

April 10, 1956

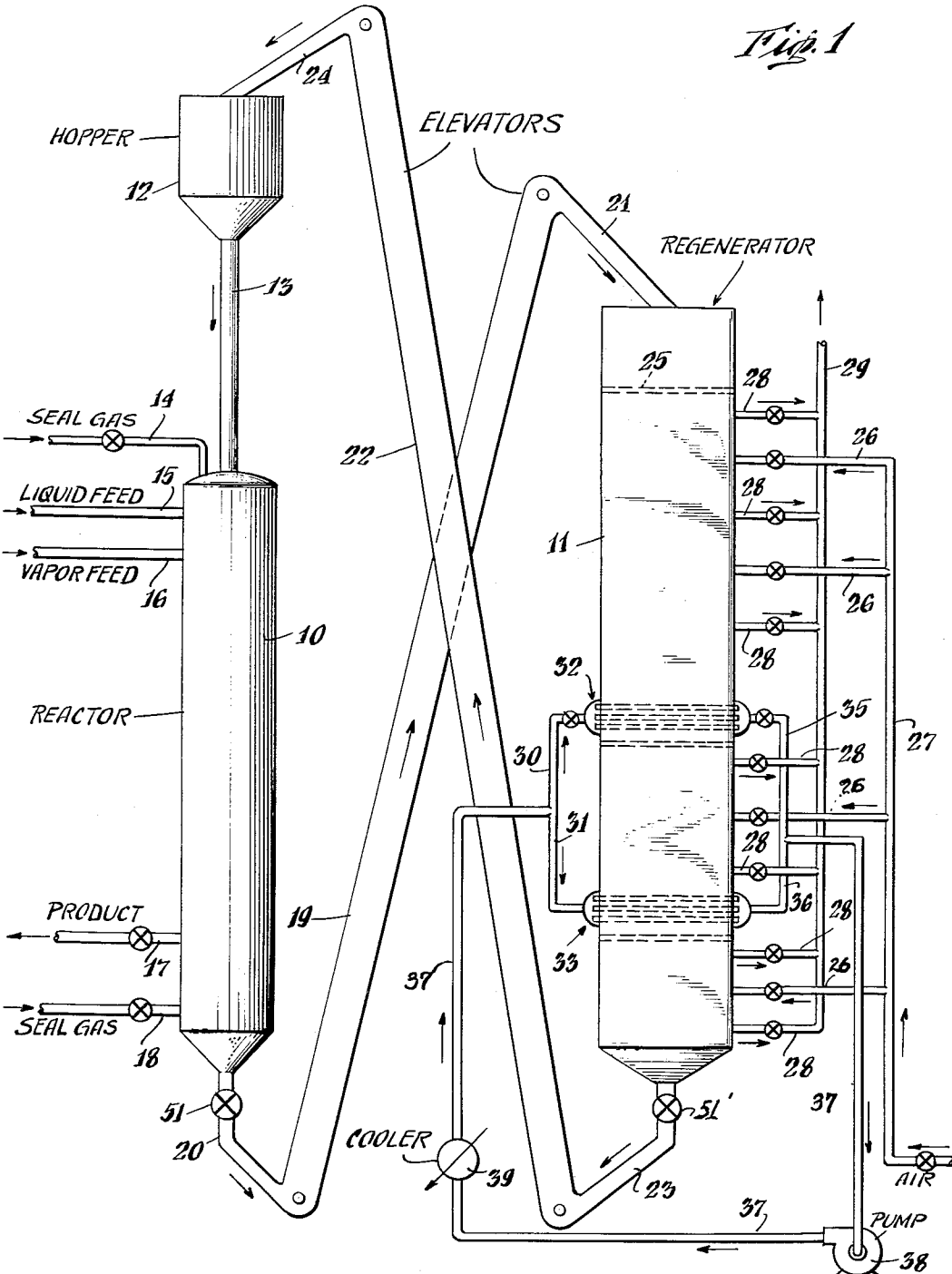
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2,741,603

METHOD AND APPARATUS FOR COOLING GRANULAR CONTACT MATERIAL

Filed Nov. 4, 1952

4 Sheets-Sheet 1



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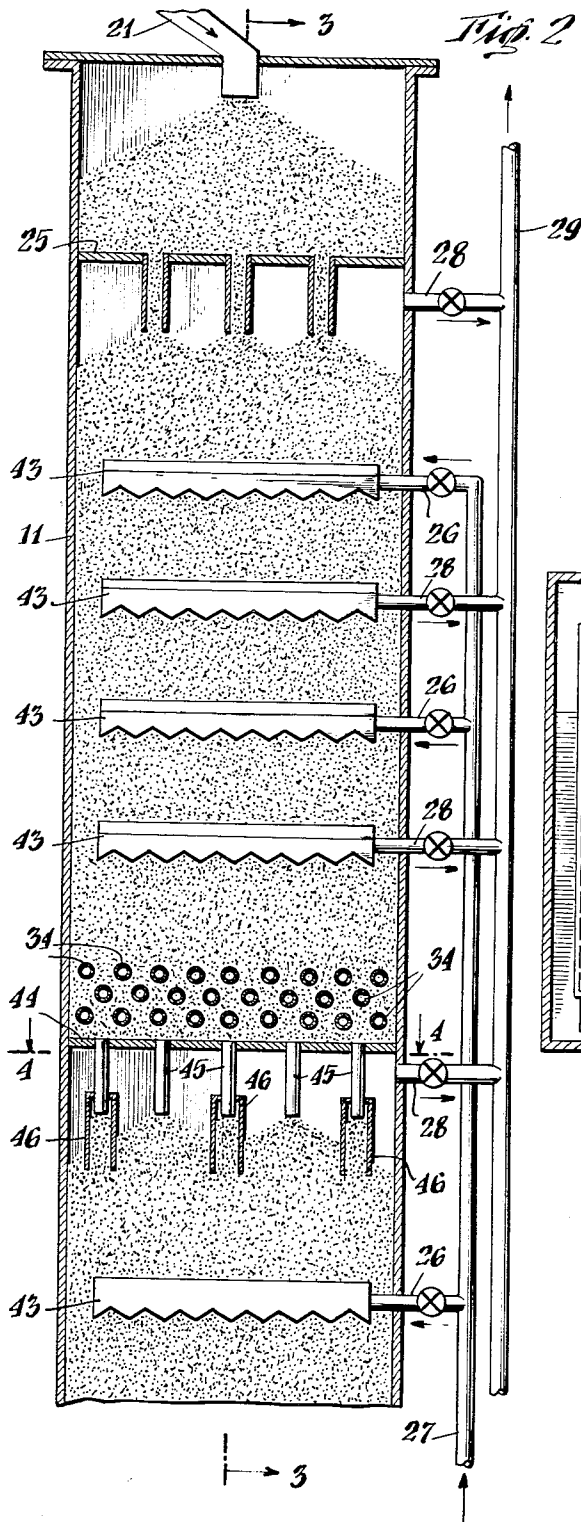
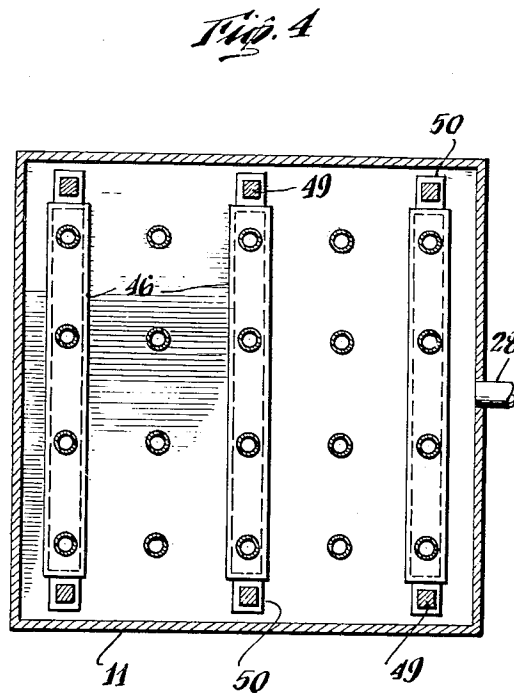
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METHOD AND APPARATUS FOR COOLING GRANULAR CONTACT MATERIAL

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4 Sheets-Sheet 2



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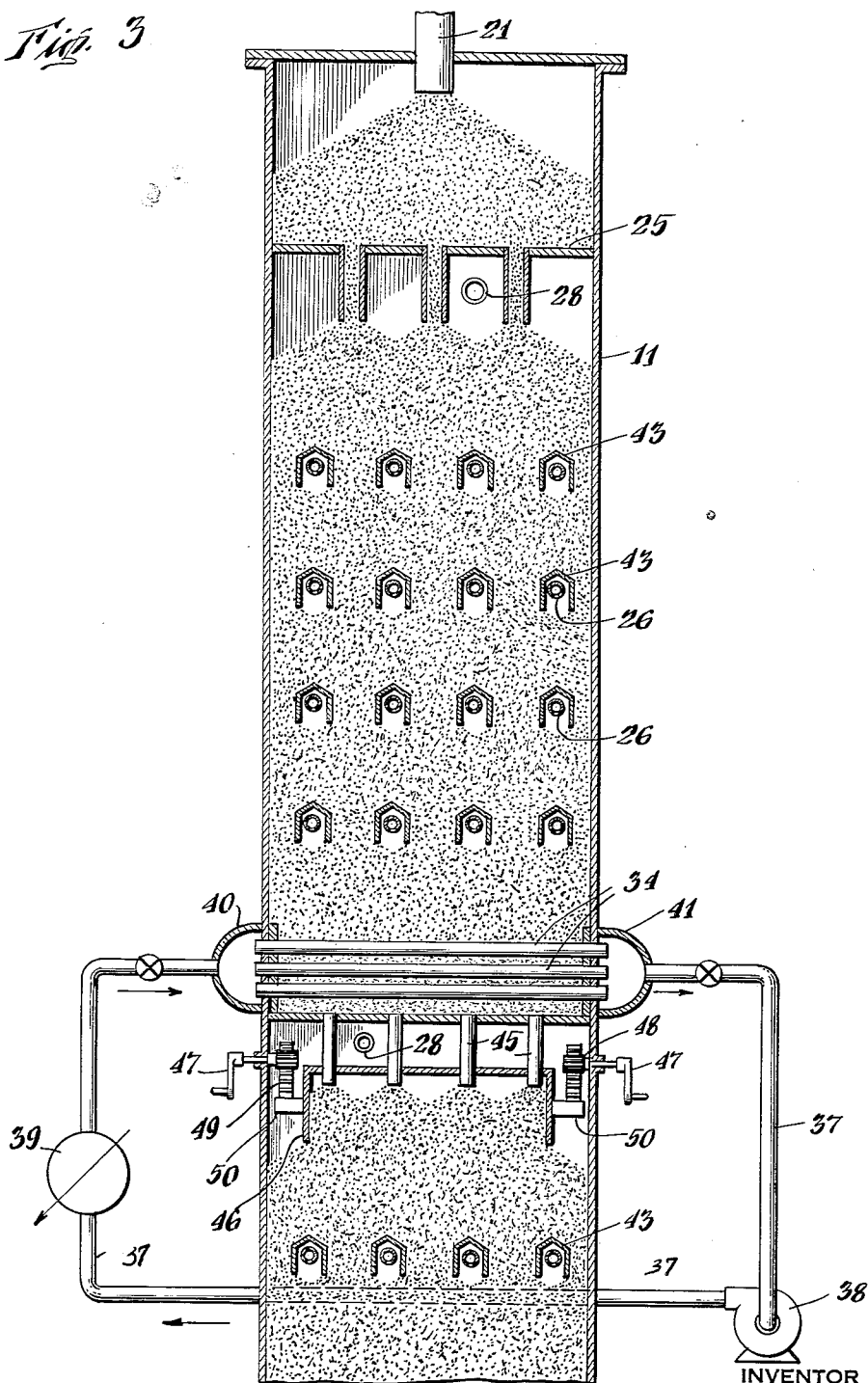
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METHOD AND APPARATUS FOR COOLING GRANULAR CONTACT MATERIAL

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4 Sheets-Sheet 3

Fig. 3



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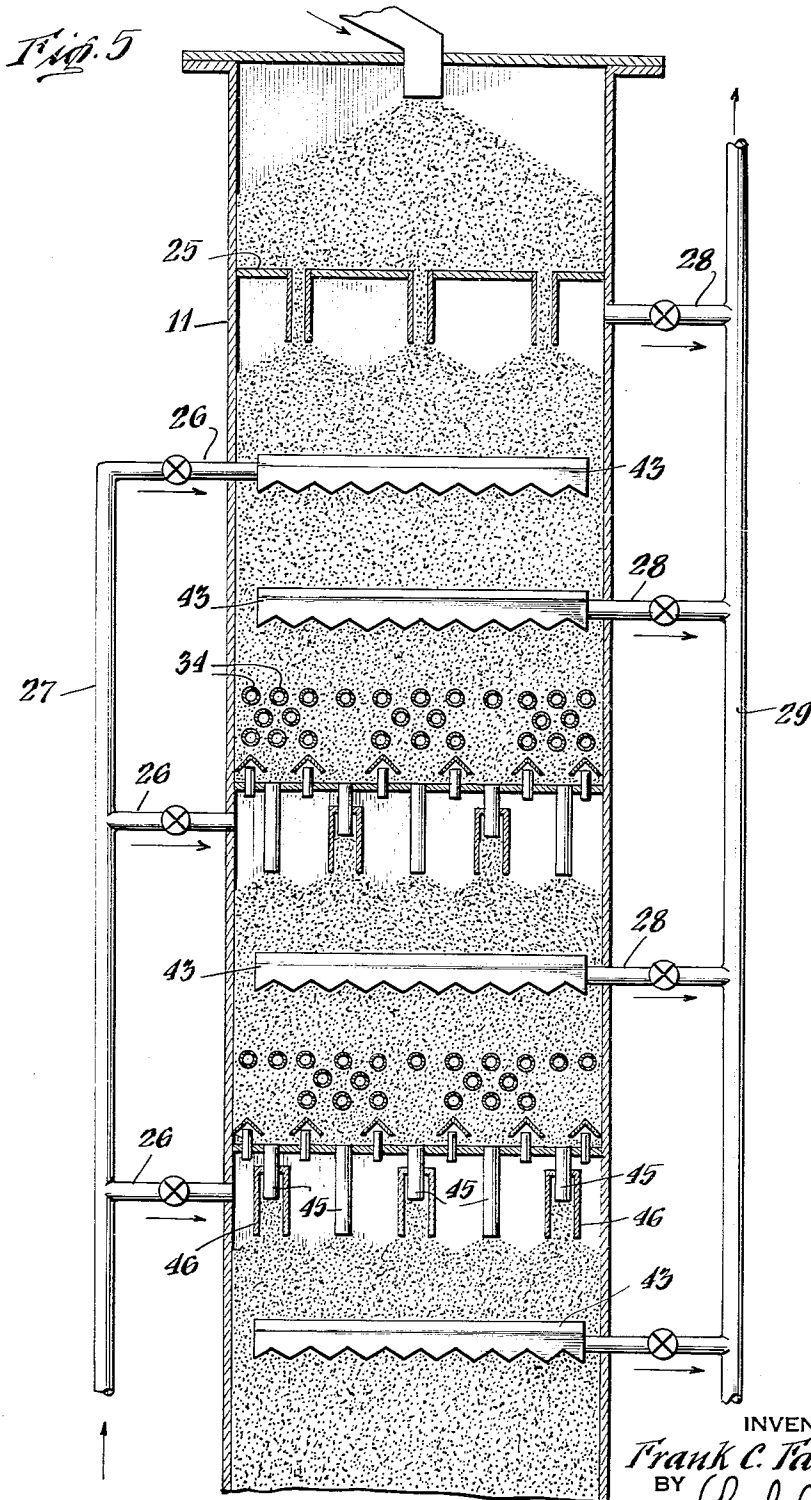
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METHOD AND APPARATUS FOR COOLING GRANULAR CONTACT MATERIAL

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4 Sheets-Sheet 4



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METHOD AND APPARATUS FOR COOLING GRANULAR CONTACT MATERIAL

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Application November 4, 1952, Serial No. 318,563

20 Claims. (Cl. 252—418)

This invention pertains to the cooling of gravitating compact masses of solid hot contact material. It is particularly directed to an improved method and apparatus for extracting heat from a gravitating substantially compact mass of particle-form contact material in a moving bed hydrocarbon conversion system.

Many processes, such as cracking, polymerization, reforming, coking and desulfurization, use gravitating columns of granular contact material in an enclosed cyclic system. For example, in cracking heavy petroleum stocks to produce lighter hydrocarbons, preferably boiling in the gasoline boiling range, the granular material is gravitated as a substantially compact bed through a reaction zone where it is contacted with hydrocarbons to effect the cracking reactions and the converted products are withdrawn continuously from the bed. During gravitation through the reaction zone, the particles of contact material acquire a deposit of carbonaceous material commonly referred to by those familiar with the art as "coke" which must be removed periodically. The particles are withdrawn from the bottom of the reaction zone and transferred to the top of a reconditioning zone. In the reconditioning zone the particles are gravitated as a substantially compact mass and blown with air to effect the combustion of the deposited material or coke. Flue gases are removed from the zone continuously carrying with them some of the heat released by the burning. The regenerated contact material is withdrawn from the bottom of the reconditioning zone and transferred to the top of the reaction zone.

The particles may be catalytic in nature or not. Catalysts, such as natural or activated clays, bauxite, montmorillonite, etc., are well known in the hydrocarbon conversion art, as are synthetic hydrogels of alumina, chromia, etc. When the process is coking or visbreaking, where only thermal cracking may be involved, the particles may be formed of inert material such as fused quartz, iron balls, coke particles or Carborundum. Cracking reactions have been found to occur most readily at a temperature of about 800–1000° F. and at an advanced pressure, for example, 5–30 p. s. i. (gauge). It is desirable, of course, to complete the reconditioning of the material as rapidly as possible and, therefore, high temperatures are used in the kiln or reconditioner, in the neighborhood of 1000–1300° F. The upper limit of temperature in the kiln is generally limited by the catalyst, because it has been found that catalytic materials lose their activity if they are heated much in excess of about 1300° F. When catalytic materials are being regenerated, therefore, it is generally necessary to extract heat during the regeneration to prevent the catalyst from being heat damaged.

The prior art shows the use of heat exchange coils in the kiln in many variant forms. It is desirable to permit temperature adjustment during operation to keep the temperature in the kiln high, permitting rapid regeneration. This has been accomplished in the past primarily by placing more or less tubes into operation by means of valves which prevent or permit cooling fluids to flow through

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portions of the tubes in the vessel. When the cooling fluid is prevented from flowing through the tubes, the tube reaches the temperature of the solids in the vessel. The cooling fluid is kept at a temperature substantially below the temperature of the contact material and thus, when the fluid is first passed through the hot tubes, the tube material is subjected to shock chilling. This has caused stress cracking and in some cases has led to accelerated corrosion and even rupture of the pipes with a release of the fluid. Although efforts to relieve this difficulty have been tried, none has been really successful.

It has been suggested that the trouble may be avoided by using a catalyst circulating rate which is high enough to permit the particles to be passed through the kiln without cooling and by using a catalyst cooler outside the regenerator as a means of balancing the heat transfer in the system. For example, in catalytic cracking it is usually necessary to extract some heat from the solids after regeneration to prevent the reaction temperature from rising to too high a level. The cooler suggested is one in which the cooling fluid is kept in contact with the entire heat exchange surface at all times and the degree of cooling is varied by varying the volume of catalyst in contact with the cooling surface at any given instant. Such a cooler is shown and claimed in copending applications for United States Patents Serial Number 154,130, filed April 5, 1950, now Patent Number 2,690,057, and Serial Number 148,669, filed March 9, 1950, now Patent Number 2,690,056. These coolers, while they are a substantial improvement of the prior art, have some undesirable features. They cannot be located within the regenerator, especially where gas transfer is being effected, because of the open passages through the cooler. Also, where the metal of the cooler is not contacting hot contact material, the temperature drops below the temperature of the metal in contact with the contact material. This causes undesirable temperature stresses to be set up in the metal, which may cause cooler failure.

It is an object of this invention to provide a cooler and method of cooling contact material in which the entire area of the cooling surface is maintained in contact with cooling fluid at all times and is also maintained in contact with hot contact material at all times.

It is a further object of this invention to provide an improved cooler and method of cooling hot contact material in which the entire area of the cooling surface is maintained in contact with cooling fluid at all times and the cooler can be located within a regenerating zone for use in preventing the contact material temperature from rising to heat-damaging levels.

It is a further object of this invention to provide an improved regenerator and method of regenerating contact material in which heat is extracted by a heat exchanger section in adjustable amounts necessary to maintain the temperature of the contact material within the desired operating range and yet the entire surface of the heat exchanger is maintained in contact with cooling fluid at all times.

These and other objects of the invention will be made more apparent in the following detailed description of the invention, made with reference to the attached diagrammatic sketches.

One broad aspect of this invention involves the passage of a substantially compact mass of hot solids through an upright vessel which has a cooling section in which cooling pipes are distributed across the vessel. The mass of solids is divided into a multiplicity of streams beneath the heat-exchanging section and the flow rate of solids through some of the streams is reduced while the flow rate through the remaining streams is increased. By this method, the rate of volumetric flow of hot solids over some of the cooling tubes is increased while a compensating opposite

change is made in the volumetric flow of hot solids over the remaining tubes. By this procedure, the temperature of the solids is adjusted to the desired temperature without entirely diverting the flow of solids away from any tubes and without preventing the flow of cooling fluid through any of the tubes. It is a feature of this invention that the change of flow rate of solids through some of the passages is effected without placing any valves or restrictions in the passage. Valves, star wheels and the like are undesirable for use in controlling the flow of solids in moving bed conversion systems because they grind the catalyst to dust, are eroded by the abrasive catalyst and are constantly breaking down because of the tendency of the particles to pack in the crevices of the throttling device and jam the moving parts.

Figure 1 is a diagrammatic showing of a moving bed conversion system.

Figure 2 is a vertical sectional view of a kiln showing the improved cooling section incorporated therein.

Figure 3 is a vertical sectional view of the kiln of Figure 2 as seen on plane 3—3 of Figure 2.

Figure 4 is a plan view of the kiln of Figure 2 as seen on plane 4—4 of Figure 2.

Figure 5 is a vertical sectional view of a multi-stage kiln incorporating the improved cooling section.

Throughout the views, similar reference characters refer to similar parts. Referring to Figure 1, a general system for the conversion of hydrocarbons in the presence of a moving bed of granular contact material is shown. A reactor 10 is shown alongside a regenerator or kiln 11. Above the reactor is a storage hopper 12 connected to the top of the reactor by an elongated conduit or gravity feed leg 13. An elevator 19 of the bucket type is located between the vessels. The connecting conduit 20 is connected between the bottom of the reactor and the bottom of the elevator 19. The conduit 21 is connected between the top of the elevator and the top of the regenerator 11. A second elevator 22 is located between the vessels. The conduit 23 is connected between the bottom of the regenerator 11 and the bottom of the elevator 22. The conduit 24 is connected between the top of the elevator 22 and the hopper 12.

The kiln cross-section is shown on Figures 2, 3 and 4. A partition 25 is located horizontally across the upper portion of the vessel. The region located below the partition 25 is utilized for reconditioning the particles. A multiplicity of pipes 26 are attached to the vessel at spaced levels to supply air for combustion from the common pipe 27. A multiplicity of pipes 28 are attached at levels intermediate the pipes 26 for removal of the flue gas through the common pipe 29. Pipes 30, 31 are attached to cooling sections 32, 33. The cooling sections 32, 33 are formed by headers 40, 41 and horizontal pipes 34 passed through the vessel 11. Referring specifically to Figure 1, pipes 35, 36 are attached to the cooling sections to effect removal of the cooling fluids. Pipe 37 is connected between pipes 30, 31 and pipes 35, 36. A pump 38 and cooler 39 is located in the pipe 37. Figure 3 shows a circulating cooling system for cooling solids at a single level. The connecting pipe 37 is located between headers 40 and 41 and has incorporated in it a pump 38 and cooler 39.

Referring particularly to Figures 2, 3 and 4, the gas introduction and collecting channels 43 are located at space levels along the vessel 11. A partition plate 44 is located horizontally across the vessel at an intermediate level. Drop pipes 45 are located uniformly across the partition 44 and alternate pipes 45 have extensions 46 about them which telescope the drop pipes, permitting alternate pipes to be lengthened or shortened. The extension members 46 shown comprise boxes with holes in their upper ends and open lower ends. The holes in each box fit one row of drop pipes. The extension members are raised by cranks 47, 47, mating bevel gears 48, 48, vertical shafts 49, 49. The shafts 49, 49 are threadably

engaged with the lugs 50, 50 on the sides of the extension members.

In operation, the catalyst is gravitated as a continuous column downwardly from the hopper 12, through the elongated seal leg 13, reactor 10 and conduit 20 to the bottom of the elevator 19. The flow of the catalyst is controlled by the valve 51 in the conduit 20. The seal leg 13 is made long enough to permit the solids to feed smoothly into the reactor against the advance pressure therein. The seal leg deters reactant gas from travelling upwardly. A seal gas is introduced through the conduit 14 into the top of the reactor 10 at a pressure slightly higher than reactor pressure to prevent reactants from flowing upwardly through the column of catalyst. The reactants may be charged in liquid form, vapor form or a mixture of both. The vapors travel downwardly through the voids in the catalyst bed and the converted products are withdrawn at the bottom of the bed. A stripping gas is introduced into the bottom of the bed of catalyst to remove vaporizable hydrocarbons from the catalyst. The catalyst removed from the bottom of the bed is contaminated with carbonaceous deposits or coke and is, therefore, transferred by the bucket elevator to the top of the kiln.

The contact material is gravitated as a compact mass through the kiln. The region above the partition 25 in the upper portion of the kiln serves as a surge space, providing storage room for catalyst in the event of a temporary unbalance of flow through the two elevator systems. Air is blown into the bed of catalyst at various levels through alternate channels 43 to travel upwardly and downwardly through the bed to the next adjacent channel. The flue gas is removed from the bed at levels intermediate the levels of gas introduction.

Referring now to Figures 2, 3 and 4, which illustrate the use of a single cooling section at an intermediate level in the kiln, details of the invention will be pointed out with more particularity. The solids are cooled by passage over cooling pipes 34. The pipes are distributed uniformly across the column, and, therefore, all the catalyst receives some cooling. The partition 44 is located just below the cooling pipes and the drop pipes 45 are distributed uniformly across the partition. When the extension members 46 are in the upper position, the lower ends of all the drop pipes 45 are at a uniform level. Therefore, catalyst feeds from each pipe at about the same rate. The pipes draw catalyst from a region above the plate 44 generally defined by the frustum of an inverted cone. The side walls of the cone are disposed at an angle with the horizontal which corresponds with the angle of internal flow of the catalyst. This angle, for most catalyst employed for hydrocarbons conversion, is generally about 65–75 degrees with the horizontal. It is seen, therefore, that the catalyst entering any given drop pipe will contact only those cooling pipes which pass through this imaginary inverted cone above that drop pipe. When the extension members are up, and the flow through the drop pipes is uniform, all catalyst particles will be cooled substantially the same amount. However, if less cooling is desired, the extension member 46 can be lowered. If the drop pipes possessing extension members were not present, the catalyst flowing through the other drop pipes would form conical piles, after discharge from the pipes. The surface of the piles would slope at the angle of repose of the catalyst, which for most catalytic materials used in moving bed conversion systems is about 30 degrees with the horizontal. The piles would spread out, therefore, to cover the entire cross-section of the vessel beneath the plate 44. The extension members are made long enough so that in the lower position, the lower end of the extension member is below the surface level of the piles formed by the drop pipes which do not possess extension members. Practically the entire cross-section of the vessel is covered with catalyst before the catalyst from

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the extension members is introduced into the bed, and therefore, the flow through the extension members is materially reduced. Catalyst from the extension members is limited to that region just below the member and is not allowed to expand laterally. This throttling action materially limits the flow rate of the catalyst over those portions of the pipes 34 above the drop pipes which possess extension members. And since the catalyst flowing through the drop pipes which do not possess extension members must expand laterally to cover a larger area below the pipes than above, the flow of catalyst through these pipes is correspondingly increased. Therefore, the bulk of the catalyst contacts approximately half the cooling area it formerly contacted and for approximately half the time it formerly contacted the cooling pipes. The result is that less heat is extracted from the catalyst, as desired.

Additional air may be blown through the column at staged levels below the cooling section as shown on the drawings. Although only one cooling section is shown on the drawings in Figures 2, 3 and 4, it is understood that several sections may be used at staged levels to meet the particular cooling requirements of any process. It is seen that variable cooling is effected in the kiln and yet the cooling pipes are maintained at all times in contact with catalyst on the one side and cooling fluid on the other. The thermal shocks involved in prior art coolers or cooling sections of the kiln are, therefore, avoided. It is seen also that no mechanical throttling device need be used in the catalyst column.

Figure 5 shows an alternate embodiment of the invention in which the cooling pipes are not uniformly distributed across the kiln. The pipes are arranged in a pattern so that there are more pipes or more cooling surface area above the drop pipes which do not have extension members. The drop pipes which possess extension members in this embodiment are made shorter than the other drop pipes, so that when the members are up, the catalyst from these drop pipes forms a bed level above the lower ends of the other drop pipes. This provides maximum flow of catalyst through those regions which contain the fewest number of cooling pipes and minimum flow of catalyst through the other regions. When the catalyst tends to overheat, the extension members are lowered to extend the effective length of the short drop pipes down to about the level of the longer drop pipes, thereby equalizing the flow of catalyst through all the pipes. This increases the amount of catalyst passing through the regions above the longer drop pipes which contain the greater portion of the cooling surface area. Additional amounts of heat are, therefore, extracted from the catalyst. The extension members may be constructed so that they can be lowered below the level of the long drop pipes, to cause the bulk of the catalyst to pass through the region possessing the greater portion of the cooling surface area, thereby providing maximum cooling of the contact material. As shown in the figure, the cooling sections may be located in those burning zones of the kiln which require cooling. For a multi-zone kiln of eight zones, this may require cooling in only the second, third and fourth zones.

The solids withdrawn from the bottom of the kiln are transferred to the hopper atop the reactor for reuse. The flow of solids through the kiln is adjusted by means of the valve 51 so that the contact material is maintained in the kiln in the form of a continuous column. The temperature of the solids is adjusted by the cooling sections of the kiln, so that coupled with the heat added via the reactants there is supplied to the reaction zone just sufficient heat to effect the desired reactions. When the reaction temperature rises to too high a level, an adjustment must be made in the cooling section of the kiln to bring the system back into heat balance.

Although the invention has been described as an im-

proved kiln, it is contemplated that a separate cooler may be designed according to these principles. It is less desirable to have the cooler separate from the kiln because the catalyst circulation rate must be maintained high to prevent heat damage in the kiln. This limits conditions in the reaction zone to a high catalyst to oil ratio. This invention, therefore, when applied to an improved kiln, permits greater flexibility of operation than other proposed systems of cooling the contact material, and is preferred in that form.

This invention is not intended to be limited to the specific embodiments shown above, being broad in its application and intended to cover all changes and modifications which do not constitute departures from the spirit and scope of the invention.

I claim:

1. The method of changing the temperature of a particle-form contact material which comprises: passing a stream of the contact material downwardly through a heat exchange zone as a compact gravitating column, into contact with a plurality of permanently located heat exchange surfaces arranged at spaced intervals across the horizontal cross-section of said column, passing a fluid heat exchange medium along the opposite sides of said heat exchange surfaces, so as to maintain the surfaces at all times at a substantially different temperature than said contact material and so as to effect a change in temperature of said contact material, and effecting a change in the volumetric flow of the contact material in some regions of the column cross-section and an opposite compensating change in the volumetric flow of the contact material in the remaining regions across the column whereby a change in the amount of contact material temperature alteration due to flow through the heat exchange zone is effected.

2. The method of cooling a particle-form contact material which comprises: passing a stream of hot contact material downwardly through a cooling zone as a compact gravitating column, into contact with a plurality of fixed cooling surfaces arranged at spaced intervals across the horizontal cross-section of said column, passing a fluid cooling medium along the opposite sides of said cooling surfaces, so as to maintain the cooling surfaces at all times at a substantially different temperature than said contact material and so as to effect a change in temperature of said contact material, maintaining some contact material flow in contact with all of the cooling surfaces at all times, and effecting a change in the volumetric flow of the contact material in some regions of the column cross-section and an opposite compensating change in the volumetric flow of the contact material in the remaining regions across the column whereby a change in the amount of cooling of the contact material is effected.

3. Method for the regeneration of a spent catalyst which is contaminated with a carbonaceous contaminant from a previous conversion reaction which comprises: passing the spent catalyst as a substantially compact column through a confined vertical regeneration zone, passing an oxygen-containing gas into contact with the catalyst to effect removal of coke by burning, passing a cooling fluid through a plurality of static spaced cooling conduits arranged across said column at at least one level along its length, so as to remove sufficient heat from the contact material to prevent overheating of the catalyst to a heat-damaging level, and changing the volumetric rate of catalyst flow in at least one region of the column at the level of the cooling conduits and changing the volumetric rate of flow a compensating amount in the opposite direction in the other regions of the column cross-section, while maintaining at least some flow of contact material at all times in contact with all of the cooling conduits.

4. The method of cooling a particle-form contact material which comprises: passing a stream of hot contact material downwardly through a cooling zone as a compact gravitating column, into contact with a plurality of im-

movable cooling conduits arranged uniformly across the column cross-section at at least one level, passing a fluid cooling medium through the conduits, so as to maintain the cooling conduits at all times at a substantially different temperature than said contact material and so as to effect a change in temperature of said contact material, maintaining some contact material flow by all of the cooling conduits at all times, increasing the flow rate of the contact material in regions of the cross-section at the level of the cooling conduits and decreasing the flow rate of the contact material in the remaining regions of the cross-section at the level of the cooling conduits, the maximum amount of cooling being effected when the flow of contact material is substantially uniform all across the column and the rate of cooling decreasing as the flow is increased in some regions at the expense of the remaining regions.

5. Method for the regeneration of a spent catalyst which is withdrawn from a previous reaction with hydrocarbons contaminated with a coke deposit which comprises: passing the contaminated catalyst as a substantially compact column through a confined vertical regeneration zone, passing an oxygen-containing gas into contact with the catalyst to effect removal of coke by burning, passing a cooling fluid through a plurality of spaced immovable cooling conduits arranged uniformly across said column at at least one level along its length, so as to remove sufficient heat from the contact material to prevent overheating of the catalyst to a heat-damaging level, maintaining some contact material flow by all of the cooling conduits at all times, increasing the flow rate of the contact material in regions of the cross-section at the level of the cooling conduits and decreasing the flow rate of the contact material in the remaining regions of the cross-section at the level of the cooling conduits, the maximum amount of cooling being effected when the flow of contact material is substantially uniform all across the column and the rate of cooling decreasing as the flow is increased in some regions at the expense of the remaining regions.

6. The method for the regeneration of a spent catalyst which is withdrawn from a previous reaction with hydrocarbons contaminated with a coke deposit which comprises: passing the contaminated catalyst as a substantially compact column through a confined vertical regeneration zone, passing an oxygen-containing gas into contact with the catalyst to effect removal of coke by burning, passing a cooling fluid through a plurality of spaced immovable cooling conduits arranged uniformly across said column at at least two levels along its length, so as to remove sufficient heat from the contact material to prevent overheating of the catalyst to a heat-damaging level, maintaining some catalyst flow by all of the cooling conduits at all times, increasing the flow rate of the catalyst in regions of the cross-section at the levels of the cooling conduits spaced uniformly across the column cross-section and decreasing the flow rate of the contact material in the remaining regions of the cross-section at the levels of the cooling conduits, said regions of increased and decreased catalyst flow rate being horizontally staggered at the levels of cooling, so as to promote overall uniform temperature along the regeneration zone, the maximum amount of cooling being effected when the flow of contact material is substantially uniform all across the column and the rate of cooling decreasing as the flow is increased in some regions and decreased in the alternate regions.

7. The method of cooling a particle-form contact material which comprises: passing a stream of hot contact material downwardly through a cooling zone as a compact gravitating column, into contact with a plurality of static cooling conduits arranged across the column cross-section in alternate regions of heavy and light concentrations of conduits at at least two levels, passing a fluid cooling medium through the conduits, so as to maintain the cooling conduits at all times at a substantially different temperature than said contact material and so as

to effect a change in temperature of said contact material, maintaining some contact material flow by all of the cooling conduits at all times, increasing the flow rate of the contact material in regions of the cross-section at the level of the cooling conduits which contain light concentrations of the cooling conduits and decreasing the flow rate of the contact material in said alternate regions of the cross-section at the level of the cooling conduits which contain heavy concentrations of the cooling conduits, so as to effect a reduction in the amount of heat withdrawn from the contact material, the regions of heavy and light concentrations of cooling conduits at the various levels being staggered horizontally across the column cross-section, so as to provide more uniform temperature of contact material across the column.

8. The method for the regeneration of a spent catalyst which is withdrawn from a previous reaction with hydrocarbons contaminated with a coke deposit which comprises: passing the contaminated catalyst as a substantially compact column through a confined vertical regeneration zone, passing an oxygen-containing gas into contact with the catalyst to effect removal of coke by burning, passing a cooling fluid through a plurality of static cooling conduits arranged across the column cross-section in alternate regions of heavy and light concentrations of conduits at at least two levels, so as to maintain the cooling conduits at all times at a substantially different temperature than said catalyst and so as to effect a change in temperature of the catalyst, maintaining some catalyst flow by all of the cooling conduits at all times, increasing the flow rate of the catalyst in regions of the cross-section at the level of the cooling conduits which contain light concentrations of the cooling conduits and decreasing the flow rate of the contact material in said alternate regions of the cross-section at the level of the cooling conduits which contain heavy concentrations of the cooling conduits, so as to effect a reduction in the amount of heat withdrawn from the catalyst, the regions of heavy and light concentrations of cooling conduits at the various levels being staggered horizontally across the column cross-section, so as to provide more uniform temperature of contact material across the column.

9. The method for the regeneration of a spent catalyst which is withdrawn from a previous reaction with hydrocarbons contaminated with a coke deposit which comprises: passing the contaminated catalyst as a substantially compact column through a confined vertical regeneration zone, passing a cooling fluid through a plurality of static cooling conduits arranged across the column cross-section in alternate regions of heavy and light concentrations of conduits at at least two levels, so as to maintain the cooling conduits at all times at a substantially different temperature than said catalyst and so as to effect a change in temperature of the catalyst, maintaining some catalyst flow by all of the cooling conduits at all times, increasing the flow rate of the catalyst in regions of the cross-section at the level of the cooling conduits which contain light concentrations of the cooling conduits and decreasing the flow rate of the contact material in said alternate regions of the cross-section at the level of the cooling conduits which contain heavy concentrations of the cooling conduits, so as to effect a reduction in the amount of heat withdrawn from the catalyst, the regions of heavy and light concentrations of cooling conduits at the various levels being staggered horizontally across the column cross-section, so as to provide more uniform temperature of contact material across the column, introducing an oxygen-containing gas into the column at staged levels along the length of the column, at least some of said levels being located just below each level of cooling conduits, directing a portion of the gas introduced below the cooling conduits upwardly through the streams of rapidly-moving catalyst and then expanding the upwardly-moving gas streams laterally to cover the entire cross-section of the column in the region of the cooling conduits, whereby

heat is transferred from the catalyst to the cooling conduits, and withdrawing the gas at staged levels along the length of the column after combustion of the contaminant coke from the catalyst.

10. The method of cooling a particle-form contact material which comprises: passing a stream of hot contact material downwardly through a cooling zone as a compact gravitating column, into contact with a plurality of cooling conduits arranged uniformly across the column cross-section at at least one level, passing a fluid-cooling medium through the conduits, so as to maintain the cooling conduits at all times at a substantially different temperature than said contact material and so as to effect a change in temperature of said contact material, passing the contact material downwardly from a portion of the bed of gravitating contact material just below the cooling conduits through a plenum space from which contact material is excluded as a plurality of horizontally spaced-apart compact streams delivering onto a continuation of the column below the plenum space, changing the length of some of said streams so that they deliver under the surface of the column continuation, whereby the flow through these streams is substantially reduced and the flow over the cooling conduits directly above these streams is substantially reduced and controlling the rate of withdrawal from the bottom of the column substantially constant, so that flow from the remaining streams which deliver onto the surface of the column continuation is increased proportionately to the flow reduction in the other streams, whereby the flow over the cooling conduits above these streams is very substantially increased to the extent that it constitutes the major percentage of the total contact material flow and the amount of temperature reduction of these streams is reduced substantially whereby the overall average temperature reduction of all of the flow is very substantially reduced, without entirely diverting the flow of contact material from any of the cooling conduits.

11. The method of cooling a particle-form contact material which comprises: passing a stream of hot contact material downwardly through a cooling zone as a compact gravitating column, into contact with a plurality of cooling conduits arranged across the column cross-section in alternate regions of heavy and light concentrations of conduits at at least one level, passing a fluid cooling medium through the conduits, so as to maintain the cooling conduits at all times at a substantially different temperature than said contact material and so as to effect a change in temperature of said contact material, passing the contact material downwardly from a portion of the bed of gravitating contact material just below the cooling conduits through a plenum space from which contact material is excluded as a plurality of horizontally spaced-apart compact streams delivering onto a continuation of the column below the plenum space, changing the length of a first group of said streams so that they deliver under the surface of the column continuation, whereby the flow through these streams is substantially reduced and the flow over the cooling conduits directly above these streams is substantially reduced and controlling the rate of withdrawal from the bottom of the column substantially constant, so that flow from the second group of remaining streams which deliver onto the surface of the column continuation is increased proportionately to the flow reduction in the other streams, whereby the flow over the cooling conduits above these streams is very substantially increased to the extent that it constitutes the major percentage of the total contact material flow, said first and second groups of streams being located beneath the regions of heavy and light concentration of cooling conduits in alternating arrangement, so that flow of contact material through said regions may be increased or decreased to provide temperature adjustment, whereby the over-all average temperature can be adjusted without

entirely diverting the flow of contact material from any of the cooling conduits.

12. A cooler for granular contact material which comprises: an upright vessel, means for introducing contact material into the top of the vessel, means for withdrawing contact material from the bottom of the vessel, a multiplicity of permanently located cooling conduits distributed across the vessel, means for supplying coolant continuously to the conduits and means for withdrawing coolant continuously from the conduits, means for changing the flow rate of the contact material in some regions of the column cross-section and an opposite compensating change in the flow rate of the contact material in the remaining regions across the vessel whereby a change in the amount of contact material cooling due to flow over the cooling conduits is effected.

13. A regenerator for spent catalyst which comprises: an upright shell, a gas inlet conduit located between the top and bottom of said shell and a gas outlet conduit located a spaced vertical distance apart from said inlet, an inlet for catalyst in the top of the shell, an outlet for catalyst in the bottom of the shell, a plurality of spaced cooling conduits arranged across the shell at at least one level along its length in a permanent location, adapted to contact the catalyst in the regenerator and prevent overheating, means for changing the volumetric rate of catalyst flow in at least one region of the column at the level of the cooling conduits and means for changing the volumetric rate of flow a compensating amount in the opposite direction in the other regions of the column cross-section, which provides at least some flow of contact material at all times in contact with all of the cooling conduits.

14. A cooler for cooling a particle-form contact material which comprises: a vertical vessel, an inlet for contact material at the top, an outlet for contact material at the bottom, a plurality of fixed cooling conduits arranged uniformly across the vessel at at least one level, means for increasing the flow rate of contact material in regions of the cross-section of the vessel at the level of the cooling conduits and means for decreasing the flow rate of the contact material in the remaining regions of the vessel cross-section at the level of the cooling conduits, whereby maximum cooling can be effected when the flow of contact material is substantially uniform in all regions of the vessel cross-section and decreased cooling can be effected by increasing the flow of contact material in some regions while decreasing the flow a like amount in the remaining regions of the vessel cross-section.

15. A regenerator for spent catalyst which comprises: a vertical vessel, an inlet at the top thereof, means for introducing an oxygen-containing gas into the vessel at at least one intermediate level, means for withdrawing a flue gas from said vessel at at least one intermediate level spaced vertically apart from the gas inlet level, a plurality of spaced permanently located cooling conduits arranged uniformly across said vessel at at least one level along its length, means for increasing the flow rate of the catalyst in regions of the cross-section at the level of the cooling conduits and decreasing the flow rate of the contact material in the remaining regions of the cross-section at the level of the cooling conduits so as to maintain some catalyst in contact with all the cooling conduits at all times, whereby the maximum amount of cooling of the catalyst can be effected by adjusting the flow controlling means to provide uniform flow across the vessel and the minimum amount of cooling of the catalyst can be effected by adjusting the flow controlling means to provide maximum non-uniform flow across the vessel.

16. A cooler for cooling a particle-form contact material comprising in combination: an upright shell, an inlet at the top of the shell and an outlet at the bottom thereof, a plurality of permanently located cooling conduits arranged across the shell in alternate bundles of heavy and light concentrations of conduits at at least two levels along the length of the shell, means for increasing

the flow rate of contact material passing alternate bundles of conduits and means for decreasing the flow rate of contact material passing and remaining bundles of conduits, so as to effect a variation of the amount of heat withdrawn from the contact material, the bundles of tubes at the various levels in the shell being staggered horizontally across the cross-section of the shell, so that bundles of heavy concentrations of conduits at one level are located above the bundles of light concentrations of conduits at the next lower level and the bundles of light concentrations of conduits at the first level are located above the bundles of heavy concentrations of conduits at said next lower level.

17. A regenerator for spent catalyst which comprises: a vertical vessel, an inlet at the top thereof, an outlet at the bottom thereof, means for introducing an oxygen-containing gas into the vessel at at least one intermediate level, means for withdrawing gas from said vessel at at least one intermediate level spaced vertically apart from the gas inlet level, a plurality of permanently located cooling conduits arranged across the vessel in alternate bundles of heavy and light concentrations of conduits at at least two levels along the length of the vessel, means for increasing the flow rate of catalyst passing alternate bundles of conduits and means for decreasing the flow rate of catalyst passing the remaining bundles of conduits, so as to effect a variation of the amount of heat withdrawn from the catalyst, the bundles of conduits at the various levels in the vessel being staggered horizontally across the cross-section of the vessel, so that bundles of heavy concentrations of conduits at one level are located above the bundles of light concentrations of conduits at the next lower level.

18. A cooler for cooling a particle-form contact material comprising in combination: an upright shell, an inlet at the top of the shell and an outlet at the bottom thereof, a plurality of cooling conduits arranged uniformly across the shell at at least one level, a partition located horizontally across the shell just below the cooling conduits, drop pipes depending from the partition at locations uniformly distributed across the partition, extension members about alternate drop pipes adapted for vertical movement, so that when the extension members are in the up position, the bottom of said members is at the same level as the bottom of all drop pipes, and means for lowering said extension members, so that the lower end of said members is below the intersection of imaginary lines drawn downwardly from the lower edge of adjacent drop pipes at an angle of about 30 degrees with the horizontal.

19. A cooler for cooling a particle-form contact material comprising in combination: an upright shell, an inlet at the top of the shell, an outlet at the bottom thereof, a plurality of cooling conduits arranged across the shell in alternate bundles of heavy and light concentrations of conduits at at least one level along the length of the shell, a horizontal partition located across the shell just below the tube bundles, a plurality of drop pipes of alternately long and short length, attached to said partition located uniformly across the shell, so that at least one conduit is located beneath each tube bundle, extension members about the short drop pipes, the short pipes being at least a sufficient amount shorter than the long drop pipes so that when the extension members are in

the up position, lines drawn downwardly from the lower end of adjacent members at about 30 degrees with the horizontal intersect above the lower end of the long drop pipes, said extension members being long enough so that when they are in the down position, the lower end of said members is below the intersection of lines drawn downwardly from the lower ends of adjacent long drop pipes at an angle of about 30 degrees with the horizontal, and means for raising and lowering the extension members.

20. A regenerator for spent catalyst which comprises: a vertical vessel, an inlet at the top thereof, an outlet at the bottom thereof, means for introducing an oxygen-containing gas into the vessel at at least two intermediate levels and means for withdrawing gas from said vessel at at least two intermediate levels spaced vertically apart from the gas inlet levels, a plurality of cooling conduits arranged across the vessel in alternate bundles of heavy and light concentrations of conduits at at least two levels along the length of the vessel, horizontal partitions across the vessel just beneath each level of cooling conduits, a plurality of alternately long and short drop pipes attached to said partitions located uniformly across the vessel, the short pipes being located beneath tube bundles of one concentration and the other pipes being located beneath bundles of the other concentration, one of said gas introduction means being located just beneath each partition, so as to deliver gas into the plenum zone formed beneath the partition by the drop pipes and one of said gas outlet means being located a substantial distance above each partition, so that some gas travels upwardly through the drop pipes and over the cooling tubes to reach said outlet means, extension members about the short drop pipes, adapted to prevent the catalyst passing through said drop pipes from spreading laterally until it reaches the bottom of said extension members, the short pipes being at least a sufficient amount shorter than the long drop pipes so that when said members are in the up position, lines drawn downwardly from the lower end of adjacent members at about 30 degrees with the horizontal intersect above the lower end of the long drop pipes, said extension members being long enough so that when they are in the down position, the lower end of said members is below the intersection of lines drawn downwardly from the lower ends of adjacent long drop pipes at an angle of about 30 degrees with the horizontal, said tube bundles being staggered horizontally across the vessel at the various levels, so that bundles of heavy concentration are located above bundles of light concentration, said drop pipes being similarly staggered, so that short drop pipes are located above long drop pipes, and means for raising and lowering said extension members external of said vessel.

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