Jan. 29, 1963 W. L. DAVIS, JR 3,075,580

HEAT EXCHANGER AND METHOD

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FIG. 1.

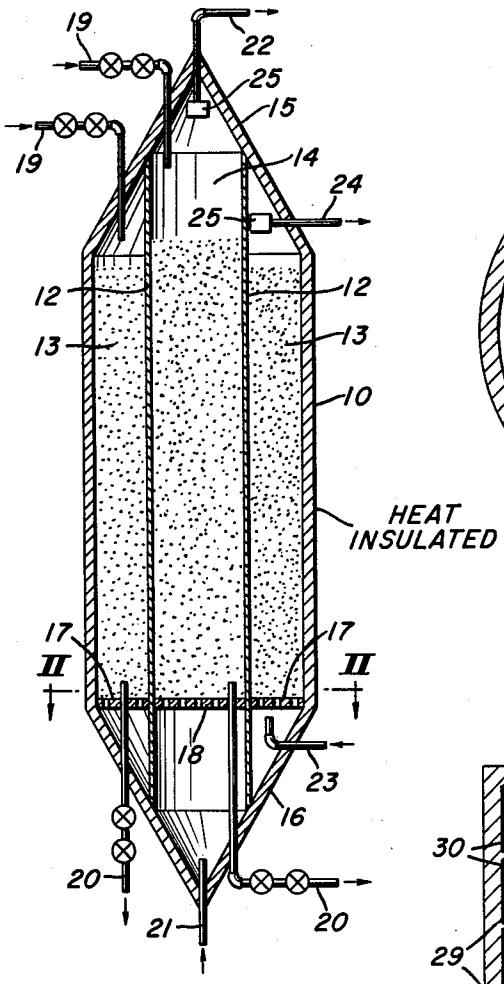


FIG. 3.

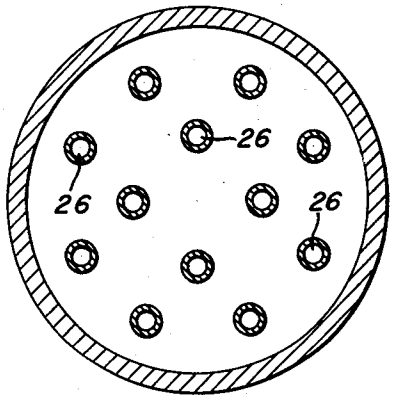


FIG. 4.

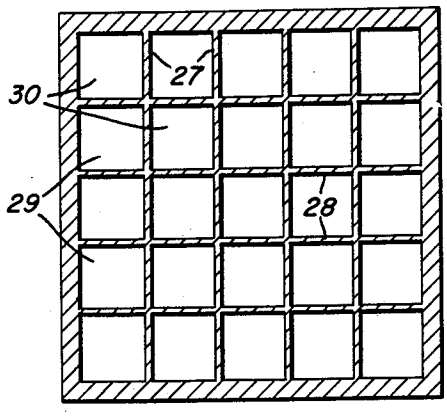
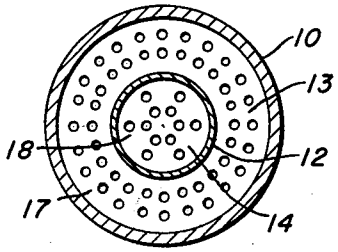


FIG. 2.



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FIG. 5.

COUNTERCURRENT SYSTEM

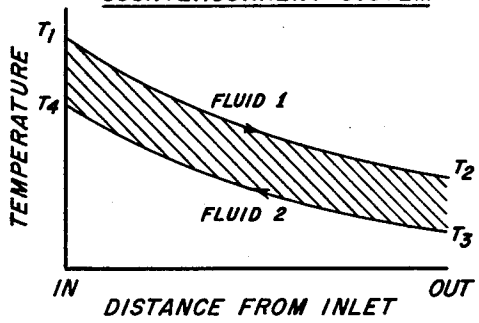


FIG. 6.

COCURRENT SYSTEM

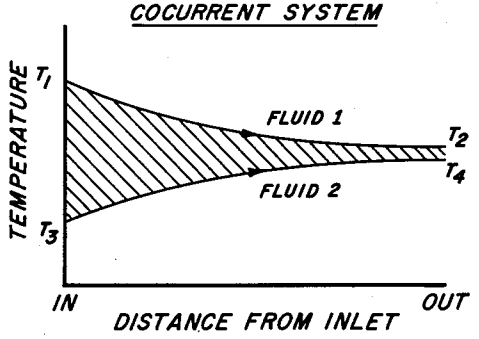
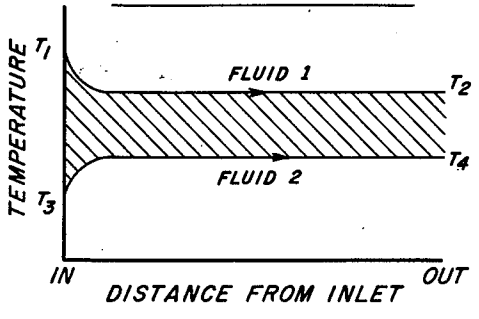


FIG. 7.

FLUIDIZED BED SYSTEM



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HEAT EXCHANGER AND METHOD

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2 Claims. (Cl. 165—1)

This invention relates to an improved recuperative-type heat exchanger and heat exchanging method.

The present application is a continuation-in-part of my earlier co-pending application Serial No. 476,969, filed December 22, 1954, and now abandoned.

In a recuperator which utilizes a gas to heat or cool another gas, each gas has its own flow passage out of communication with the other. The passages are separated by walls of heat conductive metal, and one means for increasing the rate of heat transfer between them is to include static beds of solid particles within one or both passages. Flow of the two gases can be either countercurrent or cocurrent, but in either event there is a substantial heat gradient between the inlet and outlet. This gradient creates thermal stresses within the equipment, which is thereby mechanically weakened. The coefficient of heat transfer, and hence the efficiency, usually changes with the temperature and varies in different parts of the apparatus.

An object of the present invention is to provide an improved recuperative-type heat exchanger and heat exchanging method applicable to gases wherein temperature gradients are substantially eliminated.

A more specific object is to provide a recuperative-type heat exchanger and method involving recuperative principles in which both flow systems contain beds of fluidized solids each maintained at a uniform temperature by vertical back mixing, thereby promoting efficient heat transfer therebetween and eliminating the usual temperature gradient.

In accomplishing these and other objects of the invention, I have provided improved details of structure, preferred forms of which are shown in the accompanying drawings, in which:

FIGURE 1 is a diagrammatic vertical longitudinal section of one form of heat exchanger constructed in accordance with my invention;

FIGURE 2 is a diagrammatic cross section on line II—II of FIGURE 1;

FIGURE 3 is a diagrammatic cross section of a modification;

FIGURE 4 is a diagrammatic cross section of another modification;

FIGURE 5 is a graph showing a typical relation between two fluids in a conventional countercurrent recuperative heat exchange system;

FIGURE 6 is a similar graph in a conventional cocurrent system; and

FIGURE 7 is another similar graph in a cocurrent fluidized bed system in accordance with my invention.

The heat exchanger shown in FIGURES 1 and 2 comprises outer and inner cylindrical walls 10 and 12 which define an annular flow passage 13 and a central cylindrical flow passage 14. The outer wall 10 is insulated to prevent loss of heat therethrough, while the inner wall 12 is of heat conductive material. Preferably the outer wall has conical upper and lower end portions 15 and 16. A perforate member 17 (for example, a screen or a perforated plate) is fixed within the outer wall 10 and extends across the annular passage 13 adjacent the bottom. A circular perforate member 18 is similarly fixed within the inner wall 12 and extends across the cylindrical passage 14 adjacent the bottom. The inner wall 12

is impervious throughout, whereby there is no communication between the passages 13 and 14.

Both passages 13 and 14 contain captive beds of finely divided solids, referred to in the art as a "thermophore," supported on the perforate members 17 and 18. The thermophore can be any of numerous materials that have high heat capacity, melting points higher than the temperature encountered, and are not reactive to the gases involved. Examples of materials suitable for use with hot gases are silica, silicon carbide, alumina, or hematite, and with cold gases powdered metals. The thermophore is of a particle size preferably between 10 and 100 mesh, smaller sizes being avoided to minimize dust losses. There is an approximately uniform size distribution of particles between the two extremes. The two passages are equipped with upper and lower pipes 19 and 20, each of which contain a pair of normally closed valves for introducing or removing the thermophore. The minimum bed depth is about 3 feet and the minimum horizontal dimension about 4 inches. With a bed of circular cross section and minimum diameter, the maximum depth-to-diameter ratio is about 20. This ratio is important with small diameters because too great a depth hinders vertical back mixing, but becomes less important as the horizontal dimension increases.

The gas whose temperature is farther from that of the surrounding atmosphere (either higher or lower), is introduced to the bottom of the central passage 14 via an inlet 21 and discharges from the top via an outlet 22. The other gas, which is to be heated or cooled, is introduced to the bottom of the annular passage 13 via an inlet 23 and discharges at the top via an outlet 24. Preferably the outlets 22 and 24 are equipped with dust collectors 25 shown only schematically. The gas streams in both the passages 13 and 14 travel upwardly in a cocurrent direction and at a sufficient velocity (superficially 0.5 to 2 feet per second) to fluidize the thermophore beds within these passages. In accordance with known principles, these beds physically resemble boiling liquids. They have an apparent density of 30 to 130 pounds per cubic foot. The particles in the central passage 14 quickly and uniformly acquire the temperature of gas therein, and by their movement transmit this temperature through the inner wall 12 to the particles in the annular passage 13. The gas in the latter passage quickly and uniformly acquires the temperature of the particles therein. There is little or no temperature gradient within either bed because of the vertical back mixing which results under the conditions I have described.

FIGURE 3 shows a modification in which the single central passage is replaced by a plurality of internal passages 26. FIGURE 4 shows a modification in which the heat exchanger is of rectangular cross section and is divided by a series of partitions 27 and 28 into passages 29 and 30 of rectangular cross section. The passages 29 carry one substance and the passages 30 the other. The passages in these modifications contain thermophore, and the modifications operate in the same fashion as the embodiment shown in FIGURES 1 and 2. However, they may furnish more efficient heat transfer since the passages are of relatively smaller cross section. The form shown in FIGURE 3 is particularly useful for supplying or removing heat of a chemical reaction.

FIGURES 5, 6 and 7 illustrate typical temperature relations between two gases in different recuperative heat exchange systems where no exothermic or endothermic reaction occurs. In a conventional countercurrent system shown in FIGURE 5 both gases have a decreasing temperature gradient from the hot gas inlet to the hot gas outlet. In a conventional cocurrent system shown in FIGURE 6 the hot gas has a decreasing temperature

gradient from its inlet to its outlet, while the cooler gas has an increasing gradient. In a fluidized bed system shown in FIGURE 7 there is virtually no temperature gradient except immediately adjacent the inlet. This absence of temperature gradient has several important advantages. Thermal stresses are virtually eliminated, since all parts of the apparatus are at the same temperature, thereby simplifying mechanical design, increasing equipment life and cutting maintenance costs. Throughout the apparatus there is a uniform rate of heat transfer, the coefficient of which usually varies with the temperature. Uniform temperature overcomes any localized overheating.

While I have shown and described certain preferred embodiments of my invention, it is apparent that other modifications may arise. Therefore, I do not wish to be limited to the disclosure set forth but only by the scope of the appended claims.

I claim:

1. A recuperator comprising an insulated outer wall defining a first passage, a heat conductive inner wall spaced within said outer wall defining a second passage surrounded by said first passage in heat exchange relation thereto, both said passages having a minimum horizontal dimension of about 4 inches, perforate members extending across each of said passages adjacent the bottoms thereof, beds of finely divided thermophore of a uniformly distributed particle size approximately between 10 mesh and 100 mesh and adapted for fluidization and vertical back mixing in each of said passages supported on said members, said beds having a minimum depth of about 3 feet, gas inlets to the bottoms of said passages below said members for introducing upwardly flowing cocurrent streams of gases to said beds to fluidize them and to transfer heat from one gas to the other through

said inner wall, gas outlets from said passages above said beds, and means positively confining said thermophore to the respective passages.

2. A recuperative method of exchanging heat between two gases comprising passing a stream of the gas whose temperature is nearer that of the surrounding atmosphere in an upward direction at a superficial velocity of 0.5 to 2 feet per second through a first bed of finely divided solids chemically inert to this gas and of a uniformly distributed particle size approximately between 10 mesh and 100 mesh and thus effecting fluidization and vertical back mixing of the first bed, simultaneously passing a stream of the gas whose temperature is farther from that of the surrounding atmosphere in an upward direction at a superficial velocity of 0.5 to 2 feet per second cocurrent to the first gas through a second bed of finely divided solids chemically inert to the second gas and of a uniformly distributed particle size approximately between 10 mesh and 100 mesh and thus effecting fluidization and vertical back mixing of the second bed, and positively confining the solids in both beds to their original passages out of contact with each other, said first bed surrounding said second bed in heat exchange relation to effect transfer of heat therebetween, the vertical back mixing minimizing the temperature gradient within each bed.

References Cited in the file of this patent

UNITED STATES PATENTS

1,716,333	Vuilleumier	June 4, 1929
2,520,637	Henwood	Aug. 29, 1950
2,698,171	Schoenmakers et al.	Dec. 28, 1954
2,779,716	Neuman	Jan. 29, 1957
2,858,110	Blaskowski	Oct. 28, 1958