United States Patent

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[33] **Great Britain**
[31] **1309/69**

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[54] **CERAMIC RECUPERATORS**
6 Claims, 7 Drawing Figs.

[52] **U.S. Cl.** **263/20,** 165/144
[51] **Int. Cl.** **F27l 15/04**
[50] **Field of Search** 263/20; 165/144, 145, 148

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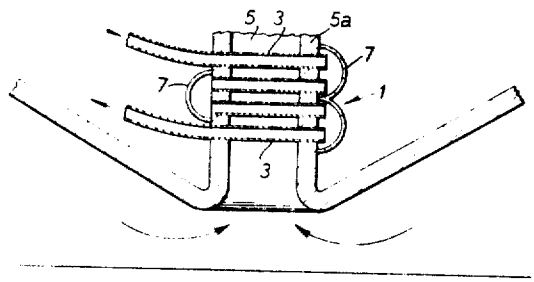
ABSTRACT: A recuperator suitable for location in the waste-gas offtake of a slab reheating furnace or soaking hearth. The recuperator includes a plurality of integrally formed tubes of ceramic material extending with clearance into each of oppositely facing portions of the offtake duct and communicating at their ends with header boxes sealed to the outside of the duct. The header boxes connect the tubes in series so that fluid to be heated during use of the recuperator pass sequentially through the series connected tubes. The clearance between one end of each tube and the duct wall is sealed by an annular seal disposed in the region of the outside surface of the duct wall, said one end being slidable relative to its respective seal to allow for longitudinal tube expansion.



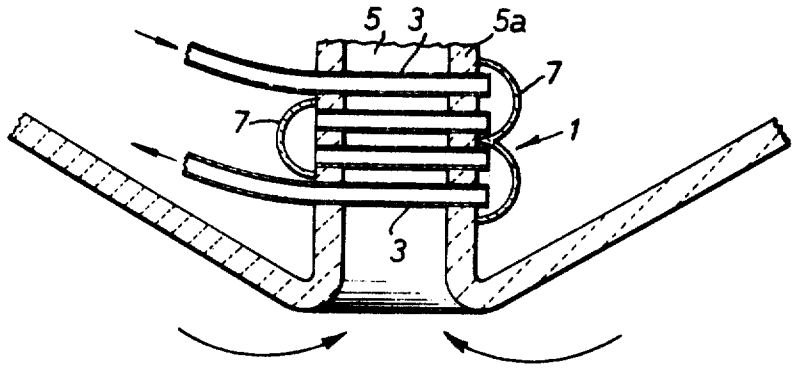


FIG. 1.

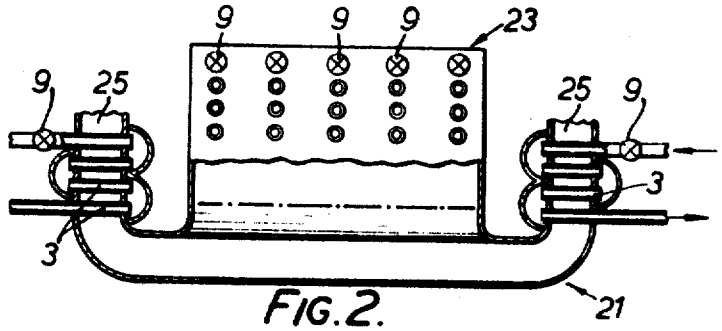


FIG. 2.

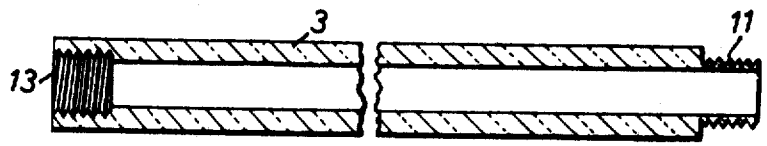


FIG. 3.

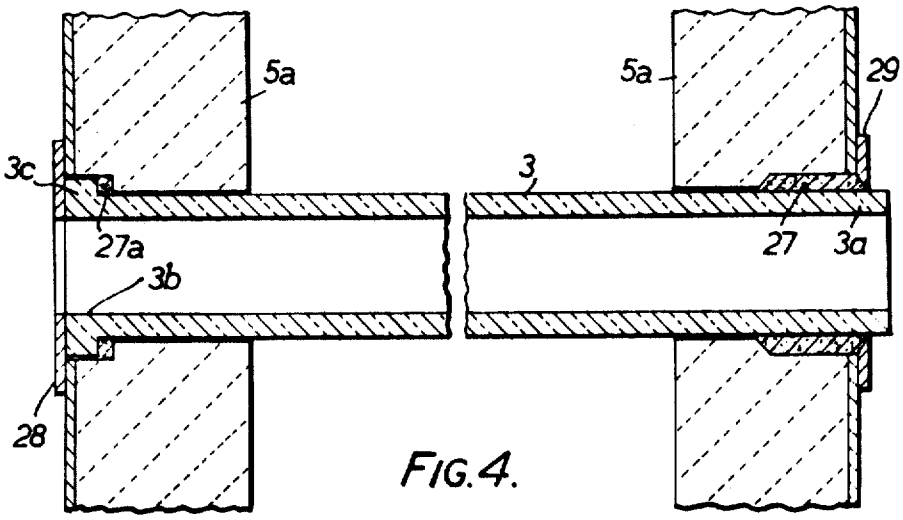


FIG. 4.

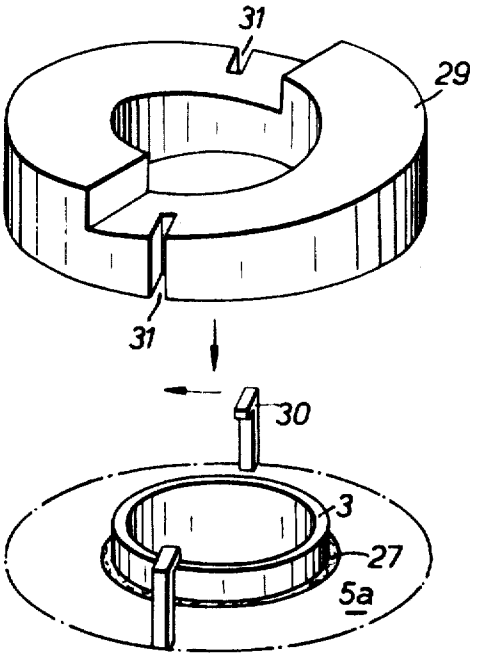


FIG. 5.

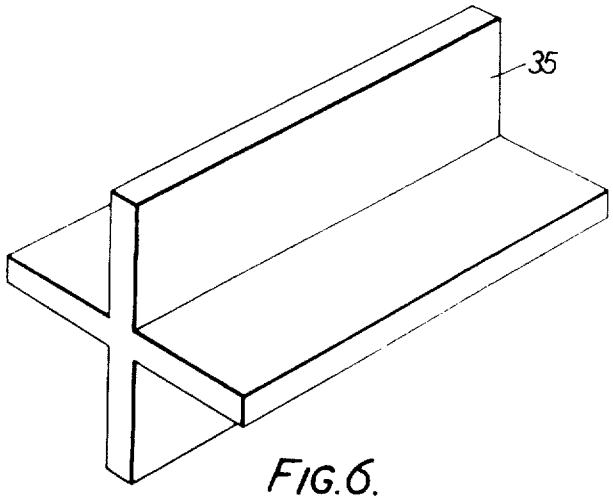


FIG. 6.

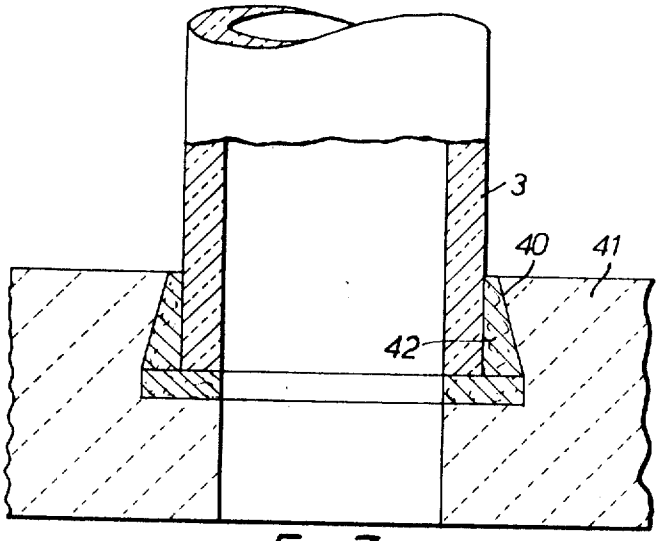


FIG. 7.

CERAMIC RECUPERATORS

This invention relates to recuperators.

It is an object of the invention to provide a recuperator which is suitable for location in the waste-gas offtake of a slab reheating furnace or soaking hearth.

According to the invention, there is provided a recuperator for transferring heat from a first, hotter, fluid to a second, colder, fluid, comprising a duct for the passage therethrough of the first fluid, a plurality of integrally formed tubes of ceramic material extending with clearance into each of oppositely facing portions of the duct wall and communicating at their ends with header boxes sealed to the outside surface of the duct wall, the header boxes connecting in series at least some of the tubes so that the second fluid, during use of the recuperator, passes sequentially through the series connected tubes, the clearance between the outer surface of one end of each tube and the duct wall being sealed by an annular seal disposed in the region of the outside surface of the duct wall, each said one end being slidable relative to its respective seal to allow for tube expansion in a longitudinal direction.

Features and advantages of the invention will be apparent from the following description of an embodiment thereof given, by way of example only, in conjunction with the accompanying drawings, in which:

FIG. 1 shows diagrammatically a recuperator according to the invention located in a central waste-gas offtake of a slab reheating furnace;

FIG. 2 shows diagrammatically in transverse section a top and bottom fired slab reheating furnace having recuperators according to the invention located in the waste-gas offtakes thereof;

FIG. 3 is a part longitudinal section through a ceramic tube of the recuperator of FIG. 1;

FIG. 4 shows in detail one form of assembly of a tube into the duct wall of the recuperator of FIG. 1;

FIG. 5 shows a clamping plate for putting under compression the sliding seal of the recuperator of FIG. 1;

FIG. 6 shows a perspective view of an insert for the tubes of the recuperator according to the invention; and

FIG. 7 shows the lower end of a vertically mounted tube of a recuperator according to the invention.

Referring to the drawings, the recuperator 1 includes a central waste-gas offtake duct 5 of a slab reheating furnace, and a plurality of horizontally disposed, integrally formed, tubes 3 of ceramic material extending with clearance into each of oppositely facing portions of the duct wall 5*a* and communicating at their ends with header boxes 7 sealed to the outside surface of the duct wall, the header boxes connecting in series at least some of the tubes so that combustion air to be heated passes sequentially through the series connected tubes. As will be seen from FIG. 4, the clearance between the outer surface of one end 3*a* of each tube and the duct wall 5*a* is sealed by an annular seal 27 disposed in the region of the outside surface of the duct wall and hence in the relatively cool low-pressure zones defined by the header boxes 7, the ends 3*a* of the tube being slidable relative to the seal 27 to allow for tube expansion in a longitudinal direction.

The clearance between the outer surface of the other end 3*b* of each tube and the duct wall 5*a* is sealed by a further seal 27*a*, the end 3*b* being held against sliding movement relative to its respective further seal by means of a clamping plate 28 secured to the outside surface of the duct wall 5*a* and operable to urge a flange 3*c* formed on the tube at end 3*b* into sealing engagement with seal 27*a*. Each seal 27 has a length dimension along the length of the tube greater than the seal thickness and in its uncompressed state extends beyond the outside surface of the duct wall 5*a*, the seal being compressed in the direction of the length by a clamping ring 29 held to the outside surface of duct wall 5*a*; the ring 29 may be secured to the duct wall by bolts (not shown), or, as is shown in FIG. 5, by a bayonet fitting consisting of lugs 30 extending from the outer surface of duct wall 5*a* and cooperable recesses 31 in the ring 29.

The seals 27 and 27*a* are preferably of a fibrous refractory material such as alumina silicate wool, and a suitable dimension for seal 27 is length 1½ inches and thickness one-half inch.

The tubes are of high heat-conducting ceramic material such as silicon carbide which is self-bonded, or bonded by silicon nitride, alumina, ethyl silicate or clay bonding material, and leakage through the walls of the tubes can be reduced to a low level by the application of a suitable glazing material to the inside and/or outside surface of the tubes.

In order to reduce to a minimum the air pressure drop through the tubes, the number of tubes connected in series should be kept to a minimum since pressure drop is proportional to the number of tubes and approximately proportional to the square of the velocity of airflow which in turn is dependent on the number of tubes; for example if the pressure drop is to be limited to 8 inches water gauge, a bank of tubes having a maximum of five tubes in series is allowable. The tube length should therefore be as long as possible; at the present time a maximum length for the ceramic tubes is 6 feet. To increase the amount of air flowing through the recuperator, a plurality of such banks of tubes are provided defining a plurality of parallel airflows through the recuperator.

Selection of the optimum internal diameter of the tubes is not straightforward. On the one hand a small diameter is better for heat transfer, but this advantage is outweighed by the attendant disadvantages of increased costs, greater leakage potential, and larger airflow resistance. After careful study, a large internal diameter of 10 cm. was selected, the outside diameter of the tubes being 14 cm. Also, to provide further improvements in heat transfer, the tubes do not lie in rows parallel to the direction of waste-gas flow through the recuperator (as shown in FIG. 2) but are staggered.

Referring to FIG. 6, the heat transfer of each tube is further increased by the insertion within the tube of a core 35 of cross cross section; the inserts are of materials having properties similar to those of the tube materials, and in addition to the above mentioned materials, high-temperature steel could be used.

Calculations have indicated that the insert could decrease the tube wall to aid side temperature drop required for a given heat flow by 65 percent; this enables the number of tubes to be reduced by 40 percent. Additional advantages provided by the insert are:

1. If the insert is made in one piece, the strength of the tube is increased.
2. By increasing the air side heat transfer coefficient, the overall temperature of the tube is reduced.
3. By reducing the number of tubes, the total leakage is reduced.

In the embodiments described above the tubes 3 have been shown with their longitudinal axes horizontal. However, the tube axes may be mounted vertically as shown in FIG. 7; the lower end of the tube is received in a recess 40 in the upper face of a horizontal recuperator wall 41 and is surrounded and sealed by a seal 42.

In the event of tube damage, airflow control valves 9 (see FIG. 2) are provided in each bank to enable the bank with the waste-gas tube to be closed down to permit the installation of a replacement tube. To remove the damaged tube, the tubes are provided with a male thread 11 (see FIG. 3) at one end a female thread 13 at the other end, the replacement tube being screwed into one of the ends to facilitate extraction of the damaged tube.

Referring to FIG. 2, a top and bottom fired reheating furnace 21 is provided with one of the above described recuperators in a central waste-gas offtake 23 for preheating combustion air for the top burners of the furnace by means of the gases leaving therefrom, and also in each of two side waste-gas offtakes 25 for preheating combustion air for the bottom burners of the furnace by means of the gases leaving therefrom; to reduce the width of the furnace to a minimum the tubes of the recuperators in the offtakes 25 are disposed at right angles to those in the offtake 23.

Although the recuperator has been described above for use with a top and bottom fired furnace, the recuperator is also suitable for use with a top fired slab reheating furnace.

We claim:

1. A recuperator for transferring heat from a first, hotter, fluid to a second, colder, fluid, comprising a duct for the passage therethrough of the first fluid, a plurality of integrally formed tubes of ceramic material extending with clearance into each of oppositely facing fixed portions of the duct wall and communicating at their ends with header boxes sealed to the outside surface of the duct wall, the header boxes connecting in series at least some of the tubes so that the second fluid, during use of the recuperator passes sequentially through the series connected tubes, the clearance between the outer surface of one end of each tube and the duct wall being sealed by an annular seal disposed in the region of the outside surface of the duct wall, each said one end being slidable relative to its respective seal to allow for tube expansion in a longitudinal direction, each said seal having a length dimension along the length of a respective tube greater than the seal thickness, and wherein means are provided to apply a compressive force to the seal in the direction of its length, which force is reacted against the adjacent duct wall.

2. A recuperator according to claim 1, in which each said seal in its uncompressed state extends beyond the outside surface of the duct wall and the means to apply a compressive force is an annular clamping ring operable to be held by means of a bayonet fitting to the duct wall.

3. A recuperator according to claim 1, wherein the clearance between the outer surface of the other end of each tube and the duct wall is sealed by a further seal, each other end being held against sliding movement relative to its respective further seal.

4. A recuperator according to claim 3, wherein each other end is held by means of a clamping means secured to the outside surface of the duct wall and operable to urge a flange formed on the tube at said other end into sealing engagement with said further seal.

5. A recuperator according to claim 1, wherein the bore surface at an end of said tube is screw-threaded or otherwise shaped to facilitate the removal of a defective tube from the recuperator.

6. A recuperator according to claim 5, wherein the outside surface at an opposite end of said tubes is screw-threaded or otherwise shaped so that a similar replacement tube may be screwed into the screw threads of the bore of a defective tube to enable the removal of the defective tube.