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TRANSPORTING AND CLASSIFYING FLUID SOLIDS

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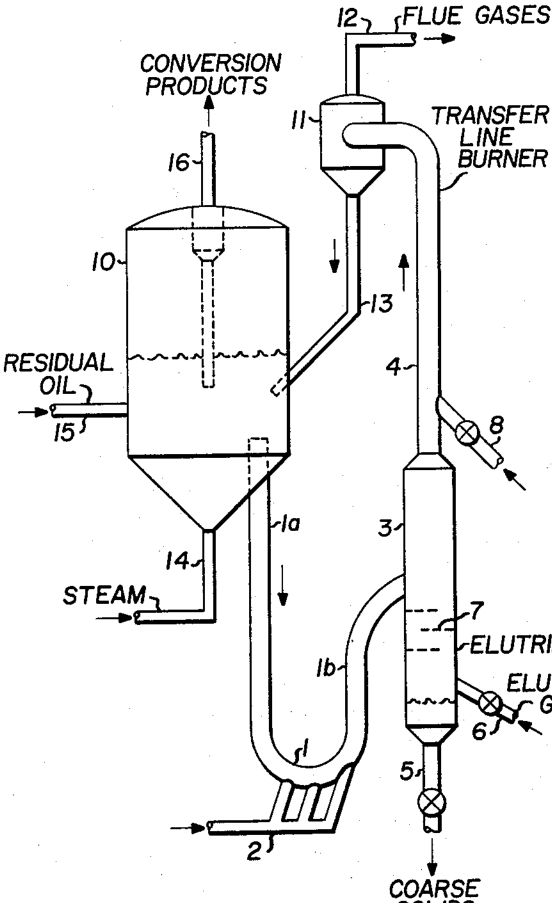

FIGURE I

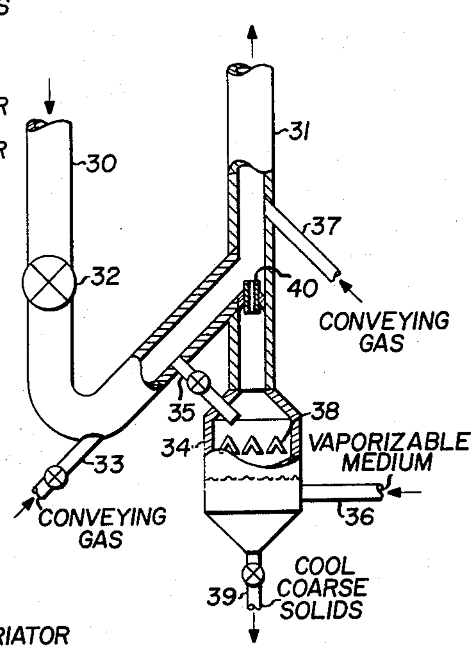

FIGURE II

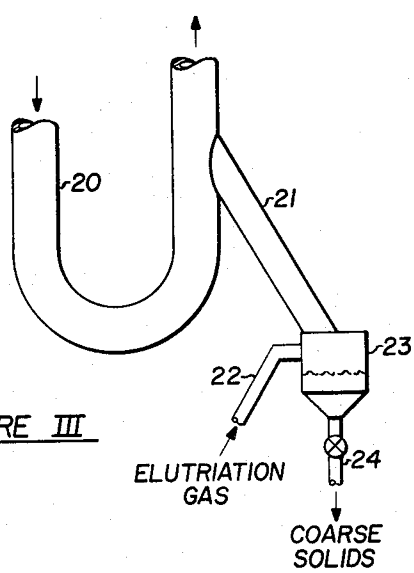

FIGURE III

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TRANSPORTING AND CLASSIFYING FLUID SOLIDS

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This invention relates to the art of handling finely divided solids. This invention more particularly pertains to a method and apparatus for transporting and classifying fluid solids. In its more particular aspects, this invention is concerned with circulating particulate coke in a hydrocarbon oil fluid coking system between reaction vessels while concurrently classifying the coke to obtain a relatively coarse coke product.

While the present invention has particular applicability to hydrocarbon oil fluid coking processes, it is capable of enjoying broader applications. It may find use in any process wherein it is desired to transport finely divided solids and to segregate the solids according to size and/or density. Typical of such processes are fluid catalytic cracking processes, fluid hydroforming processes with or without shot circulation systems, shale oil recovery processes, gasification processes and combustion processes.

Hydrocarbon oil fluid coking processes, generally well known in the art, are used to convert heavy residual oils by pyrolysis to coke and lighter distillate fractions. In one arrangement, the system comprises a reaction vessel or coker and a heater or burner vessel. Fluid beds are usually employed in both vessels but a transfer line burner or reactor may also be used. In operation, a heavy oil is injected into the coker containing fluidized high temperature coke particles, at ca. 950° F., and is partially vaporized and cracked. Product vapors are removed overhead, and coke is continuously circulated to the burner and reheated by partial combustion. Reference is made to U.S. 2,589,124 (Packie) which illustrates one type of standpipe and riser fluid solids conveying system, i.e., a "U-seal," that may be used to circulate the coke between vessels.

In such a coking process, only about 5 to 10% of coke deposited on the original solids is consumed in the burner to supply heat. Consequently, the particles continue to grow in size because of the excess of coke produced. This growth in size causes fluidization and circulation difficulties unless measures are taken to prevent it. Normally, excess coke is withdrawn from the coking process as product to maintain the weight inventory of the solids constant, and finely divided "seed coke" is added to maintain the numerical inventory and size distribution of solids substantially uniform. It has been customary in withdrawing the product coke to classify it, as by elutriation, so that only relatively coarse coke is withdrawn. This practice greatly reduces the amount of seed coke that must be supplied to the system. A gas, e.g., steam, is used to effect both circulation and elutriation of the solids.

This invention proposes a method and apparatus for concurrently circulating and classifying finely divided solids, particularly fluid coke particles used as a heat-carrying medium or contact solid in hydrocarbon oil fluid coking systems, whereby appreciable economies are

secured in the consumption of gases supplied to the process.

This invention will be made clear by reference to the attached drawings in which:

Figure I depicts a somewhat simplified embodiment of the invention as used in a hydrocarbon oil fluid coking system wherein a transfer line burner is used to heat the contact solids.

Figure II illustrates three modifications of the invention, and

Figure III illustrates yet another embodiment wherein an inclined elutriation zone is used.

Succinctly, the apparatus of this invention comprises a vertically disposed conduit for upwardly transporting fluid solids, the lower end portion thereof being adapted to classify solids by elutriation, a riser conduit for admitting fluid solids to an intermediate portion of said vertically disposed conduit, conduit means for admitting an elutriating and conveying gas to said lower end portion, and conduit means for withdrawing relatively coarse solids from said lower end portion.

With specific reference to Figure I, there is shown an elutriator incorporated into a modified U-bend fluidized solids system transporting solids, e.g., coke particles, between a fluid coker and a transfer line burner. The elutriation-circulation system of Figure I is particularly applicable to fluidized solids systems using low solids circulation rates and high gas rates, such as the transfer line system shown wherein there may be a high temperature difference between the reaction and heating zones. Figure II illustrates a more flexible system, i.e., a system wherein the conditions of elutriation can be changed without altering main process conditions.

Referring now to Figure I, finely divided solids are withdrawn from coker **10** via standpipe **1a** flowing downwardly therein. The standpipe is of sufficient height so that the column of aerated solids builds up a hydrostatic pressure sufficient to cause circulation of the solids around the bend of conduit **1** to an elutriator **3**. To decrease the density of the solids as they flow upwardly in riser **1b**, additional amounts of an aerating gas or conveying gas, e.g., steam, can be admitted to conduit **1** via manifold system **2**.

The elutriation zone in this example comprises a substantially vertically elongated conduit **3**. The solids from riser **1b** are admitted to an intermediate portion of the elutriation zone. Some of the solids so admitted fall downwardly into the elutriation zone and are met with an elutriating gas supplied to the elutriation zone by line **6**. The velocity of elutriation gas in conduit **3** is adjusted such that the desired amount of coarser solids fall downwardly to the base of the elutriation zone and the remainder of the finer solids are conveyed upwardly. The coarser solids so segregated are removed from the zone by line **5**. Distributing means **7** may be placed as shown within the elutriation zone. The distributing means may include perforated plates, screens, bars, or rods. In some instances, it may be desirable to use relatively coarse packing such as Raschig rings, the use of which in such a manner is well known in the art. The gas admitted by line **6** to the elutriation zone **3** having accomplished the desired classifying action passes upwardly, mixes with the bulk of the solids and conveying gas and serves to convey the suspension upwardly through outlet riser **4**. Conduit **4** merges into a transfer line burner wherein the coke particles are partially burned while being conveyed through the burner at velocities above 10 ft./sec., e.g., 60 ft./sec.

The elutriating gas applied to zone **3** can be inert with respect to the solids or may be reactive therewith. It can also be a reactant used in later processing steps. Thus, air can be supplied to zone **3** via line **6** if the solids being handled are coke that is being passed to a burning system, as shown, or the gas may have desulfurization characteristics, i.e., hydrogen may be used to effect desulfurization of fluid coke while it is being transferred. Additional amounts of conveying gas or reactant gas such as air may be added to the solids suspension via line 8 leaving the elutriation zone.

In other applications, conduit 4 may be used as a transfer line reactor. For example, methane may be admitted via line 8 to conduit 4 to contact the heated solids and to thereby be decomposed into hydrogen and carbon.

In the process illustrated, the coke particles heated in the transfer line burner are separated from the flue gases in cyclone system 11. The flue gases are vented by line 12 and the heated coke particles are transferred by line 13 to the coker 10. Steam is admitted by line 14 to the base of vessel 10 to fluidize the solids therein. A heavy oil, e.g., a residual oil, is injected into the coker by line 15 and upon contact with the fluidized high temperature coke particles, undergoes vaporization and pyrolysis, depositing additional amounts of coke on the fluidized particles and evolving relatively lighter hydrocarbons. The vapors are recovered overhead by line 16 as product after having entrained solids removed.

While the invention is applicable to a wide range of solids having a wide range in size and densities, it is particularly preferred to process solids having particle size ranges within the limits of about 0 to 2000 microns. The density of the solid gas suspension in the elutriation zone below the point of a juncture of riser conduit 1*b* with the elutriation zone is preferably within the range of 0.01 to 20 lbs./cu. ft. when using solids having a true particle density in the range of 30 to 300 lbs./cu. ft. This may conveniently be termed disperse phase elutriation.

In disperse phase elutriation, for the particle density and size range of particles identified, superficial gas velocities in the elutriation section can vary from 0.1 to 50 ft. per second. Superficial gas velocity is the velocity of the gas passing up through the elutriator considering the elutriator as being empty.

Example

A system as depicted in Figure I may have the following dimensions: inlet conduit 1 10" I.D. outlet conduit 4 13.2" I.D., elutriation section 3 27" I.D., 20 ft. long, with the inlet conduit joining the elutriation section 12 ft. from the bottom. Three rows of distributing grids 3 ft. apart composed of ¼" O.D. bars on 1½" centers may be located in the elutriation section. When handling fluid coke in a size range of approximately 10 to 1200 microns (about 190 microns median particle size) having a true particle density of 100 lbs./ft.^{3}, 85,000 lbs. of coke per hour as a steam-coke suspension having an inlet density of 40 lbs./ft.^{3} and temperature of 950° F. at a pressure of 29 p.s.i.a. may be admitted to the elutriation section via the inlet conduit. 94,000 s.c.f. of steam per hour at a temperature of 335° F. and a pressure of 110 p.s.i.a. are admitted to the base of the elutriation section to obtain a superficial gas velocity of 7.5 ft./sec. below the inlet conduit, and 9 ft./sec. above the conduit. Under these conditions the material segregated will be predominantly larger than about 175–246 microns. The segregated material will be removed from the main coke stream, and will be withdrawn from the elutriation section via line 5. In this design case, the material so withdrawn amounts to about 1.0 wt. percent of the coke charged to the elutriation section. The added elutriation steam, plus the steam admitted to the zone via line 1, serves to convey upwardly through line 4 the remaining finer coke at a velocity of 35–40 ft. per second and a density of about 1.3 lbs./ft.^{3} at a pressure of 29 p.s.i.a.

With reference to the above example, a more efficient and more sharply defined separation can be obtained by the use of various packings as mentioned previously and by re-adjustment of operating conditions as, for example, to a lower solids feed rate (or loading in lb. solids/s.c.f. gas) to the elutriation section. This adjustment is readily accomplished by the apparatus shown in Figure II.

With reference to Figure II, some preferred modifications of the invention will be described. Illustrated is a somewhat different standpipe 30 and riser 31 conduit system for circulating fluid solids. In this example, a valve 32 is used to regulate the flow of the solids and to prevent backflow up standpipe 30. A conveying gas is admitted at the base of the standpipe via line 33. This gas serves to convey the solids by its jet effect and also by its dilution effect upwardly through riser 31. Because the suspension in riser 31 is less dense than that of the aerated suspension in standpipe 30, a static driving force is created as has been previously taught by the art. Elutriation zone 34 is attached near the lower end portion of riser 31. The solids are admitted to this elutriation zone from riser 31 via line 35. The use of by-pass line 35 is a much preferred embodiment of this invention as it gives flexibility and control to the process. This by-pass line can also be used in conjunction with apparatus used in Figure I to regulate the quality and quantity of the classifying action, line 1*b* of Figure I connecting directly to line 4, and the by-pass line running between line 1*b* and conduit 3.

In a fluid coking system, the temperature of the coke will normally be above about 900° F. throughout the system. It is desirable, therefore, to cool the product coke in some manner before it is withdrawn in order to prevent spontaneous ignition of the coke upon contacting with the atmosphere. This is accomplished in the apparatus of Figure II by maintaining a fluidized bed in the lower portion of elutriation zone 34 and injecting a readily vaporizable medium into the fluidized bed via line 36 which will effectively serve to cool the high temperature coke and will create elutriating gas. This vaporizable medium may, for example, comprise water, light naphthas or other oils. The vapors so created pass upwardly through the elutriation zone classifying the solids admitted to the zone by line 35 and carrying upwardly the finer portion of the solids to conduit 31. Of course, if this quenching action is not desired, steam or other elutriating gas can be admitted to the base of zone 34. Distributing means 38 may be used in zone 34 if desired. The elutriation gas then serves as a conveying gas in conduit 31, conveying the suspension upwardly through the conduit. Additional amounts of conveying gas may be added to conduit 31 as by conduit 37. The segregated coarse solids are removed from the base of zone 34 by line 39.

In some applications, it may be desirable to have the spent elutriation gas entering the riser system to enter as a high velocity jet by means of a flow restricting means or nozzle. The jet serves to push the solids upwardly through the conduit. This jet action may be accomplished, for example, by restricting the outlet of the elutriation zone by a nipple 40 as illustrated. Other types of orifices can, of course, be used. This induced jet action is particularly efficacious in the "J-bend" standpipe and riser system illustrated in Figure II. In other cases, it may be desirable to inject some of the elutriation gas in such a fashion as to provide extremely high velocity jets which will grind or break up some of the solids to fine particles, as in the case of producing seed coke for fluid coking processes. These high velocity jets can be introduced in the dense bed of coarse solids collected in the base of the elutriation zone.

Another modification of the invention is shown in Figure III. There is illustrated a "U-bend" conduit system 20 transporting solids between reaction vessels. In this example, an inclined elutriator 21 is used to effect classification of the solids. The inclined elutriator is attached to the lower end portion of the riser conduit of the U-bend system. The elutriator **21** is inclined at an angle of from 1–60° from the vertical preferably 30–60° and has preferably a flat or plane surface on the lower side of the inclination upon which descending solids may slide. Solids fall out of the riser conduit into the elutriation conduit and flow downwardly therein on the flat surface while being swept by an elutriation gas supplied to the elutriator via line **22**. Instead of the customary dilute phase classifying action that occurs in vertical elutriators, "countercurrent" stripping action occurs with the fines being removed and conveyed upwardly from the surface of the sliding solids by the action of the elutriation gas. The elutriation conduit **21** may be in cascade or multiple arrangements and may have suitably placed baffles to bring about movement of solids within the sliding solids mass to cause fines to be brought to the solids-gas interface.

For the previously described coke particles, it is preferred to operate with coarse solids product rates in the range of 100 to 15,000 lbs./hr./sq. ft. cross-section of the inclined elutriation conduit and with gas velocities in the range of about 2–10 ft./sec. preferably from about 2 to 6 ft./sec.

By the time the sliding solids mass reaches the lower end of elutriation conduit **21**, the desired extent of classification has been obtained and the coarse solids fall into reservoir **23**. The coarse solids are then removed from the reservoir by line **24**. The elutriation gas carrying the entrained finer solids passes from the upper end of the elutriation conduit **21** into the riser conduit and serves as conveying and dilution gas therein.

Having described the invention, what is sought to be protected by Letters Patent is succinctly set forth in the following claims.

What is claimed is:

1. Apparatus for handling finely divided solids which includes a vertically disposed conduit for upwardly transporting fluid solids, the lower end portion thereof being enlarged and adapted to classify solids by elutriation, a riser conduit for upwardly admitting fluid solids to an intermediate portion of said vertically disposed conduit above said enlarged portion, downwardly directed means leading from the bottom interior wall of said riser conduit for passing a portion of said fluid solids from an intermediate portion of said riser conduit to said lower, enlarged end portion below the juncture of said riser conduit with said vertically disposed conduit, conduit means for admitting an elutriating and conveying gas to said lower enlarged end portion for elutriating fine solids for upward passage through said vertically disposed conduit, and conduit means at the bottom of said enlarged lower end portion for withdrawing relatively coarse solids from said lower enlarged end portion.

2. The apparatus of claim 1 which includes flow restricting means in said vertically disposed conduit immediately below the point of juncture of said riser conduit with said vertically disposed column whereby gases passing upwardly from said flow restricting means into said vertically disposed conduit thereabove have the characteristics of a jet.

3. A method for classifying by elutriation and circulating a stream of finely divided solids in a system of a size in the range of from 0 to 2,000 microns while maintaining the flow of the classified particles of said stream in an upward direction substantially undisturbed, which comprises flowing said stream of finely divided solids from a fluid solids zone through a downflow confined aerated column into an upwardly directed less dense confined column, flowing elutriation gas upwardly at a velocity in the range of 0.1 to 50 ft./second through an elongated vertically arranged elutriation zone communicating at its upper end with said upwardly directed less dense column and having its lower portion enlarged, downwardly withdrawing a portion of the flowing solids stream from an intermediate portion of said upwardly directed less dense confined column and passing withdrawn solids downwardly directly into said enlarged lower end portion, whereby relatively coarse solids fall downwardly into the lower portion of said elutriation zone collecting as a solids mass having an upper level substantially below the point of admission of the portion of said finely divided solids, removing said relatively coarse solids from said system, and continuing the flow of said elutriation gas and the major portion of said stream of elutriated finely divided solids upwardly from said elutriation zone into said upwardly directed less dense confined column, separating elutriated solids from said elutriation gas and returning said separated elutriated solids to said fluid solids zone.

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