Sept. 13, 1955 J. W. JEWELL ET AL 2,717,867

HYDROCARBON CONVERSION

Filed Nov. 26, 1949

2 Sheets-Sheet 1

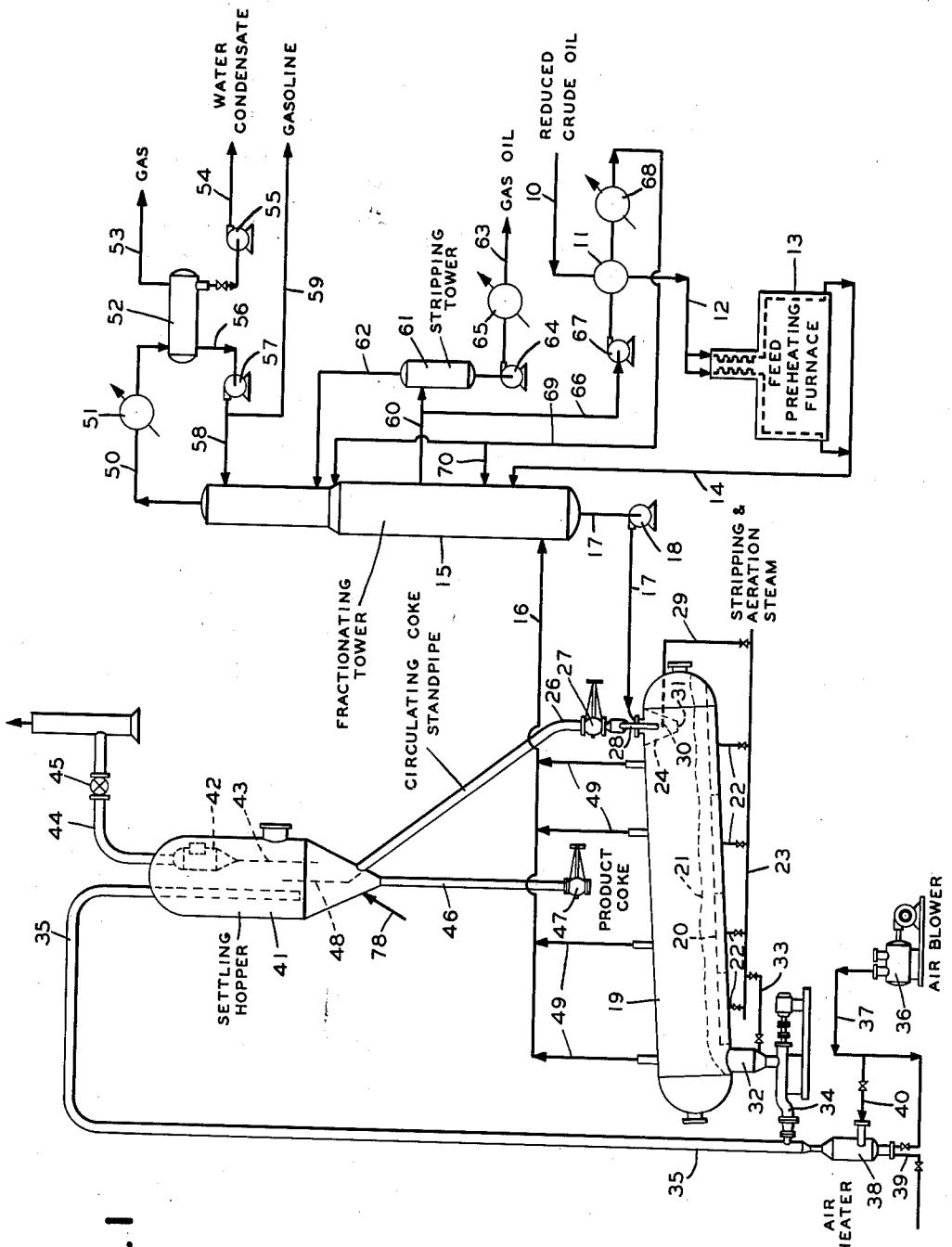


FIG. 1

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Filed Nov. 26, 1949 2 Sheets-Sheet 2

FIG. 2

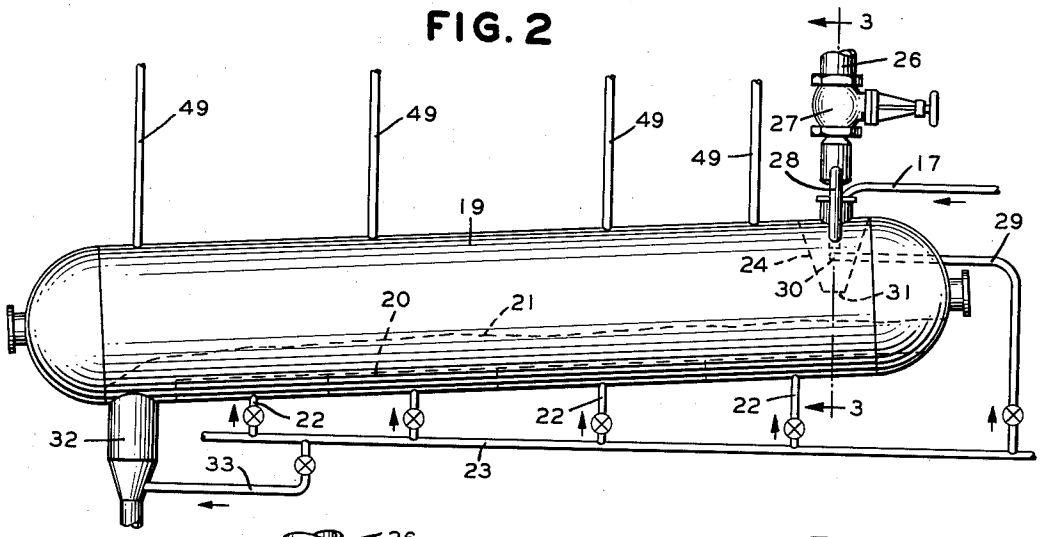


FIG. 3

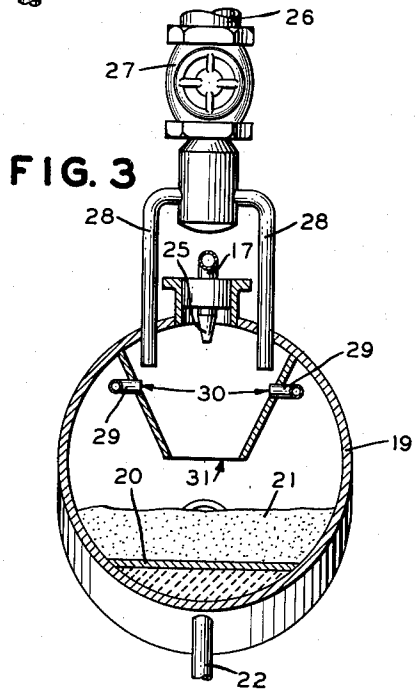


FIG. 4

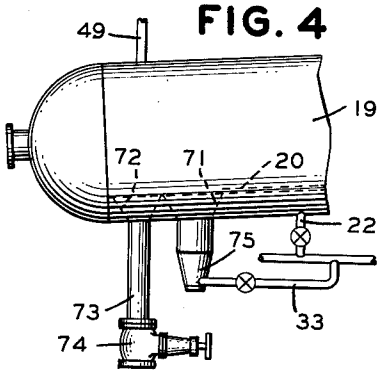


FIG. 5

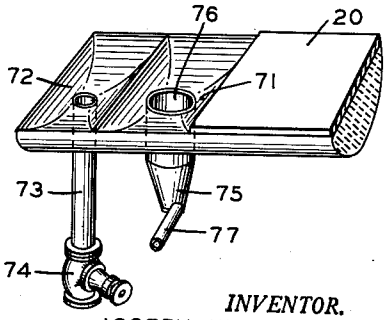
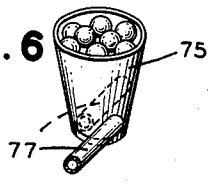


FIG. 6



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HYDROCARBON CONVERSION

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Application November 26, 1949, Serial No. 129,676

13 Claims. (Cl. 202—14)

This invention relates to an improved process for continuously coking and distilling residual hydrocarbon oils, that is, oils which cannot be vaporized completely because of the presence of unvaporizable constituents and/or constituents which decompose with formation of carbonaceous deposits on distillation. Such oils are best exemplified by reduced crudes, which are produced by subjecting crude oil to distillation to vaporize and remove lower boiling constituents. It will be understood, however, that the invention is applicable to the treatment of any such oil which it is advantageous to distill under coking conditions, such as crude oil, light reduced crude, heavy reduced crude, heavy gas oils and high-boiling synthetic hydrocarbon oils which may be produced by reacting carbon monoxide and hydrogen or by hydrogenating solid carbonaceous materials.

Continuous coking of hydrocarbon oils has certain advantages over present methods in which the coke is produced in large drums which must be emptied periodically. These advantages consist principally of the lower investment and operating cost of continuous coking. However, it is difficult in continuous coking processes to provide for positive control of the soaking time of the coke particles, the coking reaction temperature, residence time of the vaporized oil in the coking zone, and separation of vaporized oil from the coke.

An object of the invention is to provide for coking hydrocarbon oils, an improved process in which the soaking time of the coke is controlled under conditions in which all the coke particles are subjected to soaking treatment for approximately the same length of time.

Another object of the invention is to provide an improved coking process in which the coking reaction temperature may be readily controlled, or changed in response to changing requirements of the process.

Another object of the invention is to provide an improved coking process in which the residence time of the vaporized oil in the coking zone is held to a minimum.

Another object of the invention is to provide a process which is adaptable to the treatment of feed stocks of widely varying characteristics.

Another object of the invention is to provide a process for producing a coke of high porosity.

Further objects of the invention will be made apparent by the following description of the improved process.

The improved process will be described by reference to the accompanying drawings which are diagrammatic representations of apparatus suitable for carrying out the process. It will be understood that the apparatus shown merely illustrates arrangements suitable for carrying out the process and that the process is capable of other embodiments beyond the physical limitations of the apparatus shown in the drawings.

In the drawings:

Figure 1 is a diagrammatic view in elevation of an assemblage of apparatus for carrying out the coking process,

Figure 2 is an enlargement of a portion of Fig. 1,

Figure 3 is a sectional view, at line 3—3 of Fig. 2,

Figure 4 illustrates a modification of the coking drum in which means are provided for pulverizing the product coke,

Figure 5 is an enlarged view of a portion of Fig. 4, and

Figure 6 is an enlarged view of a portion of Fig. 5.

Referring to Fig. 1, a reduced crude oil is supplied to the process through line **10**, which connects with a heat exchanger **11**. The reduced crude is preheated at **11** and the preheated oil is then transferred through line **12**, to the entrance of a furnace **13** wherein the reduced crude is further heated. The preheated oil is discharged, from furnace **13**, into line **14** through which it flows into fractionating tower **15** at an intermediate point. The oil is preheated at **13** to a temperature high enough to vaporize a portion of the oil as it is discharged into tower **15**. Fractionating tower **15** is provided, with gas and liquid contact means, such as bubble trays and baffles, and is operated under temperature and pressure conditions effective to strip from oil charged thereto all light constituents undesired in the oil to be subjected to coking treatment and separate distillate fractions comprising an overhead, gasoline, fraction and an intermediate, gas oil, fraction. In tower **15** the reduced crude oil undergoes separation into vaporized and unvaporized portions, the unvaporized portion flows downwardly in countercurrent contact with oil vapors from the coking zone, which are introduced into tower **15** at a low point from line **16**.

By this treatment further preheating of the unvaporized portion of the reduced crude oil is effected and finely divided coke particles carried into tower **15**, in suspension in the oil vapors from line **16**, are entrained in the unvaporized portion of the reduced crude. The liquid which collects in the bottom of tower **15** comprises unvaporized portions of the reduced crude charge as well as oil condensed from the vapors from line **16** and is withdrawn therefrom through line **17**, by means of pump **18**, and passed to the coking treatment. The various treatments of the reduced crude described above are controlled to supply the oil to the coking treatment, through line **17**, at a temperature of approximately 650 to 750° F.

In carrying out the coking treatment, the preheated oil is contacted with hot finely divided coke in a coking zone in which there is maintained a horizontally extended bed of finely divided coke, aerated by means of inert gases flowing upwardly therethrough at a velocity at which the bed in maintained in a relatively dense fluidized condition. The fluidized bed of coke may be maintained in any suitable vessel, such as horizontally elongated drum **19** which may be cylindrical in shape. In drum **19** the fluidized bed of coke whose upper surface is indicated by dotted line **21** is supported on a perforated distribution plate **20** which extends across drum **19** from side to side and from one end to a coke withdrawal passageway opening into the other end of drum **19** at a low point. Distribution plate **20** is adapted to support a relatively thin bed of coke which moves continuously from the coke charging point to the coke withdrawal passageway, that is, from right to left in Fig. 1.

Distribution plate **20** is arranged to present a generally horizontal upper surface. The movement of the bed of coke laterally from right to left may be produced by the displacing action of coke added to the bed at the right end of drum **19**, if the upper surface of plate **20** is substantially exactly horizontal. However, this produces a coke bed which varies in depth, from a maximum near the coke inlet to a minimum near the coke outlet. Therefore, it may be advantageous to incline the distribution plate **20** downwardly toward the coke outlet sufficiently

to cause lateral flow of the coke bed at a suitable velocity, without the need for any substantial variation in the bed depth. An inclination of 1 to 10 degrees from the horizontal is usually sufficient, depending on the bed depth required. Inclination of distribution plate 20 does not necessarily require that drum 19 be mounted in a correspondingly inclined position. However, economy of construction may require that drum 19 be mounted with its longitudinal axis parallel to the plane of plate 20, and this is the arrangement illustrated in Figs. 1 and 2.

Distribution plate 20 is spaced sufficiently above the bottom of drum 19 to provide an upper surface of sufficient width in proportion to the diameter of the drum to provide adequate aeration of the coke bed and to provide a space in drum 19 under plate 20 for effective distribution therein of aerating and stripping gases. These gases are introduced into drum 19 at one or more points under plate 20, from lines 22 which connect with a supply line 23. The space under plate 20 may be subdivided by suitable partitions to permit passing differing quantities of gas through different sections of the coke bed.

The distribution plate 20 may consist of one metal plate, or a plurality of plates, containing perforations whose size and number permit passage of aerating and stripping gas up through the coke bed in a quantity and distribution such that the bed is uniformly aerated to the desired density and the displacement of volatile hydrocarbons from the bed is rapid and continuous. To effect uniform aeration and stripping the perforations should be as small, numerous, and uniformly distributed, as possible. For this reason it is preferred to form plate 20 by mounting porous metal plates in a suitable supporting grid. The methods for producing such plates are well known.

The hot finely divided coke and the preheated residual oil are discharged into the right hand end of drum 19, preferably at a point substantially above the upper surface of the fluid bed of coke, under conditions such that the relatively vaporizable portion of the oil is rapidly vaporized and the unvaporizable portion is absorbed by the hot coke particles being introduced into drum 19. The relative proportions of oil and hot coke charged to drum 19 are controlled to provide sufficient absorbent surface in relation to the unvaporized portion of the oil, whereby the latter may be absorbed by the coke while the coke remains sufficiently dry that it can be fluidized by the aerating and stripping gas flowing upwardly through distribution plate 20. The ratio in which coke and oil may be charged to drum 19, under satisfactory conditions of operation, is affected by the volatility of the oil, and the ratio may be controlled within limits by varying the temperature of the coke. Necessarily also the amount of oil which can be absorbed by the coke is affected by the absorptive capacity of the circulating coke, which absorptive capacity may be controlled, to some extent, by varying the conditions under which the coke is burned after the coking treatment.

Preferably, the temperatures of the hot coke and oil charged into drum 19 and the relative proportions of each are controlled to effect rapid vaporization of the oil and absorption of unvaporized constituents, whereby little or no liquid oil falls on the upper surface of the fluid bed of coke. This may be effected by discharging hot finely divided coke in an aerated condition into the interior of drum 19 at a high point therein while simultaneously spraying the hot residual oil into the interior of drum 19 at a point nearby the point at which the aerated coke is being introduced. The spray of oil is directed into the aerated mass of coke being introduced, to effect intimate contact of the hot coke and oil. This produces rapid vaporization of a portion of the oil and the unvaporized portion is absorbed by the coke which is settled onto the upper surface of the fluid bed of coke distribution plate 20.

Preferably, the hot coke and oil being charged to the coking treatment are mixed in a separate confined zone, which may be considered the vaporizing section of the coking zone, whereby part of the oil is vaporized and the unvaporized remainder is substantially completely absorbed by the hot coke, prior to discharge of the resulting mixture into drum 19 at a point from which the coke particles may settle onto the fluidized bed of coke. The separate confined mixing and absorbing zone may be provided outside drum 19, but, in order to simplify construction, it is provided in the upper interior of drum 19 by suitably partitioning off a space around the inlets for the oil and coke. This arrangement is shown in detail in Figs. 1 and 2, in which a partition in the form of a truncated cone 24, open at the lower small end, is attached to the upper interior wall of drum 19. Line 17 connects with a spray head 25 mounted at the top of drum 19 and arranged to spray the hot residual oil downwardly within the vaporizing section, of the coking zone, defined by partition 24. The finely divided hot coke for the coking treatment is supplied from standpipe 26 as an aerated mass. The rate of supply of the hot coke is regulated by means of slide valve 27 in the lower end of standpipe 26. The hot finely divided coke from standpipe 26 is discharged into the mixing section of the coking zone provided by partition 24 and into intimate contact with the oil being sprayed therein. In order to promote intimate mixing, the hot coke is transferred from standpipe 26 into the vaporizing section through a plurality of branch lines 28. Two of these are provided in the arrangement illustrated in the drawing but it is evident that the hot coke may be distributed through as many as such supply lines as is practical, to promote uniform distribution of the coke into the oil spray.

To assist in the mixing of the hot coke and oil within the vaporizing section of the coking zone, it may be desirable to introduce extraneous gas directly into the mixing section. For this purpose, line 29 is provided to connect line 23 with a plurality of tangential inlets, through partition 24, into the mixing section of the coking zone. The tangential introduction of the extraneous gas from line 24 through inlets 30 produces a swirling movement of the coke particles and oil droplets whereby there is intimate contact of the oil and hot coke within the vaporizing section and prior to discharge of the resulting mixture of oil vapors and hot coke, through the exit 31 of partition 24, into the soaking section of the coking zone.

The hot coke and oil are mixed in proportions such that oil not immediately vaporized may be absorbed completely by the coke particles while remaining in a relatively dry non-adhering condition in which they may be maintained as a dense free-flowing, fluidized mass on distribution plate 20 by the aerating and stripping gas flowing upwardly therethrough. It is preferred that vaporization of oil and absorption of the residue shall be accomplished solely by the coke with which the oil is first contacted in the mixing zone and that substantially no unabsorbed liquid oil be precipitated onto the surface 21 of the coke bed. Vaporization of the oil may be further promoted by preheating to vaporizing temperatures the gas injected into the vaporizing zone through inlets 30.

The ratio in which the coke and oil are mixed to effect the desired vaporization and absorption of the oil depends upon the temperatures of the coke and oil, the distillation characteristics of the oil, the proportion of the oil which is unvaporizable, and the composition of the unvaporizable portion of the oil. For coking oil, which has been preheated to a temperature just short of vaporization, the coke and oil may be mixed in a weight ratio of 1:1 to 10:1, preferably 6:1 to 2:1 depending on the temperature of the coke, which may be preheated to 1000 to 1500° F., and the ratio of vapor to liquid after mixing.

The time of residence of the oil and hot coke in the mixing and vaporizing zone is such that vaporization of the readily vaporizable components of the oil is the prin-

cipal effect of the mixing of the preheated oil and hot coke, although some decomposition incidental to coking may be initiated in that zone. In the preferred modification of the invention, as illustrated in Fig. 1, it was desired to separate the effluent vapors from the hot coke rapidly whereby cracking of vaporized hydrocarbons is kept to a minimum. It is preferred therefore to limit the residence time of the oil and coke in the confined mixing zone to the time required to effect substantially complete vaporization. However, it is within the scope of the invention to contact the oil and hot coke in a mixing zone in which substantial coking of the residual components of the oil on the coke particles is obtained.

In the preferred modification, illustrated in Fig. 1, the mixture of oil vapors and hot coke containing deposited residual hydrocarbons is discharged through opening **31** into the interior of drum **19**, and preferably above the level of the fluidized bed of coke, whereby the vapors are quickly separated from the hot coke particles and are withdrawn overhead to suitable recovery equipment. The coke particles, on which residual components of the oil are undergoing further distillation and decomposition, are precipitated onto the fluidized bed of coke whose upper level is indicated at **21**. Due to the displacing effect of the added coke particles and any inclination of the plate **20**, the coke bed flows continuously from the right hand end of drum **19**, at which the coke is added, to the left hand end. As pointed out above, the coke bed is maintained in a fluidized condition by the passage of aerating and stripping gas upwardly therethrough. Such gas maintains the coke bed in a flowable condition and displaces, from the voids between the coke particles, hydrocarbon vapors released from the coke particles as the result of distillation and cracking of hydrocarbons deposited thereon.

The time of residence of the coke particles in the fluid bed in drum **19** is sufficient to provide the soaking time required to complete the coking of the residual hydrocarbons deposited on the coke particles and the evolution of hydrocarbons released by the coking reaction. This requires, ordinarily, a residence time of 60 to 300 seconds, depending upon the temperature of the coke bed. The rate of lateral flow of the coke bed is governed by the rate at which coke is introduced into drum **19** in relation to the bed of coke at right angles to the direction of its lateral flow. The inclination of the plate **20** assists lateral flow and permits flowing the bed laterally at a satisfactory rate with no substantial difference in the bed depth at the ends thereof. However, inclination of plate **20** is not necessary to satisfactory lateral movement of the bed. Ordinarily the coke bed may be fluidized under conditions providing for uniform residence time of the particles at lateral velocities of 0.1 to 0.5 feet per second.

The lateral flow of the coke bed in accordance with the improved process provides for uniform residence time of the coke particles and also permits control of the residence time of all the coke particles in the soaking zone, that is, the zone traversed by the coke particles in passing from the vaporizing zone to the exit of drum **19**. The residence time of the coke particles may be varied by varying the rate at which coke is discharged into drum **19** and by varying the quantity of coke in drum **19**. In this manner the improved process provides means for subjecting each coke particle to the residence time required for effecting the desired decomposition and distillation of the particular oil undergoing coking treatment.

The depth of the coke bed in drum **19** is maintained relatively low, preferably 0.5 to 5.0 feet whereby effluent vapors are quickly stripped from the bed by means of aerating and stripping gas flowing upwardly therethrough at velocities sufficiently low to avoid agitation of the bed which would interfere with uniformity of residence time of the coke particles.

The quantity of stripping and aerating gas introduced into drum **19** through inlets **22** for passage up through the coke bed depends on the thickness of the bed and the quantity of stripping gas needed. It is preferred to utilize quantities of stripping and aerating gas such that the gas passes through the bed at relatively low velocity, whereby undue turbulence of the bed is avoided. Ordinarily it is desired to introduce the gas from inlets **22** at a rate such as to produce superficial upward velocity of 0.1 to 2.0 feet per second, preferably 0.2 to 0.8 feet per second. The superficial velocity is the velocity which would be assumed by the gas upon emerging from the orifices of distribution plate **20** in the absence of a bed of coke but at the coke bed temperature and pressure. It is preferred that the quantity of stripping gas and the bed depth be correlated to maintain a residence time of the stripping gas in the coke bed within the range of 1 to 6 seconds. Thus when the stripping gas is introduced at a rate corresponding to a superficial velocity of 2 feet per second into a bed of coke maintained in aerated condition by such gas at a depth of approximately 5 feet, the aerating gas will pass through the coke bed in approximately 2 seconds. Likewise when aerating gas is introduced at a superficial velocity of 0.1 foot per second it will pass through a 0.5 foot bed in approximately 3 seconds.

At the left hand, or discharge, end of drum **19** the fluid bed of coke overflows into a suitable withdrawal passageway **32** opening into the bottom of drum **19**. If necessary aerating gas may be introduced into passageway **32**, from line **33** which connects with line **23**, to maintain the withdrawn coke in aerated condition. The coke is discharged from passageway **32** into a screw conveyor **34** through which the coke is passed to the burning zone. It may be desirable to subject the coke withdrawn from drum **19** to a grinding treatment prior to burning, to reduce any large particles of coke which are formed by agglomeration or by accretion of coke from decomposed oil. Any suitable grinding means may be used for this purpose. Conveniently, screw conveyor **34** may be made to serve this purpose and the grinding effect may be promoted by mounting suitable grinding elements on the shaft of the screw of conveyor **34**. In this arrangement the screw conveyor **34** provides: means for controlling the rate of withdrawal of coke from drum **19**, means for grinding the withdrawn coke, and means for transferring the withdrawn coke to the burning zone.

The outlet of conveyor **34** connects with an elongated conduit **35** in which is located the burning zone for the coke. In conduit **35** the coke from drum **19** is carried at relatively high velocity in a gas stream containing oxygen to support the partial combustion of the coke which is desired to raise the coke to the temperature needed to carry out the coking of additional quantities of residual oil. Ordinarily the coke is discharged to drum **19** at a temperature of approximately 950 to 1150° F. The heat required to complete coking ordinarily results in the coke being cooled by 125 to 250° F. in passing through drum **19**. Consequently the coke introduced into conduit **35** is sufficiently hot to initiate combustion upon contact with air introduced at the lower end of conduit **35**. The air is supplied by a blower **36** through line **37**. If it is desired to preheat the air, when starting up or for control purposes, an air heater **38** may be provided at the lower end of conduit **35**. A portion of the air from line **37** from blower **36** is mixed with fuel gas from line **39** at the bottom of heater **38** while the remainder of the air is introduced directly into air heater **38** by means of line **40**.

The regeneration gas and suspended coke is flowed upwardly through conduit **35** at a relatively high velocity of 10–50 feet per second, preferably 15–25 feet per second, as a relatively dilute suspension. The quantity of regeneration gas employed is the amount necessary to burn coke in the burning zone to the extent necessary to impart, to that portion of the hot coke recirculated in the system, the heat required for vaporizing and coking the

oil. Air is normally employed as the regeneration gas and it is introduced at a rate of 0.5 to 2.0 cu. ft. (measured at standard condition) per pound of coke leaving the coking chamber.

In the burning zone the coke is carried in suspension in the stream of regeneration gas. At least a part of the path of flow of the regeneration gas in the burning zone is in a vertical direction, as shown in Fig. 1. This serves to lift the hot coke to a point of discharge, from the burning zone, which is substantially elevated above the coking zone, and also serves to lengthen the residence time of the coke particles in the burning zone. In the vertical section of the burning zone substantial slippage of the coke particles in the flowing gas stream occurs, the degree of slippage varying with the gas velocity. At a gas velocity in the preferred range of 15–25 feet per second the concentration of coke in the gas stream may be, in the vertical section of the burning zone, two or three times the inlet concentration. The length of the burning zone is designed to retain the coke particles therein for a time sufficient to raise their temperature at least to the temperature at which they are desired for use in the coking step.

The supply of oxygen to the burning zone ordinarily is limited to the amount necessary to cause combustion which will raise the temperature of the coke particles to the desired elevated temperature. However, under some conditions it may be desirable to apply cooling treatment at some point in the burning zone. This may be necessary, for example, under conditions wherein it is necessary, in order to decrease the volatile content of the circulating coke, to burn the coke at a higher temperature than the temperature at which it is desired to employ the coke for vaporization and coking of the oil feed.

The exit of conduit **35** opens into the interior of an enlarged settling hopper **41** in which the flue gas and hot coke particles are separated. To assist in settling the coke particles conduit **35** in connected to hopper **41** in a manner to discharge the suspension in a downward direction. To further assist in settling the coke particles conduit **35** is extended downwardly in hopper **41** to a relatively low point, as indicated in Fig. 1. The settled coke particles are accumulated in the lower part of hopper **41** and the resulting mass is maintained in a fluidized condition, which may be promoted if necessary by the injection of aerating gas into hopper **41** at a low point.

Additional means may be provided to separate the finer particles of coke from the flue gas. Such means conveniently may comprise one or more cyclone separators which, as shown in Fig. 1, conveniently may be located in the upper interior of hopper **41**. The fine coke separated in cyclone **42** is returned to a low point in hopper **41** by a suitable dip-leg **43**. The flue gas emerges from the cyclone separater **42** and from hopper **41** through line **44** which may be provided with a pressure control valve **45**. The flue gas thus discharged from the system may be passed to suitable heat exchange steps for recovery of the heat contained therein either before or after pressure release or may be discharged to the atmosphere.

Instead of, or in addition to, the use of separating devices of the cyclone type, it may be desirable to pass the flue gas through filtering means to effect a sufficient recovery of the coke particles from the flue gas. Conveniently such filters may be located in the upper interior of hopper **41**.

Regardless of the extent of stripping to which the coke is subjected as it flows in the fluid bed in drum **19** toward outlet **32**, the coke introduced into burning zone **35** contains a substantial proportion of volatile combustible material. A substantial part of the combustion which occurs in zone **35** results from the burning of such volatile matter. This tends to increase the porosity of the circulating coke. It may cause some spalling of the coke with consequent decrease in particle size. This may be desirable since there is an increase in particle size in the coking zone. Under controlled combustion the volatile materials is preferentially burned in the burning zone. Normally the heat generated by burning a part of the volatile material is sufficient to support the heat of coking in the coking zone.

The excess coke produced in the process, that is the coke laid down by the oil and not consumed in the process, is withdrawn from the process preferably from hopper **41**, as at that point in the circulation of the coke it is found to be in the best condition for withdrawal as a product of the process.

In order to maintain the circulating mass of coke in the finely divided condition which is desirable for maintenance of the aerated coke bed in drum **19**, it may be advantageous to effect a degree of classification of the coke particles in hopper **41** whereby the relatively more coarse particles are withdrawn as the product coke, while the finer coke particles are recirculated. In the arrangement shown in Fig. 1 the product coke is withdrawn from the bottom of hopper **41** through a suitable standpipe **46** provided with a control slide valve **47**. Standpipe **26** is connected at its upper end with hopper **41** at a point somewhat above the lower end of standpipe **46**. The aeration of the settled mass of particles which covers the inlets of both standpipe **26** and **46** may produce sufficient classification of the coke particles whereby the small proportion of the coke withdrawn through standpipe **46** consists predominantly of larger particles. The rate at which coke is withdrawn through standpipe **46** is only a small fraction of the rate withdrawn through standpipe **26**, as ordinarily the coke recirculated through standpipe **26** is 20 to 40 times the quantity of coke withdrawn as product through standpipe **46**.

To assist in the classification of the coke particles in hopper **41** a vertical partition **48** is provided to divide the bottom part of hopper **41** into two sections. The lower end of conduit **35** is arranged to discharge the coke and gas over the inlet to standpipe **46**, whereby material entering standpipe **26** must flow over the partition **48**. The degree of classification required in the material withdrawn through standpipe **46** may be controlled by varying the amount of aerating gas admitted above the entrance to standpipe **46**, from line **78**. The minimum aeration velocity necessary to maintain fluidization above standpipe **46** will result in little classification, whereby the particles withdrawn through standpipe **46** will have substantially the same particle size range as the coke discharged from conduit **35**. Increasing the aeration velocity, by increasing the volume of aerating gas from line **78**, will cause elutriation, the degree of which can be varied as desired. If accretion in the coking zone results in an increase in the average particle size of the coke which is not compensated for in the burning zone, the quantity of coke withdrawn through line **46** may be increased over the amount equivalent to the excess coke, so that a portion of the coke thus withdrawn may be ground up and returned to the system as fines.

The recirculated particles are withdrawn through standpipe **26** for transfer to the vaporizing zone in the manner described above. In standpipe **26** the coke is maintained in a suitable fluidized condition at relatively high densities. Ordinarily the downward velocity of the coke in standpipe **26** is sufficient to retain the aerated condition of the coke or it may be desirable to inject aerating gas at intervals along the length of standpipe **26**.

The length of standpipe **26** and, consequently, the elevation at which hopper **41** is mounted above coke drum **19** depend on the pressure drop experienced in the circulation of the coke from drum **19** through the burning zone and the settling hopper **41** and the density of the coke in standpipe **26**. Ordinarily the pressure drop is approximately 5 pounds per square inch in flowing the coke from drum **19** to the lower part of hopper **41**. The pressure drop on the coke in flowing through slide valve **27** is maintained at approximately 5 pounds per square

inch. Consequently it is desired ordinarily to provide by means of standpipe **26** an increase in pressure from the top to the bottom thereof of approximately 10 pounds per square inch. If the density of the coke in standpipe **26** is approximately 30 pounds per cu. ft. it is satisfactory to provide standpipe **26** with a length such that it rises a vertical distance of approximately 48 ft.

The stripping and aerating gas introduced into drum **19** through lines **22**, **29** and **33** and into standpipe **26** conveniently may be steam although other inert gas such as hydrocarbon gas produced in the process may be employed. Steam is preferred, however, as it introduces fewer difficulties in the recovery of the volatile products of the process. Any suitable aerating gas may be introduced into the lower part of hopper **41**, such as steam, or flue gas.

The volatile products of the process are withdrawn from high points in drum **19** preferably through a plurality of outlet lines **49** which connect with line **16** for passage of the vapors to fractionating tower **15** in the manner described. A plurality of outlet lines **49** distributed along the length of drum **19** is preferred in order to minimize the time of residence of the product vapors in drum **19**, whereby cracking of the vaporized hydrocarbons is kept to a minimum. Cooling means may be associated with the vapor outlet lines or line **16** to effect prompt cooling of the vapors to non-cracking temperatures. Heat exchange may be provided for this purpose, or means to inject cooling liquid or vapors directly into the vapor lines.

In fractionating tower **15** the vapor product is subjected to scrubbing with the charge oil, as described above, to vaporize portions of the charge oil, scrub from the product vapors fine coke particles carried therein in suspension from drum **19**, and condense the highest boiling portion of the vapors for recycling to the coking zone. In the upper portion of tower **15**, above the section in which the scrubbing treatment is carried out, the product vapors and the vaporized portion of the charge oil are subjected to fractionation in any suitable manner to recover the products of the process which include a gas oil fraction, a gasoline fraction and a gas fraction. The heat for the fractionating treatment is supplied to tower **15** in the product vapors from line **16** and in preheated feed from line **14**. Cooling at the upper end of the tower is provided by refluxing. The overhead fraction is withdrawn through line **50** which passes through cooler **51** in which condensation of the normally liquid components is effected. Separation of the condensate from the uncondensed gas is carried out in drum **52**, from which the gas is withdrawn through line **53**. Any water contained in the product vapors, as the result of the use of steam in the system, is condensed at this point and withdrawn from drum **52** through line **54**, provided with pump **55**. The liquid hydrocarbon fraction separated in drum **52** is withdrawn through line **56**, provided with pump **57**. A portion of this condensate is returned by pump **57** through line **58** to the top of tower **15** to provide the refluxing of the tower necessary for the fractionation operation. A portion of the condensate delivered by pump **57** is withdrawn by line **59** as a gasoline or naphtha product of the process.

A gas oil fraction is recovered by withdrawing a liquid stream from tower **15** at an intermediate point through line **60**. This side stream is delivered by line **60** into a stripping tower **61** in which the side stream is heated to strip light components therefrom, these being withdrawn overhead through line **62** and introduced into tower **15** at a higher point. The stripped gas oil is withdrawn as a product of the process through line **63** by means of pump **64**, a cooler **65** being provided in line **63** for cooling the gas oil product to a suitable low temperature. A portion of the side stream withdrawn from tower **15** through line **60** may be diverted therefrom through line **66** by means of pump **67** and passed through heat exchanger **11** and cooler **68** prior to being returned to a suitable point in tower **15** through lines **69** and **70**, as an intermediate reflux.

It will be understood that the introduction of the charge oil into tower **15** depends on the presence of readily vaporizable components therein. Ordinarily a crude oil or a reduced crude oil or a heavy gas oil is charged to the process by introducing it into tower **15** in the manner described. Oils which have been substantially denuded of components which can be vaporized at non-coking temperatures may be introduced into the process directly through line **17**, after being preheated to a suitable temperature. However it may be desirable to introduce reduced crudes containing volatile constituents directly into line **17**, in which case they are preheated to a higher temperature.

The operation of the process described above may be illustrated by the following specific example of the treatment of a Kansas reduced crude having a gravity of 25° A. P. I. The reduced crude is charged to the process through line **10** and distilled in fractionating tower **15** under conditions effective to produce a straight run gas oil representing 48 wt. per cent of the oil charge and a residual oil having a gravity of 18.5° A. P. I. This residual oil plus recycle oil is treated in accordance with the improved process to produce distillate oil in the coking zone equivalent to at least 36 wt. per cent of the charge oil from line **10** while producing a dry gas to the extent of 4.1 wt. per cent of the charge oil and recovering a coke product through standpipe **46** equivalent to 11.9 wt. per cent of the charge oil from line **10**.

Example

Outlet temperature of furnace 13	800° F.
Feed oil temperature in line 17	750° F.
Coke temperature in lines 28	1100° F.
Weight ratio of coke from lines 28 to combined feed oil from line 17.	3 : 1.
Temperature at upper end of coke bed	935° F.
Temperature of coke in outlet 32	850° F.
Inclination of coke bed	3°
Depth of coke bed	1.5 ft.
Density of coke bed	25 lb./cu. ft.
Stripping steam velocity in coke bed (superficial).	0.2 ft./sec.
Lateral velocity of coke bed	0.4 ft./sec.
Length of coke bed	54 ft.
Steam through lines 22	10 wt. per cent on feed.
Steam through line 29	5 wt. per cent on feed.
Air in line 35	3.8 St. cu. ft./lb feed oil.
Gas velocity in line 35	20 ft./sec.
Circulating coke to make coke	16 : 1.
Coking time	135 secs.

A modification of coking drum **19** is illustrated in Figs. 4, 5 and 6. In this modification means are provided, within the drum, for continuously reducing large coke particles formed in the coking operation. In this arrangement a hopper **71** is interposed between the lower end of distribution plate **20** and a hopper **72** which is provided to direct the coke to draw-off line **73**. In this modification a slide valve **74** is provided in line **73** to control the rate of withdrawal of coke.

The coke flows from the lower end of distribution plate **20** to and across hopper **71**. Aerating gas is passed upwardly through the coke mass during this passage whereby classification occurs, with the more coarse particles being concentrated in the bottom of hopper **71**. By this means the coarser coke particles are directed by hopper **71** into a ball mill **75** which connects with hopper **71** through an opening **76** in the bottom thereof. Ball mill **75** is provided with a plurality of steel or ceramic balls which are agitated in the lower conical portion thereof by means of steam jets introduced tangentially through line **77**. The movement of the balls reduces the larger coke particles to smaller particles capable of being lifted upwardly out of the ball mill and back to hopper **71** by the steam from line **77** which rises upwardly in the ball mill and acts as the aerating gas in hopper **71**. By this means the reduction of the coarser coke particles is carried out continuously inside the coking zone.

The operation of the coking process may be started by

supplying fine particles from any source. Petroleum coke is preferred but other coke may be used, as well as finely divided siliceous materials, such as bentonite clay. Carbonaceous starting materials may be heated initially to the desired high temperature by combustion with preheated air in zone 35. Non-carbonaceous materials may be heated to the desired temperature by heated air from heater 38. The starting materials are gradually replaced in the process by coke particles formed from the oil being processed, so that normal operation involves a circulating mass of particles of coke formed from the oil.

We claim:

1. A process for coking and distilling residual hydrocarbon oil which comprises forming and maintaining in the lower part of a coking zone a horizontally extended bed of finely divided hot coke, flowing aerating gas upwardly through said coke bed to maintain all parts thereof in a relatively dense fluidized condition whereby the bed is capable of lateral flow, discharging a mixture of hot finely divided coke and residual oil into the coking zone at one end of the coke bed whereby the added coke merges with the coke bed and the residual oil is partly vaporized by the heat of the added hot coke and the unvaporized portion is deposited on the surfaces of hot coke particles for distillation and decomposition by the heat of the coke continuously stripping said oil vapors from said horizontally flowing bed by means of said aerating gas to diminish the amount of oil vapor in said bed as it flows downstream, maintaining a disengaging space above said horizontally flowing bed for collecting said vaporized components of said residual oil above said bed, withdrawing said oil vapor from said disengaging space without further contact with said bed, withdrawing coke from the fluidized bed at an edge thereof horizontally distant from the point of introduction of hot coke into the coking zone whereby the coke bed flows laterally from the point of introduction of hot coke into the coking zone to the point of withdrawal thereof from the fluidized bed, subjecting the coke withdrawn from the coking zone to partial combustion to heat the coke substantially above the temperature of withdrawal, and discharging said heated coke into said coking zone in the manner described.

2. The process of claim 1 wherein coke withdrawn from the fluid-like bed in the coking zone is subjected to grinding treatment to reduce the average particle size thereof prior to introduction into the burning zone.

3. A process for coking and distilling a residual hydrocarbon oil which comprises, continuously supplying hot petroleum coke in finely divided form to an oil vaporizing section of a coking zone, intimately mixing the hot coke with residual oil in the oil vaporizing section to effect vaporization of a portion of the oil and decomposition of unvaporized constituents of the oil with deposition of carbon on the surfaces of the coke particles, discharging into one end of a horizontally elongated soaking section of the coking zone the mixture of oil vapors and coke particles bearing unvaporized constituents of the oil undergoing decomposition, settling the coke particles out of the oil vapors in the soaking section of the coking zone, maintaining the settled coke as a relatively dense fluid-like mass by the passage of aerating and stripping gas upwardly therethrough, flowing the fluid-like bed of coke horizontally from the inlet of the soaking section of the coking zone to a coke discharge point at the opposite end of said section, withdrawing coke from said coking zone at the coke discharge point, continuously stripping hydrocarbon vapors from said horizontally flowing bed as said vapors are formed therein and separately withdrawing said vapors and stripping gases from said coking zone above said fluid-like coke bed, suspending withdrawn coke in air under conditions effective to initiate combustion, transporting the suspension through an elongated burning zone to effect partial combustion of the coke to heat it to a temperature substantially higher than the temperature at which the coke is discharged from the coking zone, discharging the suspension of flue gas and heated coke into a settling zone, withdrawing a minor portion of the coke from the settling zone as a product of the process, and transporting the remainder of the coke separated in the settling zone to the oil vaporizing step, as described.

4. The process of claim 3 wherein the mixture of oil vapors and coke particles bearing unvaporized constituents of the oil undergoing decomposition is discharged into the coking zone above the level of the relatively dense fluid-like mass of coke particles therein.

5. The process of claim 4 wherein the mixture of oil vapors and coke particles is discharged downwardly into the space in the coking zone above the fluid-like bed of coke particles.

6. The process for coking and distilling a residual hydrocarbon oil which comprises, maintaining a column of hot petroleum coke in finely divided form wherein the mass of coke is maintained in a relatively dense fluid-like condition by reason of the presence of aerating gas therein, continuously discharging hot coke from the lower end of said column into an oil vaporizing section of a coking zone, intimately mixing the hot coke in the oil vaporizing section with residual oil to effect vaporization of a portion of the oil and decomposition of unvaporized constituents of the oil with deposition of carbon on the surfaces of the coke particles, discharging into one end of a horizontally elongated soaking section of the coking zone the mixture of oil vapors and coke particles bearing unvaporized constituents of the oil undergoing decomposition, settling the coke particles out of the oil vapors, maintaining the settled coke as a relatively dense fluid-like mass by the passage of aerated and stripping gas upwardly therethrough, flowing the fluid-like bed of coke horizontally from the inlet of the soaking section of the coking zone to a coke discharge point at the opposite end of said section, withdrawing coke from said coking zone at the coke discharge point, continuously stripping hydrocarbon vapors from said horizontally flowing bed as said vapors are formed therein and separately withdrawing said vapors from said coking zone above said fluid-like coke bed, suspending withdrawn coke in air under conditions effective to initiate combustion, transporting the suspension through an elongated burning zone to effect partial combustion of the coke to heat it to a temperature substantially higher than the temperature at which the coke is discharged from the coking zone, discharging the suspension of flue gas and heated coke into a settling zone, and supplying coke separated in said settling zone to the upper end of said first mentioned column of finely divided coke.

7. A process for coking and distilling hydrocarbon oil, which includes the steps of: flowing through an elongated coking zone a substantially horizontal stream of finely divided hot coke, the depth of said stream being shallow relative to its length in the direction of flow; flowing aerating gas upwardly through said stream to maintain it in a dense fluidized condition in the lower part of said coking zone, with a more or less distinct upper surface separating said stream from an overhead settling region containing a gas-coke mixture of relatively low density; downwardly introducing hot finely divided coke into said coking zone above said upper surface and at an upstream point of said fluidized coke stream, said coke having a temperature substantially above the temperature of said fluidized stream; spraying said hydrocarbon oil on said freshly introduced hot coke at a ratio of oil to coke adapted to partially vaporize said oil and produce a mixture dry enough to fluidize in said fluidized coke stream; depositing said mixture of introduced coke and oil on the surface of said fluidized stream and maintaining the flow of said fluidized stream at a rate which permits the distillation and decomposition by heat of a portion of the oil deposited on the surface of said coke particles, and the conversion of the remainder to coke, thereby causing an accretion of coke, during the time required for said stream to carry said particles through said coking zone; con-

tinuously stripping product vapor from said stream by means of upwardly flowing aerating gas to minimize the residence time of vaporized oil of fluidized coke; withdrawing product vapor from said settling region above said stream at points distributed along the flow of said stream; withdrawing coke from a downstream point of said fluidized coke stream; mixing said withdrawn coke with an oxygen-containing gas to partially burn said coke sufficiently to supply heat for recontacting with oil feed, and simultaneously transferring said coke particles in suspension in said gas to a point of substantially higher elevation than the point of introduction of said particles into said coking stream; settling particles of partially burned and heated coke from said suspension, and flowing them downwardly into said contacting zone in the manner described.

8. The process for coking and distilling a residual hydrocarbon oil which comprises: continuously supplying hot petroleum coke in finely divided form to an oil vaporizing section of a coking zone, intimately mixing the hot coke with residual oil in the oil vaporizing section to effect vaporization of a portion of the oil and decomposition of unvaporized constituents of the oil with deposition of carbon on the surfaces of the coke particles, discharging into one end of a horizontally elongated soaking section of the coking zone the mixture of oil vapors and coke particles bearing unvaporized constituents of the oil undergoing decomposition, settling the coke particles out of the oil vapors, maintaining the settled coke as a relatively dense fluid-like mass by the passage of aerating and stripping gas upwardly therethrough, separately withdrawing from a point above the fluid-like bed of coke in the coking zone the hydrocarbon vapors separated therein, scrubbing said withdrawn vapors with said residual oil to entrain in said residual oil coke particles carried out of the coking zone in suspension in said vapors, thereafter passing the residual oil with entrained coke particles to the oil vaporizing step, flowing the fluid-like bed of coke horizontally from the inlet of the soaking section of the coking zone to a coke discharge point at the opposite end of said section, withdrawing coke from said coking zone at the coke discharge point, suspending withdrawn coke in air under conditions effective to initiate combustion, maintaining the coke as a relatively dilute suspension thereof in said air throughout a partial combustion of the coke to heat it to a temperature substantially higher than the temperature at which the coke is discharged from the coking zone, separating the hot partially burned coke from the flue gases, and supplying the hot coke to the oil vaporing zone, as described.

9. The process for coking and distilling a residual hydrocarbon oil which comprises: continuously supplying hot petroleum coke in finely divided form to an oil vaporizing section of a coking zone, intimately mixing the hot coke with residual oil in the oil vaporizing section to effect vaporization of a portion of the oil and decomposition of unvaporized constituents of the oil with deposition of carbon on the surfaces of the coke particles, discharging into one end of a horizontally elongated soaking section of the coking zone the mixture of oil vapors and coke particles bearing unvaporized constituents of the oil undergoing decomposition, settling the coke particles out of the oil vapors, maintaining the settled coke as a relatively dense fluid-like mass by the passage of aerating and stripping gas upwardly therethrough, separately withdrawing from a point above the fluid-like bed of coke in the coking zone the hydrocarbon vapors separated therein, flowing the fluid-like bed of coke horizontally from the inlet of the soaking section of the coking zone to a coke discharge point at the opposite end of said section, withdrawing coke from said coking zone at the coke discharge point, suspending withdrawn coke in a stream of air flowing upwardly at a velocity such that the coke particles are carried therein as a relatively dilute suspension, the temperature of the coke and the air being such as to initiate combustion, flowing the relatively dilute suspension upwardly for a distance effective to heat the coke by partial combustion thereof to a temperature substantially higher than the temperature at which the coke is discharged from the coking zone, separating the hot coke from the flue gas at a level substantially higher than the level of the oil vaporizing section, and transferring the separated hot coke downwardly to the oil vaporizing section as a vertically elongated dense fluidized column effective to overcome the pressure drop experienced by the coke in flowing through the coking and burning zones.

10. A process for coking and distilling a hydrocarbon oil, which includes the steps of: flowing through an elongated coking zone a horizontally extended stream of finely divided hot coke, the depth of said stream being shallow relative to its length in the direction of flow; flowing aerating gas upwardly through said stream to maintain it in a dense fluidized condition in the lower part of said coking zone, with a more or less distinct upper surface separating said stream from an overhead settling region containing a gas-coke mixture of relatively low density; continuously introducing a mixture of hot finely divided coke and residual oil into said coking zone at an upstream point of said fluidized coke stream, said coke having a temperature substantially above the temperature of said fluidized stream at a ratio of oil to coke adapted to partially vaporize said oil and produce a mixture dry enough to fluidize in said fluidized coke stream; maintaining the flow of said fluidized stream at a rate which permits the distillation and decomposition of a portion of the oil deposited on the surface of said coke particles, and the conversion of the remainder to coke, thereby causing an accretion of coke, during the time required for said stream to carry said particles through said coking zone; continuously stripping product vapor from said stream by means of upwardly flowing aerating gas to minimize the residence time of vaporized oil in said fluidized coke; withdrawing product vapor from said settling region above said stream; withdrawing coke from a downstream point of said fluidized coke stream; mixing said withdrawn coke with an oxygen-containing gas to partially burn said coke sufficiently to supply heat for recontacting with oil feed, and simultaneously transferring said coke particles in suspension in said gas to a point of substantially higher elevation than the point of introduction of said particles into said coking stream; settling particles of partially burned and heated coke from said suspension, and flowing them downwardly into said contacting zone in the manner described.

11. A process for coking and distilling a hydrocarbon oil, which includes the steps of: flowing through an elongated coking zone a substantially horizontal stream of finely divided hot coke, the depth of said stream being shallow relative to its length in the direction of flow; flowing aerating gas upwardly through said stream to maintain it in a dense fluidized condition in the lower part of said coking zone, with a more or less distinct upper surface separating said stream from an overhead settling region containing a gas-coke mixture of relatively low density; introducing hot finely divided coke into said coking zone at an upstream point of said fluidized coke stream, said coke having a temperature substantially above the temperature of said fluidized stream; spraying said hydrocarbon oil on said freshly introduced hot coke at a ratio of oil to coke adapted to partially vaporize said oil and produce a mixture dry enough to fluidize in said fluidized coke stream; maintaining the flow of said fluidized stream at a rate which permits the distillation and decomposition by heat of a portion of the oil deposited on the surface of said coke particles, and the conversion of the remainder to coke, thereby causing an accretion of coke, during the time required for said stream to carry said particles through said coking zone; continuously stripping product vapor from said stream by means of upwardly flowing aerating gas to minimize the residence time of vaporized oil in said fluidized coke; withdrawing product

vapor from said settling region above said stream; withdrawing coke from a downstream point of said fluidized coke stream; mixing said withdrawn coke with a gas to transfer said coke particles in suspension in said gas to a point of substantially higher elevation than the point of introduction of said particles into said coking stream; settling particles of coke from said suspension, and flowing them downwardly into said contacting zone in the manner described; heating said coke during said transfer steps to a temperature between 950° F. and 1150° F.; and introducing said hot coke into said coking zone at a rate such that the coke is not cooled to a temperature lower than 750° F. during its passage to said coke-discharge point.

12. A process for coking and distilling a hydrocarbon oil, which includes the steps of: flowing through an elongated coking zone a substantially horizontal stream of finely divided hot coke, the depth of said stream being shallow relative to its length in the direction of flow; flowing aerating gas upwardly through said stream to maintain it in a dense fluidized condition in the lower part of said coking zone, with a more or less distinct upper surface separating said stream from an overhead settling region containing a gas-coke mixture of relatively low density; introducing hot finely divided coke into said coking zone at a relatively hot upstream point of said fluidized coke stream, said coke having a temperature substantially above the average temperature along said fluidized stream; spraying said hydrocarbon oil on said freshly introduced hot coke at a ratio of oil to coke adapted to partially vaporize said oil and produce a mixture dry enough to fluidize in said fluidized coke stream; flowing said fluidized stream at decreasing temperature and diminishing oil vapor content to a downstream discharge point; maintaining said flow at a rate which permits the distillation and decomposition by heat of a portion of the oil deposited on the surface of said coke particles, and the conversion of the remainder to coke, thereby causing an accretion of coke, during the time required for said stream to carry said particles through said coking zone; continuously stripping product vapor from said stream by means of upwardly flowing aerating gas to minimize the residence time of vaporized oil in said fluidized coke; withdrawing product vapor from said settling region above said stream; withdrawing coke from a downstream point of said fluidized coke stream; mixing said withdrawn coke with an oxygen-containing gas to partially burn said coke sufficiently to supply heat for recontacting with oil feed, and simultaneously transferring said coke particles in suspension in said gas to a point of substantially higher elevation than the point of introduction of said particles into said coking stream; settling particles of partially burned and heated coke from said suspension, and flowing them downwardly into said contacting zone in the manner described.

13. A process as described in claim 10 in which said coking is initiated by introducing hot non-carbonaceous particles into said coking zone at said upstream point to start the flow of fluidized solids through said horizontally extended coking zone.

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