

Nov. 9, 1954

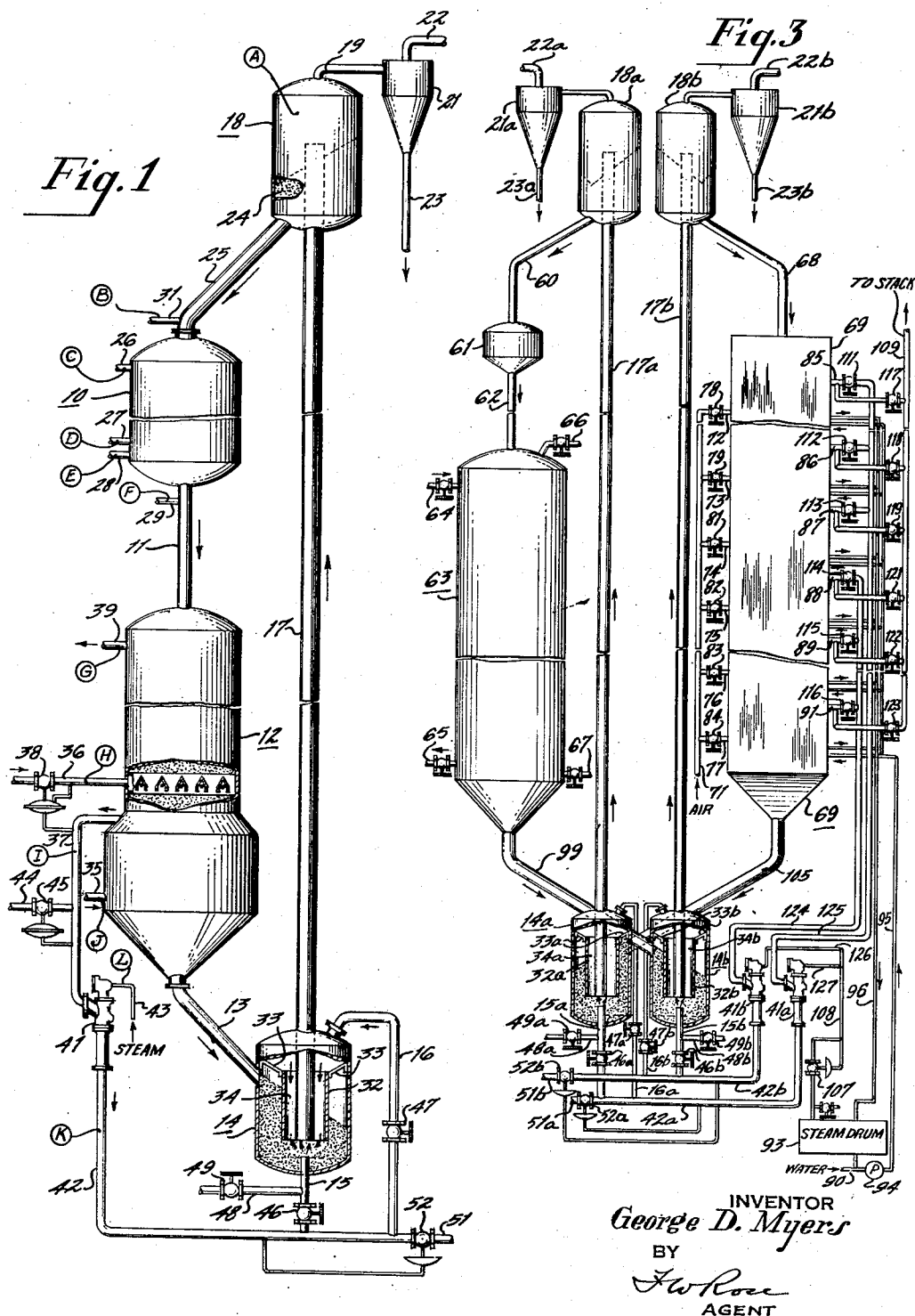
G. D. MYERS

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LIFTING FLUENT SOLIDS IN HYDROCARBON CONVERSION SYSTEMS

Filed Oct. 29, 1949

2 Sheets-Sheet 1



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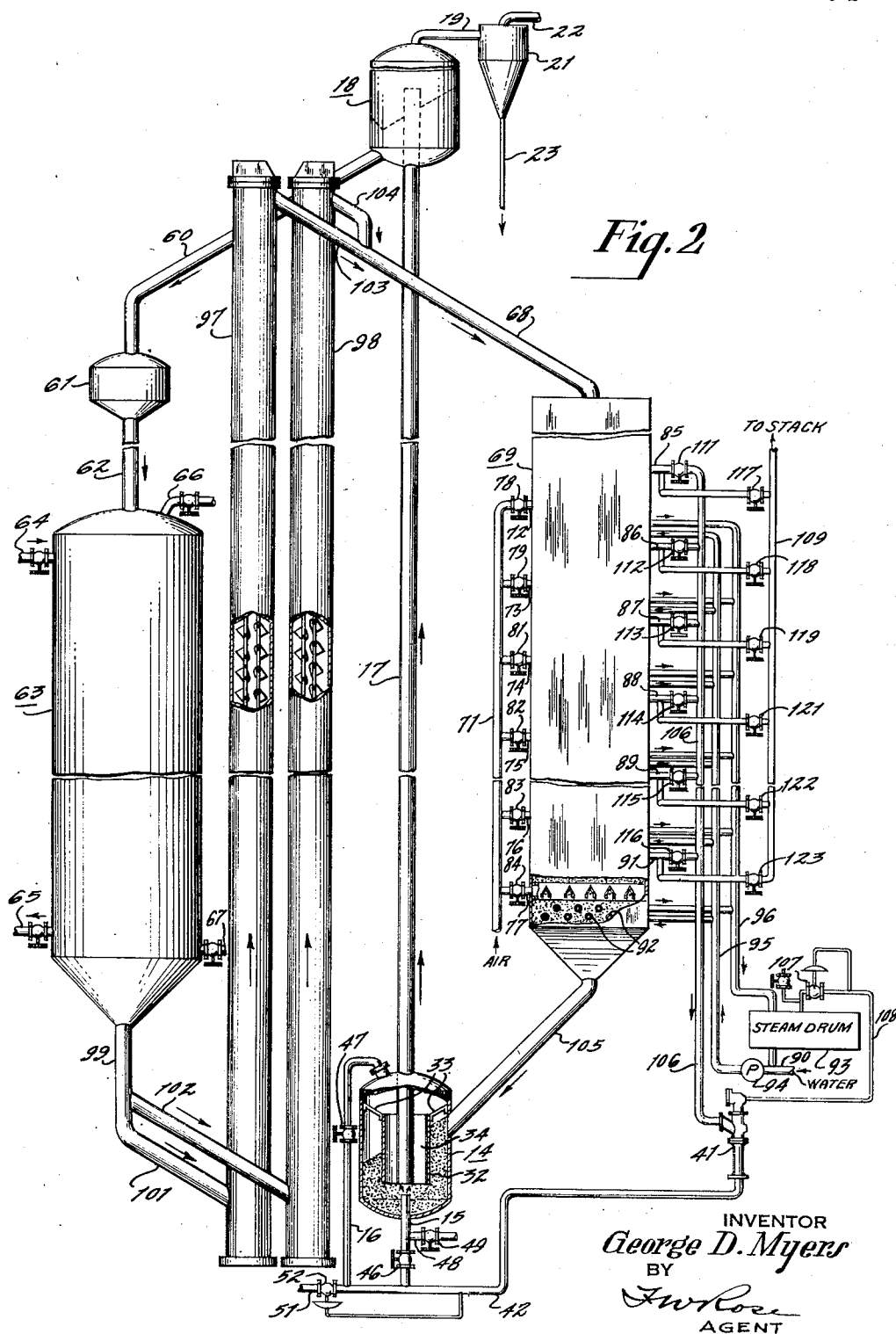
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LIFTING FLUENT SOLIDS IN HYDROCARBON CONVERSION SYSTEMS

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Application October 29, 1949, Serial No. 124,293

2 Claims. (Cl. 196—52)

This invention relates to continuous hydrocarbon conversion processes, such as cracking, reforming, dehydrogenation, aromatization, viscosity-breaking, coking and the like, of the type in which particles of solid contact material, such as a hydrocarbon conversion catalyst or a relatively catalytically inert heat carrier, contact hydrocarbons under conversion conditions and thereby concomitantly accumulate a deposit of coke; the coked contact material being thereafter contacted with oxygen containing gas under combustion conditions so as to remove at least a portion of said coke and thereby regenerate or reactivate the contact material for further use, the solid contact material employed in such processes having been prepared in such a form and handled in such a manner as to be fluent or capable of flowing.

The present invention involves flowing relatively large particles or granules, such as sized particles, pellets, formed spheres and the like ranging in size from about 0.01 to 0.5 inch in diameter, principally or solely by the influence of gravity through a downflow path or paths of a system in which there are one or more process zones in such downflow paths. The gravitational flow of solids through process zones as compact downwardly moving non-turbulent beds is discussed generally in "The T. C. C. catalytic cracking process for motor gasoline production," by R. H. Newton, G. S. Dunham and T. P. Simpson, "Transactions of the American Institute of Chemical Engineers," volume 41, page 215, April 25, 1945, and in articles there cited.

In the compact non-turbulent bed type of system, it has been found advantageous to transport the fluent particulate solid (i. e., contact material) by one or more gas lifts of the type described herein in order to effect circulation of such particles through a system comprising at least one upflow path and at least one downflow path in which there are one or more reaction or process zones (i. e., a conversion or regeneration zone or both) wherein said solid contacts a reactive or process material (i. e., hydrocarbons in the conversion zone and oxygen containing gas in the regeneration zone). The process zones may be at different heights in a single downflow path so that the solid particles need be transported by the gas lift only once in a complete cycle of operation or a plurality of gas lifts and of downflow paths may be employed. An exemplary system of the former type has been described in an article entitled "Houdrflow: New design in catalytic cracking," appearing in the "Oil and Gas Journal," page 78, January 13, 1949.

In such systems, when the solid particles, after disengagement from the transporting gas, are thereafter moved downwardly in compact non-turbulent flow, the rate of transportation and circulation through the system is easily controlled, at least partially, by controlling the operation of the gas lift. Since the rate of circulation of contact material will, at constant oil throughput, determine the contact material to oil ratio, it will be easily appreciated that the manner of operation of the gas lift or pneumatic conveyor is an important phase of the process and that it is important to provide an adequate source of lifting gas under substantially constant conditions as economically as possible. However, considerable volumes of lifting gas are necessary, particularly at high contact material to oil ratios, such as from 5 to 1 to 20 to 1, and the cost of supplying such gas at the superatmospheric pressure needed at the bottom of the lifting zone is an important item in the total cost of operating such a system.

Moreover, since it is important that the circulating solid

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be maintained during its conveyance pneumatically at elevated temperature desired for the next succeeding reaction, either burning or hydrocarbon conversion, the lifting gas should be at such elevated temperature that excessive heat absorption by such gas during the lifting operation is avoided.

In systems of the type referred to herein, it has been found that flue gas discharged from the regeneration or burning zone is an excellent medium for lifting the contact material particularly when employed for this purpose while still hot from the regeneration. During normal operation of hydrocarbon conversion systems, flue gas is usually available in quantities adequate to transport the desired amounts of contact material. In addition, such flue gases are usually sufficiently inert chemically that, when in contact with particles of contact material, they have no substantial adverse effect on the catalytic properties of the contact material or extent of the reactions effected by or in the presence of the contact material subsequent to its pneumatic conveyance. Hence no special treatment of the contact mass after the lifting step is necessary to remove adsorbed or occluded gases therefrom.

For economy it is desirable that the regeneration zones in systems of the type with which this invention is concerned operate at low superatmospheric pressure. On the other hand, for efficient pneumatic lifting of the contact material, the pressure of flue gas admitted to the lift should be somewhat higher than the most economical regeneration pressure. Thus, in previously proposed systems wherein flue gases were conducted from a regeneration zone to a pneumatic lift, it has been proposed either to supply the original regenerating medium, such as air, to the system at sufficiently high pressure (above the economical pressure for regeneration alone) to overcome pressure drop in the regenerating and auxiliary equipment and deliver flue gas to the bottom of the lift at the necessary pressure, or to mechanically recompress the large volume of hot flue gases discharged from the regeneration zone. In either event, the investment and operating costs of effecting the additional compression became substantial items.

The use of other inert gaseous conveying medium, notably steam, has been proposed. Although steam has certain inherent advantages that otherwise would make it a desirable pneumatic conveying medium, such as its low molecular weight and easy, economical presentation to a system at reasonable pressures, it presents certain drawbacks for use as such in systems of the type to which this invention is directed. For example, substantial investment and operating costs are required to heat the steam to a sufficiently high temperature to avoid heat loss by the contact material during lifting. Furthermore, steam under pressure and at high temperature (the conditions existing in the gas lift) exhibits a pronounced and cumulative deactivating action on many of the commercially available hydrocarbon conversion catalysts, and with certain of the commercially available catalysts, appears to affect adversely the physical strength and attrition characteristics of molded units of such catalysts so as to decrease their effective service life.

In practice of the invention flue gases from regeneration and steam are combined and employed together as conveying medium of contact material in such manner that the advantages of each gaseous material for lifting purposes are realized, and otherwise efficient and economical operation is obtained.

According to the present invention, high velocity steam is injected into a stream of low pressure hot flue gases flowing from a burning zone toward a gas lift in such manner and amount that the pressure of the resulting mixture is at least as great as the pressure desired for lifting. The cumulative lifting effect of the steam and flue gases is thereafter utilized for transportation of the contact material at pressure higher than and independent of the pressure used in the regeneration.

The principles involved in the present invention are set forth in detail below in connection with the description of drawings in which:

Figures 1, 2 and 3 are schematic representations of the major parts of systems embodying the present in-

vention with parts broken away to reveal the internal construction of some of the vessels.

Although the present invention includes within its scope a variety of processes as set forth herein, the drawings will be explained in terms of a catalytic hydrocarbon cracking process, since those skilled in the art will understand thereby how to operate analogous or equivalent processes by the same principles.

As illustrated in Figure 1, relatively large particles of solid cracking catalyst, such as particles between about 1 to 15 and preferably about 2 to 6 millimeters in diameter, flow downwardly through a converter vessel or reactor indicated generally at 10 as a downwardly moving non-turbulent bed, and are transferred by conduit 11 to a regenerator vessel or kiln indicated generally at 12 in which the coke deposited on the catalyst particles in the cracking zone is removed. Compositions effective as hydrocarbon conversion and/or cracking catalysts (typically natural or synthetic aluminosilicates) and the conditions in reactor 10 and kiln 12 are well known to the art and need not be repeated here.

Catalyst particles are withdrawn from regenerator 12 and flow downwardly in conduit 13 as a compact non-turbulent column to a gas lift inlet chamber at the bottom of a gas lift, this chamber being indicated generally at 14, and are transported, lifted or elevated vertically upward as a continuous stream of solid particles by a transporting, elevating or lifting gas introduced to the gas lift by conduits 15 and 16, the particles of contact material passing upwardly through an elongated vertical cylindrical passageway or conduit 17 to a closed housing, vessel or separator indicated generally at 18, which vessel comprises a disengaging zone. The disengaged lifting gas is removed from vessel 18, as from the top thereof by conduit 19. If desirable, disengaged gases may then pass to a cyclone separator 21, in which entrained fine particles of catalyst are separated from the lifting gas. The fluent particulate solid contact material during use is subjected to grinding and abrasion so that a range of particle sizes results, and hence the fine particles are preferably continuously removed, as by the cyclone shown or by an elutriator, so as to leave a range of particle sizes such that a gas can be passed countercurrently through a downwardly moving mass of contact material at a pressure drop in the range of about 4 to about 8 inches of water per foot of mass depth. Gas, freed of fine particles, is removed from the top of separator 21 by conduit 22; the fine particles are removed from the bottom of cyclone 21 through conduit 23 and pass to a bin (not shown). Solid catalyst particles disengaged from the transporting or lifting gas settle on the surface of bed 24 in vessel 18, from which bed catalyst particles flow to the reactor through conduit 25 as a relatively compact non-turbulent column of particles. It is to be understood that a particular type of separator, such as vessel 18, is not a part of this invention and that separators other than the one illustrated, which perform the function of separating the lifting gas and the particles of contact material by various specific methods, may be employed.

Hydrocarbon fractions to be cracked or reformed, ranging from naphthas to heavy residual stocks, are introduced from a feed preparation zone of a type known to the art in vapor, liquid or mixed phase conditions to reactor 10, such as through conduit 26, and contacted by the catalyst particles therein, using known methods and apparatus. The hydrocarbons are passed downwardly through the bed of contact material in reactor 10 in vapor form and under conversion conditions, disengaged from the contact material, removed from the reaction through conduit 27 and thereafter directed to a fractionation zone for appropriate processing to products such as gasoline, fuel oil, recycle stock and the like. As is apparent to those skilled in the art, hydrocarbons may enter reactor 10 through conduit 27, pass upwardly through the bed of contact material and be removed by conduit 26, suitable adjustments being made in the pressure relationships described below. A purge gas such as steam, inert flue gas and the like may be introduced to reactor 10 by conduit 28 to purge the contact material of volatile hydrocarbons.

In order to keep separate the gases in reactor 10 and kiln 12, a sealing gas, such as steam, inert flue gases,

carbon dioxide or other gases compatible with both the cracking reaction in the reactor 10 and the combustion reaction in kiln 12, may be introduced to conduit 11 by conduit 29. A similar provision for introducing sealing gas to conduit 25 may be provided, as by conduit 31. Where reactor 10 and/or kiln 12 are constructed in a known manner so that there is a sealing or contact material introduction chamber in the top thereof, which chamber provides a vapor space above a bed of contact material and constitutes a process zone separate from the cracking or regeneration zone, respectively, a sealing gas may be introduced to the chamber instead of the conduits as shown in Figure 1. It is to be understood that reactor 10 and kiln 12 may be equipped with various other devices known to the art but not shown in the drawings; for example, reactor 10 may contain a device for contacting contact material with liquid oil and kiln 12 may contain cooling coils at appropriate positions.

The gas lift described herein has been found to operate at a high efficiency and an economically low rate of particle attrition when maximum average velocity of travel of the catalyst particles is advantageously above about 10 and below about 60 feet per second, and preferably between about 20 to 40 feet per second. (The average velocity is the velocity of all of the particles averaged over the horizontal cross sectional area of the lift pipe; the maximum velocity is the velocity after final acceleration.) Such lifts are advantageously operated at between about 1 to 7 and generally below about 20 pounds per square foot per foot of lift height (when using catalyst particles having about 40 to 55 pounds per cubic foot apparent density). Thus a lift of 200 feet may have above 1 and up to about 10 pounds per square inch total pressure drop across the ends thereof.

In the system illustrated in Figure 1, the regeneration is effected in two series of vertically superimposed adjacent regeneration stages through which the coked catalyst flows successively, by introducing in each stage a stream of fresh oxygen containing gas, such as air or air fortified with oxygen, through conduits 35 and 36. The stages may be separated from each other by any of various means known to the art and may even, within the scope of the invention, be in separate vessels with a seal leg or legs between the vessels. It is, however, preferred to have the stages in a single vessel as shown and to have the catalyst pass therethrough in continuous non-turbulent flow. As will be described more fully below, the flow of gases through the various stages in a desired manner is effected by proper control of the pressure relationship of the various entering and exit gases.

Thus the oxygen containing gas introduced to the bottom of the lowermost regeneration stage, as by conduit 35, passes upwardly through the lowermost portion of the bed under combustion conditions and is disengaged from the catalyst, the resultant flue gas being removed through conduit 37. Where the pressures in conduit 35 and at the bottom of the lift are different, conduit 13 operates as a seal leg and thus insures that most, if not all, of the oxygen containing gas passes upwardly. A separate stream of oxygen containing gas is introduced to the bottom of the uppermost portion or stage of the regeneration zone as by conduit 36 at a pressure controlled by valve 38 to be substantially equal or only slightly greater, such as 0.1 to 0.2 pound per square inch, than the discharge pressure in conduit 37. The oxygen containing gas introduced by conduit 36 passes upwardly through the uppermost stage countercurrent to the flow of catalyst and is disengaged from the catalyst, the resultant flue gas being removed through conduit 39.

In accordance with the embodiment of the invention illustrated in Fig. 1, the advantages of both low pressure operation of the regeneration zone and of the use of flue gas for lifting are gained by maintaining flow conditions of the oxygen containing gas introduced by conduit 35 through the bed of catalyst in the regeneration zone such that the pressure of introduction is relatively low and the pressure of the stream of flue gas discharged through conduit 37 is substantially below, such as from 10 to 50 percent of the absolute pressure, the static gaseous pressure at the bottom of the lifting zone, passing this flue gas to a steam jet thermocompressor 41 wherein a mixture of said flue gas and steam having a pressure higher than that of the flue gas alone and at least equal to the

pressure at the bottom of the lifting zone is formed by injecting high velocity steam obtained by expanding high pressure steam, such as steam at a pressure from about 50 to about 200, preferably between 100 to 175, pounds per square inch gauge, from conduit 43 through the nozzle of steam jet thermocompressor 41 into the stream of flue gas passing therethrough. The mixture of steam and flue gas thus formed is thereafter used for elevating particles through lift pipe 17 by passing it through conduit 42 to either or both conduits 15 and 16.

In general, it is preferred to operate the steam jet thermocompressor so that the absolute pressure of flue gas in conduit 37 (referred to as the suction pressure of the steam jet thermocompressor) is related to the absolute pressure of the mixture of steam and flue gas in conduit 42 (referred to as the discharge pressure of the steam jet thermocompressor) in a manner such that the ratio of the latter to the former is between about 1.1 to 1.5 and preferably in the lower end of this range, such as 1.1 to 1.3. Such a ratio can be achieved by injecting from about 0.1 to 0.6 pound of steam per pound of flue gas, the amount of steam depending upon the pressure thereof, less steam being needed at higher pressures. Such amounts of steam achieve the desired increase in pressure while maintaining good economy in the use of both flue gas and steam; moreover, any deactivating effect of steam on the catalyst is within commercially acceptable limits. The steam injected through conduit 43 is, in general, lower in temperature than the temperature of the flue gas, the latter ranging from about 900 to 1100° F. and the former from approximately 300° to 400° F. when in a dry and saturated condition. However, if desired, the steam may be superheated to temperatures from 700 to 900° F. (Further details of the construction, operation and control of steam jet thermocompressors have been discussed in articles by Philip Freneau appearing in "Power," January 1945 and February 1945, and need not be repeated here.)

From the above discussion, it can be seen that flue gas can be discharged at substantially atmospheric pressure and a mixture of steam and flue gas formed having a pressure of about 1 to 2 pounds per square inch gauge by adding minimum amounts of steam or a higher pressure of the resultant mixture of flue gas and steam, such as from 5 to 7 pounds per square inch gauge, can be produced by using greater amounts of steam. In systems where flue gas discharges at a pressure above atmospheric, such as 2 to 5 pounds gauge, the steam jet thermocompressor can operate with small amounts of steam to produce a discharge pressure (of steam and flue gas) of from 8 to 10 pounds per square inch gauge. However, since, in all systems employing the present invention, the pressure at which the flue gas discharges from the regeneration zone is below the pressure at the bottom of the lifting zone, a considerable economy over former systems is effected; this economy being measured by the difference in (a) the cost of pumping the oxygen containing gas at a pressure necessary to flow it through the bed in the regeneration zone and thereafter have sufficient pressure available so that the gas can be used for lifting and (b) the cost of pumping such gas at a pressure less than the first named pressure by the amount of pressure increase in passing through the steam jet thermocompressor. Moreover, as noted below, the amount of flue gas produced in the system may be considerably greater than that needed for lifting; hence the energy expended in pumping the oxygen containing gas that forms the unused flue gas is not recovered in former systems. Such a difference may mean the difference between an expensive compressor and a cheap blower.

In a desirable mode of operation of the regeneration zone, more gas is discharged from the lowermost section of the regeneration zone than will be needed, in conjunction with high pressure steam, for lifting. In this event, excess flue gas is discharged through conduit 44, valve 45 serving to maintain a constant pressure in conduit 37. Such a mode of operation is distinctly advantageous in that only that amount of flue gas necessary for lifting is raised to the high pressure even though the operations of regeneration and lifting are independent of each other so that the system has great flexibility. The mixture of steam and flue gas discharged from the steam jet compressor may constitute the sole source of gas employed in lifting, valves 46 and 47 being adjusted to apportion the relative amounts of the mixture of steam and flue

gas flowing in conduits 15 and 16, respectively. However, if desired, all of the mixture of steam and flue gas employed in lifting may be passed through conduit 16, valve 46 being closed and a small amount of another gas, such as steam, may be added to conduit 15 through conduit 48 in an amount controlled by valve 49, the lifting gas thus predominantly comprising the mixture of steam and flue gas from conduit 42. The auxiliary gas admitted by conduit 48 furnishes a convenient control on the concentration of catalyst in the total lifting gas without changing the flow of gas in conduit 42. If desired, the amount of steam and flue gas passed through conduit 42 may be slightly in excess of that required for normal operation, the excess discharging through conduit 51, with valve 52 serving to maintain a constant pressure in conduit 42.

In systems where the amount of flue gas discharged from a lower stage of regeneration is insufficient for lifting, the flue gas which discharges from a higher stage, analogously to the flue gas from conduit 39, at a lower pressure than the discharge pressure of the flue gas in the lowermost zone, can pass through a steam jet thermocompressor under conditions such that the pressure of the resultant mixture of steam and flue gas is equal to the pressure of the flue gas discharged from the lower stage and thereafter used to supplement the latter. In such an operation, the mixture of steam and flue gases from the two zones can thereafter be passed through a second steam jet compressor in the manner shown in Figure 1.

Other methods of flowing the oxygen containing gas through the regeneration zone can be employed in connection with the use of a steam jet thermocompressor to form a mixture of steam and flue gas having a pressure which renders it suitable as a lifting medium. Thus the oxygen containing gas can be introduced at an intermediate level in the regeneration zone and thereafter flow upwardly and downwardly to produce two streams of flue gas, either of which may be used as described or more regeneration stages than two can be used. When the pressure drop through the uppermost and lowermost stages is different, the flue gas having the higher discharge pressure is more suitable for passage through a steam jet thermocompressor.

In accordance with a specific form of the invention, combustion conditions in the regeneration zone, including the amount of cooling produced by indirect heat exchange, are selected so that the temperature of the flue gas discharged from the lowermost stage (or stages) is in the range of from about 1000 to 1100° F. such a temperature being substantially higher, such as of the order of 100 to 200° F., than the temperature of the flue gas ordinarily discharged from the uppermost stage (or stages). Such hot flue gases afford means of heating relatively low temperature high pressure steam so that the catalyst thereafter contacted in the lifting operation is not cooled to any great extent.

A typical example of the pressures employed in a commercial sized plant, in accordance with the embodiment illustrated in Figure 1, is given in the table in which pressures at the points indicated in that figure are given.

Table.—Static gaseous pressures at the points indicated, pounds per square inch gauge

A	B	C	D	E	F	G	H	I	J	K	L
0.3	8.5	8.4	6.0	6.1	6.2	0.2	2.0	1.9	3.0	6.1	140

The present invention affords a means of adapting moving bed systems which now employ only mechanical elevators to systems employing higher catalyst flow or circulation rates.

A difficulty is encountered when it is desired to increase the rate of contact material circulation in moving bed catalyst systems by supplementing existing mechanical bucket elevators by a gas lift or, instead, by completely substituting gas lifts for mechanical elevators. The regenerating vessels or kilns in such systems now in use are designed to withstand gas pressures only a small amount above atmospheric, such as less than 2 pounds per square inch gauge, the flue gas being discharged substantially at atmospheric pressure, such as less than 0.5 pound per square inch gauge.

Illustrative of such a system is that in Figure 2, in

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which catalyst flows through conduit 60 to storage hopper 61, through seal leg 62 to a reactor indicated at 63 where hydrocarbons are introduced and removed by conduits 64 and 65, respectively. A seal gas may be introduced to reactor 63 through conduit 66 and a purging gas through conduit 67. Coked catalyst from reactor 63 passes down conduit 68 and thence into a regenerator or kiln indicated generally at 69. Coked catalyst gravitates downwardly through regenerator 69 and is regenerated by contacting it in a plurality of regeneration stages, by passing oxygen containing gas through manifold 71 through inlets 72, 73, 74, 75, 76 and 77 in amounts controlled by valves 78, 79, 81, 82, 83 and 84, respectively. The oxygen containing gas so introduced passes upwardly and downwardly from each inlet through the bed of catalyst in regenerator 69, is disengaged from the catalyst and removed through a plurality of outlets 85, 86, 87, 88, 89 and 91; intermediate outlets 86, 87, 88 and 89 serving to collect gas passing upwardly from a lower inlet and gas passing downwardly from a higher inlet (the manner of construction and operation of such kilns, including the use of gas collection and distributing devices of the type illustrated in the broken away portion of the bottom of kiln 69, is described in the article by Newton et al. referred to above). The catalyst in the course of its passage downwardly through kiln 69 is cooled by indirect heat exchange by cooling coils 92 (cooling coils similar to those shown in broken away view are, it is to be understood, placed in each combustion stage) by passing water at a pressure of from about 50 to 250 pounds per square inch from steam drum 93 through pump 94 and conduit 95 to the cooling coils 92. In cooling coils 92, water is converted to a mixture of high pressure steam and water, this mixture of steam and water passing by manifold 96 back to the top of the steam drum. Makeup water, equal in amount to the steam removed from the system, is added through conduit 90.

In presently existing systems, catalyst flow between reactor 63 and regenerator 69 is effected by two mechanical elevators, one of which receives coked catalyst, elevates it to above the regenerator and discharges it into the regenerator and the other of which receives regenerated catalyst, elevates it to above the reactor and discharges it into the reactor. However, the process flexibility of such systems is limited by the capacity of the mechanical elevators and it is generally difficult to maintain catalyst to oil ratios substantially over 2 to 1 without a substantial sacrifice of the throughput of oil. By applying the present invention to such systems, the catalyst circulation rate can be at least doubled by the system shown in Figure 2 in which elevators 97 and 98 operate in parallel, both receiving coked catalyst from conduit 99 through conduits 101 and 102, respectively, and discharging coked catalyst through conduits 103 and 104 so as to send a common stream of catalyst through conduit 68 to regenerator 69. Freshly regenerated catalyst is removed from regenerator 69 through conduit 105 and thereafter elevated through lift pipe 17 by a lifting gas. (Parts in Figure 2 having identical numbers with those in Figure 1 are similar in arrangement and function to those described in detail in connection with Figure 1, further description being omitted for brevity.)

The gas for lifting is obtained by injecting high velocity steam into the stream of flue gas flowing in manifold 106 into which outlets 85, 86, 87, 88, 89 and 91 discharge. In accordance with a specific form of the invention, the high pressure steam for the operation of the steam jet compressor 41 is obtained by removing high pressure steam from the top of steam drum 93 and passing it through a pressure control valve 107, so as to discharge at a pressure slightly lower than the pressure of the steam in drum 93, and thence to steam injector 41. In this manner, the high pressure steam generated in the regeneration zone is effectively and economically employed in forming the mixture of steam and flue gas used in lifting, thus obviating the necessity for a continuous outside source of high pressure steam with the attendant expense of constructing and operating such an outside system. Excess flue gas formed in regenerator 69 can be sent to a stack through manifold 109 by appropriate manipulation of valves 111, 112, 113, 114, 115 or 116 and 117, 118, 119, 121, 122 or 123.

In the event that the indirect heat exchange system is operated at a pressure, such as from 250 to 500 pounds

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per square inch, that is substantially higher than the pressure of steam which is desired for use in the steam jet compressor, the steam taken off from steam drum 93 may be passed through a suitable device, such as a turbine, to recover some of the energy of the steam and/or reduce the pressure to that desired for use in a steam jet compressor. Such a turbine is conveniently interposed in the line from the steam drum prior to valve 107. Indeed, valve 107 may be eliminated and the desired pressure control effected by means of the turbine.

In Figure 3, a similar system to that shown in Figure 2 is shown except that catalyst is elevated in two upflow paths or gas lifts, from the tops of which catalyst is discharged to the regenerator and reactor respectively, the elevators thus being eliminated. (Parts in Figure 3 numbered similarly to those in Figures 1 and 2, including parts having numbers with *a* or *b* as suffixes, are similar in function and construction and their description will not be repeated.) In Figure 3 the flue gas, instead of discharging into a single manifold, discharges into two manifolds 124 and 125, the two streams of flue gas passing through two steam jet compressors 41*a* and 41*b*, to both of which are fed steam from steam drum 93 through conduits 126 and 127 in a similar fashion to that described in connection with Figure 2.

The system shown in Figure 3 presents certain advantages in that the flue gas from the uppermost stages of regeneration is employed in lifting the coked catalyst from the regenerator while the flue gas from the lowermost stages is employed in lifting the freshly regenerated catalyst. Since the flue gases from the uppermost and hence initial stages of regeneration are predominantly, if not entirely, spent flue gases, in the sense that they have little if any oxygen for combustion, coked catalyst will not, in the course of its elevation, burn so as to have an uncontrolled temperature rise. On the other hand, the flue gas from the lowermost regeneration zones is characteristically hotter than the flue gas from the uppermost zones and thus affords a better means of lifting the freshly regenerated catalyst without effecting undesired cooling. Moreover, if desired, catalyst may be discharged from conduit 69 with a residual coke deposit slightly higher than that desired for use in the cracking reaction and the conditions of lifting in conduit 17*a* may be such that the flue gases from the lowermost stages of the regeneration zone, which contain excess oxygen, effect regeneration during the lifting operation.

Obviously many modifications and variations of the invention as hereinbefore set forth may be made without departing from the spirit and scope thereof and therefore only such limitations should be imposed as are indicated in the appended claims.

I claim as my invention:

1. In a hydrocarbon conversion process in which fluent particles of solid hydrocarbon conversion catalyst continuously circulate through a system wherein freshly regenerated catalyst contacts hydrocarbons under conversion conditions within a conversion zone, thereby concomitantly accumulating a deposit of coke; wherein a downwardly moving non-turbulent bed of coked catalyst withdrawn from said conversion zone contacts oxygen-containing gas in a regeneration zone under combustion conditions such that the temperature of said catalyst is higher in the lower portion of said regeneration zone than in the upper portion thereof; and wherein said particles are elevated upwardly through a lifting zone by a lifting gas for subsequent flow through the conversion and regeneration zones; the steps which comprise passing oxygen-containing gas through an upper portion of the bed of catalyst in the regeneration zone; discharging a first stream of flue gas from said upper portion; passing oxygen-containing gas through a lower portion of the bed of catalyst in the regeneration zone; discharging a second stream of flue gas from said lower portion at a pressure lower than the static gaseous pressure at the bottom of said lifting zone, the temperature of said second stream of flue gas being substantially higher than that of said first stream of flue gas; injecting steam at high velocity into said second stream of flue gas so as to form a mixture of said flue gas and steam having a pressure at least equal to the pressure at the bottom of the lifting zone; and elevating said particles through said lifting zone by lifting gas predominantly comprising said mixture of steam and flue gas.

2. In a hydrocarbon conversion process in which fluent

particles of solid hydrocarbon conversion catalyst continuously circulate through a system wherein freshly regenerated catalyst contacts hydrocarbons under conversion conditions within a conversion zone, thereby concomitantly accumulating a deposit of coke, and flows by gravity into a regeneration zone therebelow; wherein a downwardly moving non-turbulent bed of coked catalyst from said conversion zone contacts oxygen-containing gas under combustion conditions in said regeneration zone; and wherein particles of freshly regenerated catalyst from the regeneration zone are elevated upwardly through a lifting zone by a lifting gas for subsequent flow through the conversion and regeneration zones; the steps which comprise passing oxygen-containing gas upwardly through the lowermost portion of the bed of catalyst in the regeneration zone under flow conditions such that a stream of flue gas is discharged from said lowermost portion at a pressure substantially below that at the bottom of said lifting zone; passing oxygen-containing gas upwardly through the upper portion of the bed of catalyst in the regeneration zone, the pressure of oxygen-containing gas at the locus of introduction to said upper portion being not substantially greater than the discharge pressure of

the flue gas from said lower portion; discharging a second stream of flue gas from said upper portion; injecting sufficient high velocity steam into said second stream to form a mixture of steam and flue gas having a pressure substantially equal to the pressure of the stream of flue gas discharged from said lower portion; commingling said mixture with flue gas from the lower portion; injecting sufficient high velocity steam into the commingled steam and flue gases from said upper and lower portions to form a resultant mixture of steam and flue gas having a pressure at least equal to that at the bottom of the lifting zone; and employing said resultant mixture as lifting gas.

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