

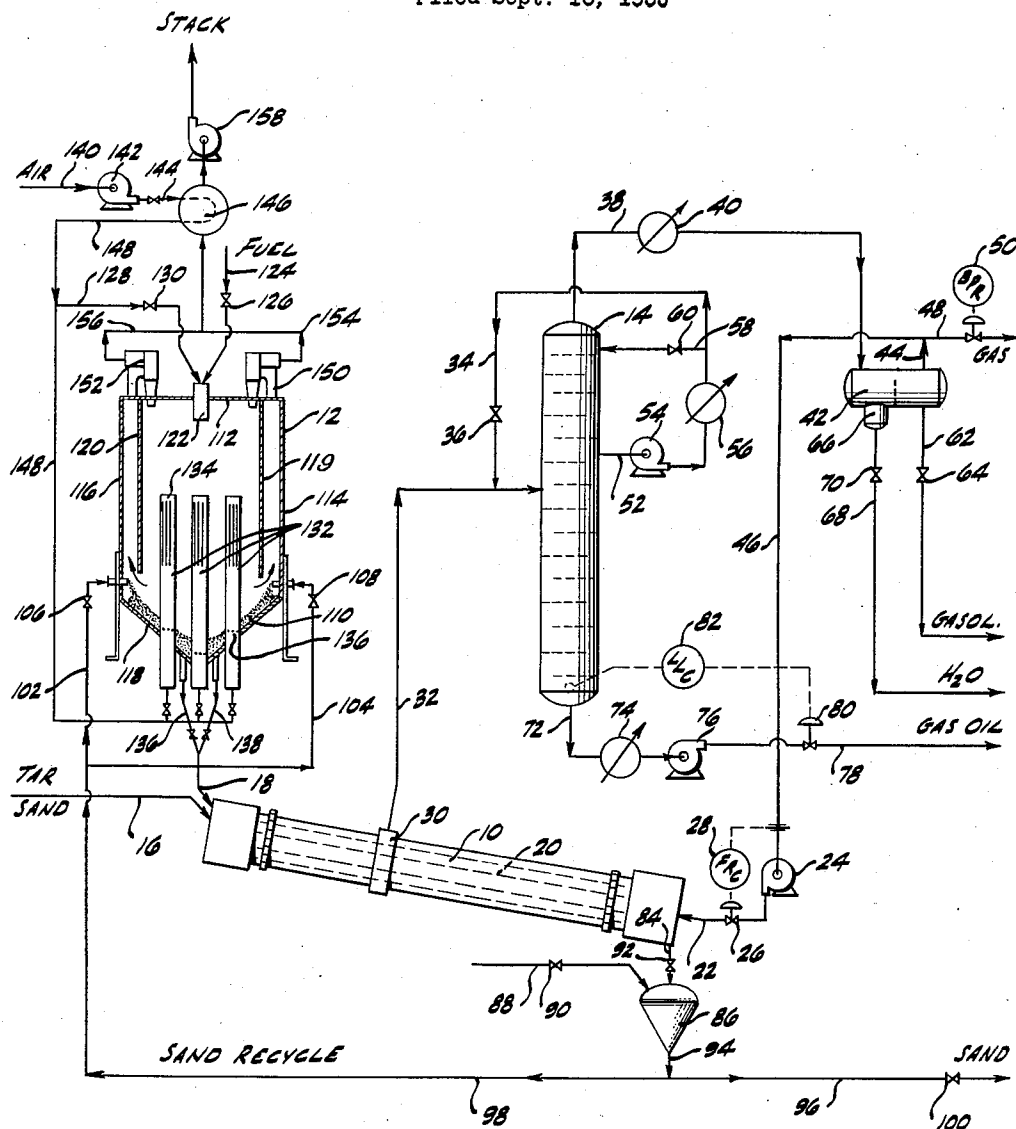
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TAR SAND DISTILLATION PROCESS AND APPARATUS

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TAR SAND DISTILLATION PROCESS AND APPARATUS

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This invention relates to the treatment of oil producing solids such as tar sand and in particular relates to an improved process and apparatus for the direct production of distillate hydrocarbon fractions from hydrocarbon saturated solids such as tar sand, bituminous sands, bituminous diatomite, and the like.

Extensive deposits of tar sands or bituminous sands are known to exist at widely separated places in the world. These materials are essentially a silicious matrix, such as sands, sandstones, or diatomaceous earth, saturated with relatively heavy hydrocarbon materials resembling low gravity crude petroleum. They exist near the surface of the earth and are generally discovered through location of their outcroppings at the surface. Extensive deposits of such materials have been discovered in the Athabaska region of northern Alberta, Canada, in the Uinta Basin near Vernal in northeastern Utah, and in the Santa Maria area of southern California about 130 miles northwest of Los Angeles. In this area extensive deposits are found in the Sisquoc River Valley and near Casmalia, and elsewhere.

Surveys of these deposits have revealed that they contain tremendous quantities of hydrocarbon materials very similar to low gravity crude petroleum and individual deposits have been estimated to contain of the order of 60 to 70 million barrels of tar sand oil. Extensive recovery of these oils has not been achieved primarily because of the expense in relation to crude petroleum in spite of the fact of the accessibility of the material near the earth's surface. However with rising costs of crude petroleum production and depletion of known petroleum reserves, an efficient and economical process and apparatus for the treatment of such bituminous sands has become highly desirable. Some of the previously proposed processes utilize hot water and various chemical reagents as extraction agents. The principal disadvantages of such processes involve the low gravity of the separated oil and the expense of reagent makeup which is inevitably required. Furthermore such processes are susceptible to operating difficulties caused by the presence of clay in the sand matrix which has an adverse effect upon the aqueous fluids required in the process.

The present invention overcomes these difficulties and provides an improved process and apparatus for the efficient and economical recovery of the hydrocarbon values in bituminous sands and produces the oils in a partially refined distillate form so that they may be fed directly to existing refining processes without preliminary treatment. This process produces the sand as a valuable by-product, requires no chemical reagents for separating the oil from the sand, and has very low operating expense.

It is thus a primary object of this invention to provide an improved process for the recovery of hydrocarbon materials from bituminous sand deposits.

It is a more specific object of this invention to combine with the tar sand eduction process a specific form of treatment whereby the hydrocarbon is partially refined to produce distillate oils and gases.

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It is a more specific object of this invention to provide a tar sand treating process in which a recycled stream of hot sand is utilized to heat the heavy hydrocarbon materials in the bituminous sand to produce a coked sand and to produce a coker gasoline and gas oil which are directly useable as feed stocks to existing refinery processes.

It is an additional object of this invention to provide an improved process for the combustion and reheating of coke laden sand produced from the coking process to produce the heated sand recycle required in the process.

It is also an object of this invention to provide an improved apparatus in which the aforementioned objects may be realized.

Other objects and advantages of this invention will become apparent to those skilled in the art as the description and illustration thereof proceed.

Briefly the present invention comprises an improved process for the recovery of hydrocarbons from the so-called bituminous or tar sands or similar oil producing solid materials in which a heavy hydrocarbon oil coking process is combined to produce coker gas, gasoline and gas oil as distillate hydrocarbon products and to produce a hydrocarbonaceous or coke laden sand stream which is used in the process. This coked sand is contacted with an oxygen containing gas such as air to effect combustion of the coke deposited on the sand grains and to produce a clean hot sand stream which is recirculated in the process. Sometimes the quantity of coke is insufficient to supply all of the heat requirements of the process in which case additional fuel, such as fuel gas or fuel oil or the like, is burned simultaneously with the coked sand combustion.

The heat liberated during the coked sand burning is recovered in two forms. In the first the hot flue gases are heat exchanged with the incoming air and in the second at least a portion of the heated clean sand is recycled for admixture with fresh raw tar sand and the mixture is introduced directly into a coking kiln. Herein the hot sand recycle gives up its sensible heat and supplies the eduction heat required to heat the fresh tar sand, to coke and crack the hydrocarbon materials contained therein, and to vaporize the volatile products in the kiln. This reaction is effected at temperatures between about 700° F. and 1200° F., the sand is mixed and allowed to react for a period of from 0.1 to 10 hours, and the spent sand is stripped by countercurrent contact with a portion of the coker gas produced in the process. The remaining amount of this gas may be used as fuel in heating and burning the spent sand or produced as a product.

The total coker distillate is removed from the kiln and introduced into a bubble tower which serves to fractionate the coker gasoline and gas from the coker gas oils. The gas is then separated from the coker gasoline and the liquid products are sent to storage or further processing facilities which are conventional in hydrocarbon refining techniques. Such processes include catalytic cracking, desulfurization, reforming and the like and in this way high quality automotive and aviation internal combustion engine fuels are readily produced.

The coked sand produced from the coking kiln in the process of this invention may be treated in several ways. It may be burned completely to convert all of the sand entering with the tar sand to the process into clean hot sand free of coke residues. Part of this is then recycled to the coking kiln and the remainder is produced as a valuable by-product suitable for glass production and the like. In another treatment, part of the spent sand is produced as a product and discarded and the remaining sand is burned to produce the hot sand recycle needed in the process.

In the preferred form of the process of this invention

the recycle sand and raw tar sand mixing and coking steps are carried out in an elongated cylindrical rotary kiln. The sand mixture is fed to the kiln at its upper end and a stripping gas such as a portion of the coker gas produced in the process is introduced at its lower end. The kiln is provided with flights or lifts extending longitudinally along the inner wall which serves to mix the recycle and fresh feed sands and to lift them inside the kiln and drop them more or less diametrically therein through the stream of stripping gas passed countercurrent to the solids. The mixing and heating and coking steps are effected in this environment and the mixture of stripping gas and total coker distillate is withdrawn from an intermediate point along the length of the kiln. If desired the mixture may be withdrawn at the upper or sand inlet end.

The coked sand is conveyed from the coking kiln outlet to a reheating zone wherein the coke burn-off and sand heating may be conveniently effected in several ways. First, the coked sand may be passed downwardly as a moving bed through the heating zone comprising a vertical contacting column which may contain a series of alternate gas disengaging and engaging zones. A plurality of oxygen containing gas streams are introduced by means of the engaging zones and a plurality of streams of flue gas are cooled at the disengaging zones.

In the second manner of heating, the coked solids are introduced in suspension in a gas upwardly into the heating zone comprising a contacting chamber of extensive cross sectional area. The upward velocity of the oxygen containing gas suspending the solids is controlled so as to maintain the sand grains suspended in the lower portion of the chamber as a dense fluidized phase overlaid by a relatively dilute sand suspension. The advantage of this process lies in its extremely uniform temperature from point to point throughout the combustion zone.

The third and preferred method of burning and heating the coke laden sand grains is in a specially designed gas lift furnace, the details of which are more particularly pointed out below, and in which the coke laden sand is suspended in a plurality of parallel vertical burning zones and recycled through a furnace zone surrounding these vertical tubes. The granular solids are in part fed back into the vertical gas streams by gravity and recirculated therein with fresh oxygen containing gas and fresh spent sand.

The combustion is controlled, with added fuel if necessary, to produce coke free sand at temperatures of the order of 1000° F. to 2500° F. The amount recycled is dependent upon the raw tar sand feed rate and the desired coking temperature. Simple material and heat balance calculation by one skilled in the art will determine the recycle sand rate. Typical recycle rates for the above temperatures are between about 5 and 0.5 ton of coke free recycle sand per ton of raw tar sand.

The construction of the coking kiln and sand heating apparatus and the operation of the process of this invention will be more clearly understood by reference to the accompanying drawing in which an elevation view in partial cross section of a preferred form of spent sand burner is shown together with elevation views of the coking kiln and the distillation equipment. The drawing also constitutes a schematic flow diagram of the process of this invention. The description of the drawing is conducted in the form of a practical example of this process applied to the treating of Sisquoc tar sand obtained from Sisquoc ranch in Santa Barbara County, California.

Referring now more particularly to the drawing the three essential elements of the apparatus of this invention include coking kiln 10, coked sand furnace 12, and coker distillate fractionating column 14. Sisquoc tar sand is introduced at a rate of 10,000 tons per day by means of conveyor 16 into the upper or sand inlet end of rotary coking kiln 10. Simultaneously recycle sand removed from the bottom of coked sand furnace 12 through line

18 is combined therewith and introduced at a rate of 20,000 tons per day and at a temperature of 1445° F. The coking kiln 10 is approximately 16 feet in diameter, 90 feet long, is rotated at a rate of about 3 r.p.m., and has a total slope of about 3.2 feet. It is provided with a plurality of longitudinal baffles or flights 20 by means of which the sand is mixed forming a uniform mixture at about 900° F.

The sand mixture progresses downwardly through coking kiln 10 which provides a residence time of approximately one hour. As indicated briefly above a stripping gas comprising the coked noncondensable gas product is introduced into the bottom of coking kiln 10 by means of line 22 under the influence of blower 24 at a rate of 2490 M s.c.f./day (1 M s.c.f.=1,000 standard cubic feet) controlled by valve 26 under the influence of flow recorder controller 28.

The stripping gas sweeps the coker distillate upwardly through the kiln and it is removed from disengager 30 by means of line 32 at a temperature of 900° F. This total coker distillate is combined with 9180 barrels per day of 200° F. quench oil flowing through line 34 controlled by valve 36 and the mixture is introduced at 500° F. into coker distillate fractionation column 14.

The overhead vapor is removed from column 14 through line 38 and is cooled and partly condensed at 100° F. in cooler 40. The mixed overhead phases are introduced into vapor liquid separator 42 wherein the noncondensable gases which are in vapor form at 100° F. and approximately atmospheric pressure are removed at a rate of 5980 M s.c.f./day per line 44. Of this produced coker gas approximately half is passed through line 46 by means of blower 24 previously described and is introduced as a stripping gas into the bottom of coking kiln 10. The remainder is removed through line 48 at a rate controlled by back pressure regulator 50. This gas may be used for fuel as subsequently described in the coked sand furnace 12.

A side cut is removed from column 14 above the coker distillate inlet through line 52 at a temperature of about 400° F. This material is pumped by means of pump 54 at a rate of 43,880 barrels per day through side cut cooler 56 wherein it is cooled to 200° F. This cooled stream includes the 9180 barrels of quench oil referred to previously, and the remainder is introduced through line 58 at a rate of 34,700 barrels per day controlled by valve 60 as reflux into the top of column 14.

The coker gasoline is removed from separator 42 through line 62 at a rate of 853 barrels per day controlled by valve 64 actuated by means of a conventional liquid level controller not shown. Water is removed from trap 66 through line 68 at a rate of about 570 barrels per day as controlled by valve 70 actuated by a conventional differential liquid level controller also not shown.

From the bottom of distillation column 14 is removed the heavy or gas oil fraction of the total coker product and which boils above about 400° F. This material flows through line 72 through bottoms cooler 74 at a rate of 5360 barrels per day. It is pumped by pump 76 through line 78 at the rate given controlled by valve 80 which in turn is actuated by liquid level controller 82. The coker gas oil thus produced constitutes a feed stock for a catalytic desulfurization unit to produce a low sulfur cracking stock or the like.

The coked sand product is removed from the bottom of coking kiln 10 through line 84 at the rate of 28,806 tons per day. This material is either intermittently or continuously introduced into coked sand induction zone 86. A conveyance gas under pressure is introduced thereinto through line 88 at a rate controlled by valve 90. With the solids inlet sealed by element 92, which may constitute either a solids feeder or a valve adapted to seal line 84 against a counter flow of gas, the conveyance gas depressures through line 94 and through lines 96 and

98 concurrently with an elongated gas-permeable moving mass of coked sand. The gas flow is controlled at a rate sufficient to overcome opposing forces of gravity and friction acting on the sand so as to permit solids movement. Through line 96 controlled by valve 100 a flow of coked sand is produced from the process at a rate of 8,756 tons per day. Through line 98, which later divides into a plurality of parallel lines 102 and 104, each in turn controlled respectively by valves 106 and 108 which serve to restrict the discharge of solids from the outlet of lines 102 and 104, a sand recycle flowing at a rate of 20,150 tons per day is introduced into a plurality of points along each side near the bottom of coked sand furnace 12 forming a moving bed 110 therein. By restricting the discharge of solids from the outlet of lines 96, 102 and 104 without causing any substantial restriction on the discharge of gas therefrom, the sand is caused to move through the lines in the form of a nonfluidized dense or compact continuous moving mass of solids. The quantity of gas required to convey the solids is roughly less than 10% of that required to convey the same solids at the same rate as a gas lift suspension in a conventional pneumatic conveyor, and the conveyor conduit is approximately 80% smaller in diameter.

Coked sand furnace 12 is shown in the attached drawing as it appears in vertical cross section. It is actually an elongated furnace having a flat or curving top 112, flat parallel sides 114 and 116 and a trough shaped bottom 118. The slope of the trough is about 45° or any slope sufficient to cause downward flow of the solids therein. Extending longitudinally along each side of the furnace and spaced apart therefrom are bridge walls 119 and 120 extending downwardly from roof 112 to a point just above the sand inlets and forming flue gas removal flues.

The coked sand furnace is 20 feet wide, 36 feet high, 100 feet long, and is provided with a series of ten surface combustion gas burners 122 disposed in a row along the top thereof. Fuel gas is introduced thereinto through line 124 at a rate of 1300 M s.c.f./day controlled by valve 126 together with air flowing through line 128 at a rate of 37,700 M s.c.f./day controlled by valve 130. The combustion of this fuel supplies approximately 35% of the heat required in the process, the remaining 65% being generated within furnace 12 through combustion of the coke deposited on the coked sand. The fuel and air rates are controlled to produce coke free sand at the desired rate and temperature.

Disposed in three parallel rows along the length of furnace 12 and extending upwardly through trough shaped bottom 118 are gas lift tubes or zones 132. These tubes are 10-inch nominal iron pipe size conduits approximately 35 feet high disposed vertically in three rows each containing about 65 tubes, being spaced apart about 1.5 feet. The upper part of each of these lines is provided around its periphery with six slots 134 each 10 feet long and 2 inches wide. Provided around the periphery of each of these tubes at a point thereon just above the trough shaped bottom of the kiln are apertures 136. Moving bed of coked sand 110 flows downwardly and enters these apertures, the sand is suspended in an upwardly flowing stream of preheated 1000° F. combustion air to form a sand suspension. The lift gas velocity is about 25 feet per second in the lift lines. The suspension velocity is decreased in the slotted portion of the combustion tubes and the gas and sand move radially outward through the slots and the sand falls by gravity back onto moving bed 110. The recirculation rate of the sand through the combustion tubes 132 may be varied at a rate sufficient to adequately reduce the coke content of the sand. In the process of this example this recycle rate was controlled at a value of about 27 to 1, that is, with a coked sand feed rate of 20,150 tons per day, the internal sand recirculation rate was 540,000

tons per day. The hot spent sand is withdrawn from the bottom at a plurality of points along the bottom of the trough shaped furnace section through lines 136 and 138 and passes as previously described through line 18 as the hot sand recycle into coking kiln 10.

Combustion air for operating the coked sand furnace is introduced at a rate of 116,000 M s.c.f./day through line 140 by means of blower 142 and passes through line 144 into and through air preheater 146. Herein the air is heated from 80° F. to about 1000° F. and passes through line 148 at a rate of 78,300 M s.c.f./day into the bottom of vertical sand combustion tubes 132. Herein they suspend and burn the coke from the coked sand grains as previously described.

The flue gas produced by sand combustion and by fuel combustion in burners 122 passes downwardly there-through under the lower edge of bridge walls 118 and 120 and then upwardly between these bridge walls and the outer walls of the furnace. Herein part of the suspended sand grains are separated and the gas passes through a plurality of dust collectors 150 and 152 disposed along the edge of the top of furnace 12. Herein the dust is separated from the flue gases and is returned to the furnace and the dust free flue gas passes through lines 154 and 156 through air preheater 146. Herein the gases are cooled from 1445° F. and discharged by means of blower 158 to the atmosphere at a temperature of 550° F.

The furnace is constructed of mild steel and has 6 inches of internal insulation. The gas lift tubes exposed to 1000° F. gas and sand are fabricated of type 314 stainless steel containing 25% chromium, 20% nickel, and 2.5% silicon.

The raw tar sand used as a raw material in the above example analyzed 1% water, 12.1% hydrocarbon material, and 86.9% silica sand by weight. The product obtained in the process includes a total condensable coker distillate amounting to 72.8% of the hydrocarbon contained in the raw tar sand feed and the average gravity thereof is 19.1° API if the coker gasoline and the coker gas oil are combined. The coke production is 18.3% of the hydrocarbon fed and approximately 70% of this is burned to supply heat to the process. The gas production is 8.9% by weight of the hydrocarbon content of the raw tar sand feed to the process.

The present invention as described and illustrated above successfully treats hydrocarbon saturated sands to produce a coker distillate hydrocarbon without the use of aqueous phases or flotation reagents and the like. It is characterized by producing directly a distillate product rather than a heavy residual oil which often is heavier than water and thus difficult to treat in aqueous systems. Frequently the raw tar sand contains a hydrocarbon phase containing substantial quantities of hydrocarbon derivatives of sulfur. In some cases the hydrocarbon phase will analyze between 4% and 6% by weight of sulfur. In the combined tar sand retorting and hydrocarbon coking process of this invention a substantial desulfurization is effected with the production of hydrogen sulfide in the gas phase and a coker distillate containing less than about 3% by weight of sulfur.

Although the coked sand furnace described and illustrated above is a preferred modification of the present invention, other methods for contacting the coked sand with the oxygen containing gas may be substituted if the physical characteristics of the sand permit. With tar sands having relatively large sized grains such as larger than about 20 mesh, the coked sand granules may conveniently be passed downwardly by gravity through successive stages of combustion in the form of a moving solids bed. A plurality of streams of oxygen containing gas are passed through the solids bed to effect coke burn-off. When the sand grains are smaller than about 80 mesh then the coke combustion may be conveniently effected by fluidizing the coked sand grains in an upward

flow of oxygen containing gas in which the velocity is carefully controlled to generate and maintain a dense phase fluidized suspension. However such uniform sized sand grains are not frequently encountered and accordingly the described and illustrated means for coke burn-off is employed since it is readily applicable to combustion of sand grains having a wide size range and including fine as well as coarse grains.

The process of the present invention has been found to be well adapted to the recovery of valuable hydrocarbon fractions from hydrocarbonaceous sands previously indicated. The method essentially employs a recirculated stream of hot solids to vaporize and coke and crack the hydrocarbon fraction to produce a total coker distillate. It is possible that the principles of this invention may well be applied to the recovery of hydrocarbons from other oil producing solids such as bituminous coal having high ash contents, oil shale, and the like. It is therefore not intended that the present process be limited to the processing of tar sand alone but rather be applicable to oil producing solids of the type mentioned.

A particular embodiment of the present invention has been hereinabove described in considerable detail by way of illustration. It should be understood that various other modifications and adaptations thereof may be made by those skilled in this particular art without departing from the spirit and scope of the invention as set forth in the appended claims.

I claim:

1. In an apparatus for thermally treating oil-producing solids by admixture of such solids with a hot recycled stream of substantially hydrocarbon-free solids as a heat source to produce hydrocarbon vapors as a product leaving spent carbonaceous solids, the improved apparatus for the conversion of said spent carbonaceous solids into said hot substantially hydrocarbon-free solids which comprises a closed combustion chamber having a trough-shaped bottom, means for introducing spent carbonaceous solids along the upper edges of said trough-shaped bottom so that they flow downwardly toward the common lower edge thereof, a plurality of vertically parallel elongated gas lift conduits extending upwardly through said trough-shaped bottom to points below the roof of said combustion chamber, each of said conduits having peripheral apertures disposed just above said trough-shaped bottom adapted to be submerged in said downwardly moving bed of solids, each of said conduits being further provided with a plurality of peripheral apertures for the removal of gas and solids adjacent the upper ends thereof, means for introducing a stream of air directed upwardly through each of said gas lift conduits whereby spent carbonaceous solids entering through said lower apertures are suspended and burned in said air as they move upwardly and are discharged therefrom through the upper apertures, means for removing hot flue gas from said closed combustion chamber, and a plurality of outlet means opening from the lower edge of said trough-shaped bottom for the removal of said hot substantially hydrocarbon-free solids from said combustion chamber.

2. An apparatus according to claim 1 in combination with a pair of parallel bridge walls spaced apart from the sides of said combustion chamber and extending from the top thereof downwardly to a level just above the trough-shaped bottom, a plurality of centrifugal solids fluid separators disposed along the top of said combustion chamber adjacent each side thereof, a conduit for hot flue gas opening into each of said centrifugal separators from a point between said bridge wall and the adjacent side of said combustion chamber, a solids return conduit opening from the bottom of each of said centrifugal separators into the top of said combustion chamber, and an outlet conduit for gas opening from each of said centrifugal separators.

3. In an apparatus for thermally treating oil-producing solids by admixture of such solids with a hot recycled

stream of substantially hydrocarbon-free solids as a heat source to produce hydrocarbon vapors as a product leaving spent carbonaceous solids, the improved apparatus for the conversion of said spent carbonaceous solids into said hot substantially hydrocarbon-free solids which comprises a closed combustion chamber having a trough-shaped bottom, flat parallel double-walled sides, each including an inner bridge wall extending from the roof down to a level above the bottom, and flat parallel ends, means for introducing spent carbonaceous solids at a plurality of points spaced along the upper edges of said trough-shaped bottom so that they flow downwardly as a moving bed toward the lower common edge thereof, a plurality of vertical parallel elongated gas lift conduits disposed in several rows and extending upwardly through said trough-shaped bottom to points below the roof of said combustion chamber, each of said conduits having peripheral apertures disposed just above said trough-shaped bottom adapted to be submerged in said downwardly moving bed of solids, each of said conduits being further provided with a plurality of peripheral apertures for the removal of a suspension of gas and solids adjacent the upper ends thereof, means for introducing a stream of air directed upwardly through each of said gas lift conduits whereby spent carbonaceous solids enter through the lower apertures, are suspended and burned in said air as they move upwardly, and are discharged therefrom through the upper apertures, a plurality of cyclone separators disposed along the top of said combustion chamber connected in gas receiving relation to a plurality of aligned points between each bridge wall and the adjacent side of said combustion chamber, an outlet for solids from each cyclone into the top of said combustion chamber between the bridge walls, means for removing hot flue gas from the top of each of said cyclones, and a plurality of outlet means opening from adjacent the lower common edge of said trough-shaped bottom for the removal of hot substantially hydrocarbon-free solids from said combustion chamber.

4. A process for the eduction of hydrocarbon values from hydrocarbonaceous mineral solids which comprises: (1) introducing said hydrocarbonaceous solids into an elongated eduction zone together with hot educted solids in an amount sufficient to maintain said eduction zone at a temperature at which hydrocarbon values are educted in vapor form from said hydrocarbonaceous solids; (2) intimately admixing said hydrocarbonaceous solids and said hot educted solids within said eduction zone in the absence of appreciable amounts of materials which react chemically with hydrocarbons while maintaining the mixture of solids in the form of a compact bed and while passing the hereinafter defined stripping gas through said eduction zone at a rate insufficient to cause said solids to be suspended therein; (3) withdrawing from said eduction zone a vapor phase comprising educted hydrocarbon vapors and said stripping gas; (4) treating said vapor phase to separate the normally gaseous components therefrom; (5) returning at least a part of the separated normally gaseous components to said eduction zone as said stripping gas; (6) withdrawing from said eduction zone a solids mixture comprising mineral solids containing combustible carbonaceous material; (7) introducing at least a part of said solids mixture into a combustion zone wherein said solids are maintained in the form of a relatively shallow downwardly moving compact bed; (8) introducing an oxygen-containing gas into a plurality of elongated laterally confined gas lift zones extending upwardly through said downwardly moving bed into a common enlarged space at the top of said combustion zone; (9) introducing said solids mixture from said compact downwardly moving bed into the lower end of said gas lift zones; (10) controlling the rate of flow of said oxygen-containing gas through said gas lift zones at such a value that the solids introduced thereinto are suspended in and are carried upwardly with said oxygen-containing

gas; (11) maintaining within said gas lift zones an elevated temperature sufficient to support combustion of said combustible material in said oxygen-containing gas; (12) discharging the suspension of solids from said gas lift zones into said enlarged space; (13) allowing said solids to fall by gravity to the surface of said compact downwardly moving bed; (14) withdrawing flue gas from the top of said combustion zone; (15) withdrawing solids from said compact bed at a point below that at which solids are introduced into said gas lift zones; and (16) introducing at least a part of said withdrawn solids into said eduction zone as said hot educted solids.

5. A process for the eduction of hydrocarbon values from bituminous sand which comprises: (1) passing a stream of raw bituminous sand into the higher end of an elongated eduction zone having its major axis inclined at a relatively small angle from the horizontal; (2) passing a stream of hot educted sand into said end of said eduction zone, the amount of said hot educted sand being sufficient to maintain said eduction zone at a temperature at which hydrocarbon values are educted from the raw bituminous sand; (3) intimately admixing said raw bituminous sand with said hot educted sand within said eduction zone; (4) passing the resulting mixture in the form of a compact bed through said eduction zone to the lower end thereof in the absence of appreciable amounts of materials which react chemically with hydrocarbons; (5) introducing the hereinafter defined stripping gas into the lower end of said eduction zone; (6) passing said stripping gas through said eduction zone countercurrent to and in intimate contact with the said compact bed therein and at a rate insufficient to cause said sand mixture to be suspended therein; (7) withdrawing from said eduction zone a vapor phase comprising educted hydrocarbons and said stripping gas; (8) treating said vapor phase to separate the normally gaseous components therefrom; (9) passing a part of said separated normally gaseous components to said eduction zone as said stripping gas; (10) withdrawing from the lower end of said eduction zone educted sand containing combustible material; (11) passing a part of said educted sand to a relatively shallow bed of sand maintained within the lower part of an elongated vertical combustion zone; (12) introducing an oxygen-containing gas into a plurality of elongated laterally confined gas lift zones extending upwardly through said bed of sand and opening

into a common enlarged space in the upper part of said combustion zone; (13) introducing sand from beneath the surface of said relatively shallow bed into said gas lift zones; (14) controlling the rate of flow of said oxygen-containing gas through said gas lift zones at such a value that the sand introduced therein is suspended in and is carried upwardly with said oxygen-containing gas; (15) discharging said suspension from the upper end of said gas lift zones into said enlarged space; (16) allowing said sand to fall by gravity to the surface of said relatively shallow bed; (17) maintaining within said gas lift zones an elevated temperature sufficient to support combustion of said combustible material in said oxygen-containing gas; (18) withdrawing flue gas from the top of said combustion zone; (19) withdrawing hot educted sand having a substantially reduced content of combustible material from said bed of sand at a point below that at which the sand is introduced into said gas lift zones; and (20) passing at least a part of said withdrawn sand into said eduction zone as said stream of hot educted solids.

6. A process as defined in claim 5 wherein the amount of hot educted sand introduced into said eduction zone is sufficient to maintain a temperature between about 700° F. and about 1200° F. therein.

7. A process as defined in claim 5 wherein between about 0.5 and about 5.0 tons of hot educted sand are introduced into said eduction zone per ton of raw bituminous sand, and said hot educted sand is at a temperature between about 1000° F. and about 3500° F.

8. A process as defined in claim 5 wherein the transit time of the sand through said eduction zone is between about 0.1 and about 10 hours.

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