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HEAT EXCHANGE APPARATUS

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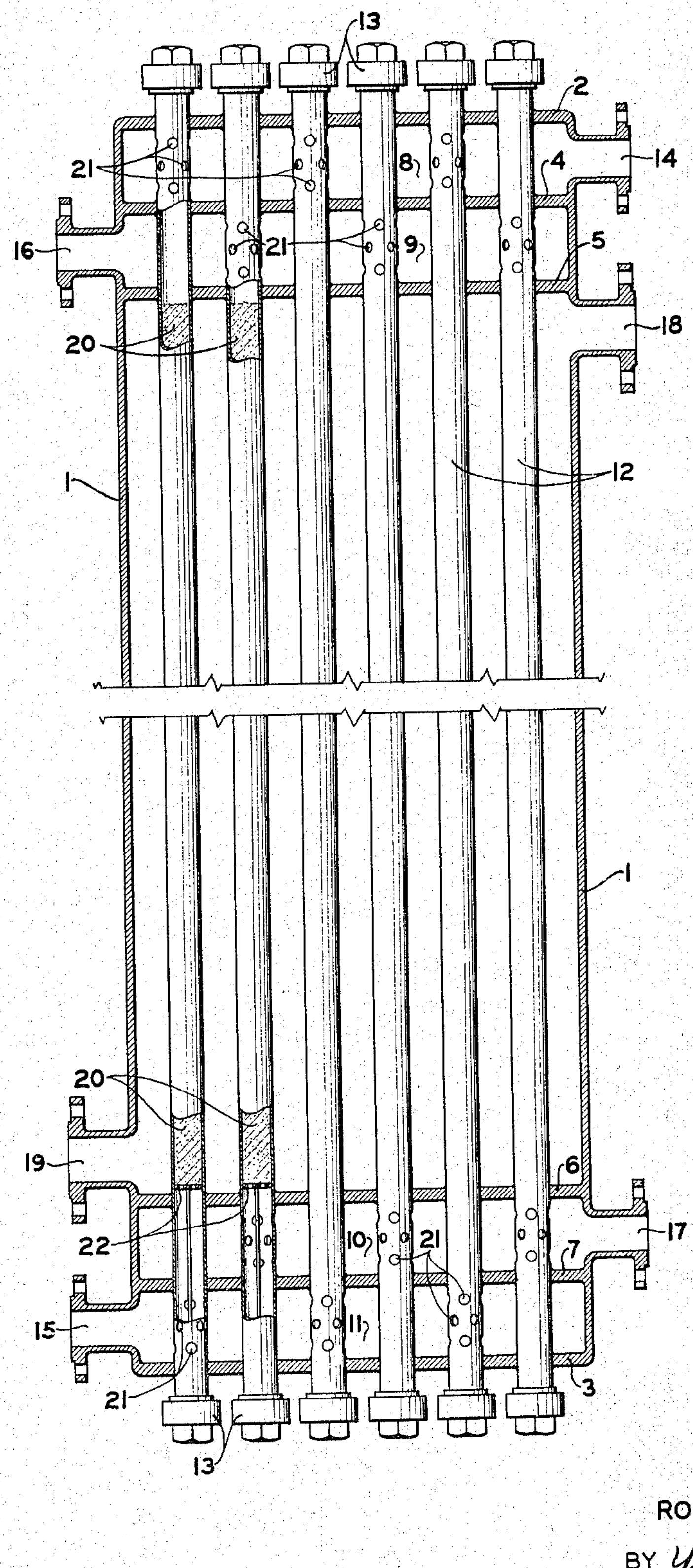

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HEAT EXCHANGE APPARATUS

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1 Claim. (Cl. 257—224)

The invention relates to an improved form of heat exchange apparatus of the tubular type. The features of the invention are applicable to tubular heat exchangers generally and may be employed in heat exchangers for any class of service. They will, however, be found particularly advantageous as applied to tubular reactors of the heat exchanger type and, more particularly, those wherein the reaction is conducted in the presence of a mass of solid granular contact material or catalyst.

The features and advantages of the invention will be best understood with reference to the accompanying diagrammatic drawing which illustrates in sectional elevation a specific form of tubular heat exchanger type reactor embodying features of the invention.

Referring now to the drawing, the form of apparatus here illustrated comprises a substantially cylindrical outer metal shell 1 closed at its upper and lower ends by means of heads 2 and 3, respectively, which in this particular instance are integral with or permanently secured to the cylindrical shell. Across the interior of the shell adjacent its opposite ends and permanently secured to the cylindrical wall thereof, tube sheets 4, 5, 6 and 7 are provided. The tube sheets are spaced from each other and from the heads 2 and 3 to provide header compartments 8 and 9 at the upper end of the shell and header compartments 10 and 11 at the lower end of the shell. A nest of elongated tubular elements 12 is provided within shell 1, each of which tubes extends continuously through the shell and protrudes from the heads 2 and 3 at its opposite ends.

Closure members of any convenient form, such as caps 13, threaded to the protruding ends of the tubes are provided at the opposite ends of each of the tubes 12 and are so constructed that they are readily removable from the tubes to give access to the interior of the latter.

A nozzle 14 which may serve either as an inlet or as an outlet connection is secured to shell 1 at the elevation of header compartment 8 and communicates with the latter. Another nozzle 15, which serves as an outlet connection when nozzle 14 is employed as an inlet connection and vice versa, is secured to the shell at the elevation of header compartment 11 and communicates with the latter. Another nozzle 16 which may serve as either an inlet or an outlet connection is secured to shell 1 at the level of header compartment 9 and communicates therewith. Another nozzle 17, which serves as an outlet connection when nozzle 16 serves as an inlet connection and vice versa, is secured to the shell at the elevation of header compartment 10 and communicates therewith. Part of the tubes 12 have openings 21 provided through their walls in that section of the tube which passes through header compartment 8 and 11, so that communication is established through these tubes and header compartments between nozzles 14 and 15. The remainder of the tubes 12 have openings 21 provided through their walls in that section of the tube which passes through header compartments 9 and 10, so that communication is established through these tubes and header compartments between nozzles 16 and 17.

Another nozzle 18 which serves as either an inlet or as an outlet connection is secured to shell 1 adjacent and beneath tube sheet 5 and communicates with the space about the tubes within that portion of the shell between the innermost tube sheets 5 and 6. Another nozzle 19, which may serve as an outlet connection when nozzle 18 is employed as an inlet connection and vice versa, is secured to shell 1 above and adjacent tube sheet 6 and also communicates with the space about the tubes in that portion of the shell between the tube sheets 5 and 6.

To illustrate the utility and operation of the apparatus illustrated in the drawing, we will assume that it is employed as a reactor in which to conduct a catalytically promoted hydrocarbon conversion reaction, such as, for example, the dehydrogenation of butane. This reaction, in common with many other hydrocarbon reactions, involves the deposition of deleterious heavy materials of a carbonaceous or hydrocarbonaceous nature on the particles of catalytic material employed to promote the reaction and these deposits must be periodically and frequently removed to restore the activity of the catalyst. This is generally accomplished by burning the combustible deposits from the catalyst particles in a stream of oxygen-containing gases. The catalyst in this particular instance comprises solid granular particles consisting essentially of alumina and chromia and is disposed within tubes 12, as indicated at 20. The reactants to be converted, which consist in this instance primarily of butanes, are heated by well known means, not illustrated, to a temperature suitable for effecting their substantial dehydrogenation upon contact with the active catalyst and are supplied through nozzle 14 to compartment 8 and enter through openings 21 into the tubes which have openings communicating with this compartment. The reactants pass downwardly through the catalyst bed within these tubes to the lower end thereof wherefrom they are discharged through the openings 21 into compartment 11 and thence from the reactor through nozzle 15.

When the catalyst in the tubes which establish communication between compartments 8 and 11 becomes relatively inactive due to the deposition of heavy hydrocarbonaceous products of the dehydrogenating reaction thereon, the stream of reactants to be converted is diverted from compartment 8 through nozzle 16 to compartment 9 and the dehydrogenating reaction is continued in the other tubular elements 12 which have openings adjacent their opposite ends communicating with compartments 9 and 10, the flow through these tubes being from compartment 9 through openings 21 downwardly through the catalyst beds within the tubes and from adjacent the lower end of the latter through openings 21 into compartment 10 wherefrom the resulting fluid reactants and conversion products are discharged through nozzle 17.

During use of the catalyst in one set of the tubes 12 for promoting the dehydrogenating reaction, the catalyst in the remaining tubes, which has become fouled or rendered relatively inactive by previous use, is regenerated. Thus the dehydrogenating reaction and regeneration of the catalyst take place simultaneously within the reactor, the zones of reaction and regeneration being periodically shifted between the two sets of tubes which communicate, respectively, with compartments 8 and 11 and with compartments 9 and 10. For example, during use of the catalyst within the tubes which establish communication between compartments 8 and 11 for promoting the dehydrogenating reaction, reactivating gases comprising, for example, a relatively small amount of air in a relatively large volume of inert gases, such as carbon dioxide, for example, is supplied through nozzle 13 to compartment 9 and passes therefrom to compartment 10 through tubes which have openings 21 communicating with these two compartments. During passage of the reactivating gases through the catalyst bed within these tubes, the combustible deleterious deposits are burned from the catalyst particles and the resulting spent or partially spent reactivating gases are discharged from compartment 10 through nozzle 17.

During the entire operation a convective fluid, such as, for example, combustion gases, molten salt, molten metal or any other suitable heat transfer medium, is circulated through the space around tubes 12 within shell 1 between the innermost tube sheets 5 and 6, this material being supplied to the reactor through nozzle 19, for example, and discharged therefrom through nozzle 18. Since the dehydrogenating reaction is endothermic and regeneration of the catalyst involves the liberation of heat by combustion of the deleterious hydrocarbonaceous deposits, heat is transferred through the convective fluid from the zone of reactivation to the zone in which dehydrogenation is taking place.

When, as in this particular instance, the heat available from reactivation of the catalyst for transfer to the dehydrogenating zone is less than the heat of reaction required in the latter zone, additional heat may be supplied thereto through the medium of the convective fluid by passing the same, subsequent to its discharge through nozzle 18 and prior to its introduction into the reactor through nozzle 19, to a suitable heating zone, not illustrated, wherein the required additional heat is supplied thereto.

In case combustion gases are employed as the convective medium, said additional heating of the latter may be accomplished in a convenient manner by passing the gases being recirculated through a combustion zone wherein their temperature is increased by the addition of fresh increments of hotter combustion gases generated therein. In such cases a portion of the combustion gas discharged from the reactor through nozzle 18 is released from the system to keep the quantity of gases flowing through the reactor substantially constant.

When a liquid, such as molten salt, molten metal or the like is employed as the convective fluid, it may be passed, for example, through a tubular heating coil within a suitable furnace structure in order to supply the additional quantity of heat required thereto.

In case the heat available for transfer from the zone of reactivation to the zone of catalytic reaction is more than that required to accomplish the desired reaction, the excess heat may be extracted from the convective fluid by passing the same through a suitable cooler or heat exchanger after it is discharged from the reactor through nozzle 18 and before it is returned thereto through nozzle 19.

It is also possible, although rather unusual, that the heat available for transfer from the zone of reactivation to the catalytic reaction zone substantially equals the requirements of the latter. In such instances, that portion of the tubes 12 between the innermost tube sheets 5 and 6 may be immersed in a bath of liquid, such as molten salt, molten metal or the like, through which heat is readily transferred from the tubes in which reactivation of the catalyst is taking place to the tubes in which the conversion reaction is taking place, and except when desirable for maintaining substantially uniform temperatures throughout the reaction zone, little or no recirculation of the convective fluid will be required. Alternatively, in such instances, the tubes 12 between tube sheets 5 and 6 may be embedded in a pulverulent or granular solid heat transfer material, such as, for example, metal filings, magnesium oxide or the like.

When employed in service where relatively high temperatures are encountered and particularly in instances where the shell 1 will be heated to a substantially higher or substantially lower temperature than the tubes 12, suitable means of any conventional form, not illustrated, such as, for example, a packed joint, may be provided in shell 1 intermediate its length between tube sheets 5 and 6 to accommodate differential expansion and contraction between the shell and the tubes.

It will be apparent to those familiar with the art that the construction illustrated and above described has numerous advantages over previous tubular heat exchangers and tubular heat exchanger type reactors. By extending the tubes through the tube sheets, header compartments and top and bottom heads of the reactor shell and securing them to the heads and tube sheets by welding, expanding or in any other convenient manner, they serve as stays for the heads and tube sheets, thereby materially increasing their strength and reducing their required thickness. This also eliminates the necessity for providing removable flanged heads, such as ordinarily required in apparatus of this class, for gaining access to the tubes, since the latter extend through the top and bottom fixed heads and are provided with removable individual caps or other convenient closure means. To inspect, remove or replace the catalyst within the tubes, it is only necessary to remove the top and bottom closure members 13 therefrom and remove the catalyst supports 22 which may comprise, for example, a member such as shown and described in Perkins Uuited States Patent No. 2,203,840.

I claim as my invention:

An apparatus of the class described comprising a shell, spaced parallel plates extending across the shell and forming in the end portions of the shell a first inlet compartment, a second inlet compartment, a first outlet compartment and a second outlet compartment, a plurality of tubes extending through the shell and said compartments and having their end portions outside the shell, closure means for the end portions of the tubes outside the shell, perforations in some of said tubes in the portions thereof disposed in said first inlet compartment and in said first outlet compartment, and perforations in others of said tubes in the portions thereof disposed in said second inlet compartment and said second outlet compartment.

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