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HYDROCARBON CONVERSION SYSTEM

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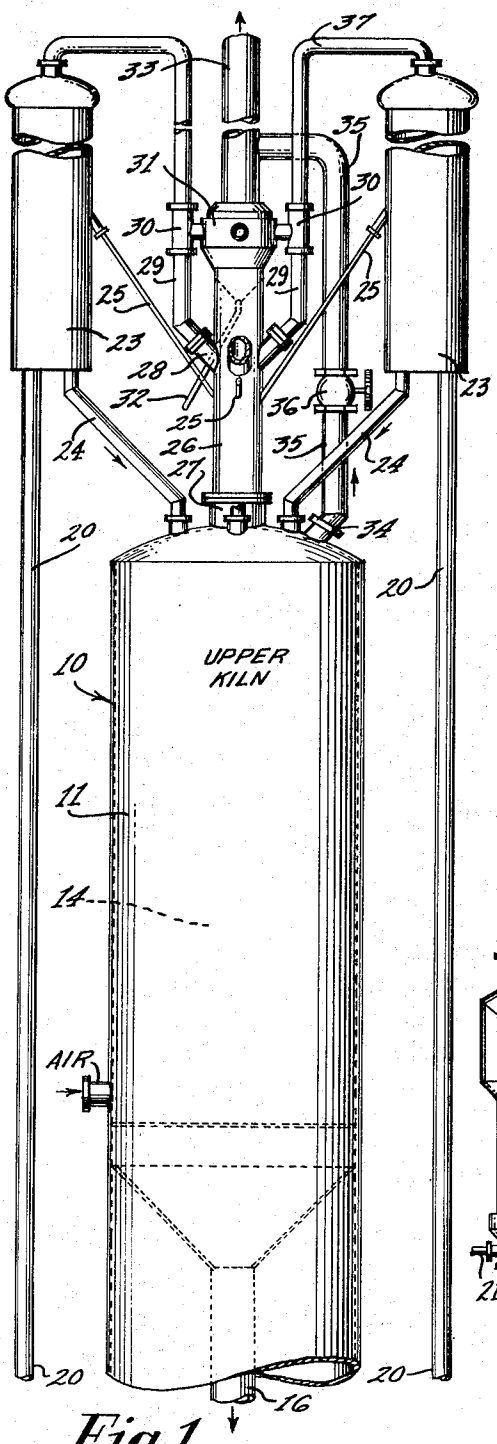


Fig. 1.

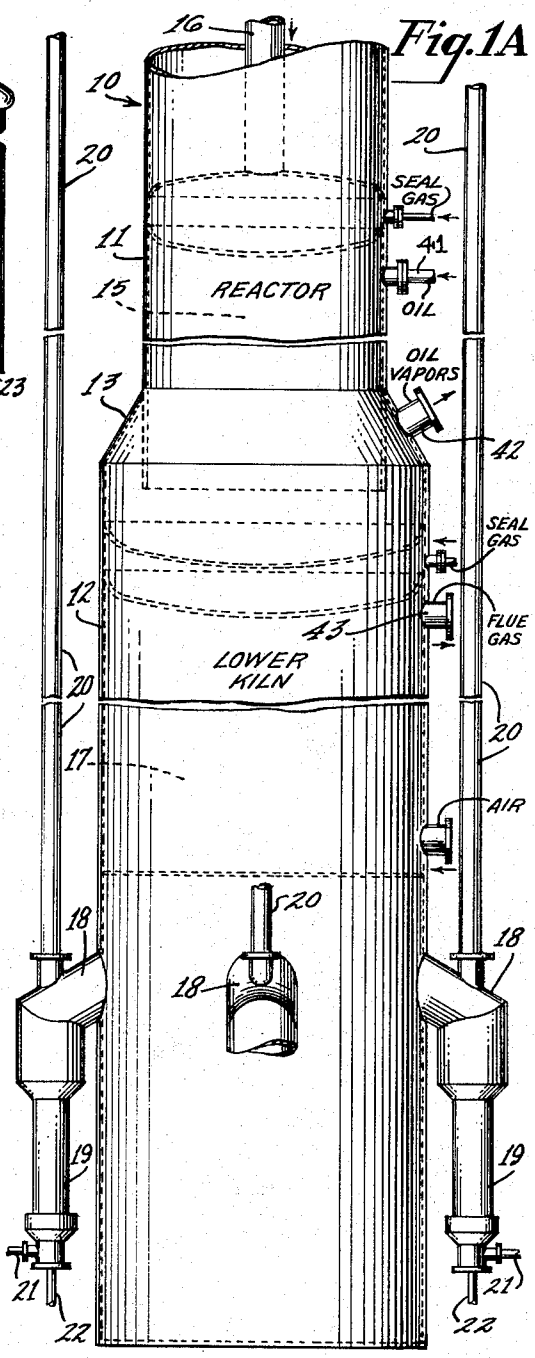


Fig. 1A

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HYDROCARBON CONVERSION SYSTEM

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5 Claims. (Cl. 196—52)

This invention relates to a method and apparatus for carrying out hydrocarbon conversions, particularly as applied to systems involving the continuous circulation of granular contact material. The invention is especially applicable to those cyclic systems wherein the granular contact material is passed by gravity flow downwardly through a plurality of superimposed contact zones combined into a single unitary structure and, upon discharge from the lower end of the unitary structure, is elevated by a pneumatic lift, comprising one or more confined lift paths, to a raised level substantially higher than the conversion unit, where the contact material is then disengaged from the lift gas and is returned by gravity flow into the upper end of the conversion unit. A typical example of such conversion unit is disclosed in an article entitled "Houdriflow: New design in catalytic cracking," appearing at page 78 of the January 13, 1949, issue of the "Oil and Gas Journal."

In such systems, it is common practice to locate the reactor or hydrocarbon conversion zone directly over the kiln or regeneration zone, with sufficient vertical space therebetween to accommodate the usual seal leg. The granular contact material is introduced into the upper end of the conversion zone and passes downwardly therethrough in the form of a compact moving mass. The hydrocarbons to be converted are introduced in known manner into the conversion zone, and are passed through the moving mass of contact material. The gaseous products of conversion are subsequently separated from the contact material, removed from the conversion zone, and conveyed to other portions of the systems for further processing. The contact material, after suitable purging with steam or other inert gas, is passed downwardly through an elongated seal leg and introduced into the upper end of the kiln or regeneration zone. Within the kiln, the carbonaceous material which formed on the contact material during the hydrocarbon conversion is removed by combustion in the presence of oxygen-containing gas. The aforesaid seal leg connecting the conversion and regeneration zones is of such length as to maintain a continuous flow of contact material therebetween and, in conjunction with the usual sealing gas, to prevent undesirable migration of the incompatible gaseous material between the two zones.

The contact material continues to gravitate as a compact moving mass in passing through the kiln or regeneration zone, which zone may comprise one or more stages of regeneration. The gaseous products of combustion, or flue gases are separated from the contact material and withdrawn from the kiln. The contact material is discharged from the lower end thereof as a compact moving stream, and is introduced into the engager or introduction chamber of the pneumatic lift. The lift engager surrounds the lower end of the lift pipe, and forms therewith an annular space wherein the contact material gravitates about the lower end of the lift pipe as a compact moving mass. Within the lift engager the contact material is engaged by a stream of lift gas, such as air, flue gas, etc., and is elevated thereby through the lift pipe to a disengager vessel surrounding the upper end of the lift pipe. Within the disengager the contact material is separated from the lift gas by gravitational deceleration. The disengaged contact material is then passed by gravity flow into the upper end of the reactor conversion zone. Provision is normally made for a surge supply of contact material, either by a supply hopper located in the upper end of the unitary structure, immediately above the conversion zone, or by an accumulated bed of the contact material maintained in the lower region of the disengager vessel.

In the operation of such units, the regenerated contact material is usually withdrawn from the lower end of the kiln at a temperature in the range of about 1050–1150° F., and is thereafter passed directly, and without substantial loss of heat, into the lift engager for pneumatic elevation through the lift pipe. The temperature loss while the contact material is being conveyed from the discharge outlet of the kiln to the lift engager and then from the lift engager through the lift to the lift disengager is normally in the order of about 20–30° F. At the slightly lower temperature the contact material is then passed downwardly into the conversion zone. Since in certain operations, such as those employing liquid hydrocarbon feed in the conversion zone, a maximum efficiency, from the standpoint of beneficial utilization of available heat, is obtained when the regenerated contact material is introduced at the maximum practicable temperature into the conversion zone, the loss in temperature of the contact material during conveyance from the kiln to the reactor must subsequently be compensated for in the conversion zone. Compensation therefor by increasing the circulation rate of the contact material is undesirable because it imposes a heavier duty on the lift system.

In conversion systems wherein the kiln is operated at maximum permissible temperatures, from the standpoint of avoiding deactivation of the particular contact material, and wherein the contact material is introduced at maximum practicable temperatures into the conversion zone, a common practice is to convey the contact material between the two zones as nearly as possible at the temperature at which it is withdrawn from the kiln. Such temperature is usually above the allowable maximum for carbon steel, thus requiring more expensive alloy steel fabrication for those elements, such as the regenerated contact material withdrawal conduits, the lower seal leg, the lift engager, the lift pipe, the disengager, and the return conduit, which are subjected to the high temperaures. Fabrication of such affected elements with temperature-resistant alloys represents a susbtantial increase in cost.

In accordance with the present invention, separate kilns or regeneration zones are provided at opposite ends of the unit, that is, both above and below the reactor or conversion zone. A partial regeneration of the contact material, in one or more stages, is effected within the lower regeneration zone, and the partially regenerated contact material is withdrawn therefrom at a temperature substantially lower than the temperature which would normally be attained if regeneration were complete. The partially regenerated contact material is then introduced into and conveyed through the lift system at temperatures substantially below the acceptable maximum for carbon steel equipment. After disengagement from the lift gas, the partially regenerated contact material is introduced into the upper end of the upper regeneration zone, wherein the regeneration of the contact material is resumed to the desired degree of completion. The fully regenerated catalyst is then passed by gravity flow, and with negligible heat loss, through a seal leg directly into the upper end of the conversion zone. The contact material may therefore be contacted with the hydrocarbons

to be converted at the highest practicable temperature. The countercurrent flow of gas through the compact moving bed of contact material within the upper regeneration zone provides an additive pressure drop which reduces the length of seal leg required between the upper regeneration zone and the conversion zone to balance the pressure differential between the two zones.

For a fuller understanding of the invention reference may be had to the following specification and claims taken in connection with the accompanying drawing forming a part of this application, in which:

Figure 1 is a fragmentary elevational view showing the upper end portion of a multiple lift hydrocarbon conversion unit embodying the present invention, and comprising the upper kiln or regeneration zone; and

Figure 1–A is a fragmentary elevational view showing the lower portion of the multiple lift hydrocarbon conversion unit of Figure 1, and comprising the reactor or conversion zone and the lower kiln or regeneration zone. Figure 1 may be superimposed over Figure 1–A to show the complete hydrocarbon conversion unit.

Referring to the drawing, the conversion unit as a whole comprises an elongated upright cylindrical vessel or housing, generally indicated by the numeral **10**. Vessel **10** is divided into an upper portion **11**, shown in Fig. 1 and in the upper half of Fig. 1–A, and a lower portion **12** of substantially greater diameter than upper portion **11**, the two portions being joined by a frusto-conical section **13**.

Upper cylindrical portion **11** of the vessel **10** is partitioned internally, as shown diagrammatically by broken lines, to form a confined regeneration zone **14** at its upper end and a confined conversion zone **15** at its lower end, the two zones being connected by a contact material transfer conduit or seal leg **16** of sufficient length to preclude the migration of incompatible gaseous material between the two zones.

Lower cylindrical portion **12** is likewise internally partitioned to form a confined regeneration zone **17**. The vessel **10** extends below the regeneration zone **17** to form a supporting skirt. Although, in the specific form illustrated, the vessel or housing **10** is of increased diameter in its lower portion, it is to be understood that the vessel may, if desired, be of uniform diameter throughout or be of increased diameter in its intermediate or its upper portions. Structural support considerations are a primary factor in influencing the selection of the base of the vessel for enlargement.

The bottom of regeneration zone **17** is located a sufficient distance above grade to permit the contact material to flow by force of gravity from the bottom of the kiln downwardly and outwardly through a plurality of sloping conduits **18** to a corresponding plurality of lift engagers **19**, each associated with a lift pipe **20**. The invention is not limited with respect to the number of lift pipes which may be employed or with respect to whether or not the lift pipes are fed from a common engager vessel or are discharged into a common disengager or individual disengager vessels. The present embodiment of the invention utilizes four lift pipes, uniformly spaced in a circle concentric to the conversion unit. Since the four separate pneumatic lifts are thus located at an angular spacing of 90° about the periphery of the unit, a plan view has not been considered necessary, and has therefore been omitted.

Within each lift engager **19** the partially regenerated contact material gravitates as a compact moving column about and below the lower end of the associated lift pipe **20**. Lift gas introduced into the lift engager, as by conduits **21** and **22**, engages the contact material and transports it upwardly through the lift pipe **20** to a disengager vessel **23** individual to and surrounding the upper end of the lift pipe. Within the disengager **23** the contact material is separated from the lift gas in known manner. The disengaged contact material is then passed, in major part, from the lower end of each disengager **23** through conduit **24** into the upper end of the upper kiln or regeneration zone **4**. A minor portion of the disengaged contact material is separately withdrawn from the disengager **23** through conduit **25** and is passed downwardly and inwardly to an elutriator **26** mounted axially on top of the vessel or housing **10**. The lower end of the elutriator is connected to a central flue gas outlet **27**, through which it receives a portion of the flue gases discharged from upper kiln **14**.

Separation of the fines from the larger-size particles of contact material is effected in known manner within the elutriator **26**. A detailed description and illustration of the elutriator are omitted, since they are disclosed in a companion application filed concurrently herewith.

The flue gases and entrained fines are discharged from the elutriator through outlets **28**, and are conveyed through conduits **29** to the side inlets **30** of a cyclone separator **31** mounted on top of the elutriator. The separated larger-size particles flow downwardly from the bottom of the elutriator into the upper kiln.

The cyclone separator **31** separates the fines from the flue gases, the former being discharged from the elutriator, and from the system, through conduit **32**, and the latter being passed upwardly directly into a stack **33** extending axially upward from the cyclone separator.

The upper kiln **14** is provided with a second flue gas outlet **34** through which flue gases are removed and conveyed by conduit **35**, under control of a damper or valve **36**, directly into the stack **33**. By adjustment of the valve **36**, any desired proportion of the flue gas may be made to flow through the elutriator **26**.

The lift gas separated from the contact material within the disengager **23** is discharged from the latter through overhead conduit **37**, and is conveyed directly to the inlet **30**, where it admixes with the gas discharge from the elutriator **26** and passes into the cyclone separator. Thus, a single cyclone separator is used for removing fines from the gas streams discharging from both the elutriator **26** and the several lift disengagers **23**. By reason of the symmetrical arrangement of the elutriator and the disengagers with respect to the axis of the vessel **10**, conduit and support requirements, as well as equipment for the removal of fines from the system are held to a minimum.

In a typical operation in accordance with the invention and, for convenience of description, considering the reaction zone **15** as a starting point, the contact material admitted to the reaction zone through seal leg **16** is contacted with the hydrocarbons to be converted while the contact material gravitates in the form of a compact moving bed. The hydrocarbon charge is introduced into the upper end of the conversion zone through an inlet conduit **41** and in known manner is brought into contact with the gravitating bed of contact material. The gaseous products of conversion flow concurrently with the contact material to the lower end of the conversion zone, where the gaseous products are disengaged and purged from the gravitating contact material and are separately withdrawn from the conversion zone through outlet **42**. The separated contact material continues its gravitation as a compact moving mass downwardly into the lower regeneration zone **17**, wherein a portion of the carbonaceous deposit formed on the contact material within the conversion zone **15** is removed by combustion in air introduced at the lower end of the zone **17** and passed countercurrently to the contact material. Combustion is continued until the residuary coke deposit is about 0.4 to 1.0 weight percent, and preferably about 0.6 to 0.7 weight percent. At the upper end of the lower kiln gaseous combustion products are disengaged from the contact material and are separately withdrawn through outlet **43**. Controlled regeneration in the lower kiln, or cooling at the lower end thereof, is provided so that the contact material discharges therefrom at a tem-

perature substantially below the temperature at which the contact material is introduced into the reaction zone.

The partially regenerated contact material, at a relatively low temperature compared to the temperatures heretofore employed at this point, is then introduced to the lift system and is elevated through the one or more lift pipes by means of lift gas comprising at least a portion of the flue gas discharged from the lower regeneration zone together with additional gas, such as steam, introduced through lift gas inlets **21** and **22**, respectively. At the upper end of the lift system the contact material is disengaged from the lift gas within the disengagers **23** and is then passed downwardly by gravity flow into the upper regeneration zone **14**, the temperature of the contact material having been slightly reduced in passing through the lift system. Within the upper regeneration zone **14** the contact material is more completely regenerated by contact with combustion-supporting gas introduced into the lower region of the upper regeneration zone through an inlet, not shown. This final stage of regeneration is carried out to the point where the weight percent of carbon has been reduced to the desired minimum. The gaseous products of regeneration are removed through outlets **27** and **34**. The contact material, now substantially at its maximum temperature, is then passed downwardly into and through conversion zone **15**, thus ending a complete cycle of circulation of the contact material.

The transfer of contact material from the upper regeneration zone **14** into the conversion zone **15** through seal leg conduit **16** is effected with a minimum heat loss, so that the contact material when it initially contacts the hydrocarbons to be converted is at the maximum practicable temperature. The length of the seal leg conduit **16** for conveying fresh regenerated contact material into the conversion zone **15** is substantially shorter than that required in a system where the seal leg receives the contact material directly from a supply hopper which is either separate from or incorporated within the lift disengager, since the pressure drop through the moving bed of the upper kiln **14** is additive to the pressure drop through the moving column in conduit **16** for maintaining a pressure balance.

The following data will exemplify a typical application of the split kiln arrangement of the illustrated conversion unit. In a unit adapted to receive an oil charge of about 10,600 barrels per day, and having a nominal coke-burning capacity of about 6,000 lbs. per hour, contact material comprising bead catalyst having an average particle-size of between about 1–15, and preferably 2–8 millimeters in diameter, may be circulated through the system at a rate of approximately 250 tons per hour. To maintain such catalyst circulation the lift system may comprise four lift pipes arranged as illustrated in the drawing accompanying this application and having an inside diameter of 12". During the operation, the temperatures and pressures within the various portions of the system may vary as indicated below:

Table I

Zone	Temp., °F.	Pressure, p. s. i. g.
Reactor (15):		
Top (oil temperature)	700	9
Bottom	860	6
Lower Kiln (17):		
Top	850	2
Bottom (before cooling)	1,125	4
Bottom (after cooling)	967	4
Lift Engager (19)	960	5
Lift Disengager (23)	950	0.5
Upper Kiln:		
Top	942	0.5
Bottom	1,125	4

It is to be noted that the present arrangement permits the elimination of the usual supply or surge hopper at the top of or above the conversion zone, since the surge capacity may be provided in the upper regenerator bed.

While the total bed depth of contact material in the two regeneration zones of the herein disclosed embodiment of the invention may, by reason of the smaller diameter of the upper kiln, exceed the bed depth which would be required in a single elongated lower kiln of the same diameter as the present lower kiln **17**, there is nevertheless a substantial saving in total height of the entire conversion unit. This saving in total height is obtained for two principal reasons. First, the surge hopper normally required in the path of contact material flow between the point of disengagement from the lift gas and the surface of the bed within the conversion zone is eliminated, and the required surge capacity is provided in the bed of contact material in the upper kiln or regeneration zone. Second, the length of the seal leg or compact moving column of contact material required between the source of supply of fresh regenerated contact material and the conversion zone is substantially reduced, since the pressure drop through the bed of the upper regeneration zone is additive to the pressure drop through the shortened seal leg for the purpose of sealing the conversion zone against undesirable gas migration.

In a unit of the type disclosed in the foregoing example, which may be in excess of about 200 feet in overall height, the required length of seal leg between the upper kiln and the reactor or conversion zone may be in the order of about 40 feet. In a comparable unit comprising a single regenerator vessel with an overhead reactor, the required length for the seal leg would be approximately 60 feet. Thus, the net saving in overall height which may be attributed to the split-kiln arrangement is in the order of about 20 feet. Obviously, the amount of saving in overall height will depend upon the design of the particular unit under consideration. In any case, however, the saving would be substantial.

When it is considered that the shortening of the seal leg is reflected in a comparable shortening of the supporting structure, the utility lines, and the lift system, it is readily apparent that considerable savings in costs of material and construction are effected.

Furthermore, by reason of the fact that the temperature of the contact material, as delivered to the lift system, is low enough to permit the use of carbon steel rather than more expensive alloys in the fabrication of the catalyst withdrawal system of the lower kiln, and those portions of the lift system which are usually adversely affected by the transportation of material at extremely high temperatures.

An additional substantial advantage in the use of the herein disclosed method and apparatus is that, by reason of the fact that the catalyst may be delivered from the upper kiln into the conversion zone at maximum temperatures, the split kiln arrangement permits the use of substantially lower contact material circulation rates.

The fact that the regeneration of the contact material is carried out in two separate kilns does not preclude the use, where desired, of multi-stage regeneration in one or both of the kilns.

The invention is applicable also to conversion units employing means other than pneumatic means for elevating the contact material, such as a bucket conveyor, and, where a pneumatic lift is employed, the invention is not limited to a multiple lift pipe system or to the particle arrangement of multiple lift pipes herein disclosed as illustrating one embodiment of the invention. It is to be understood also that other elutriator means may be employed for the removal of fines from the system.

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.

What is claimed is:

1. In a hydrocarbon conversion process in which granular contact material gravitates successively through superimposed conversion and regeneration zones, and is thereafter pneumatically elevated through a lift pipe for return to said conversion zone, and in which the elevated temperature at which regenerated contact material is to be introduced into said conversion zone is of such magnitude as to be detrimental to the materials of construction usually employed in the fabrication of lift pipes, the method of transporting contact material from said regeneration zone to said conversion zone so that its temperature while being pneumatically lifted is substantially below, and its temperature of introduction to said conversion zone is at, said elevated temperature which comprises the steps of: effecting only partial regeneration of said contact material in the presence of oxygen-containing gas within said regeneration zone; introducing said partially regenerated contact material into said lift pipe at a relatively low temperature substantially below such detrimental temperature; elevating said low-temperature contact material through said lift pipe to an elevated location substantially above said conversion zone by means of lift gas comprising gaseous combustion products withdrawn from said regeneration zone; separating said partially regenerated contact material from said lift gas at said elevated location; passing said contact material by gravity flow through a second regeneration zone located above said conversion zone to complete the desired regeneration of said contact material in the presence of additional oxygen-containing gas, thereby raising the temperature of said contact material to said elevated temperature; and passing said regenerated contact material by gravity flow and without substantial reduction in temperature directly to said conversion zone.

2. A method as defined in claim 1, including the step of cooling said partially regenerated contact material to said relatively low temperature before introducing the same into said lift pipe.

3. A method as defined in claim 1 in which said relatively low temperature at which partially regenerated contact material is introduced into said lift pipe is in the range of about 950–1025° F., and said elevated temperature at which regenerated contact material is introduced into said conversion zone is in the range of about 1100–1150° F.

4. A method as defined in claim 1 in which said regenerated contact material is passed from said second regeneration zone to said conversion zone as a compact moving stream adapted to provide a seal leg sufficient to prevent undesirable migration of gaseous material between said zones.

5. A method as defined in claim 1 in which said partial regeneration of contact material within the first regeneration zone is such as to reduce the carbonaceous deposit on said contact material to approximately 0.4 to 1.0 wt. percent thereof.

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