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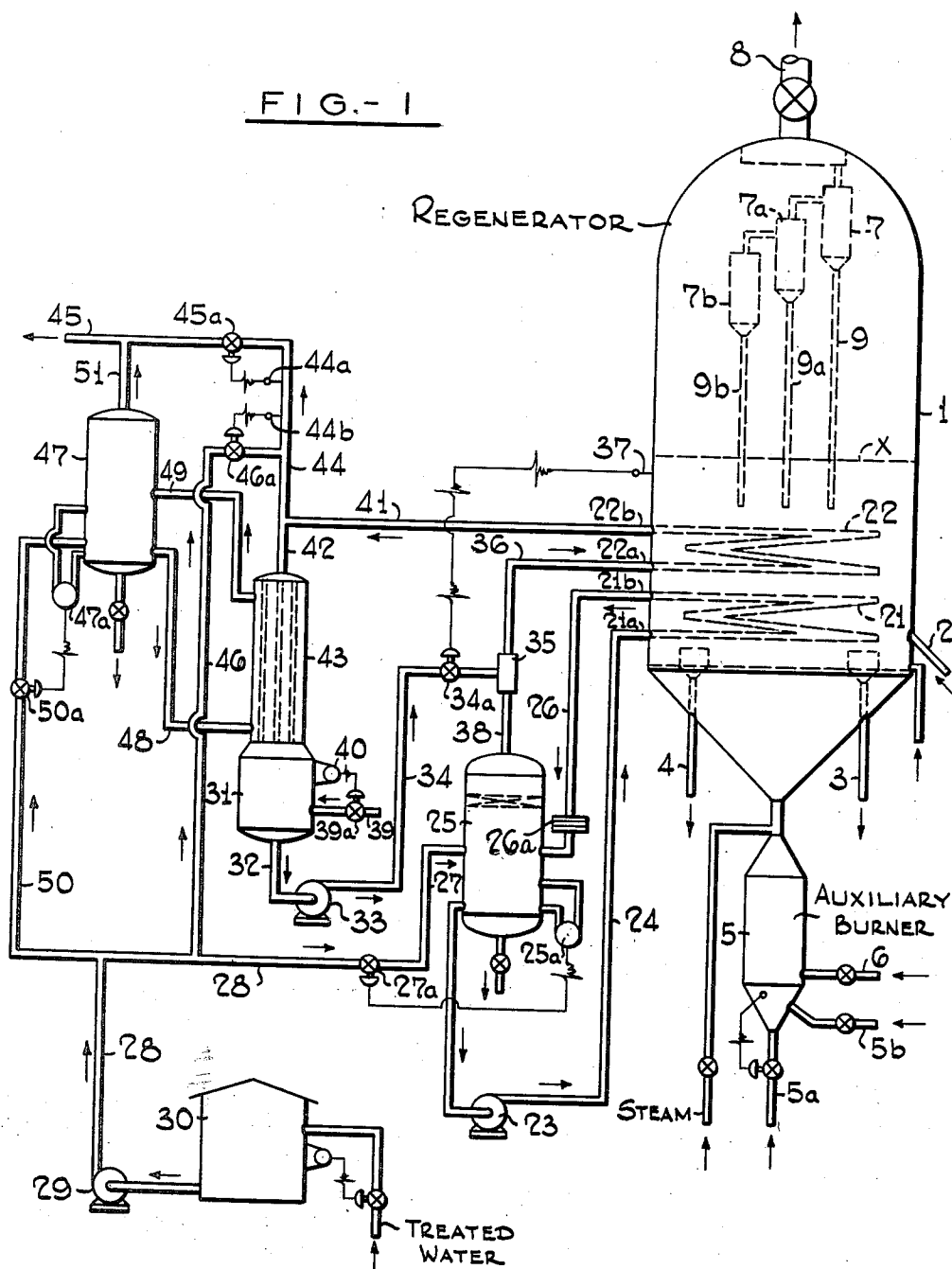
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HEAT EXCHANGE SYSTEM AND METHOD OF OPERATION

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FIG.-1



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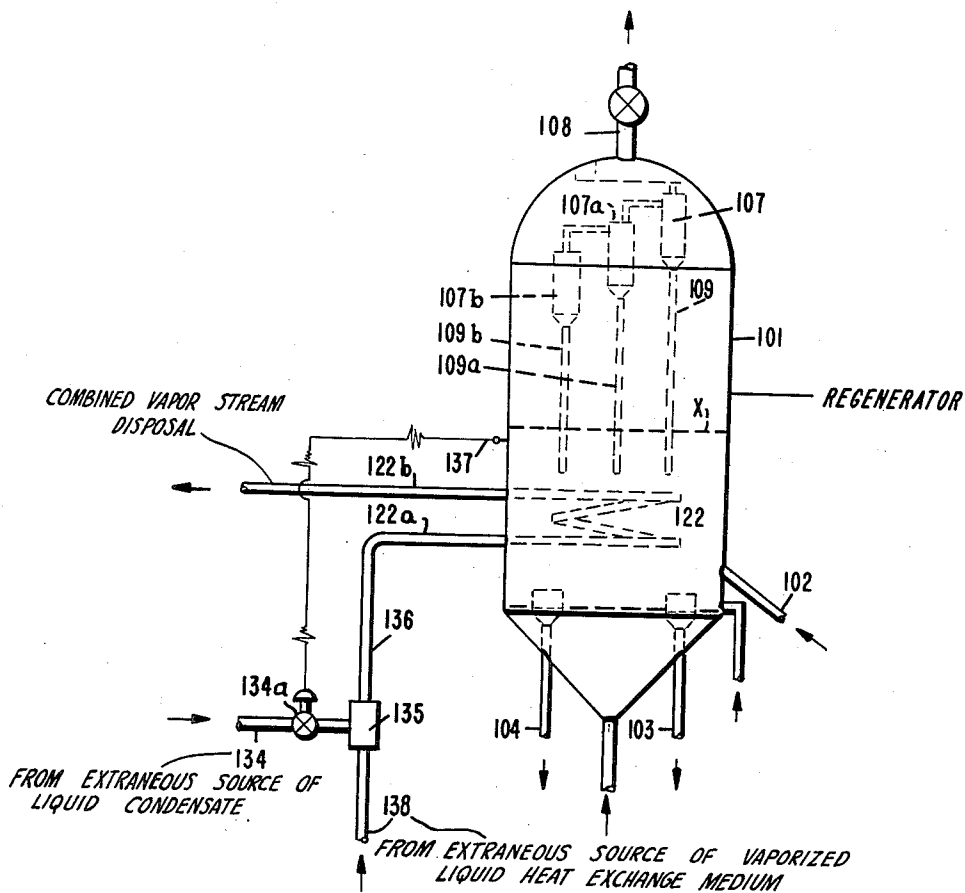


FIG. - 2

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HEAT EXCHANGE SYSTEM AND METHOD OF OPERATION

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11 Claims. (Cl. 62—168)

The present invention relates to a heat exchange system and method of operation. More particularly, the invention relates to a method and means for removing heat from materials undergoing exothermic reaction in a reaction vessel, and especially in the presence of fluidized, finely divided materials which may enter into or promote such reaction. More specifically, the invention relates to a heat exchange system and method of operation in which a liquid heat exchange medium is atomized and introduced in the presence of a vaporous heat exchange medium into a heat exchange conduit means submerged in a body of reactant materials in a reaction zone.

In an exothermic reaction, it is quite customary to control temperatures in the reaction zone by indirect heat exchange with a liquid heat exchange medium circulated through an exchanger conduit or coil disposed in the zone. The liquid medium abstracts heat from the reaction and the zone, and normally is vaporized thereby. As a typical example, water may be circulated through an exchanger coil and be converted to steam by absorption of heat from the reaction zone. Control and regulation of heat removal is difficult in such a system. Normally, control is attempted either by varying pressure on the coil to vary the vaporization temperature of the liquid, or by varying the rate of flow of the liquid medium. Neither method of control has proved entirely satisfactory. Where pressure on the medium is employed to retard vaporization, extremely high pressures may be necessary at relatively low rates of heat abstraction. Where heat control is attempted by varying liquid flow, only comparatively small temperature differences between the reaction temperature and the heat exchange temperature can be accommodated due to stresses developed in the conduit as a result of surging of the liquid medium produced either by variation in flow rate, or fluctuations in the reaction temperature to be controlled.

In the latter system, at some point in the conduit circulating the liquid heat exchange medium, there is a transition from a predominance of liquid to a predominance of vaporized liquid. This transition point is not fixed, and as a result the liquid phase of the exchange medium surges back and forth in the conduit containing it. Surging of the liquid produces a shock chilling effect on the conduit metal, producing stresses which result in early failure of the conduit.

It is an object of the present invention to provide a heat exchange system, and a method of operating such system in which the extraction of heat from a reaction zone may be flexibly controlled by variation of the flow rate of a liquid medium, without subjecting the system to extreme temperature or pressure variations, and while avoiding shock chilling effects in the heat exchange conduit within the reaction zone. It is a further object of the invention to provide a heat exchange system in which a single liquid medium provides both a primary and a secondary heat exchange medium, and also one in which the latter is derived from the former during operation of the system. More specifically, it is an object of the invention to provide a heat exchange system and method of operation in which the reaction temperatures of an exothermic reaction, such as one in which contaminant materials are removed from a fluidized, finely divided catalyst material by combustion in the presence of air, are controlled by circulation of water through heat exchanger conduit means in the reaction zone, without shock chilling of said conduit.

The invention is described with reference to its employ-

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ment in conjunction with the regeneration of finely divided solid catalyst materials such as may be derived from a catalytic cracking operation but is broadly applicable to any operating condition requiring heat exchange or removal with control of operating temperatures, and without detrimental shock chilling of the heat exchanger elements. The invention may be more fully understood from the following description when it is read in conjunction with the accompanying drawings, in which:

Fig. 1 is a semi-diagrammatic illustration of the heat exchange system as applied to a typical reaction vessel and zone for carrying out an exothermic reaction process; and

Fig. 2 is a similar view of a portion of the system of Fig. 1 showing a modified form thereof.

In the system as illustrated by Fig. 1, the numeral 1 designates a reaction vessel provided with an inlet conduit 2, opening into a lower portion of the vessel, for introduction of a fluidized, finely divided, solid, catalyst material contaminated by carbon and other combustible substances, and in which a relatively dense bed of such material is maintained, with an upper level substantially as indicated by the dotted line at X. Conduit means 3 and 4 provide for withdrawal of regenerated catalyst from the vessel, the conduit 3 leading to storage or a point of reuse for the regenerated catalyst, while conduit 4 may provide for recirculation of the regenerated catalyst to vessel 1 in conjunction with the contaminated catalyst introduced through conduit 2. Communicating with the lower end of vessel 1, is an auxiliary fuel burner 5 with burner fuel line 5a and primary air line 5b connected thereto. The burner 5 supplies heated air to the vessel 1 to initiate and maintain combustion of the catalyst contaminating materials in the vessel 1. A conduit 6 provides for introduction of the air to be heated in burner 5, and supplied therefrom to the vessel 1. The heated air and combustion gases from the burner pass from the burner 5 into the bed of contaminated catalyst material, fluidizing the bed, the heated air from line 6 providing oxygen required for combustion of the contaminating materials carried by the finely divided solids. In the upper portion of the vessel 1, a series of cyclone separators 7, 7a, and 7b provide for removal of solids entrained in the gaseous reaction products withdrawn from the vessel 1 by way of an outlet conduit 8 opening therefrom. Dip-leg conduit connections 9, 9a and 9b provide for the return of separated solids from the cyclone separators 7, 7a and 7b respectively to the fluidized bed of solid material, below the indicated level X thereof.

Heat exchange means to permit extraction of excess heat from the reaction zone, and to control reaction temperatures in vessel 1 is provided by a primary exchanger conduit or coil 21, and a secondary exchanger conduit or coil 22, each disposed within the vessel so as normally to be submerged in the body of reaction materials contained by the vessel. The coils are respectively provided with inlet portions 21a and 22a, and outlet portions 21b and 22b, thereof, extending outwardly through the vessel wall. The primary coil inlet 21a is connected to the discharge of a pump 23 by a conduit connection 24, the inlet of pump 23 being connected to a suitable source for a primary liquid heat exchange medium, as to an intermediate reservoir 25. The intermediate reservoir serves also as a disengaging drum in the system illustrated. The primary coil outlet 21b is connected to the inlet 22a of secondary coil 22 by way of a disengaging drum, or the reservoir 25, above the level of the liquid therein by means of conduit 26. Means may be provided in the conduit 26 for maintaining a pressure differential between the conduit and the reservoir 25 such as orifice means in the conduit 26 as indicated by the numeral 26a. In the system as illustrated, the primary heat exchange liquid is supplied to reservoir 25, initially, and to restore any predetermined level of such liquid therein, by way of a conduit 27 connected to a main supply conduit 28 fed by pump 29 from a main source of primary liquid, as from storage vessel 30. The level in the reservoir 25 is maintained within predetermined limits by means of a level control 25a connected into the reservoir, and a valve 27a in line 27 actuated by the level control. The inlet 22a of the secondary heat exchanger conduit

or coil 22 is connected to a source of such liquid. As shown, it is connected to a reservoir 31 therefor by means of conduit 32 from the reservoir to the inlet of a pump 33, conduit 34 from the outlet of pump 33 to an atomizer 35, and conduit 36 from the atomizer to the inlet 22a. The secondary heat exchange medium normally is derived by condensation of vapors from the primary medium but may be initially supplied or augmented from a source exteriorly of the system. A valve 34a in the conduit 34 is actuatable by means of temperature control means 37 to regulate flow of the secondary medium to the atomizer 35 and coil 22. A discharge conduit 38 for vaporized, primary heat exchange liquid opens into the atomizer 35 from the reservoir 25, and provides for introduction of the primary liquid vapors and, if desired, for the atomization of the secondary liquid medium. Flow through the conduit 38 is continuous during operation of the system. Auxiliary means for supplying the secondary liquid medium to the reservoir 31 from a separate source is provided by a supply conduit 39. A valve 39a in the conduit 39 controls flow therethrough, and is actuatable by low level control 40.

The outlet 22b of the secondary heat exchange coil 22 is connected by means of conduit 41 to any desired means of disposing of the vaporized heat exchange medium. As shown, it is connected into a conduit forming a T-connection therewith. One conduit element 42 of the T opens into a heat exchange vessel 43, while the other element 44 opens into a conduit 45 for venting any excess of the vaporized secondary medium which may develop during operation of the system. A pressure control means 44a is utilized to actuate a valve 45a in conduit 45 to maintain any desired pressure on the system. A conduit 46 connected from the supply line 28 into the conduit element 44 is provided to introduced primary liquid for cooling vaporized secondary liquid discharged into the conduit 45. A temperature control means 44b in conduit 44 is employed to actuate a valve 46a in line 46 so as to maintain any desired temperature in the vented material.

As shown, the heat exchanger 43 is a tube and shell exchanger vessel, vertically disposed with reference to the reservoir 31, with the lower outlet ends of the tubes thereof communicating directly with the reservoir. The conduit 42 communicates with the upper, inlet ends of the tubes. A heat exchange liquid derived from the storage vessel 30 is supplied to the shell side of the exchanger 43 from an intermediate reservoir 47 by means of the conduit 48, and returned from the shell side exchanger 43 to the reservoir 47 by way of the conduit 49. The initial supply of heat exchange liquid and make-up liquid is supplied to reservoir 47 by means of conduit 50 connected thereto from the main supply line 28 for primary heat exchange liquid. The reservoir 47 is in effect a disengaging drum for vapor from the liquid returned from exchanger 43, and the liquid in the reservoir is maintained at an intermediate level therein. A level control means 47a connected into reservoir 47 is employed to actuate a valve 50a in line 50 so as to maintain any desired level in the reservoir. Vapors released from the liquid returned to the reservoir by conduit 49 are discharged into the conduit 45 by means of conduit 51 connected therebetween.

In operation of the system disclosed, as for example in conjunction with a vessel for regeneration of spent catalyst from a catalytic cracking process, such as a suspensoid cracking process, the contaminated catalyst material may be supplied to the regenerator reaction vessel continuously while withdrawing regenerated material therefrom at an equivalent rate to maintain a relatively dense fluidized bed of the material in the reaction zone below the indicated level X. The temperature of the reaction zone and in the vessel is preferably to be maintained at about 1050° F., with heat being extracted by means of the heat exchange system as required.

In the heat exchange system, the primary liquid heat exchange medium is pumped to the intermediate reservoir and disengaging drum 25 to establish a predetermined level therein. Liquid from this reservoir is then passed through the primary exchange coil 21 by pumping from the intermediate reservoir at such rate and pressure as to avoid substantial vaporization in the coil. Upon return to the reservoir 25 through conduit 26 the liquid is partially vaporized, and the vaporized portion discharged through atomizer 35 and conduit 36 into the secondary heat exchange coil 22. Thence the vaporized portion of

the primary liquid passes through lines 41 to a point of consumption. In the system as illustrated, this portion passes through line 42 into the heat exchanger 43, being condensed therein by the primary liquid heat exchange medium which is circulated through the shell side of the exchanger, and the reservoir 47, by gravity and thermosiphon effect. The reservoir 47 also acts as a vapor disengaging drum and the liquid therein is maintained at an intermediate level therein. Vapor released in the drum 47 is discharged by way of line 51 into line 45 and removed from the system. The condensate of the primary liquid vapor, which is collected in the reservoir 31, provides the secondary liquid heat exchange medium supplied to the secondary heat exchange coil 22. This liquid may be augmented from any suitable separate source of primary liquid condensate.

As the temperature in the reaction vessel 1 rises, the temperature control means 37 is energized to actuate the valve 34a, opening the valve to permit flow of liquid condensate from the reservoir 31 under pressure of the pump 33. This liquid passes into the atomizer 35, where it is atomized by, or in the presence of vapors from the disengaging drum 25, and carried thereby in atomized form into the coil 22, and until the liquid particles are themselves vaporized by indirect heat exchange with the reaction zone. The temperature control means 37 and valve 34a increase or decrease the volume of secondary liquid supplied through atomizer 35 to coil 22 as required to maintain the reaction zone temperature substantially constant. The rate and volume of flow of secondary liquid through the coil 22 is preferably adjusted so as to permit complete vaporization within the coil. In a preferred operation, the volume of condensate liquid passed into the coil 22 is not in excess of 10% of the total volume of the stream. Stated with reference to the volume of vapors discharged from the reservoir 25 the volume of condensate passed into the coil 22 is about 11% of the volume of the carrier vapor stream supplied thereto by way of the conduit 38, atomizer 35 and conduit 36. Expressed as a proportional weight relationship, the weight percent of carrier vapor in the total stream passed through the coil 22 will be from about 5% to about 10% while the weight percent of the atomized liquid condensate will be from about 95% to about 90%.

The vapors discharged from the coil 22 may be employed or disposed of in any suitable fashion. In the system contemplated, they pass through the line 41 into either the conduit element 42, or both elements 42 and 44. Inasmuch as the vapor employed for atomization of the secondary liquid medium is in effect an addition to the volume of the secondary medium, unless an equal portion is removed from the secondary medium circulation lines, these would be flooded and pressure therein increased. Accordingly, to maintain a substantially constant volume of the secondary medium, a portion of the vapors is vented by way of line 44 into the discharge line 45, and thence from the system, the pressure control means 44a being adjusted so as to maintain a predetermined pressure and release vapors at substantially the rate of introduction by way of line 38 and atomizer 35. These vapors may be cooled to any desired extent by direct heat exchange with primary heat exchange liquid injected by way of line 46, as controlled by temperature control means 44b and valve 46a.

Typical of the system as set forth above, it may be described in its employment with a process and apparatus for the regeneration of catalyst materials derived from a suspensoid, catalytic cracking operation. In such an operation, the contaminated catalyst materials may be supplied to a regeneration vessel at a temperature of about 850° F. and at the rate of about 57,000 pounds per hour, containing contaminants in the form of carbon and coke totaling about 15% by weight. This catalyst material is scrubbed and substantially dried prior to introduction into the regeneration vessel in a fluidized condition at a temperature of about 850° F.

In the regeneration vessel, the contaminated catalyst material is contacted with heated air from the fuel burner 5 to ignite and maintain combustion of the contaminant materials. Normally, the combustion temperature should be maintained at about 1050° F., and as the reaction is exothermic, heat must be removed from the reactant materials, and the vessel.

In a process of the capacity set forth, with the vessel to be maintained at a temperature of about 1050° F.,

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heat must be removed from the vessel at the rate of from about three million to thirteen million B. t. u. per hour. To accomplish this result, the primary coil 21 is provided to remove about three million B. t. u. per hour, and the secondary coil from zero to ten million B. t. u. per hour.

When both coils 21 and 22 are functioning, and the regeneration process is in controlled operation, the primary liquid from reservoir 25 will enter the coil 21 at a temperature of about 407° F., and a pressure of about 432 p. s. i. g. Flow through the coil 21 will be maintained at such rate that not more than about five to about ten percent of the primary liquid passed therethrough will be vaporized in the coil, in order to maintain a liquid flow stream and to prevent excessive deposition of solid materials in the coil. The primary heat exchange medium leaving the coil 21 and in the reservoir 25 has a temperature of about 432° F., and is at a pressure of about 340 p. s. i. g. Under such conditions, the liquid entering the reservoir 25 will be vaporized therein at a rate of about 2800 pounds per hour for continuous supply to the atomizer 35, and thence through the coil 22.

With the desired temperature of about 1050° F. to be maintained in the coil 22, the secondary liquid heat exchange liquid may be supplied from reservoir 31 at the rate of about 10,200 pounds per hour, at a pressure of about 370 p. s. i. g. and a temperature of about 400° F. The total fluid enters the coil 22 at a rate of about 13,000 pounds per hour, at a temperature of about 420° F. By heat exchange, the temperature of the secondary heat exchange medium, including liquid from reservoir 31, and vapor from reservoir 25 is raised in the secondary coil 22 to about 600° F. at the outlet.

The discharge from outlet 22a, through conduit 41, is regulated by means of the pressure and temperature controls 44a and 44b respectively, so that vapors are vented from the system at the same rate as introduced from the reservoir 25, and so as to return about 10,200 pounds of the vaporized secondary heat exchange medium to the reservoir 31 by way of the line 42 and heat exchanger 43. Where the heat exchange medium is water, the vapors vented by way of the conduits 44 and 45, combined with vapors vented from the reservoir 47, may be discharged as utility steam at a pressure of about 120 p. s. i. g. In the system as described, steam produced will be at the rate of about 12,145 pounds per hour. The secondary liquid heat exchange medium will be maintained in the reservoir 31 at a temperature of about 415° F. and a pressure of about 280 p. s. i. g. Primary heat exchange liquid will be supplied to cool vapors vented through the conduit 44, by way of line 46 and valve 46a at the rate of about 250 pounds per hour. Pressure in the conduit 28 as imposed by the pump 29 should be about 370 p. s. i. g.

Although illustrated and described with reference to a specific structural system and a method of operating such a system, both structure and method may be varied within limits while retaining the inherent characteristics of the invention. For example, the vaporized primary heat exchange medium may be derived from any source other than the conduit means 21 and supplied directly to the inlet 22a of coil 22 through atomizing means such as indicated by the numeral 35. Likewise, the liquid secondary medium may be separately derived and initially supplied to the inlet 22a by way of the atomizer 35, and also the vapors issuing from the outlet 22b of coil 22 may be disposed of without condensation and reuse in the system itself. Such modification of the apparatus is illustrated by Fig. 2. In the form of the apparatus thus shown, the parts indicated by the numerals 101, 102, 103, 104, 107, 107b, 108, 109, 109a, 109b, 122, 122a, 122b, 135, 136, and 137 are identical with the parts 1, 2, 3, 4, 7, 7a, 7b, 9, 9a, 9b, 22, 22a, 22b, 35, 36, and 37 of Fig. 1, and in the modification as illustrated by Fig. 2 perform corresponding functions as described with reference to Fig. 1. The atomizer 135 of Fig. 2 is provided with a first conduit connection 138 for the introduction thereto of vapors of the liquid heat exchange medium. The atomizer 135 is also provided with a second conduit connection 134 for the introduction thereto of a liquid condensate derived from said liquid heat exchange medium. Suitable valves such as 138a in line 138 and 134a in line 134 are provided to control the flow of vapors and liquid through the respective conduit connections. As shown, the valve 134a is an automatic control valve similar to the valve 34a of

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Fig. 1. The valve 134a is energized as by means of a temperature control means 137 corresponding to the means designated by the numeral 37 in Fig. 1.

Operation of the apparatus as illustrated by Fig. 2, corresponds substantially with the operation of the apparatus as shown by Fig. 1 except that the vaporous portion of the liquid heat exchange medium and the liquid condensate thereof may be derived from sources extraneous to the system as shown in Fig. 1. A first portion of the liquid heat exchange medium is thus separately heated and vaporized by any suitable means, not shown, and delivered to the inlet portion 122a of the heat exchange coil 122 by way of the conduit connection 138, atomizer 135 and the conduit 136. A second portion of the liquid heat exchange medium, in the form of a liquid condensate thereof, is delivered to the atomizer 135 by way of the conduit connection 134. The liquid condensate is atomized in the presence of the vapors delivered to the atomizer 135 and after atomization the finely divided liquid particles produced are carried by the vapors into the coil 122 substantially as discrete liquid particles. The liquid particles themselves are vaporized in the coil 122 to combine with the vapors initially supplied as a carrier stream and the combined stream of vapors is then discharged by way of the coil outlet portion 122b.

What is claimed is:

1. A method of heat exchange for removing heat from a high temperature zone, comprising continuously passing a stream of a liquid heat exchange medium through a first confined flow path, heating said liquid medium during passage through said path, while restricting substantial vaporization therein; introducing said heated liquid medium into a vapor disengaging zone, vaporizing at least a portion of said heated medium in said zone; continuously discharging a stream of vapors from said disengaging zone into a second confined flow path extending through said high temperature zone and passing said stream therethrough at a substantially constant rate of flow; in the presence of said stream of vapors, atomizing a liquid condensate derived from vapors of said heat exchange medium, dispersing said atomized condensate in said vapor stream; introducing said atomized condensate into indirect heat exchange relation to said high temperature zone as a dispersion of condensate in said stream and carried thereby; vaporizing the dispersed liquid condensate during passage through said second confined flow path and said high temperature zone; and discharging a combined stream of vapors from said second flow path.

2. A method according to claim 1 in which the volume of liquid condensate atomized in the presence of said vapor stream does not substantially exceed about 10% of the total volume of said stream after dispersion of the condensate therein.

3. A method according to claim 1, in which as introduced into said confined flow path, said vaporized medium and said dispersed liquid condensate of said medium are present in the proportion of from about 5% to about 10% by weight of the vaporized medium and about 95% to about 90% by weight of the dispersed liquid condensate.

4. A method according to claim 1, in which said liquid condensate is atomized and introduced into said second confined path at a rate of flow variable in direct relation to the increase and decrease of temperature in said high temperature zone.

5. A method according to claim 1, in which said liquid condensate is derived by condensing at least a portion of the combined stream of vapors discharged from said second confined flow path.

6. A method according to claim 1, in which vaporization of said liquid heat exchange medium during passage through said first confined flow path is restricted to from about 5% to about 10% of said liquid medium.

7. A method according to claim 1, in which a first portion of said stream of vapors discharged from said second confined flow path is condensed to provide at least a portion of said liquid condensate, and a second portion is vented from said confined flow path.

8. A method according to claim 7, in which said second vented portion is not substantially less than the volume of vapors discharged from said disengaging zone.

9. A method of heat exchange for removing heat from a high temperature zone, comprising continuously pass-

ing a stream of a liquid heat exchange medium in a first confined flow path through said high temperature zone; heating said liquid medium during passage through said zone, while restricting substantial vaporization therein; introducing said heated liquid medium into a vapor disengaging zone; continuously discharging a stream of vapors from said disengaging zone into a second confined flow path extending through said high temperature zone and passing said stream therethrough at a substantially constant rate of flow; in the presence of said stream of vapors, atomizing a liquid condensate derived from vapors of said heat exchange medium, dispersing said atomized condensate in said vapor stream; introducing said atomized condensate into indirect heat exchange relation to said high temperature zone as a dispersion of condensate in said stream and carried thereby; vaporizing the dispersed liquid condensate during passage through said second confined flow path and said high temperature zone; and discharging a combined stream of vapors from said flow path.

10. A heat exchange system of the character described, comprising a source of a liquid heat exchange medium, an intermediate reservoir for said medium, a primary heat exchange conduit means disposed in indirect heat exchange relationship in a container vessel for high temperature material, and for submergence therein, a secondary heat exchange conduit means similarly disposed in said vessel, conduit means for circulating said liquid heat exchange medium from and to said intermediate reservoir through said primary conduit means, atomizer means for introducing vapors disengaged from said liquid in said intermediate reservoir into said secondary heat exchange conduit means, a reservoir for a liquid condensate derived from vapors of said liquid heat exchange medium, conduit means for withdrawing said liquid condensate from said reservoir, and for introducing said condensate into said secondary heat exchange conduit means by way of said atomizer, a condenser exteriorly of said vessel in direct communication with said reservoir for the liquid condensate, said exchanger connected to

said secondary heat exchange conduit means in said vessel receiving and condensing vapors therefrom, and means for venting a portion of said vapors from the system.

11. In a process for regenerating finely divided solid catalyst materials which have been contaminated with deposits of carbonaceous and other oxidizable materials, wherein the contaminants are removed by exothermic oxidation reaction with an oxygen containing gas in a high temperature reaction zone, while maintaining said solid materials as a dense fluidized bed thereof in said reaction zone, and wherein the temperature of said zone is controlled by passing a heat exchange medium in a confined flow path through said reaction zone in indirect heat exchange relation to said bed of solid materials, the steps which comprise initially heating and vaporizing a stream of a liquid heat exchange medium to form a continuous stream of vapors thereof, separately providing a stream of liquid condensate derived from vapors of said liquid heat exchange medium, atomizing said liquid condensate in the presence of said stream of vapors and dispersing said condensate in said vapor stream as substantially discrete liquid particles of condensate, forming a combined stream of vapors and liquid condensate particles suspended in said vapors, passing said combined stream into said confined flow path, said vapors carrying said condensate particles into indirect heat exchange relation with said bed of solid materials maintained in said reaction zone, thereby vaporizing said liquid particles, and discharging a total stream of vapors from said confined flow path and said zone.

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