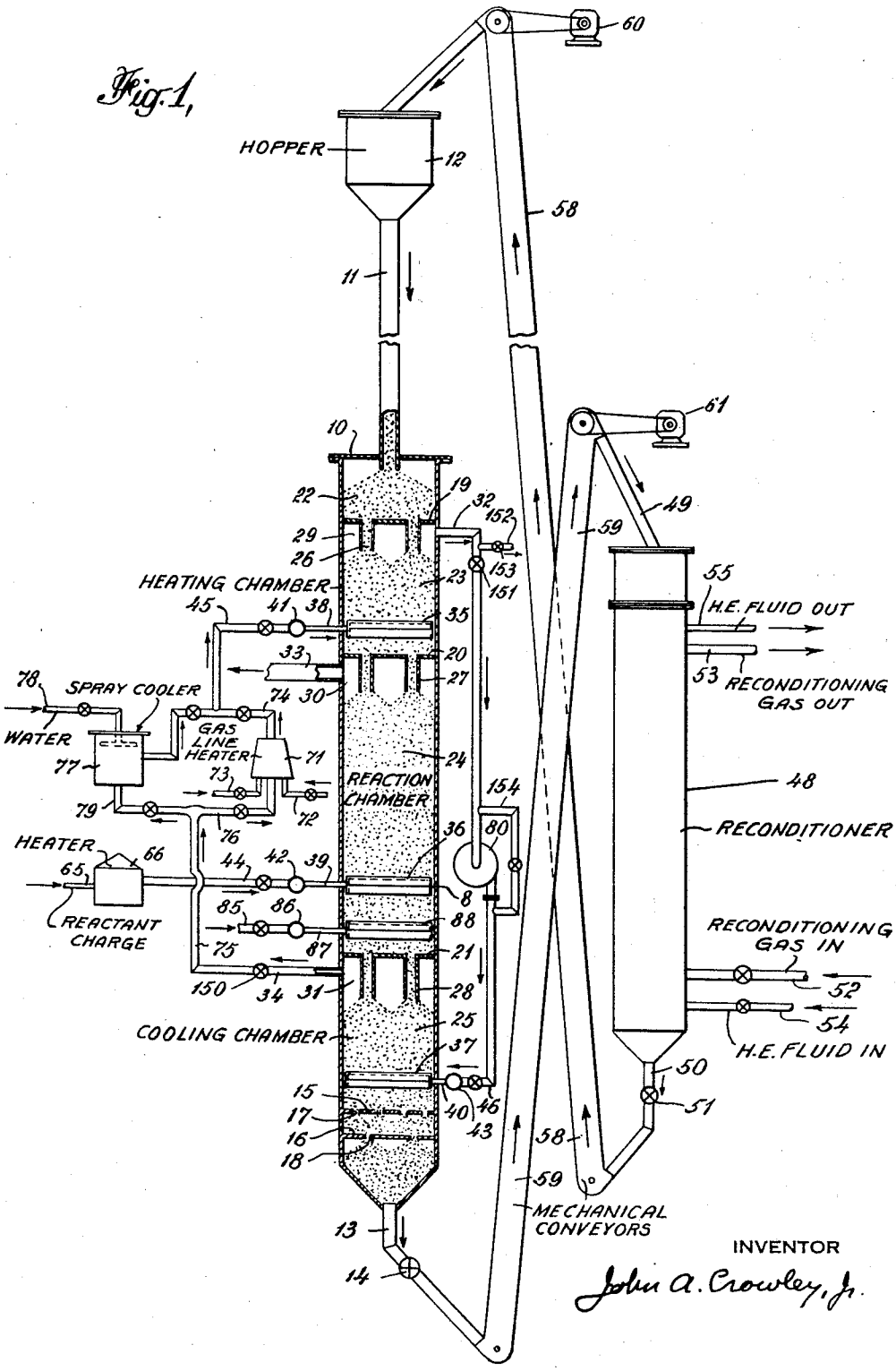
May 23, 1950 J. A. CROWLEY, JR 2,508,993

METHOD FOR CONDUCTING GASEOUS REACTIONS IN THE PRESENCE OF A MOVING PARTICLE FORM SOLID

Filed May 16, 1947 2 Sheets-Sheet 1

Fig. 1,



INVENTOR

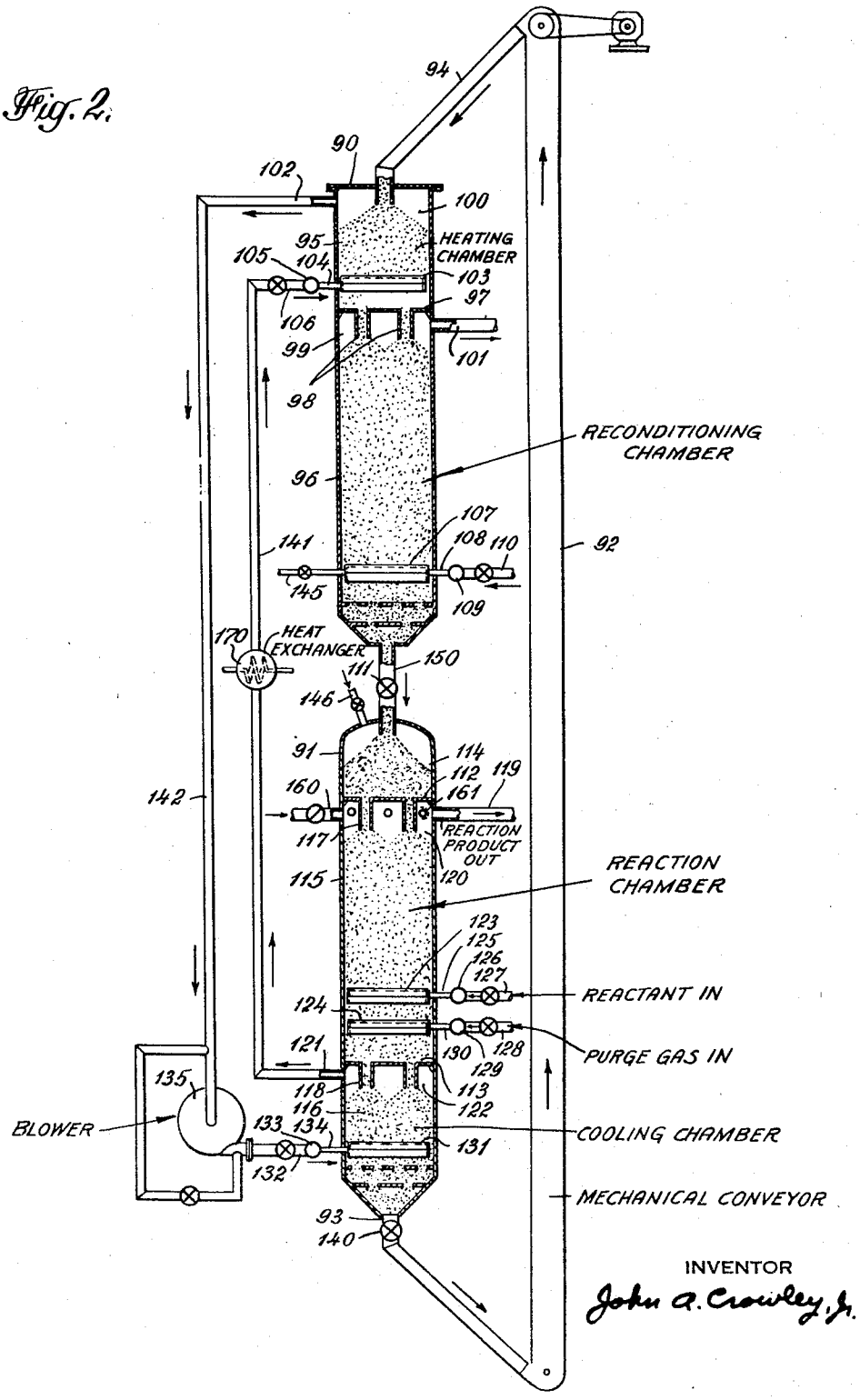
John A. Crowley, Jr.

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METHOD FOR CONDUCTING GASEOUS REACTIONS IN THE PRESENCE OF A MOVING PARTICLE FORM SOLID

Filed May 16, 1947 2 Sheets-Sheet 2

Fig. 2.



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Patented May 23, 1950 2,508,993

UNITED STATES PATENT OFFICE

2,508,993

METHOD FOR CONDUCTING GASEOUS REACTIONS IN THE PRESENCE OF A MOVING PARTICLE FORM SOLID

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Application May 16, 1947, Serial No. 748,578

19 Claims. (Cl. 196—52)

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This invention has to do with a method for conducting gaseous reactions in the presence of a particle form contact material moving through the reaction zone as a substantially compact column. The method of this invention is particularly adapted for conducting gaseous reactions which require reaction temperatures above those temperatures at which solid material can be practically conveyed in conventional conveyor equipment. Exemplary of such processes is the high temperature catalytic cracking conversion of hydrocarbons at temperatures of the order of 1000° F. to 1200° F. to high yields of aviation gasoline and C_4 fractions. Another process is the conversion of propane to acetylene at temperatures of the order of 2300° F. in the presence of an inert solid material. Another process is the dehydrogenation of butene to di-olefins at temperatures of the order of 1000° F. to 1300° F. in the presence of a dehydrogenation catalyst such as chromic oxide on alumina. Still another reaction is the pyrolysis of pentene-2 to butadiene at temperatures of the order of 1200–1300° F. Another reaction is the preparation of thiophene and butadiene by reaction between n-butane and sulfur vapors at temperatures of the order of 900–1200° F. Another process is the manufacture of ethylene by the cracking of heavier hydrocarbons such as gas oils or by the cracking of propane or ethane at temperatures of the order of 1400° F.–1800° F. In the case of all of these reactions the operation is carried out at relatively low pressures of the order of atmospheric to about 100 pounds per square inch gauge.

An important practical difficulty arises in attempting to conduct such processes as enumerated above in the so-called "moving bed type" of processes. Such moving bed type processes for proper operation require the use of a granular or particle form contact material as distinguished from powdered contact material and it is of the utmost importance in moving bed processes to limit the amount of catalyst attrition to fines to an absolute minimum. In order to attain this objective it has been found necessary in such systems wherein cyclic flow of the contact material is involved to utilize mechanical conveyors to complete the cyclic event. One of the most satisfactory types of mechanical conveyors for this purpose is the continuous bucket elevator which is adapted to transfer solid particles from one level to another with a minimum of breakage and attrition of said solid particles. However, in processes of the type described hereinabove, the required contact material temperatures are so high that attempts to mechanically

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convey the contact materials at such temperatures would result in failure and very rapid wear of the metal parts of the mechanical conveyor. It has been found unpractical to attempt to mechanically convey contact materials at the temperatures involved in most of the above described reactions. On the other hand to cool the contact material down before conveying and then to reheat the contact material again after conveying to render it suitable for use in the convertor results in a loss from the cyclic system of an uneconomically high amount of heat which renders the whole process unfeasible. The use of gas conveyors or gas lifts to transfer the contact material in such processes is also unfeasible because of the excessive amount of contact material attrition that inherently occurs in that type of conveying equipment.

A major object of this invention is the provision of a method for conducting such processes as described hereinabove which method overcomes the above described difficulties.

Another object of this invention is the provision of a practical method for conducting reactions involving gaseous reactants in the presence of a mass of moving solid material particles at reaction temperatures above those at which it has been heretofore found practical to convey solid particles.

Another object is the provision of a practical continuous process for conducting high temperature gaseous reactions in the presence of a substantially compact column of moving solid particles.

A specific object of this invention is the provision of an improved cyclic process for the high temperature conversion of saturated fluid hydrocarbons to ethylene containing products.

Another specific object is the provision of an improved cyclic process for catalytic cracking conversion of petroleum fractions to gaseous products containing substantial amounts of hydrocarbons containing four carbon atoms in the presence of a moving mass of particle form catalyst.

These and other objects of this invention will become apparent from the following discussion thereof.

The invention may be most readily understood by reference to the attached drawings of which

Figure 1 is an elevational view, partially in section, of a system for conducting the method of this invention; and,

Figure 2 is a similar view of a modified and preferred form of this invention. Both of these drawings are highly diagrammatic in form.

Turning now to Figure 1 there is shown an elongated vertical vessel 10, which may be supplied with contact material at its upper end through an elongated feed conduit 11 extending downwardly from a supply hopper 12. A contact material discharge conduit 13 bearing a throttling valve 14 is connected into the downwardly tapered bottom of vessel 10. Above the discharge conduit 13 there are provided across the vessel 10 two vertically spaced apart horizontal partitions 15 and 16. The partition 15 has a plurality of uniformly spaced orifices 17 therein. The partition 16 has a smaller plurality of orifices 18 therein, positioned in horizontally staggered relationship with the orifices 17. The arrangement is such that the contact material flowing from the column thereof above partition 16 is split into a plurality of streams uniformly distributed over the vessel cross-section, which streams are then proportionately merged in steps until only a single outlet stream in conduit 13 is provided. By this arrangement it is possible to withdraw contact material uniformly from all portions of the vessel horizontal cross-sectional area to the single outlet 13. This invention is not to be construed as limited to this arrangement and it is contemplated that any other arrangement adapted to accomplish the same purpose may be substituted therefor. The vessel 10 is divided into four superposed chambers by means of vertically spaced horizontal partitions 19, 20 and 21 positioned at intervals within the vessel. The chambers so formed are, reading downwardly, contact material surge chamber 22, heating chamber 23, conversion chamber 24, and cooling chamber 25. Uniformly distributed tubes 26, 27 and 28 depend from partitions 19, 20 and 21 respectively for flow of contact material from each chamber to the chamber next below. The tubes 26, 27 and 28 also serve to provide gas collecting spaces 29, 30 and 31 in the upper ends of chambers 23, 24 and 25 respectively. Gas outlet conduits 32, 33 and 34 connect into the vessel shell at the levels of collecting spaces 29, 30 and 31 respectively. Within the lower sections of chambers 23, 24 and 25 there are provided rows of spaced, horizontally extending inverted gas distributing troughs 35, 36 and 37 respectively. Only one trough in each row is visible in Figure 1. In a preferred form these troughs may have gable shaped roofs and they are open along their bottoms and closed by plates such as 8 on their ends. Gas may be supplied under troughs 35, 36 and 37 by through pipes 38, 39 and 40 respectively which in turn connect outside the vessel to manifolds 41, 42 and 43 respectively. Reactant charge may be supplied to manifold 42 through conduit 44 and gas may be supplied to manifolds 41 and 43 through conduits 45 and 46 respectively. Positioned alongside of the vessel 10 is a separate vertical reconditioning vessel 48. In the form shown the reconditioner is provided with a solid inlet chute 49 at its upper end and a solid outlet conduit 50 on its lower end. A flow throttling valve 51 is provided on conduit 50. A gas inlet conduit 52 connects into the lower end of vessel 48 and may communicate within the vessel with suitable gas distributing devices (not shown). A gas outlet conduit 53 is provided near the upper end of vessel 48. Heat transfer tubes (not shown) supplied with fluid through conduit 54 may be positioned within vessel 48. The heat exchange fluid may be withdrawn from the tubes through conduit 55. The type of reconditioner shown is one of several possible types which may be employed for operations in which the reaction

process involves deposition of carbonaceous contaminant on a solid catalyst, which contaminant must be burned in order to regenerate the catalyst. The reconditioner may take other forms depending upon the particular reaction involved. In some reactions involving hydrocarbon conversion in the presence of inert refractory type particles, the contaminant burning step may not require close temperature control, in which case the heat transfer tubes may be omitted. In other processes, substantially no contaminant may be deposited on the contact material, in which case the reconditioner may simply take the form of apparatus adapted to permit an adjustment in the contact material temperature to render it suitable for reuse in the conversion zone. This temperature adjustment may be upward or downward depending upon whether the particular conversion reaction involved is endothermic or exothermic. It should be understood that the term "reconditioning zone" as employed herein in describing and in claiming this invention is intended to mean any zone properly adapted to suitably recondition the contact material, be it inert or catalytic, after its use in the conversion zone for reuse in the conversion zone. This reconditioning may involve the removal of a contaminant deposit, the heating or cooling of the contact material or both burning off of the contaminant and heating or cooling of the contact material to a level suitable for its subsequent introduction to the conversion zone or at least suitable for introduction into the conversion zone after it has passed through a heating zone of the type of zone 23 in Figure 1. A conveyor 58 is provided to transfer reconditioned contact material from vessel 48 to supply hopper 12 and another conveyor 59 is provided to transfer contact material from cooling chamber 25 to reconditioner 48. These conveyors 58 and 59 are mechanical conveyors being driven by motors 60 and 61 respectively. Preferably they may be continuous bucket elevators.

As a typical example of the operation according to the method of this invention the high temperature catalytic cracking of petroleum gas oil fractions to products containing large amounts of aviation gasoline and of hydrocarbons containing four carbon atoms may be considered. In this operation the gas oil charge boiling within the range about 450° F.–800° F. for example, may be introduced through conduit 65 to furnace 66 wherein it is vaporized and heated to a suitable temperature which is below that at which substantial pyrolytic cracking will take place at low pressures. For example, the gas oil may be heated to about 900° F. and passed through conduit 44 to manifold 42 and thence through pipes 39 to distributors 36 by which it is distributed into the lower section of a substantially compact column of gravitating catalyst particles maintained within conversion chamber 24. The catalyst may consist of particles of 4 to 16 mesh size, by Tyler standard screen analysis, for example. These particles may partake of the nature of a synthetic silica-alumina gel, for example. The catalyst may be introduced into the upper end of chamber 24 via tubes 27 at a temperature sufficiently high to supply the endothermic heat of hydrocarbon conversion without itself being cooled to a temperature below the desired conversion temperature range. For this type of reaction the desired reaction temperature range may be of the order of about 1000° F. to 1200° F. and the drop in catalyst tem-

perature in the conversion zone may vary from about 50 to 200° F. depending upon the particular operating conditions and severity of the reaction. For example, the catalyst may enter chamber 24 at about 1200° F. and leave chamber 24 through tubes 28 at about 1100° F. The hydrocarbons are converted to gaseous products containing substantial amounts of aviation gasoline and C_4 hydrocarbons, which are withdrawn from the conversion zone through conduit 33. It should be understood that the word "gaseous" as used herein in describing and in claiming this invention is used in the broad sense as meaning material existing in the gaseous phase under the particular conditions of temperature and pressure involved regardless of the normal phase of that material under ordinary atmospheric conditions. The used catalyst bearing a carbonaceous contaminant deposited during the hydrocarbon conversion is then purged substantially free of gaseous reactants by means of a suitable inert purging gas such as steam or flue gas introduced through conduit 85, manifold 86 and pipes 87 to distributor 88 within the lower section of chamber 24. The purged catalyst then passes as a substantially compact column downwardly through cooling chamber 25 wherein it is cooled by a suitable inert heat exchange gas which is introduced under distributors 37 from conduit 46 at a temperature substantially below the temperature in zone 24. The heat exchange gas should be substantially inert under the condition of its use to reaction with the hydrocarbon reactants. Steam, flue gas, CO_2 or N_2 are examples. The heat exchange gas flows upwardly through the column in the zone 25 countercurrently to the catalyst flow and the rate of gas flow is controlled so that the catalyst upon reaching the lower end of chamber 25 has been cooled to a temperature at which it may be practically mechanically conveyed. It will be understood that the expression, "a temperature at which it may be practically mechanically conveyed" as used in the above sentence and as similarly used in claiming this invention, is intended to mean a temperature at which the contact material may be mechanically conveyed in mechanical conveyors adapted for transfer of the solids without excessive attrition thereof without frequent mechanical failure of the working elements of the conveyor because of the high temperatures involved. It has been found that mechanical conveyors, for example continuous bucket elevators, cannot be expected to practically handle contact material at temperatures above about 1100° F. without frequent failure, and that preferably the contact material temperature should be below about 1000° F. In the present example the catalyst may enter cooling zone 25 at about 1100° F. and be cooled therein to about 950° F. at which temperature the catalyst is withdrawn from vessel 10 through conduit 13 at a suitable rate controlled by valve 14. The catalyst is then mechanically conveyed to reconditioner 48 which in this instance is a regenerator wherein it moves downwardly as a compact column while being subjected to contact with air or oxygen to burn off the contaminants. A suitable heat exchange fluid is passed through heat transfer tubes within vessel 48 so as to limit the temperature of the catalyst below a heat damaging level and so as to provide a regenerated catalyst at conduit 50 which may be practically mechanically conveyed. The heat damaging temperature is the level above which the catalyst will suffer permanent substantial impairment in its catalytic effectiveness for the particular reaction involved. The heat damaging temperature will vary depending upon the nature of the contact material involved being above about 1150 to 1250° F. for many clay catalysts and above about 1350° F. to about 1500° F. for synthetic silica-alumina gel catalysts. In the present example the catalyst containing only about 0.1% to .8% by weight of residual carbon is mechanically conveyed by conveyor 58 to hopper 12 at a temperature of the order of 950° F. The regenerated catalyst then passes downwardly through leg 11 to surge zone 22 and then through heating chamber 23 wherein it moves as a substantially compact column. The heat exchange gas from cooling chamber 25 passes via conduits 34, 75 and 76 to a conventional line burner 71, supplied with fuel at 72 and air at 73 and then via conduits 74 and 45 to distributor 35 in chamber 23. The gas then passes upwardly through the column in chamber 23 transferring to the catalyst substantially all the heat picked up by the gas from the catalyst in cooling chamber 25. The heat exchange gas then passes from chamber 23 at about 950° F. through conduit 32 to blower 80 by which it is forced through conduit 46 back into the cooling chamber 25. Since the catalyst temperature decreased somewhat in the conversion chamber 24 due to the heat required for the reaction, that amount of heat is still missing in the catalyst in chamber 23 even after transfer thereto of all the heat picked up in zone 25 by the heat exchange gas. To make up for this heat of hydrocarbon conversion, the heat exchange gas is heated a controlled amount in line burner 71 so that the contact material in zone 23 may be heated again to the desired reactor inlet temperature of 1200° F. (in this example) by the time it reaches the bottom of heating chamber 23. In those cases wherein the reaction in chamber 24 is exothermic instead of endothermic, for example polymerization reactions, it is then desirable to cool the heat exchange gas an amount approximately equal to the heat released in the convertor. In such cases the heat exchange gas may be conveniently steam which instead of being heated in line heater 71, is passed via conduit 79 to spray cooler 77 wherein it is cooled by a water spray introduced at 78. The excess steam produced in cooler 77 or the excess flue gas and nitrogen produced by line burner 71 may be bled from the closed cyclic heat exchange gas system through vent 152. It will be apparent that by proper control of the rate of heat exchange gas cyclic flow (using bypass 154) and by proper adjustment of its temperature at line cooler 77 or line heater 71, the desired amount of heat may be transferred from catalyst in cooling zone 25 to catalyst in heating zone 23, while maintaining the gas inlet temperature to the catalyst cooling zone 25 at 46 substantially constant. It is desirable to control the gaseous pressures in chambers 23 and 25 slightly higher than that in chamber 24. This may be accomplished by conventional methods, for example, when the operating pressure in conversion zone 24 is about 10 pounds per square inch gauge. the pressure in chambers 23 and 25 may be maintained by means of differential pressure control instruments operating valves—150 and 151 on conduits 34 and 32 respectively or valve 153 on vent 152 at a pressure of about 10½ pounds per square inch gauge. In this manner the chambers 23 and 25 serve not only as cata-

lyst cooling and heating chambers but also as seal zones, to prevent escape of hydrocarbon reactants from either end of the conversion zone 24.

In the case of reactions wherein the endothermic heat required for the reaction in the conversion chamber is very great, it is preferable to conduct the process of this invention in the manner shown in Figure 2. In Figure 2 there are shown two superposed vessels 90 and 91, through which the contact material flows serially, and a mechanical conveyor 92 to convey the contact material from the outlet conduit 93 of the lower vessel 91 to the solids inlet conduit 94 at the top of the upper vessel 90. If desired a catalyst surge chamber (not shown) may be incorporated in conduit 94 or positioned above the top of vessel 90 as shown at 22 in Figure 1 to permit greater flexibility to the operation. The vessel 90 is divided into an upper heating chamber 95 and a lower reconditioning chamber 96 by horizontal partition 97 positioned thereacross. Tubes 98 depend from partition 97 for flow of contact material from chamber 95 to chamber 96 and to provide a gas collecting space 99 in the upper end of chamber 96. A similar gas collecting space 100 is provided within the upper end of chamber 95 by the downward extension of solid inlet 94 within the chamber 95 a short distance below the upper end thereof. Gas outlet conduits 101 and 102 are provided on the shell adjacent spaces 99 and 100 respectively. A row of gas distributor troughs 103 supplied by pipes 104 from manifold 105 and conduit 106 is provided within the lower section of chamber 95 and a similar row of troughs 107 supplied by pipes 108 from manifold 109 and conduit 110 is positioned within the lower section of chamber 96. Contact material passes from the lower end of vessel 90 through conduit 150 bearing throttling valve 111 to the upper end of vessel 91. Vessel 90 is divided by horizontal partitions 112 and 113 into an upper seal chamber 114, an intermediate conversion chamber 115 and a lower cooling chamber 116. Tubes 117 and 118 depend from partitions 112 and 113 respectively for contact material flow. A gas outlet 119 connects into the shell of vessel 91 opposite the gas collecting space 120 in the upper end of chamber 115 and a gas outlet conduit 121 connects into the shell opposite gas collecting space 122 in the upper end of cooling chamber 116. Reactant distributing troughs 123 are provided across the lower section of chamber 115 and a row of purge gas distributing troughs 124 is also provided within chamber 115 below the troughs 123. The troughs 123 are supplied with reactant fluid through pipes 125 which connect into manifold 126, in turn supplied by conduit 127. The troughs 124 are supplied with gas from conduit 128 via manifold 129 and pipes 130. A similar row of troughs 131 supplied from conduit 132 via manifold 133 and pipes 134 is provided within the lower section of cooling chamber 116. A blower 135 is provided to cyclically circulate heat exchange gas through the cooling chamber 116 and heating chamber 95.

As a typical example of the operation according to the method of this invention, the process of ethylene manufacture by the high temperature cracking of ethane may be considered. In this operation a particle form solid refractory material, such as fused alumina, mullite or zirkite, for examples, which material is substantially inert to the reacants may be employed. Generally the particle size range should fall within the range 0.006 to 1.0 inch and preferably within the range 0.03 to 0.5 inch average diameter. The solid material is introduced into the upper end of vessel 91 at a temperature of the order of 1750–1800° F., for example. Ethane which may be preheated in a conventional external heater to a suitable temperature of the order of 500 to 1000° F. for example may be introduced, at a pressure of about 5–20 pounds per square inch for example, through conduit 127, to manifold 126 and thence via pipes 125 to distributor 123 in the conversion chamber 115. The ethane to which steam may be added in controlled amounts, if desired, passes upwardly through the column of contact material in chamber 115 so as to be converted to gaseous ethylene containing products which are withdrawn at 119. If desired an initial quench may be effected by spraying water into the effluent gas either in space 120 in conduit 119. Perforated pipes are provided in space 120 for that purpose and are supplied with quench liquid from header 160. The products are then finally quenched to a temperature usually at least below about 900° F. in a suitable external apparatus (not shown). The rate of contact material flow may be controlled by valve 140 on conduit 93 so as to adjust the drop in contact material temperature as it passes through chamber 115 to any set amount. In the present example the rate of contact material flow may be controlled so that the contact material passing through tubes 118 to chamber 116 exists at about 1500° F. The contact material may be purged by steam or flue gas introduced at 128 to distributor 124 before it is withdrawn from chamber 115. In chamber 116 the contact material is cooled by direct contact with gas introduced from conduit 132 to distributors 131. The contact may be cooled in chamber 116 from an inlet temperature of about 1500° F. to an outlet temperature of about 1100° F., for example, and then be mechanically conveyed by mechanical conveyor 92 to conduit 94 supplying the heating chamber 95. In heating chamber 95 the contact material is reheated from about 1090° F. to about 1490° F. by heat exchange gas leaving chamber 116 at about 1500° F. and passing through conduits 121 and 141 to inlet 106 and thence into the distributor 103 in chamber 95. The gas after transferring its heat to the contact material in chamber 95 then passes at about 1100° F. through conduits 102 and 142 to blower 135 by which it is forced back into chamber 116. The rate of gas flow may be controlled by controlling the rate of speed of the blower 135 or by other suitable means such as by use of bypass 143 so as to accomplish the desired transfer of heat from cooling chamber 116 to heating chamber 95. It will be understood that depending upon the rate of gas flow the temperature differentials between the gas leaving zones 95 or 116 and the entering solids may be somewhat greater or less than those given in the above example. The contact material, after being so heated in zone 95, may pass to reconditioning chamber 96 at about 1500° F., for example. As it passes through chamber 96, the contact material may be heated by means of a suitable hot gas introduced through conduit 109 to distributor 107 to a temperature of about 1750–1800° F. and then it may be returned via conduit 110 to the vessel 91 for reuse. If desired the heating in chamber 96 may be accomplished by burning of a gaseous fuel intro-

duced from conduit 145 by air introduced at 110 within the column in chamber 96. On the other hand often a certain amount of carbonaceous material may be deposited on the contact material during the hydrocarbon conversion reaction in chamber 115, and the contaminant may be burned in chamber 96 to supply part or all of the required heating to be accomplished therein. The cyclic system may be maintained at constant temperature levels in the various zones by proper adjustment of the operation of reconditioner 96. Added flexibility may be provided by provision of a small heat exchanger 170 on conduit 141 or in a surge chamber for contact material positioned above zone 95 or below zone 116. A suitable seal gas such as steam or flue gas may be introduced into seal chamber 114 through conduit 146 at a sufficient rate to maintain a gaseous pressure in chamber 114 above that in chambers 96 and 115 thereby preventing interflow of gas therebetween.

The system shown in Figure 2 may also be employed for the same type of reaction described in connection with Figure 1. In this case the heating chamber 95 may be positioned as shown or it may be positioned vertically between chamber 96 and the vessel 91. In the latter case by proper control of the inert gaseous pressure in chambers 95 and 116, the need for seal chamber 114 may be eliminated, if desired.

It will be apparent from the above discussion that the method of this invention permits the conducting of gaseous reactions in the presence of a moving particle form solid material at very high reaction temperatures without the necessity of subjecting the solid conveying equipment to the high reaction temperatures. Inasmuch as it is usually undesirable to convey solid materials of this type in mechanical conveyors, bucket elevators, for example at temperatures in excess of about 1100° F., this feature permits the conducting of a large number of reactions in a continuous moving column type operation, which reactions heretofore could not be so conducted. Moreover this advantage is accomplished without the loss of any heat from the cyclically moving catalyst stream. Inasmuch as such processes on a commercial scale involve the circulation of about 50 to 400 tons of contact material per hour, the large amount of heat saved by the use of the cyclic gaseous heat exchange system involving substantially no gas reject is a highly important factor. For many operations the amount of heat recovered by burning contaminants in the reconditioning zone is sufficient to balance the heat required for endothermic hydrocarbon conversions. Such operations when conducted by the method described hereinabove become substantially thermally independent and self-sustaining. Moreover, there is very little cooling load involving the use of expensive heat transfer tubes.

It will be understood that the dimensions of the apparatus employed, the rates of reactant and solid flow, and the type of solid material and heat exchange gas employed are subject to wide variation depending upon the particular process to which this invention is applied. In general, the reaction zone should be of such size as will permit the proper time of reactant contact with the suitable solid material therein for any given process. The contact material heating and cooling zones need only be of sufficient size to permit the desired amount of gas-solid heat transfer. Due to the very high co-efficients of heat transfer between gases and solid when passed in direct contact relationship in the manner described hereinabove, the heating and cooling zones may be of relatively small size, and of very simple and economical construction. In operations wherein very high volumetric gas throughput rates are required in the heating and cooling zones, these zones may be of somewhat larger cross-sectional area than the reaction zone therebetween in order to insure adequate gas throughput capacity without interference with the solid flow.

The reactant space velocity in the conversion zone will of course vary depending upon the particular operation involved. Where petroleum gas oils are to be converted to products containing high amounts of aviation gasoline and four carbon atom hydrocarbons in the manner described in the example given hereinabove in connection with Figure 1, the oil space velocity may vary from about 0.5 to 5.0 volumes of oil charge (measured as a liquid at 60° F.) per hour per volume of catalyst in the conversion zone (measured as a substantially compact flowing column). The catalyst to oil charge ratio to the convertor in such an operation may fall within the range about 1 to 10 parts by weight of catalyst per part by weight of oil charged. In the case of the example considered hereinabove in connection with Figure 2, the solid throughput amounting to about 5 to 15 pounds of solid per pound of ethane charge is satisfactory. The volume of the reaction zone 24 should be such as to provide a reactant residence time of about 1.0 to 1.7 seconds.

The type of solid material used may vary from an inert solid such as corhart material, a fused alumina, which may be used for ethylene manufacture to an adsorbent type catalytic material which may be used for catalytic dehydrogenation reactions and for catalytic cracking reaction. Such catalytic materials may take the form of natural or treated clays, bauxites, inert carriers containing deposited metallic oxides such as deposits of the oxides of molybdenum, chromium or tungsten, or certain synthetic associations of silica, alumina or silica or alumina to which small percentages of other materials such as metallic oxides may be added for special purposes. In general, it has been found that the particle size of such contact materials should fall broadly within the range about .006 to 1.0 inch average diameter and preferably within the range about 0.03 to 0.5 inch average diameter. It should be understood that the expression "suitable particle form contact material" as used in describing and in claiming this invention is used in a sense sufficiently broad to cover either so-called catalytic or non-catalytic materials which may be found suitable for the particular reaction involved. The term is to be considered as limited, however, only to those solid materials which have physical and chemical characteristics making them suitable for the particular process involved. Thus, for example solids, which would enter substantially into the main reaction or which would be decomposed or otherwise damaged under the reaction conditions involved, are not intended to be included in the term.

The expression "suitable heat exchange gas" as used in describing and in claiming this invention is intended to mean a gas capable of carrying heat into the heating zone and giving it up by direct heat transfer therein and similarly removing heat from the cooling zone and which is suitable chemically and physically for the par-

ticular process involved. Thus, a gas used for any particular reaction process which would undergo an undesirable reaction under the conditions in the reaction zone or which would injure the solid material or reaction vessel is not intended to be included within the meaning of the above expression.

In the claiming of this invention the expressions "suitable conversion temperature" and "range of suitable conversion temperatures" are intended to mean a temperature or range of temperatures which are suitable for conducting the particular reaction involved at a practical rate and to practical yields of the desired products.

It should be understood that the foregoing description of the method of this invention and examples of its applications and of the apparatus to which it may be applied are merely exemplary in character and are not intended to limit the scope of this invention except as it is limited in the following claims.

I claim:

1. A method for conducting thermo-chemical conversions of fluid reactants at controlled elevated temperatures in the presence of a suitable moving particle-form solid contact material which comprises: contacting said fluid reactants at a suitable elevated conversion temperature with a substantially compact column of downwardly moving solid particle-form contact material in a confined reaction zone to effect said conversion of said reactants, withdrawing fluid conversion products from said reaction zone, withdrawing used contact material from said reaction zone and passing it as a substantially compact column through a confined cooling zone, introducing a suitable heat exchange gas into said column in said cooling zone at a temperature substantially below that of said contact material entering said cooling zone and passing said gas through said column in said cooling zone to cool the contact material substantially below the temperature in said reaction zone, passing the cooled contact material from said cooling zone through a separate reconditioning zone wherein it is treated to render it suitable for reuse in said reaction zone, passing the reconditioned contact material to a heating zone and passing it through said heating zone as a substantially compact column, withdrawing said heat exchange gas from said cooling zone and passing it through said column in said heating zone so as to transfer heat removed from said contact material passing through said cooling zone back to said contact material passing through said heating zone, withdrawing the resulting cooled heat exchange gas from said heating zone and returning it to said cooling zone.

2. In a process for conversion of fluid hydrocarbons in the presence of a moving particle-form contact material at elevated temperatures which are substantially above those at which said contact material may be practically handled in mechanical conveying equipment, wherein said contact material is passed through a cyclic path of travel in which it passes through a conversion zone wherein it flows as a substantially compact column while being contacted with fluid hydrocarbons to effect the conversion thereof and through a reconditioning zone wherein it flows as a substantially compact column while being contacted with a suitable reconditioning fluid to at least partially recondition it for reuse in said conversion zone and in which path of travel the hot contact material from said conversion zone is passed to a mechanical conveying zone to be conveyed through a portion of its cyclic path of travel, the improvement which comprises: passing said hot contact material at a point in its cyclic path of travel intermediate said conversion zone and the mechanical conveying zone, through a separate cooling zone as a substantially compact column while cooling it therein to a temperature suitable for its handling by mechanical conveying equipment; passing the contact material, after having been mechanically conveyed, and before its return to said conversion zone through a heating zone as a substantially compact column while heating it therein, said heating zone being a separate zone in said cyclic path of travel in addition to said cooling, reconditioning and conversion zones; passing a suitable heat exchange gas as a cyclically moving stream through the column of contact material in said cooling and heating zones to effect the cooling of said contact material in said cooling zone and to effect the transfer of the heat removed from said contact material in said cooling zone to said contact material moving through said heating zone so as to accomplish said aforesaid heating therein, and adjusting the heat content of said cyclically moving stream of heat exchange gas at a point in its cycle outside of said heating and cooling zones to maintain the gas inlet temperature to said cooling zone substantially constant.

3. In a continuous cyclic process for hydrocarbon conversion at elevated temperatures wherein a particle-form contact material is passed continuously through a cyclic path of travel which includes a conversion zone wherein it is contacted with fluid hydrocarbons at elevated temperatures to effect the conversion thereof, a mechanical conveying zone in which is mechanically conveyed from a low level to a higher level and a reconditioning zone in which it is treated to render it suitable for reuse in said conversion zone, the improvement which comprises: passing said contact material as a substantially compact gravitating column through a separate cooling zone at a location in its path of travel prior to its entrance into said mechanical conveying zone, passing a suitable inert heat exchange gas through said column in said cooling zone to effect a sufficient removal of heat from said contact material to lower its temperaturer to a level at which it may be practically mechanically conveyed, and passing said contact material as a substantially compact gravitating column through a heating zone at a location in its cyclic path of travel after it has been mechanically conveyed and before it is returned into said conversion zone, said heating zone being a separate zone in said cyclic path of travel in addition to said cooling conversion and reconditioning zones, passing the heat exchange gas from said cooling zone through said column in said heating zone under conditions controlled to effect transfer to the contact material therein at least a substantial part of the heat removed from the contact material in said cooling zone, and returning the heat exchange gas to said cooling zone.

4. A method for conversion of fluid hydrocarbons at elevated temperatures above about 1000° F. in the presence of a moving particle-form contact material which comprises: contacting said fluid hydrocarbon reactants at a suitable elevated conversion temperature which is

above about 1000° F. with a substantially compact column of downwardly moving solid particle-form contact material in a confined reaction zone to effect said conversion of said reactants, withdrawing fluid conversion products from said reaction zone, withdrawing used contact material from said reaction zone and passing it as a substantially compact column through a confined cooling zone, introducing a suitable heat exchange gas into said column in said cooling zone at a temperature substantially below that of said contact material entering said cooling zone and passing said gas through said column in said cooling zone to cool the contact material to a temperature within the range about 700° F. to 1100° F., mechanically conveying the cooled contact material to a regeneration zone, passing said contact material through said regeneration zone as a substantially compact column while contacting it with an oxygen containing gas to burn off therefrom carbonaceous contaminant, passing the regenerated contact material through a heating zone as a substantially compact column, passing said heat exchange gas from said cooling zone through said column in said heating zone to transfer to said contact material the heat removed by said gas from the contact material in said cooling zone returning the gas from said heating zone to said cooling zone, and flowing the heated contact material from said heating zone to said conversion zone.

5. A continuous process for conversion of fluid hydrocarbons at elevated temperatures in the presence of a suitable moving particle-form contact material which comprises: passing said contact material cyclically in a closed path of travel which includes a conversion zone wherein it moves downwardly as a substantially compact column and is contacted at a suitable elevated conversion temperature with a fluid hydrocarbon charge to effect the conversion thereof with resultant deposition of carbonaceous material on said contact material, through a burning zone wherein the carbonaceous material is burned to raise the temperature of said contact material so as to supply thereto heat for said hydrocarbon conversion, and through at least one mechanical conveying zone wherein it is mechanically conveyed from a given level to a higher level; passing the cyclically moving contact material through a cooling zone as a substantially compact gravitating column at a point in its cyclic path of travel after the conversion zone and before at least one conveying zone, passing a suitable inert heat exchange gas through said contact material column in said cooling zone under conditions controlled to cool said contact material to a temperature within the range about 700° F. to 1100° F., passing the contact material as a substantially compact gravitating column through a confined heating zone at a point in its cyclic path of travel after at least one conveying zone and before it passes to said conversion zone, said heating zone being a separate zone in said closed path of travel in addition to said conversion, burning, cooling and mechanical conveying zones, passing said heat exchange gas from said cooling zone through the column in said heating zone under conditions controlled to effect transfer thereto approximately the amount of heat removed thereby from said cooling zone and returning the heat exchange gas after passage through said heating zone to said cooling zone.

6. A method for conducting thermochemical conversions of fluid reactants at controlled elevated temperatures in the presence of a moving particle-form contact material which comprises: passing a suitable heated contact material as a substantially compact column of gravitating particles through a confined reaction zone in contact with fluid reactants at a temperature suitable for effecting the desired conversion of said reactants, withdrawing fluid reaction products from said zone, withdrawing used contact material from the lower section of said zone substantially separately of said fluid products and flowing said used contact material by gravity to a confined cooling zone, passing said used contact material downwardly through said cooling zone as a substantially compact column, passing a suitable heat exchange gas upwardly through said column in said cooling zone under such conditions as to cool said contact material to a level at which it may be practically mechanically conveyed, mechanically conveying the cooled contact material to a level suitable for introduction thereof into a confined reconditioning zone, passing said contact material downwardly through said reconditioning zone as a substantially compact column while subjecting it to a treatment to render it suitable for reuse in said conversion zone, maintaining a confined heating zone at a level above said conversion zone, passing reconditioned contact material to said heating zone, passing the contact material as a substantially compact column downwardly through said heating zone, passing said heat exchange gas from said cooling zone upwardly through said column in said heating zone to transfer to said contact material moving therethrough the heat removed by said gas from said cooling zone and maintaining the temperature of the contact material entering said heating zone sufficiently below that of the contact material entering said cooling zone to insure said transfer of heat between said zones, returning the heat exchange gas to said cooling zone and flowing the heated contact material from said heating zone into said conversion zone.

7. A method for conducting thermochemical conversions of fluid reactants at controlled elevated temperatures in the presence of a moving particle-form contact material which comprises: passing a suitable heated contact material as a substantially compact column of gravitating particles through a confined reaction zone in contact with fluid reactants at a temperature suitable for effecting the desired conversion of said reactants with a resultant change in the contact material temperature due to the heat of the reaction, withdrawing fluid reaction products from said zone, withdrawing used contact material from the lower section of said zone substantially separately of said fluid products and flowing said used contact material by gravity to a confined cooling zone, passing said used contact material downwardly through said cooling zone as a substantially compact column while cooling it to a temperature at which it may be practically mechanically conveyed, mechanically conveying the cooled contact material to a level suitable for introduction thereof into a confined reconditioning zone, passing said contact material downwardly through said reconditioning zone as a substantially compact column while subjecting it to a treatment to render it suitable for reuse in said conversion zone, maintaining a confined heating zone at a level above said conversion

zone, passing reconditioned contact material to said heating zone, passing the contact material as a substantially compact column downwardly through said heating zone, passing a suitable heat exchange gas cyclically through the columns of contact material in said cooling and heating zones to effect the contact material cooling in said cooling zone and to transfer at least a substantial portion of the heat removed from the contact material moving through said cooling zone to the contact material moving through said heating zone and maintaining the temperature of the contact material entering said heating zone sufficiently below that of the contact material entering said cooling zone to insure said transfer of heat from said cooling zone to said heating zone, adjusting the temperature of said cyclically moving heat exchange gas at a location in its cyclic path of travel outside of said cooling and heating zones in a direction opposite to that of the temperature change of the contact material passing through said conversion zone and in an amount sufficient to counteract said contact material temperature change and to maintain a substantially constant gas inlet temperature to said cooling zone, and flowing the heated contact material from said heating zone to said conversion zone.

8. A method for conducting an endothermic conversion of fluid hydrocarbon reactants at controlled elevated temperatures in the presence of a moving particle-form contact material which comprises: introducing a suitable particle-form contact material into the upper section of a confined conversion zone at an elevated temperature suitable for supporting said endothermic hydrocarbon conversion, passing said contact material as a substantially compact column downwardly through said conversion zone, passing fluid hydrocarbon reactants through said column to effect said endothermic conversion thereof thereby reducing the temperature of said contact material and causing deposition of carbonaceous material thereon, withdrawing fluid conversion products from said zone, separately withdrawing used contact material from the lower section of said conversion zone, flowing said used contact material as a substantially compact column downwardly through a confined cooling zone while cooling it therein to a temperature at which it may be practically mechanically conveyed, maintaining a confined burning zone separate from said conversion zone, mechanically conveying the cooled contact material to a location suitable for its introduction to said burning zone, passing said contact material as a substantially compact column downwardly through said burning zone while contacting it with a combustion supporting gas to burn off said contaminant, removing at least a substantial portion of the heat liberated by said burning from the contact material, passing the reconditioned contact material to a mechanical conveying zone at a temperature at which it may be practically mechanically conveyed, maintaining a confined heating zone above said conversion zone, mechanically conveying said reconditioned contact material to a location suitable for its introduction into said heating zone, passing the contact material downwardly through said heating zone as a substantially compact column, passing a suitable gaseous heat exchange medium cyclically through said columns in said cooling and heating zones to cool said contact material in said cooling zone as aforesaid and to transfer the heat removed from said contact material in said cooling zone to the contact material in said heating zone, adding heat to said heat exchange medium at a location in its cyclic path of flow outside of said heating and cooling zones and prior to its entry into said heating zone in sufficient amount to substantially compensate for the amount of heat removed from said contact material in said conversion zone and flowing the heated contact material from said heating zone to said conversion zone.

9. A method for conducting an endothermic conversion of fluid hydrocarbon reactants at controlled elevated temperatures in the presence of a moving particle-form contact material which comprises: introducing a suitable particle-form contact material into the upper section of a confined conversion zone at an elevated temperature suitable for supporting said endothermic hydrocarbon conversion without said contact material being cooled below about 1100° F., passing said contact material as a substantially compact column downwardly through said conversion zone, passing fluid hydrocarbon reactants through said column to effect said endothermic conversion thereof thereby absorbing heat from said contact material and causing deposition of carbonaceous material thereon, withdrawing fluid conversion products from said zone, separately withdrawing used contact material from the lower section of said conversion zone, flowing said used contact material as a substantially compact column downwardly through a confined cooling zone while cooling it therein to a temperature below about 1100° F., maintaining a confined burning zone separate from said conversion zone, mechanically conveying the cooled contact material to a location suitable for its introduction to said burning zone, passing said contact material as a substantially compact column downwardly through said burning zone while contacting it with a combustion supporting gas to burn off said contaminant, removing at least a substantial portion of the heat liberated by said burning from the contact material, passing the reconditioned contact material at a temperature below about 1100° F. to a mechanical conveyor, maintaining a confined heating zone above said conversion zone, mechanically conveying reconditioned contact material to a location suitable for its introduction into said heating zone, passing the contact material downwardly through said heating zone as a substantially compact column, passing a suitable gaseous heat exchange medium cyclically through said columns in said cooling and heating zones to cool said contact material in said cooling zone as aforesaid and to transfer the heat removed from said contact material in said cooling zone to the contact material in said heating zone, flowing the heated contact material from said heating zone to said conversion zone to complete a cyclic path of contact material stream travel, adding sensible heat to the cyclically moving stream of contact material at at least one location in its path of travel to compensate for the heat absorbed by the reaction in said conversion zone and maintaining the temperature of the contact material entering said heating zone sufficiently below that of the contact material entering said cooling zone to insure said transfer of heat from said cooling to said heating zone by said heat exchange gas.

10. A process for catalytic cracking conversion of fluid hydrocarbons in the presence of a mov-

ing particle-form adsorbent catalytic contact material at temperatures above those at which said contact material may be practically mechanically conveyed which process comprises: introducing a suitable particle-form contact material into the upper section of a confined conversion zone at an elevated temperature suitable for supporting said endothermic hydrocarbon conversion, which temperatures are above about 1000° F., passing said contact material as a substantially compact column downwardly through said conversion zone, passing fluid hydrocarbon reactants through said column to effect said endothermic conversion thereof thereby causing deposition of carbonaceous material on the contact material, withdrawing fluid conversion products from said zone, separately withdrawing used contact material from the lower section of said conversion zone, flowing said used contact material as a substantially compact column downwardly through a confined cooling zone while cooling it therein to a temperature at which it may be practically mechanically conveyed, maintaining a confined burning zone separate from said conversion zone, mechanically conveying the cooled contact material to a location suitable for its introduction to said burning zone, passing said contact material as a substantially compact column downwardly through said burning zone while contacting it with a combustion supporting gas to burn off said contaminant, removing heat from said contact material during said burning to control it below a heat damaging temperature, withdrawing regenerated contact material from said burning zone, maintaining a confined heating zone at an elevational level above said conversion zone, passing said regenerated contact material to said heating zone, passing the contact material downwardly through said heating zone as a substantially compact column, passing a suitable gaseous heat exchange medium cyclically through said columns in said cooling and heating zones in a direction countercurrent to the direction of contact material flow in said zones so as to cool said contact material in said cooling zone to a practicable mechanical conveying temperature which is below about 1000° F. and to transfer the heat removed from said contact material passing through said cooling zone to said contact material passing through said heating zone, adjusting the temperature of said gas at a point in its cyclic path of travel outside of said cooling and heating zones in sufficient amount to maintain its temperature range substantially constant in said cooling and heating zones and passing the heated contact material from said heating zone to said conversion zone as the supply thereto.

11. A cyclic process of conducting endothermic conversions of fluid reactants in the presence of a moving mass of contact material at temperatures above those at which the contact material may be practically mechanically conveyed which comprises introducing said fluid reactant into contact with a substantially compact column of downwardly gravitating suitable contact material particles existing at a suitable temperature for the endothermic conversion of said fluid reactants, maintaining said reactants in contact with said contact material for a sufficient time to effect said endothermic conversion and then withdrawing the fluid conversion products from said conversion zone, continuously replenishing said column at its upper end with reconditioned contact material existing at a suitable temperature for supporting said conversion, passing the used contact material from the lower section of said conversion zone to a separate cooling zone and passing it downwardly therethrough as a substantially compact column, passing a suitable heat exchange gas through said column in said cooling zone under conditions controlled to cool said contact material to a temperature at which it may be practically mechanically conveyed, mechanically conveying said contact material to the level of a separate heating zone, passing said contact through said heating zone as a substantially compact column of gravitating particles, passing said heat exchange gas from said cooling zone through said column in said heating zone to transfer the heat removed from said cooling zone by said gas to said contact material moving through said heating zone and maintaining the temperature of the contact material entering said heating zone sufficiently below that of said contact material entering said cooling zone to insure said transfer of heat, returning the heat exchange gas after passage through said heating zone to said cooling zone, passing the contact material from said heating zone through a separate reconditioning zone wherein it moves as a substantially compact column, passing a suitable reconditioning gas through said contact material column in said reconditioning zone to further heat said contact material to a suitable temperature for supply to said conversion zone and passing the reconditioned contact material to said conversion zone as aforesaid.

12. The method for conversion of a fluid hydrocarbon charge containing a substantial amount of saturated hydrocarbons to gaseous ethylene containing products which comprises: passing a suitable particle-form refractory type contact material serially downwardly through an uppermost heating zone, a reconditioning zone, a conversion zone and a cooling zone arranged in vertical series, said contact material moving through each of said zones as a substantially compact column of gravitating particles, and mechanically conveying the contact material from the cooling zone to the level of said heating zone for supply thereinto; contacting said contact material in said reconditioning zone with suitable gaseous material to heat it to a temperature within the range about 1400 to 1800° F. which is suitable for its supply to said conversion zone, passing said fluid hydrocarbon charge into contact with the heated contact material in said conversion zone to effect the conversion of said charge to gaseous ethylene containing products, withdrawing said gaseous products from said conversion zone substantially separately from said contact material, passing a suitable inert heat exchange gas through said column in said cooling zone at a rate controlled to cool by direct heat transfer the contact material to a temperature below about 1100° F. withdrawing the heat exchange gas from said cooling zone and passing it through said column in said heating zone to transfer the heat removed from said contact material in said cooling zone to the contact material in said heating zone and returning the gas after passage through said heating zone to said cooling zone.

13. A process for catalytic conversion of petroleum hydrocarbon fractions to gaseous products containing substantial amounts of C_4 hydrocarbons and of aviation gasoline which comprises: contacting said petroleum fraction at a temperature within the range about 1000° F.-

1200° F. with a substantially compact column of downwardly moving adsorbent particle-form catalyst in a confined conversion zone to effect the conversion of said hydrocarbons to gaseous products containing C_4 hydrocarbons and aviation gasoline, withdrawing said gaseous products from said conversion zone, withdrawing used catalyst from said conversion zone and passing it as a substantially compact column through a confined cooling zone, introducing a suitable heat exchange gas into said column in said cooling zone at a temperature substantially below that of said catalyst entering said cooling zone, passing said heat exchange gas through said column in said cooling zone countercurrently to the catalyst flow to cool said catalyst to a temperature below about 1000° F., mechanically conveying the cooled catalyst to a regeneration zone, passing said contact material through said regeneration zone as a substantially compact column while contacting it with an oxygen containing gas to burn off therefrom carbonaceous contaminants, passing the regenerated catalyst through a confined heating zone as a substantially compact column, passing said heat exchange gas from said cooling zone through said catalyst in said heating zone countercurrently to the catalyst flow to transfer by direct heat transfer the heat removed by said gas from the catalyst passing through said cooling zone to the catalyst passing through said heating zone, returning the heat exchange gas from said heating zone to said cooling zone and flowing the heated catalyst from said heating zone to said conversion zone.

14. A continuous process for conducting the thermochemical conversion of fluid hydrocarbons at elevated temperatures in the presence of a suitable moving particle-form contact material which comprises: passing said contact material cyclically in a closed path of travel which includes a conversion zone wherein it moves downwardly as a substantially compact column and is contacted at a suitable elevated conversion temperature with a fluid hydrocarbon charge to effect the conversion thereof with a resultant change in the heat level of the contact material due to the thermochemical reaction heat, through a reconditioning zone wherein it is treated to condition it for reuse in said conversion zone, and through at least one mechanical conveying zone wherein it is mechanically conveyed from a given level to a higher level; passing the cyclically moving contact material through a cooling zone as a substantially compact gravitating column at a point in its cyclic path of travel after the conversion zone and before at least one conveying zone, passing a suitable inert heat exchange gas upwardly through said contact material column in said cooling zone under conditions controlled to cool said contact material to a temperature within the range about 700° F. to 1100° F., passing the contact material as a substantially compact gravitating column through a confined heating zone a point in its cyclic path of travel after at least one conveying zone and before it passes to said conversion zone, said heating zone being a separate zone in said closed path of travel in addition to said conversion, reconditionining, cooling and mechanical conveying zones, passing said heat exchange gas from said cooling zone upwardly through the column in said heating zone while maintaining the temperature of the contact material entering said heating zone substantially below that of the contact material entering said cooling zone whereby heat removed by the gas from said cooling zone is transferred to the column of contact material in said heating zone, returning the heat exchange gas after passage through said heating zone to said cooling zone to complete its cyclic path of travel, and substantially counteracting the change in heat level of the contact material in passing through said conversion zone by making an appropriate adjustment in the heat level of said heat exchange gas at at least one point in its cyclic path of travel outside of said heating and cooling zones.

15. In a process for conducting endothermic conversion of fluid hydrocarbon reactants at controlled elevated temperatures in the presence of a moving particle-form contact material wherein said contact material is passed through a cyclic path in which it moves as a substantially compact column through a conversion zone in which it supplies the reaction heat for effecting the endothermic conversion of a fluid hydrocarbon charge thereby undergoing a drop in temperature and through a reconditioning zone in which it flows as a substantially compact column while being subjected to reconditioning fluid to effect at least its partial reconditioning for reuse in said conversion zone and in which cyclic path of travel the contact material is at least once mechanically conveyed from one level to a higher level in at least one mechanical conveying zone, the improvement which comprises, passing the hot contact material just prior to its passage to said mechanical conveying zone 1 through a separate cooling zone as a substantially compact column while cooling it therein to a temperature below about 1100° F. and passing the contact material after having been mechanically conveyed and prior to its passage through at least one of said zones other than the conveying and cooling zones through a confined heating zone wherein it flows as a substantially compact column, passing a suitable gaseous heat exchange medium cyclically through said columns in said cooling and heating zones in a direction countercurrent to the contact material flow in each zone so as to cool said contact material in said cooling zone to a practical conveying temperature which is below about 1100° F. and to transfer at least a substantial part of the heat removed from said contact material in said cooling zone to the contact material in said heating zone, adding sensible heat to the cyclically moving stream of contact material at at least one location in its path of travel to compensate for the heat absorbed by the reaction in said conversion zone and maintaining the temperature of the contact material entering said heating zone substantially below that of the contact material entering said cooling zone to insure the transfer of heat from said cooling zone to said heating zone by the heat exchange gas as aforesaid.

16. A cyclic process for conducting thermochemical conversions of fluid reactants in the presence of a moving mass of particle-form contact material at temperatures above those at which such contact material may be practically mechanically conveyed which comprises, passing said contact material downwardly through two separate, superposed, contacting zones through which it flows as a substantially compact mass, passing a fluid reactant into contact with said contact material in one of said contacting zones

to effect the thermochemical conversion thereof at a suitable range of elevated conversion temperatures and withdrawing fluid conversion products from said zone, passing a suitable conditioning gas through the mass of contact material in the other of said contacting zones to condition said contact material therein for return to the zone of fluid reactant conversion, passing the contact material from the lower of said contacting zones downwardly through a cooling zone wherein it flows as a compact mass while being cooled to a temperature substantially below that in the contacting zone thereabove and which is suitable for practicable mechanical conveying of said contact material, mechanically conveying said cooled contact material to a level above said contacting zones, passing the contact material after being conveyed and prior to its flow again through at least one of said contacting zones through a heating zone in which it flows as a compact mass of particles while being heated, then passing the heated contact material from said heating zone to the contacting zone immediately therebelow, passing a suitable heat exchange gas cyclically through the mass of contact material in said heating and cooling zones to absorb heat from the contact material in said cooling zone and thereby effect said cooling thereof and to transfer at least a substantial part of the heat absorbed in said cooling zone to the contact material in said heating zone.

17. In a cyclic process for the endothermic conversion of fluid hydrocarbon reactants in the presence of a suitable heated particle-form solid contact material at temperatures above those at which it is practical to mechanically convey said contact material wherein the contact material passes in series through two superposed contacting zones in each of which it flows as a substantially compact column, one of said zones being a conversion zone and the other being a burning zone, and wherein a fluid hydrocarbon charge is passed into contact with the column of contact material in said conversion zone to effect the endothermic conversion of said reactants to lower boiling fluid hydrocarbon products, at a suitable elevated conversion temperature which is substantially above that at which said contact material may be practically mechanically conveyed, said conversion resulting in the deposition of carbonaceous material on said contact material, and wherein an oxygen containing gas is passed through said column in said burning zone to burn carbonaceous material from the contact material and to effect the increase in the sensible heat content of said contact material to a level at which it may supply the heat of endothermic reaction in said conversion zone without being cooled below a suitable elevated conversion temperature, the improvement which comprises, passing the hot contact material from the lower of said contacting zones through a cooling zone in which it flows as a compact column while being cooled, then mechanically conveying the cooled contact material to a level above either of said contacting zones, passing the contact material after being conveyed and prior to its passage through at least one of said contacting zones through a separate heating zone in which it flows downwardly as a substantially compact column, then passing the heated contact material from said heating zone to the contacting zone immediately therebelow, passing a suitable inert heat exchange gas through said column in said cooling zone to cool said contact material to a temperature at which it may be practically mechanically conveyed, which temperature is below about 1100° F., passing the heat exchange gas from said cooling zone through the column of contact material in said heating zone to transfer the heat removed from the contact material in said cooling zone to the contact material moving through said heating zone, returning the heat exchange gas after passage through said heating zone to said cooling zone.

18. In a cyclic process for conversion of fluid reactants at elevated temperatures wherein a particle-form solid material is passed continuously through a cyclic path of travel which includes two contacting zones and at least one mechanical conveying zone wherein it is mechanically conveyed from a low level to a higher level, one of said contacting zones being a conversion zone wherein the solid material is contacted with fluid reactants at elevated temperatures to effect conversion of said reactants to valuable conversion products and the other contacting zone being a reconditioning zone in which the solid material is at least partially conditioned for reuse in said conversion zone, the improvement which comprises, passing said solid material as a substantially compact gravitating column through a separate cooling zone at a location in its path of travel prior to its entrance into said mechanical conveying zone, passing a suitable inert heat exchange gas through said column in said cooling zone to effect a sufficient removal of heat from said solid material to lower its temperature to a level at which it may be practically mechanically conveyed, and passing said solid material as a substantially compact gravitating column through a heating zone at a location in its cyclic path of travel after it has been conveyed and above at least one of said contacting zones, said heating zone being a separate zone in said closed path of travel in addition to said conversion, reconditioning, cooling and conveying zones, passing a suitable heat exchange gas upwardly through said columin in said cooling zone to effect sufficient removal of heat from the solid material to lower its temperature to a level at which it may be practically mechanically conveyed, said level being substantially below that in the contacting zone immediately above said cooling zone, passing the heat exchange gas from said cooling zone upwardly through said column in said heating zone to transfer to the solid material therein the heat removed from the solid material in said cooling zone and returning the heat exchange gas to said cooling zone, and maintaining the temperature of the solid material entering said heating zone below that of the solid material entering said cooling zone by an amount which will insure substantially complete transfer of said heat removed from said cooling zone to said heating zone by exchanging heat with the solid material to compensate for the reaction heat in said conversion zone at at least one point in the cyclic path of solid travel outside of said heating and cooling zone.

19. In a cyclic process for conversion of fluid reactants at elevated temperatures wherein a particle-form solid material is passed continuously through a cyclic path of travel which includes two contacting zones and at least one mechanical conveying zone wherein it is mechanically conveyed from a low level to a higher level, one of said contacting zones being a conversion zone wherein the solid material is contacted with fluid reactants at elevated tempera-

tures to effect conversion of said reactants to valuable conversion products and the other contacting zone being a reconditioning zone in which the solid material is at least partially conditioned for reuse in said conversion zone, the improvement which comprises, passing said solid material as a substantially compact gravitating column through a separate cooling zone at a location in its path of travel prior to its entrance into said mechanical conveying zone, passing a suitable inert heat exchange gas through said column in said cooling zone to effect a sufficient removal of heat from said solid material to lower its temperature to a level at which it may be practically mechanically conveyed, and passing said solid material as a substantially compact gravitating column through a heating zone at a location in its cyclic path of travel after it has been conveyed and above at least one of said contacting zones, said heating zone being a separate zone in said closed path of travel in addition to said conversion, reconditioning, cooling and conveying zones, passing a suitable heat exchange gas upwardly through said column in said cooling zone to effect sufficient removal of heat from the solid material to lower its temperature

to a level at which it may be practically mechanically conveyed, said level being substantially below that in the contacting zone immediately above said cooling zone, passing the heat exchange gas from said cooling zone upwardly through said column in said heating zone to transfer to the solid material therein substantially all of the heat removed from the solid material in said cooling zone and returning the heat exchange gas from said heating zone to said cooling zone, and maintaining the temperature of the contact material entering said heating zone sufficiently below that of the contact material entering said cooling zone to insure said heat transfer by said heat exchange gas from said cooling zone to said heating zone.

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