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2,684,929

METHOD FOR HANDLING SOLIDS MATERIAL
IN THE CONVERSION OF HYDROCARBONS

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Fig. 1.

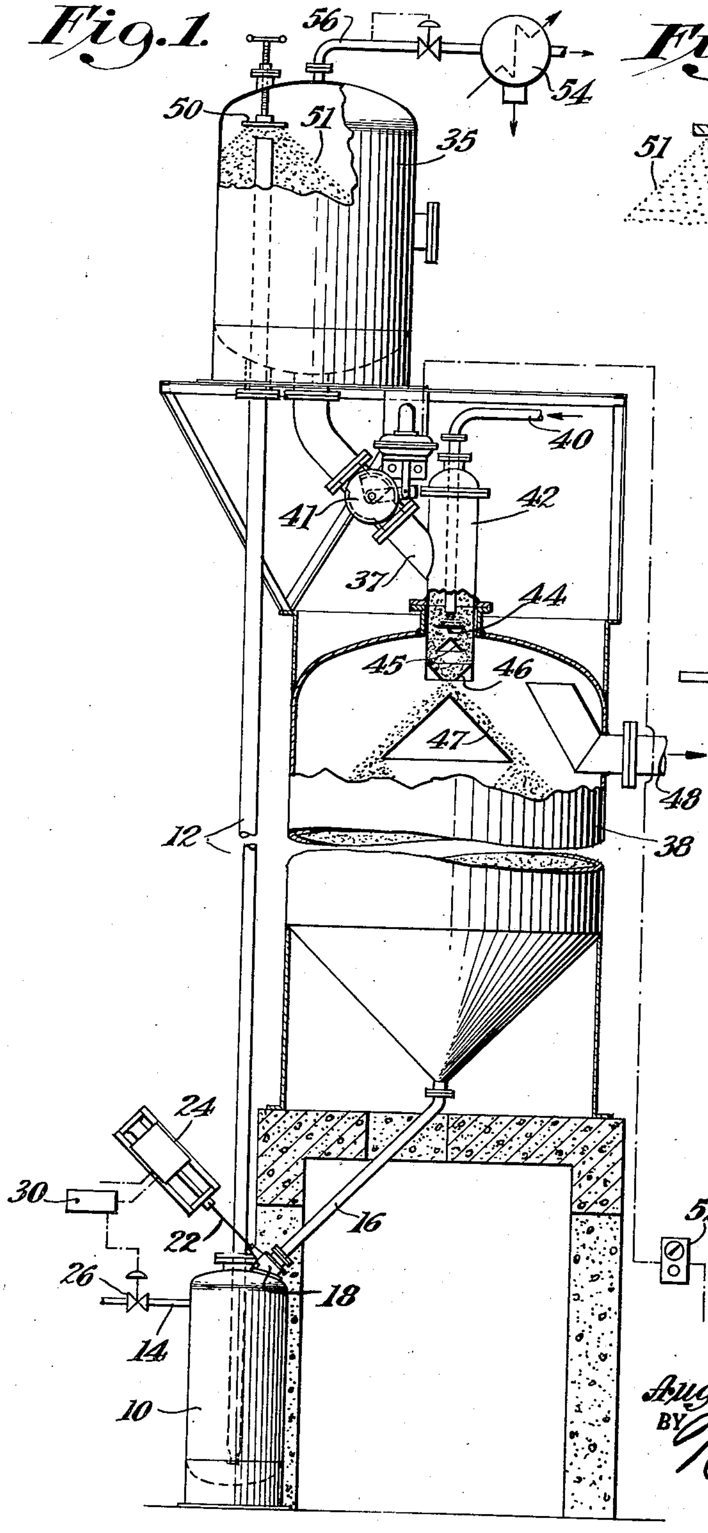


Fig. 2.

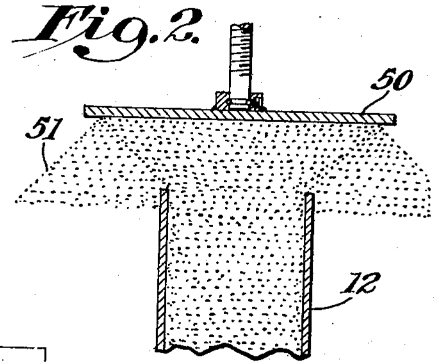
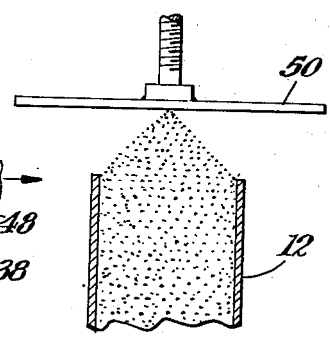


Fig. 3.



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METHOD FOR HANDLING SOLIDS MATERIAL IN THE CONVERSION OF HYDROCARBONS

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Application July 29, 1949, Serial No. 107,458

3 Claims. (Cl. 196—52)

This invention relates to improvements in the handling of subdivided solids material and particularly to the transfer of such material by gases or vapors between zones of different pressures. It is a continuation-in-part of my copending application Serial No. 90,026, filed April 27, 1949.

As described therein, it has been found desirable to transfer large quantities of solids contact material such as catalyst or coke in a closed circuit between zones at different pressures and at different vertical elevations. For the very fine dust-like materials of the order of 100 to 200 mesh particle size, the aerated manometric or "fluidized" technique has been developed. Larger particles, having average particle sizes in the range of 40 mesh to ½ inch, do not lend themselves satisfactorily to this type of transport due to attrition and excessive requirements for transporting or carrying vapor. These latter materials have been handled by mechanical elevators or by low differential pressure vapor lifts employing a relatively small concentration of solids in the ascending leg. Conveying of these materials by mechanical elevators has been done successfully but the equipment is costly in installation and maintenance.

The designer of continuous vapor lifts for the larger particle size material must limit the net upward velocity of the solids particles in order to avoid undue attrition and he must limit the percentage of solids in the lift leg in order to minimize the required pressure at the bottom of the lift leg. A high differential pressure between the vessel from which the solids material is being withdrawn and the bottom of the lift leg would require an excessively long vertical seal leg to dissipate the differential pressure while still permitting downward flow of solids into the base of the seal leg. Since non-turbulent seal legs require about five feet in height to overcome one pound per square inch differential pressure, it follows that a 10 pound differential pressure across the solids inlet seal leg will require a 50 foot vertical height for the seal leg. This in turn means that the bottom outlet of the lowest process vessel must be at least 50 feet above grade. This not only increases the vertical height through which the solids must be elevated but also increases the overall height of the process unit and adversely affects the design of the supporting and structural members. The above difficulties are multiplied to an absurd degree when bottom lift leg pressures of 20 to 80 pounds per square inch are required for operation in conjunction with reaction vessels operating at approximately five pounds per square inch.

The result of the above limitations is that the

vapor lift for commercial units must be designed for a low bottom pressure in the order of five to ten pounds per square inch gauge. Since the bottom pressure must be greater than the weight of the vertical column in transport, it is necessary with conventional designs to use a low solids loading or low percent of solids per cubic foot, in the lift leg.

In such case, large volumes of lifting vapors must be handled at relatively high velocity and in commercial operations difficulties with particle attrition and equipment erosion may be expected. Furthermore, as all of the commercial solids contact materials have a considerable variation in individual particle size and particle density, the lift must be designed with sufficient vapor velocity to maintain a moderate upward velocity for the heaviest and largest particles; otherwise elutriation will occur and the lift leg will choke up with an accumulation of maximum size particles. With velocity sufficient to carry the largest and heaviest particles the smaller and/or lighter particles will be moving considerably faster than the large critical particles and they will, therefore, collide with the larger particles, and by deflecting from the wall of the lift leg, traverse and retraverse the stream; resulting in attrition and particle erosion. This situation becomes more serious as the gas velocity is increased and the particle density in the lift leg is decreased, thus increasing the relative velocity of the particles and increasing their travel between collisions.

One of the broad objects of this invention is to improve the vapor lift handling of solids contact or catalytic materials by designing the equipment in such manner that the pressure conditions at the bottom of the lift leg may be completely independent of the pressure in the processing vessels; thus permitting optimum design for both the processing and solids conveying systems.

It is a further object of the invention to simplify the control of the circulating rate of the contact material by using a single top inlet valve which automatically tends to stop the flow of contact material in elevation if the elevation rate exceeds the draw off rate, such operation avoiding the use of level controls and other equipment.

Further objects and advantages of the invention will appear from the following description of a preferred form of embodiment thereof taken in connection with the attached drawing illustrative thereof and in which:

Fig. 1 is an elevation with parts in schematic outline of a continuous conversion system.

Fig. 2 is an enlarged vertical section of the upper end of the lift leg and associated parts.

Fig. 3 is a view similar to Fig. 2 at another stage in the operation.

Referring to Fig. 1, granular solids material is supplied to solids inlet line 16 from a reservoir or vessel 38 and its gravity flow into vessel 10 is controlled by valve 18. Line 16 and the process vessel 38 connected to it will normally be under considerably lower pressure than that required to lift the solids material up the lift leg 12 by the action of lifting vapor introduced through valve 26 and vapor line 14 into vessel 10.

The cycle for the lifting device is as follows: Vessel 10 contains an inventory of solids material above the bottom of lift leg 12. With valve 18 closed, timing device 30 opens valve 26 in the lifting vapor inlet 14 and introduces high pressure lifting vapors into vessel 10 at a controlled rate. As the internal pressure of vessel 10 increases, the slidable member of valve 18 is driven back against its seat, effectively preventing back flow of lift vapors through line 16. The increase in pressure is accompanied by flow of vapors down through the solids bed in vessel 10 and up the lift leg 12 until sufficient pressure and velocity has been obtained to entrain and lift solids material. As this lifting action continues, the inventory in vessel 10 decreases and when the level of solids has dropped to a suitable point, but before the vessel is completely evacuated of entrainable solids, timer 30 closes valve 26, shutting off the supply of lifting vapors.

With no further supply of lifting vapors the vapor flow up the lift leg 12 rapidly decreases until the pressures at the top and bottom of this leg are equalized at a pressure far lower than that prevailing during the lifting operation and essentially equal to the pressure in solids supply line 16. The timer 30 after this short delay, then opens valve 18 by actuating operating mechanism 24 in turn withdrawing valve arm 22; leaving valve 26 closed. The solids material then enters the vessel and fills it to a fixed height which may be conveniently set by the natural flow angle of repose of the solids material. Timer 30 then closes valve 18 and the cycle is repeated.

Valve 18 is so constructed that the movement of the slidable member in closing the valve is a movement through a free pile or cone of repose of the solids material at a section where the solids are free to move laterally out of the way of the member. This prevents jamming of the valve mechanism, crushing the solids particles, or difficulty in valve operation due to accumulation of fines in the guiding ways (not shown) for the slide member.

It will be appreciated that, if the valve were located in a closed conduit which is always full of gravity packed particles it would be impossible to move the valve member into the column of particles in the line, since the particles would be prevented by their natural arching tendency from moving out of the way. The valve 18 shown in Fig. 1 is a preferred design but other types of valves may be used if they satisfy the above conditions.

The application of the lifting and sealing devices to a variety of industrial operations may be accomplished. As an example, the application to a petroleum conversion operation such as catalytic cracking, coking, or pyrolysis is shown in Fig. 1. In the case of catalytic cracking the solids material handled would be active cracking catalyst of the type well known in the art. In the case of hydrocarbon coking or pyrolysis the solids material may be coke produced in the process or an inert refractory material. In these processes it is usual to recirculate the solids material at rates of 100 to 1,000 tons per hour through reaction or regeneration vessels which may be separate or may be combined in one shell as shown diagrammatically by vessel 38. Lifting heights of 100 to over 200 feet are usual and with high solids loading in the lift leg, a bottom pressure in the lift leg is required which is high compared to the pressure existing in the process vessel. By utilizing the intermittent lifting principle of this invention and completely sealing off the bottom of the lift leg from the process vessel during the lifting cycle while allowing the pressures to equalize before the solids filling cycle, the necessity for extensive seal legs or other continuous sealing devices operating under high differential pressure and subject to severe erosion is eliminated. Two or more lift legs and lower chambers may be used for staggered operation to reduce fluctuations in loading if desired.

The vessel 38 diagrammatically indicates both the hydrocarbon conversion or reaction chamber as well as the solids reconditioning and regenerating chamber. As more particularly shown at the upper part of the chamber, a hydrocarbon feed unit is shown such as is particularly described in my copending application Serial No. 69,657, filed in January 7, 1949, now Patent No. 2,561,420.

In such construction the liquid charge at 40 enters the housing 42 to which the contact material is introduced through the line 37. Below the end of the extension of the conduit 40 is a baffle 44 which tends to distribute the oil laterally into the path of the flow contact material. Other baffles 45, 46 and 47 are so arranged as to move the conduit material in an irregular path for uniform contact.

In the oil charge contacting zone 42 direct contact of the oil with the preheated particles may provide the entire heat requirements to carry on the desired conversion in the main reactor bed. The particles fall freely by gravity over the baffles in the contacting zone 42 at maximum velocity and maximum concentration and the walls and baffles defining this zone are subjected to the continuous flow and scrubbing action of the particles thereby preventing the accumulation of any coke growth which would result in interruption of normal flow. No spray nozzles, atomizing or distributing devices requiring small orifices are required. The high concentration of the particle flow and the initial foaming action at the zone of mixing of the oil and the highly preheated particles insures a uniform contacting between hydrocarbon charge and the particles.

The vapors are removed through the vapor outlet 48 and the contacted particles pass downwardly through the remainder of the reactor-regenerator 38 with the typical flow of a compact columnar mass and with subsequent regeneration or revivication, which may amount to a reheating of particles so that they may be returned to the reaction zone at the predetermined temperature.

A principal feature of my present invention is the simplified flow control by which the particles are uniformly and regularly carried from the low pressure, low end of reactor-regenerator 38 to the elevated position in hopper 35. This flow control includes the flat plate or baffle 50, which is mounted above the open end of the lift leg 12 as shown in Fig. 2 and intercepts the submerged active flow angle of the particles.

As the contact material moves upward through lift leg 12, it tends to move out of lift leg 12 on a submerged active flow angle of about 17° from the vertical and as the hopper fills up, the cone of flow 51 of about 45° is ultimately reached. The material flow then stops although the gas keeps on flowing up the lift leg. In other words, with the application of sufficient pressure to chamber 10 to raise the contact particles as a moving maximum density column the amount of particles which is handled by the lift leg will be controlled by the rate of removal of the contact particles from hopper 35 through the line 37.

So long as the timer 30 is set so that the system is capable of delivering more material than is being drawn off through line 37, the lifting device will operate to maintain the chamber 35 substantially full. Also no solids level detecting and controlling device is required in chamber 10 since a minimum inventory of contact particles will always remain in this chamber at the end of each lifting cycle.

Submerging or baffling the solids discharge at the top of the lift pipe so that the submerged active flow angle of the dense packed particles at the exit is intercepted, not only serves to permit the simple flow control, but it also prevents gas surges from fluidizing the lift leg. It maintains the lift leg as a dense packed body.

Fig. 3 shows the normal position of the contact particles when flow through lift leg 12 stops and the level is below the upper edge of the lift leg.

If desired condenser 54 may be used on vapor outlet line 56 to recover all oil stripped from the contact material by the stream pressuring and depressuring obtained in lift leg 12. This usually varies from a bottom pressure of 100 or 150 p. s. i. g. to 5 p. s. i. g. at the top which effectively purges all oil vapors from the solids pores.

The draw off leg 37 is at a sufficiently sharp angle to permit free gravity flow into the upper part of regenerator-reactor 38. The rate of catalyst circulation is controlled by the setting of valve 41 in line 37 as by control 52. Valve 41 may be accurately calibrated in terms of weight per hour versus valve setting, since the flow through such a valve is insensitive to the solids head above the valve when there is an upstream catalyst level equivalent to more than about two pipe diameters.

The lift leg is preferably stepped or tapered from bottom to top with the largest diameter at the top to approximate the difference in gas pressure and density and to obtain a substantially uniform unit pressure drop. A lift leg of 14 to 16 inches diameter at the lower end will be sufficient to move 600 tons per hour. With a lifting height of 150 feet the pressure in the bottom catalyst chamber 10 during the lifting period will be about 100 to 150 p. s. i. g.

It is of course, well known that the reaction and reheating or regeneration chambers may be side by side using two lift legs if desired and in such case, the pressure required on each lift leg will be substantially less due to the lower maximum elevation. Whether the reaction chamber is at the top or bottom of a vertical processing unit makes no material difference in operation of the lift leg however.

It is also usually found desirable to reduce the cross section of the lift leg 12 at its lower extremity in order to produce a local velocity sufficient to impel the particles into the lower end of the pipe.

It is also within the scope of my invention to establish a pressure within chamber 10 by the periodic application of a volatile liquid such as water or vaporizable hydrocarbons including for example, a part of the feed stock which will vaporize to an extent sufficient to produce the necessary lifting vapor flow. It is to be understood that a constant flow of such liquid is not desired as it is necessary to have the periodic inflow of solids from the vessel 38. If, however, the timer 30 simultaneously closes the valve 18 and permits a limited injection of a liquid which will vaporize and drive the solids upward, the same effect will be obtained as if steam, air or inert gas such as flue gas under pressure is introduced in line 14.

While I have shown and described a preferred form of embodiment of my invention, I am aware that modifications may be made thereto within the scope and spirit of the description herein and of the claims appended hereinafter.

I claim:

1. In a continuous cyclic contact method in which discrete particles of solid material of a minimum size of at least 40 mesh are passed repeatedly through a contact zone, a reconditioning zone, a transfer zone, a gas releasing zone, and interconnecting conduits forming a closed cyclic path, one of said conduits constituting a lift leg extending upwardly from the transfer zone to the gas releasing zone from which the particles return by gravity flow, the improvement which comprises the sequential steps of: 1, flowing solid particles into said transfer zone until it fills to a fixed height at which the apex of the cone of the solid particle pile intercepts the solids inlet to said transfer zone so as to stop the solids flow, 2, then closing and positively sealing said solids inlet by moving a slidable valve member at substantially right angles to the movement of said solid particles at the end of said solids inlet thus displacing solid particles therefrom into an adjacent recess in said transfer zone without jamming said valve or crushing said solid particles, 3, introducing a gas into said transfer zone at a level above the lower end of said lift leg and under sufficient pressure to force said valve member in a direction transverse to its first movement and against said solids inlet to form a fluid-tight seal against said inlet thereby preventing gas leakage upwardly therefrom through said solids inlet and simultaneously causing a gas flow through said lift leg creating a pressure drop in excess of the gravitational weight of the column of solid particles plus the frictional resistance to flow of said particles through said lift leg, then intercepting the discharge flow of a dense-packed mass of solid particles from said lift leg directly upon discharge from the upper end of said lift leg and thereby diverting said discharge flow to form a flowing pile of particles which submerges the discharge end of said lift leg and extends to the bottom of said gas release zone, controlling the rate of flow of particles from said pile to maintain a maximum-packed non-fluid density throughout the upwardly moving mass of solids in said lifting leg, and controlling said sequence of steps at a rate to make the system capable of delivering more solid material to said gas release zone than is withdrawn therefrom to maintain said gas release zone substantially full of said solid particles.

2. In a process for converting hydrocarbons in

the presence of granular particles of contact material having a minimum size of at least 40 mesh wherein the particles move as a gravity-packed column by gravity downwardly through a reaction zone and a reheating zone and into a transfer zone, and then upwardly as a dense-packed moving mass therefrom to a gas releasing zone, and through interconnected conduits forming a closed cyclic path, one of said conduits constituting a lift leg extending upwardly from the lower part of said transfer zone to the gas releasing zone from which the particles return by gravity flow, and wherein the hydrocarbon in liquid form is applied to the preheated contact particles and the gaseous products of conversion are removed from said reaction zone, the improvement which comprises the sequential steps of: 1, flowing solid particles into said transfer zone until it fills to a fixed height at which the apex of the cone of the solid particle pile intersects the solids inlet to said transfer zone so as to prevent further solids flow thereinto, 2, then closing and positively sealing said solids inlet by moving a slidable valve member at substantially right angles to the movement of said solid particles at the end of said solids inlet thus displacing solid particles from said apex into an adjacent recess in said transfer zone without crushing said solid particles, 3, introducing steam into said transfer zone at a level above the lower end of said lift leg and under a pressure of at least several atmospheres for a lift leg in the order of 100–200 feet high to force said valve member in a direction transverse to its first movement and against said solids inlet to form a fluid-tight seal against said inlet thereby preventing gas leakage upwardly therefrom through said solids inlet and simultaneously causing a gas flow through said lift leg creating a pressure drop in excess of the gravitational weight of the column of solid particles plus the frictional resistance to flow of said particles through said lift leg, maintaining a pressure in said gas releasing zone in the order of substantially atmospheric pressure to depressure completely said particles and maintain said

steam flow through said lift leg, then intercepting the discharge flow of a dense-packed mass of solid particles from said lift leg directly upon discharge from the upper end of said lift leg and thereby diverting said discharge flow to form a flowing pile of particles which submerges the discharge end of said lift leg and extends to the bottom of said gas release zone, controlling the rate of flow of particles from said pile to maintain the particles as said dense-packed moving mass throughout said lift leg, and maintaining said sequence of steps at a rate sufficient to make the system capable of delivering solid particles as a dense-packed mass to said gas release zone at a rate greater than that at which said particles are removed from said pile therein to maintain said gas release zone substantially full of said particles.

3. A process for converting hydrocarbons according to claim 2 wherein said granular particles are coke which has circulated repeatedly through said closed cyclic path.

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