

March 25, 1952

K. B. RIS
HEAT EXCHANGER

2,590,465

Filed Nov. 14, 1944

2 SHEETS—SHEET 1

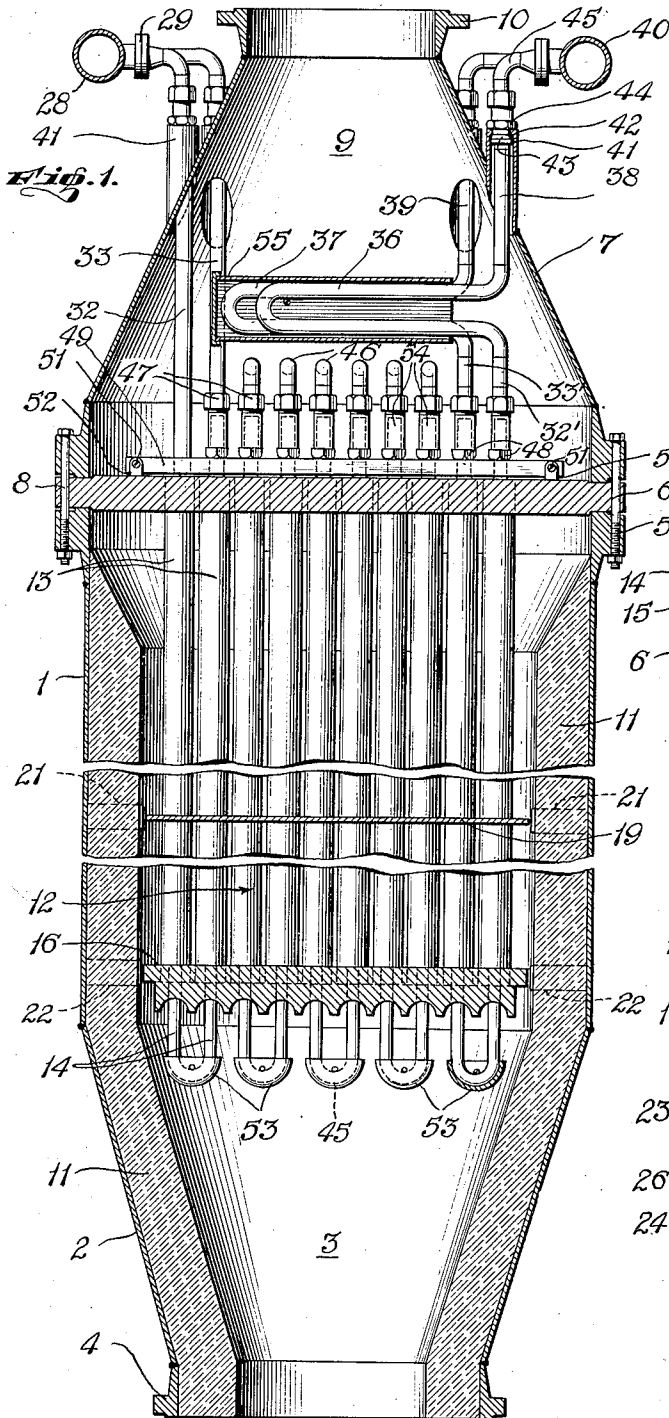
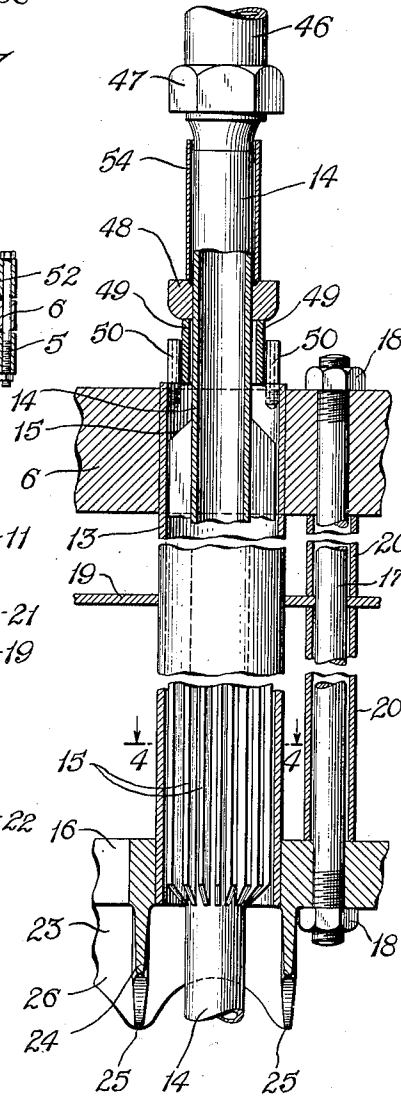


Fig. 3.



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2 SHEETS—SHEET 2

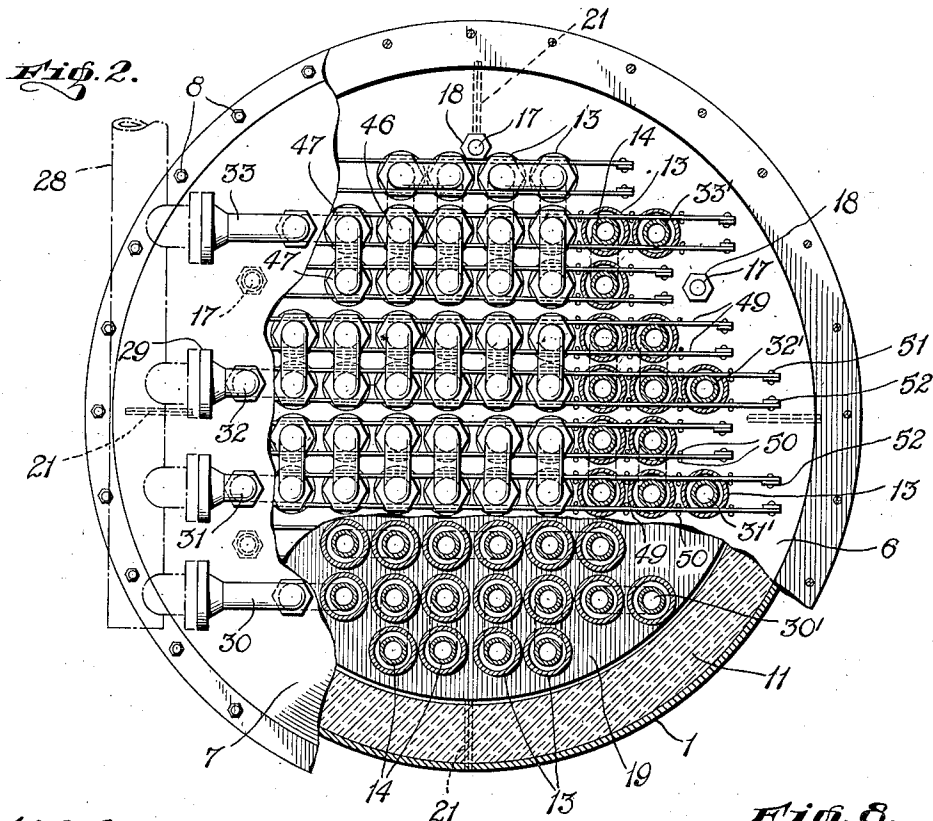


Fig. 4.

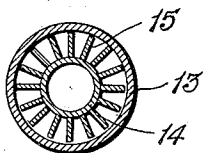


Fig. 8.

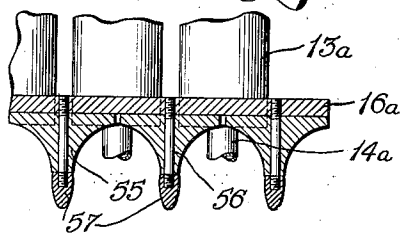


Fig. 6.

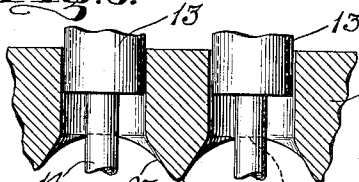


Fig. 7.

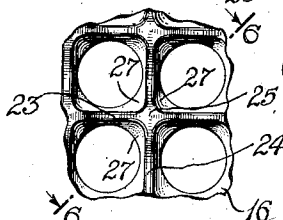
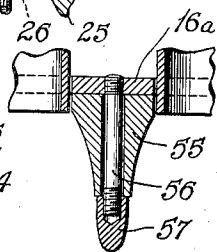


Fig. 5.

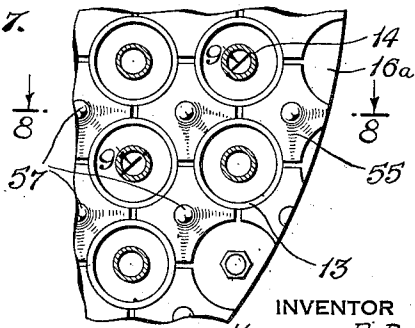


Fig. 9.

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HEAT EXCHANGER

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4 Claims. (Cl. 257-228)

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This invention relates to heat exchange apparatus, and, more particularly, to heat exchangers for cooling powdered solid material with which is mixed a sufficient amount of gaseous material to cause the powdered material to flow like a fluid through the exchanger.

Certain types of catalysts are employed in finely divided form and when used in carrying out certain chemical reactions become contaminated with carbon. Such catalysts may be reactivated by burning the carbon from the individual particles of the catalyst. This may be accomplished in a reactivating chamber wherein provision is made for suitably controlling the rate of combustion. To this end the powdered catalyst is recirculated between the reactivating chamber and a heat exchanger. Ordinarily the heat exchanger is located at a lower level than the reactivating chamber, for example, on a lower floor of the building.

The powdered catalytic material flows by gravity from the reactivating chamber through a suitable conduit to approximately the level of the bottom of the heat exchanger and may have a density of approximately 25 pounds per cubic foot. At the lowest point of its travel gaseous material in the form of an inert gas is introduced into the catalyst mass, lowering the density of the mixture to about 1.1 pounds per cubic foot. In this condition the finely divided solid and gas mixture is caused to rise through the heat exchanger and then return to the reactivating chamber, the purpose of the heat exchanger being to control the average temperature existing in the reactivating chamber. The temperature of the mixture entering the inlet chamber at the bottom of the heat exchanger may be in the neighborhood of 1100° F. and its temperature as it leaves the outlet chamber at the top of the heat exchanger may be in the neighborhood of 950° F.

The object of the present invention is to provide a heat exchanger to meet these requirements. A number of problems are involved on account of the comparatively high average temperature of operation, the temperature differences between different parts of the apparatus, the eroding effect of the finely divided solids and the necessity of maintaining reasonably uniform velocity of flow of the finely divided solid and gas mixture throughout the heat exchanger in order to avoid such a low velocity that the solid material will not be carried along by the gaseous material and in order to avoid such high velocity as to produce damaging erosion.

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Another object of the invention is to provide a heat exchanger for the purpose described which can be taken apart without difficulty or undue expense in order to clean both sides, that is, both the passages for the fluid and the passages for the mixture of gaseous and finely divided solids.

The invention will be understood from a consideration of the accompanying drawings illustrating one embodiment of the invention by way of example. In these drawings:

Fig. 1 is a view of the heat exchanger in vertical central section;

Fig. 2 is a plan view of the heat exchanger with certain parts broken away to show the heat exchanger tube layout and with certain of the tubes and a portion of the heat exchanger shell shown in horizontal section;

Fig. 3 is a view in vertical section drawn to an enlarged scale showing the details of a single heat exchange element, the arrangement for supporting its two concentric tubes and the arrangement for directing the gaseous mixture into the lower end of the element;

Fig. 4 is a horizontal section taken on line 4-4 of Fig. 3;

Fig. 5 is a bottom plan view of a fragment of the lower tube supporting and mixture directing plate;

Fig. 6 is a section taken on line 6-6 of Fig. 5;

Fig. 7 is a fragmentary bottom plan view of the lower tube supporting plate, showing a modification;

Fig. 8 is a section taken on line 8-8 of Fig. 7; and

Fig. 9 is a section taken on line 9-9 of Fig. 7.

Referring now to the accompanying drawings, the heat exchanger comprises a cylindrical shell 1 of any suitable length and diameter, but the length usually being several times the diameter, making an elongated structure. At its lower end the cylindrical shell terminates in a conical portion 2 within which is the inlet chamber 3 for the mixture of gaseous and finely divided solid materials. Conical portion 2 is provided at its lower end with a suitable inlet connection 4.

At its upper end cylindrical shell 1 has a flange 5 by means of which a tube sheet 6 and a conical hood 7 are secured to it through the instrumentality of a series of bolts 8. Within the hood 7 is the mixture outlet chamber 9 which extends from the top of the tube sheet 6 to the outlet connection 10 at the top. The interior walls of inlet chamber 3 and of cylindrical shell 1 are lined with a substantial thickness of insulation 11.

The heat exchanger mechanism, which may for

convenience be referred to as the tube bundle 12, consists of a plurality of shell tubes 13 for conveying the mixture of gaseous and finely divided solid materials, and within which is mounted a tube 14 for the fluid, in this case a cooling fluid, tube 14 being of considerably smaller diameter than shell tube 13 and preferably provided with external longitudinal fins 15. One such element 13, 14 of the tube bundle 12 is illustrated in Fig. 3. The cooling fluid passes through the interior of tube 14 and the mixture of gaseous and finely divided solid materials passes upwardly between the fins 15 through the annular space bounded by the outside surface of tube 14 and the interior walls of shell tube 13.

The shell tubes 13 are fitted at their upper ends into apertures in tube sheet 6. The heat exchange elements 13, 14 extend downward from tube sheet 6 to the inlet chamber 3 where the shell tubes 13 are held in suitably spaced relation by means of a floating plate 16, the lower ends of tubes 13 being received in perforations in plate 16. Floating plate 16 also serves as a partition for directing the mixture into shell tubes 15. It is suspended from tube sheet 6 by means of rods 17 having substantially the same coefficient of expansion as the heat exchange elements and having holding nuts 18 threaded on their upper and lower ends. A thin perforated plate 19 may be placed intermediate tube sheet 6 and floating plate 16 for the purpose of providing lateral support for the heat exchange elements. This plate 19 is also supported on rods 17 and the position of the plate as well as the spacing of tube sheet 6 and plate 16 is maintained by means of sleeves 20 surrounding rod 17.

Perforated plate 19 and floating plate 16 are maintained in centered relation to cylindrical shell 1 of the apparatus by means of vertical guide strips 21 and 22 (Fig. 1). There are four of these guide strips 21 cooperating with the periphery of plate 19 at points 90° apart, as may be seen in Fig. 2. Guide strips 22 are similarly arranged to coact with the periphery of floating plate 16. Guide strips 21 and 22 extend radially inward from the interior of shell 1 slightly more than the thickness of insulation 11. They loosely engage the edges of plates 19 and 16; hence the tube bundle 12 may be easily inserted and removed from shell 1 for cleaning purposes. Insulation 11 may, if desired, be provided with an interior metal sheathing to assist in holding the insulation in place and to prevent damage thereto through the insertion or removal of tube bundle 12.

The heat exchange elements 13, 14 are so arranged, as shown in plan view, Fig. 2, as to cause the tube bundle 12 to substantially fill the central space within the exchanger. Such spaces as are left between the outside tubes and the surface of insulation 11 and between the various shell tubes constitute dead spaces, that is to say, there is no circulation other than that which may be produced thermally. Such spaces become filled with the mixture of inert gas and finely divided solids, which works its way upward around the periphery of floating plate 16 and performs an insulating action supplementing that of insulation 11.

The mixture of gaseous and pulverized solid materials is directed from inlet chamber 3 into the open lower ends of shell tubes 13 by means of guiding or deflecting elements formed on the lower surface of the floating plate 16 (see Figs. 3, 5 and 6). These elements are formed by in-

tersecting fin-like formations 23 and 24 at right angles to one another and projecting downwardly from the lower surface of floating plate 16 between the perforations for shell tubes 13. Fin-like formations 23 and 24 intersect one another at equally spaced points 25 between pairs of diagonally related tubes 13.

Between such intersecting points both sets of fins 23 and 24 are preferably scalloped along their lower edges, as shown at 26 in Figs. 3 and 6. Fins 23 and 24 are thicker at their bases adjacent the surface of plate 16 than at their lower edges, and substantially fill the spaces between adjacent perforations for tubes 13 so as to be substantially tangential with the surfaces of the tubes (see Figs. 3 and 5). The walls of fins 23 and 24 at each intersection 25 are filleted to form curved surfaces 27 (Fig. 5) sloping outwardly and upwardly from the lowest point of the intersections 25 towards the outer periphery of the edges of shell tubes 13. Thus at each point of intersection 25 with these curved sloping surfaces 27 there is formed a deflecting element for directing the mixture towards the mouths of the shell tubes. In this way the mouth of each shell tube is surrounded by what amounts to an inverted funnel, square in outline along the lower edges of fins 23 and 24 and gradually becoming round, in proximity to the lower edges of shell tubes 13.

Such an arrangement offers little opportunity for erosion by the particles of solid catalyst material carried along by the inert gas. The single stream moving upwardly through inlet chamber 3 is divided into small sections when it meets the lower sharpened edges of the fins 23 and 24 and the gently sloping surfaces of these fins and of the deflecting elements just described direct the mixture into the shell tubes with a minimum of erosion.

As mentioned above, there is within each shell tube 13 a coolant tube 14 having radial longitudinal fins 15. Thus the tube bundle 12 includes a group of these tubes 14 for the coolant which is of the same arrangement and number as the shell tubes 13. This group of coolant tubes 14 is divided into sections, in this instance 4, as shown in Fig. 2, and the coolant, usually reduced crude petroleum at high temperature and also usually at high pressure, may be delivered to the heat exchanger through an inlet pipe 28 which is connected by flange connections 29 to each of the four inlet tubes 30, 31, 32 and 33. The coolant is thus divided into four streams, each flowing through an equal number of tubes 14 in series. The outlet tubes at each of these sections are shown at 30', 31', 32' and 33' and are connected to expansion bends, two of which are shown at 36 and 37. These are connected by outlet connections 38 and 39 to outlet pipe 40.

Both the outlet connections such as 38 and 39 and the inlet pipes 31—33, inclusive, are led out of and into the heat exchanger, respectively, through the conical hood 7. In this way the usual stationary head for the tube side of a unit is eliminated and there are a minimum of parts in the path of the upwardly flowing catalyst and gas mixture. The inlet pipes and the outlet connections extend in the same general direction as the motion of the stream of mixture from the upper ends of shell tubes 13 to the outlet connection 10. In order to provide tight joints for the inlet tubes 30—31 and the outlet connections such as indicated by 38 and 39, sleeves 41 are welded into suitable apertures cut through the hood 7 and the

upper ends of each of these sleeves is restricted to form a conical seat 42. Coacting with this seat is a member 43 which is brazed or welded to the exterior surface of the outlet connection such as 38, and has an upper conical surface which is held in engagement with the seat 42 by means of a nut 44 threaded onto the outlet connection above the end of sleeve 41.

The tubes 14 for the coolant fluid system adjacent heat exchange elements 13, 14 are made in pairs; that is to say, they are constructed in the form of hairpin or U-shaped tubes having parallel legs coming together at the bottom as shown in Fig. 1. That is, the elbow 45, or return bend, is integral with the tube legs. These U-shaped tubes having the longitudinal fins 14 on their leg portions are inserted within adjacent pairs of shell tubes 13 with their upper ends projecting beyond the tops of these shell tubes. They are then connected in series with neighboring hairpin tubes of the same section by means of return bends 46 and couplings 47. The arrangement of the successive connections between the coolant fluid tubes of the various heat exchange elements 13, 14 is shown in Fig. 2. All of the U-shaped or hairpin tubes have equal length legs except those which include inlet tubes 30, 31, 32 and 33, wherein the legs constituting these four inlet tubes extend through the hood 7 in order to connect with the inlet pipe 28. The opposite legs of these four tubes, therefore, are shorter, inasmuch as they extend only to the couplings 47 of certain of the return bends 46.

The arrangement for supporting the coolant tubes 14 will now be described. Welded to the outside surface of each of tubes 14 a short distance below couplings 47 is a collar 48 (Fig. 3) preferably hexagonal in shape, to receive a wrench to prevent the tube from turning when couplings 47 are applied or removed. Collar 48 rests upon a pair of flat metal strips or bars 49. These strips are thus spaced apart slightly more than the diameter of tubes 14 and a pair of such strips extends along each row of tubes as laid out in Fig. 2, across the top of tube sheet 6. Strips 49 are maintained in edgewise upright position by means of pins 50 which are threaded into the upper surface of tube sheet 6 on both sides of both strips between each two apertures for the shell tubes 13 as illustrated in Fig. 2. Strips 49 are fastened at their ends by means of small bolts 51 to upright clips 52 which may be welded to the upper surface of tube sheet 6 (see Figs. 2 and 1).

By means of this construction, the tube bundle 12 can be removed from the heat exchanger 1 and completely taken apart for cleaning. This procedure, furthermore, is not particularly difficult or expensive. It involves disconnection of the flanged couplings for the inlet fluid pipes 30-33, inclusive, and the corresponding outlet pipes on the other side of hood 7 and the removal of hood 7 by taking out bolts 8 which also hold tube sheet 6 in position. Then the tube bundle 12 can be lifted out bodily. After this each heat exchange element 13, 14 can be disassembled by removing couplings 47 and return bolts 46, then unfastening the ends of the edgewise placed supporting strips 49 from the clips 52 and sliding them laterally between the rows of pins 50. Thereupon each of the tube bars 14 or hairpin tubes, can be removed from the floating plate end of the tube bundle.

With the heat exchanger of the present invention, the path of travel of the mixture of gaseous and finely divided materials is nearly straight from the entrance chamber 3 to the exit chamber

9. The velocity of the mixture in the inlet and exit chamber is preferably somewhat more than seven feet per second, which insures that a stream of gas will carry the powdered catalyst along with it. However, the impingement of the solid particles against objects directly in its path necessarily tends to produce erosion. Accordingly, the return bends 45 for each pair of tubes 14 at the bottom are provided with metallic hoods or protecting boots 53. Also tubes 14 between supporting shoulders 48 and couplings 47 are preferably provided with protecting sleeves 54. Also an elongated tubular hood of oval section 55 is placed over each of the temperature expansion bends 36 and 37.

Referring now to Figs. 7, 8 and 9, there is here shown a modification of the means for deflecting or directing a mixture of gaseous and finely divided solid materials into the lower ends of shell tubes 13. This is a composition structure instead of being formed integrally with tube sheet 16 as are the devices previously described in connection with Figs. 3, 5 and 6. Tube sheet 16a (Fig. 8) which is perforated as before to receive the shell tubes 13a within which are the coolant tubes 14a, has secured to its lower surface a plurality of deflecting elements 55. These are mounted, one centrally between each set of four of the shell tubes 13 which will be understood from Fig. 7. They are held in place by means of bolts 56 which are threaded at both ends and have their opposite ends screwed into taped holes in floating plate 16a. Nuts 57 are threaded on the lower ends of bolts 56 and hold elements 55 in place. These nuts are preferably streamlined, as shown in Figs. 8 and 9, in order to sharpen the apexes of elements 55.

By means of the present invention, there has been provided a heat exchanger for the purpose specified through which the mixture of powdered catalyst and inert gas will flow readily without clogging, and which, because of the arrangement for direct straight line flow through the exchanger, prevents the various parts thereof from being eroded by impact of the solid particles. Moreover, the heat exchanger can be readily taken apart for cleaning both sides of the unit, that is to say, both the passages through which the mixture flows, and also the tubular passages through which the coolant flows. This is of considerable importance where a material such as reduced crude petroleum is used as the coolant.

It will be understood that the preferred embodiment of the invention has been illustrated by way of example but that changes may be made in the arrangement and construction and without departing from the spirit of the invention, the scope of which is set forth in the appended claims.

I claim:

1. In a heat exchanger for transferring heat between a fluid and a mixture of gaseous and finely divided solid materials, a shell supported in upright position having an inlet chamber for the mixture at the bottom and an outlet chamber therefor at the top, a tube sheet adjacent said outlet chamber, a plurality of upright mixture conveying tubes having their upper ends secured in said tube sheet and descending to said inlet chamber, tubes for conveying said fluid disposed one within each of said mixture conveying tubes leaving a flow space for said mixture between the walls of said two tubes, a partition in said inlet chamber having perforations coacting with the lower ends of the mixture conveying tubes

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to maintain them in spaced relation, and deflecting elements on said mixture directing partition for directing the said mixture into said tubes.

2. In a heat exchanger for transferring heat between a fluid and a mixture of gaseous and finely divided solid materials, a shell supported in upright position having an inlet chamber for the mixture at the bottom and an outlet chamber therefor at the top, a tube sheet adjacent said outlet chamber, a plurality of upright mixture conveying tubes having their upper ends secured in said tube sheet and extending between said outlet and inlet chambers, tubes for conveying said fluid disposed one within each of said mixture conveying tubes, and means on said tube sheet for individually suspending said fluid conveying tubes to provide passages for said mixture from said mixture conveying tubes into said outlet chamber.

3. In a heat exchanger for transferring heat between a fluid and a mixture of gaseous and finely divided solid materials, a shell supported in upright position having an inlet chamber for the mixture at the bottom and an outlet chamber therefor at the top, a plurality of upright mixture conveying tubes arranged to receive said mixture at the inlet chamber and discharge the same into the outlet chamber, a tube sheet adjacent the outlet chamber, said tube sheet having rows of perforations therein into each of which the upper end of a mixture conveying tube is secured, tubes for conveying said fluid disposed one within each of said mixture conveying tubes, and

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means for supporting said fluid conveying tubes comprising a pair of thin metal bars disposed on the upper side of said tube sheet in parallel relation and on the opposite sides of the fluid conveying tubes in each row, said fluid conveying tubes extending above the tops of said bars and each having a collar secured thereto and resting on the upper edges of said bars, thereby providing free access to said outlet chamber for the said mixture entering the outlet chamber from the upper ends of said mixture conveying tubes.

4. A heat exchanger as claimed in claim 1 in which the deflecting elements are formed individually and separately from the mixture directing partition and bolted thereto.

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