterized in that an array of tubes (1) is positioned in holes of adjacent pairs (5) and (6) of preformed fibre-containing refractory boards (5), which pairs of boards are associated with non-wetting sidewalls (11) to form moulds into which a said fibrous refractory paste (4) is placed and dried before removing the sidewalls (11).

8. A method for the production of a tube heat exchanger unit according to claim 7, characterized in that the non-wetting sidewalls (11) are formed of or lined with polyethylene.

9. A method as claimed in 7 or 8, characterized in that moulds formed of non-wetting sidewalls (11) are first attached to substantially horizontal pivotable support means (12,13) at positions spaced apart at a distance approximating to the length of said unit, preformed refractory boards (5) having aligned openings for said tubes are positioned in said moulds as bottoms therefor, the tubes (1) are inserted through the openings in said boards, the support means (12,13) is tilted and while retaining the tubes in said boards refractory cement (4) is applied to the uppermost refractory boards surface of the assembly thus produced, the refractory cement is covered by another said refractory board (6) passed over the ends of the tubes thereadjacent, the assembly is tilted into an opposite disposition and while retaining the tubes (1) in said boards (5,6), refractory cement (4) is applied to the then uppermost board surface before being covered by another said refractory board (6) passed over the ends

of the tubes thereadjacent, the assembly is returned to a substantially horizontal disposition and the cement is then cured.

10. A method as claimed in claim 9, characterized in that the assembly is tilted to an angle of about 45° to the horizontal when the refractory cement is applied.

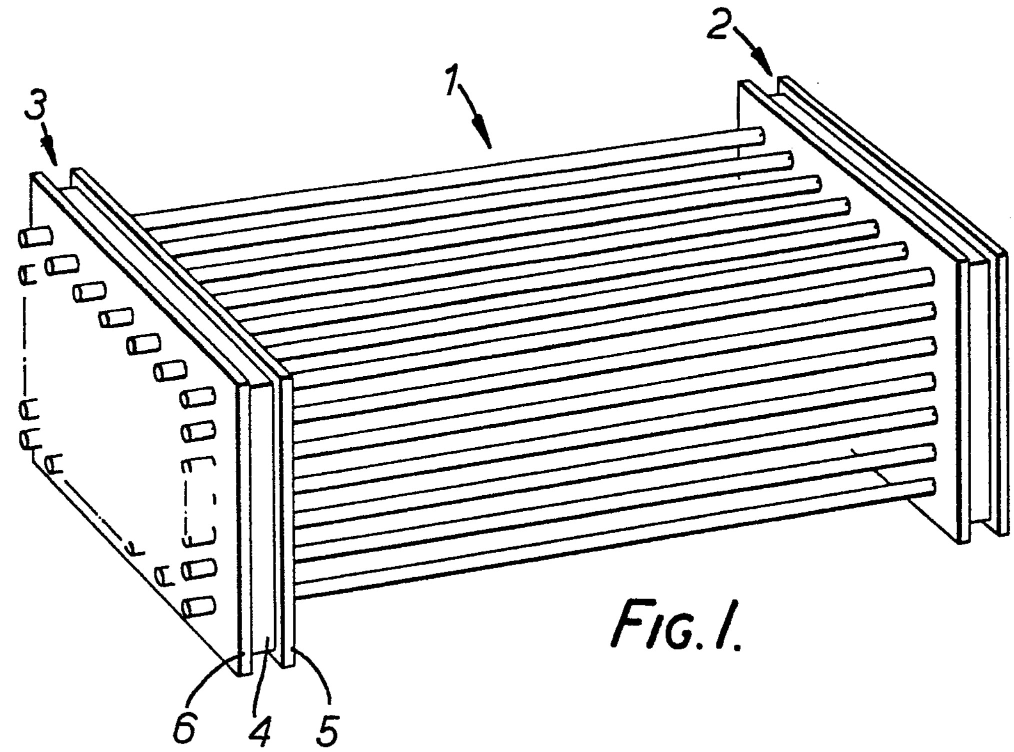

FIG. 1.

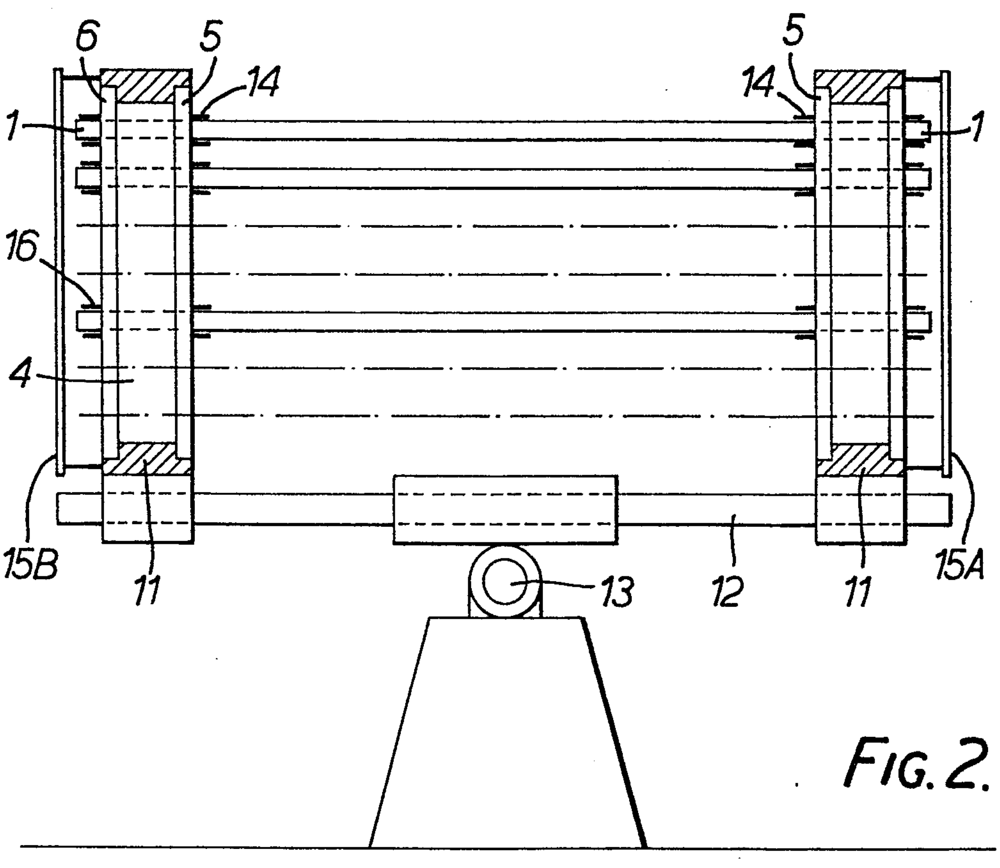

FIG. 2.

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EUROPEAN SEARCH REPORT

Application number

EP 83 30 2479

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)
			F 28 F 21/00 F 28 F 9/16
Y	GB-A-2 022 490 (NORTON) * Page 2, lines 7-65 * ---	1,4	
Y	FR-A-2 356 494 (A.C.B.) * Page 3, lines 9-27; page 6, lines 9-16; figures 1,2 * ---	1,7,8	
A	DE-A-2 440 535 (QVF GLASTECHNIK) * Page 4, lines 8-13; figure 1 * ---	1,2	
A	US-A-4 122 894 (LAWS) * Column 2, line 64 - column 3, line 5; figures 1,2 * ---	1,4	
A	US-A-4 130 160 (DZIEDZIC) * Column 4, line 40 - column 5, line 46 * ---	3-5	TECHNICAL FIELDS SEARCHED (Int. Cl. 3)
A	US-A-3 422 884 (OTTEN) * Column 3, lines 8-52; figures 4-6 * ---	6,7	F 28 F
A	FR-A-1 397 694 (LLOYD-ROACH) * Page 2, right-hand column, lines 41-49; figure 3 * ---	9	
A	US-A-3 266 129 (FRÖHLICH) * Column 3, lines 25-29; figures 2,3 * --- -/-	9,10	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	29-07-1983	SCHOUFOUR F.L.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
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T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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EUROPEAN SEARCH REPORT

0093612

Application number

EP 83 30 2479

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- 994 934 (CORNING GLAS)		

A	US-A-3 506 249 (COOPER)		

TECHNICAL FIELDS SEARCHED (Int. Cl. 3)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	29-07-1983	SCHOUFOUR F.L.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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