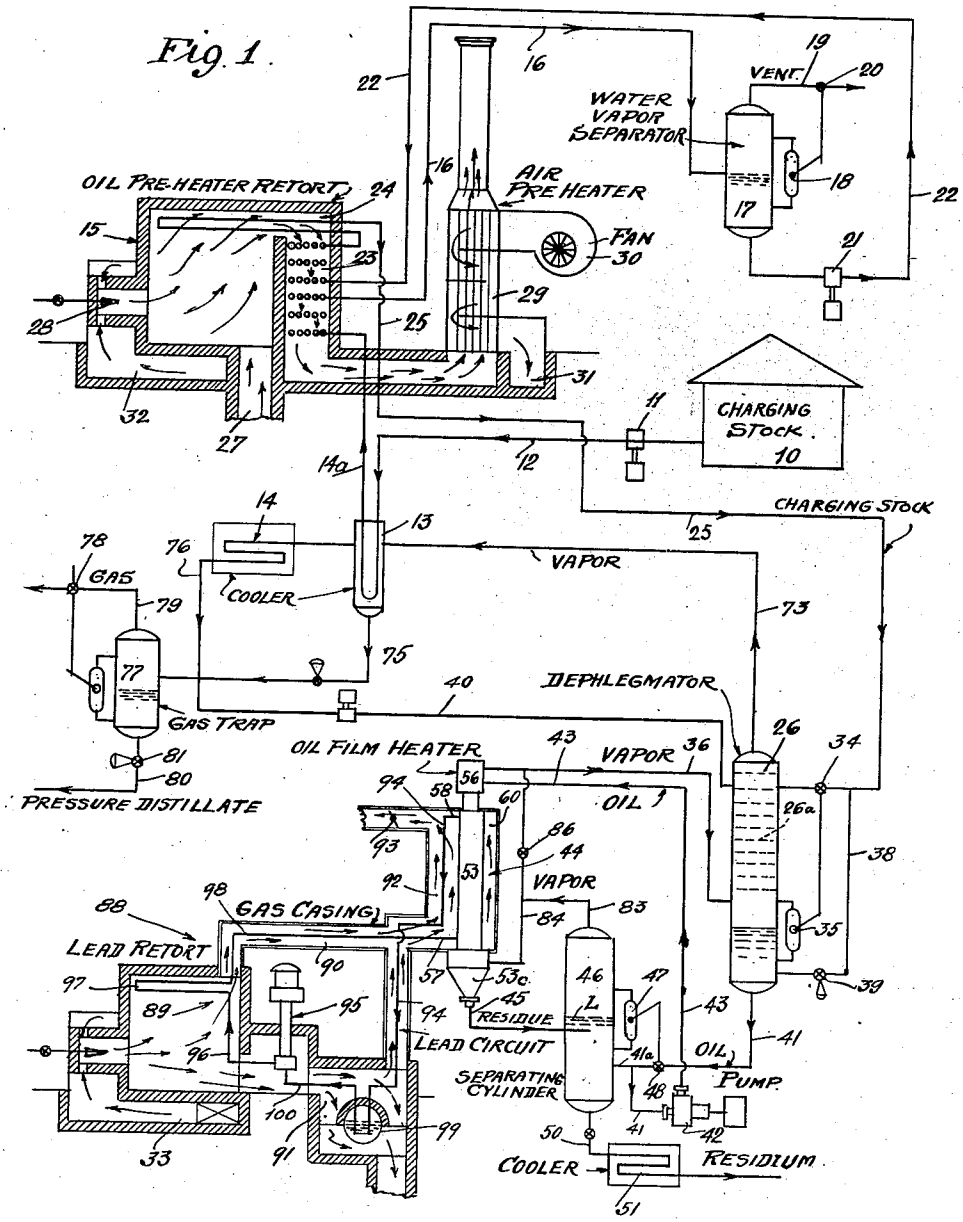
April 6, 1937. W. A. S. HARMON 2,075,896

OIL CRACKING PROCESS

Filed May 21, 1934 3 Sheets-Sheet 1

Fig. 1.



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OIL CRACKING PROCESS

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Fig. 4.

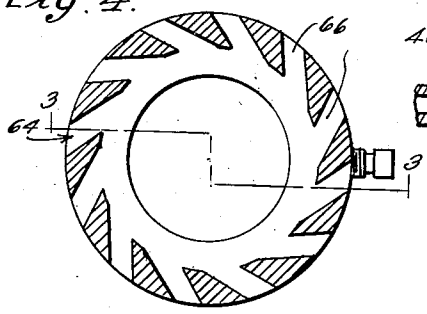
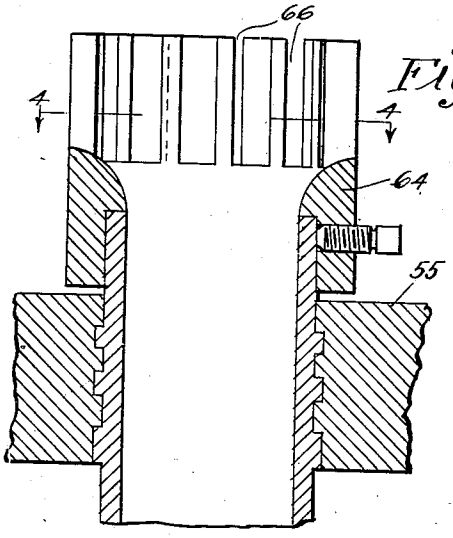


Fig. 2.

Fig. 3.



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OIL CRACKING PROCESS

Filed May 21, 1934 3 Sheets-Sheet 3

Fig 5.

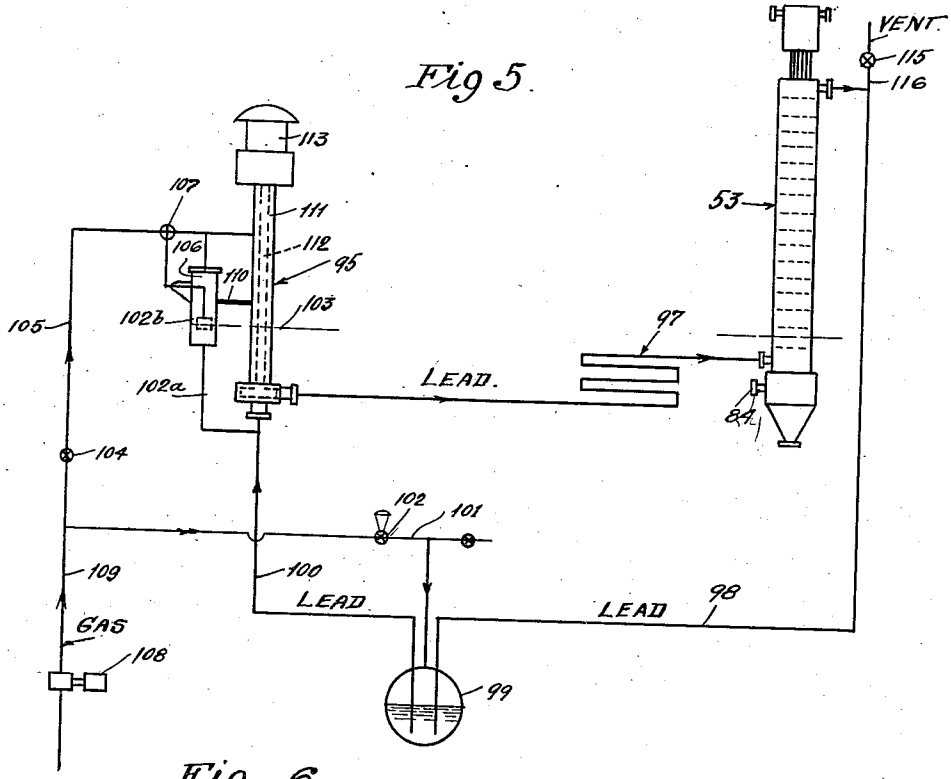
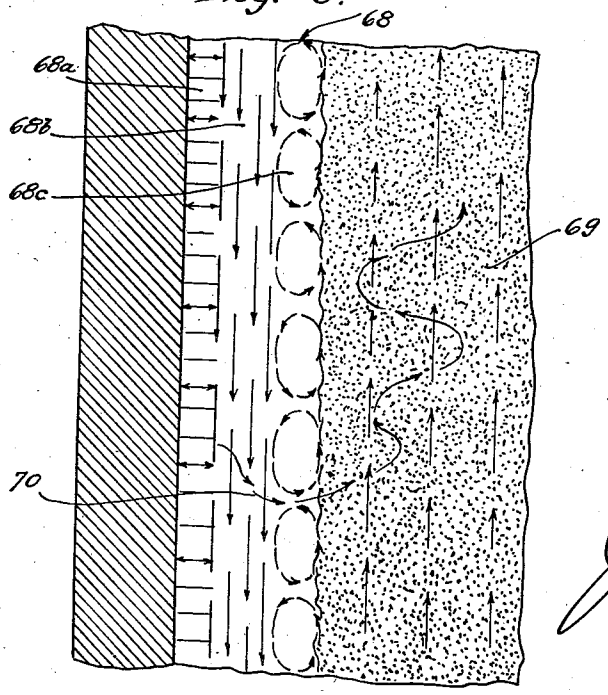


Fig. 6.



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UNITED STATES PATENT OFFICE

2,075,896

OIL CRACKING PROCESS

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Application May 21, 1934, Serial No. 726,653

5 Claims. (Cl. 196—128)

This invention relates generally to the refining of petroleum oils, and deals particularly with an improved liquid phase oil cracking system for producing from comparatively heavy oils, gasoline or other light products. The broad objects of the invention correspond to those generally sought, but usually accomplished to a limited extent only, in the operation of systems of this character; for example, to obtain maximum available yields of gasoline from a given charging stock, to reduce to a minimum the fixed gas production and carbon deposits on the heating surfaces, and to obtain highest operating efficiency and economy in the system as a whole. The invention also involves a great many specific objects, which, in general, are directed to particular means for accomplishing the broad objects. A proper understanding of all these can perhaps best be given by first stating certain principles indispensable to the accomplishment of the desired ends, and by comparing and contrasting certain prevailing cracking methods with the present system.

In all liquid phase cracking operations wherein the oil is heated in vessels or tubes to cracking temperatures, high proportionate conversion to light fractions or cuts, reduction of fixed gas formation and carbon deposits on the heating surfaces, speed of conversion and production of pressure distillate, and general efficiency, are dependent upon certain considerations. These include the nature of the charging stock, temperatures and pressures in the system, heat transfer rates from the heating medium to the vessel or tube and from the latter to the oil, disposition or treatment of vapors after initial cracking, control of carbon formation and removal of carbon from the oil heating surfaces, and flexibility and controllability of the system as a whole. It may be well to observe how these considerations are met in the most prevalent cracking systems, the "tube-and-tank" type, in which the oil is heated under high pressure to cracking temperatures during passage through externally fired tubes, and then maintained in a pressure reaction chamber over a time period sufficient to allow the cracking reaction to complete itself as far as possible within practical limits.

There is of course a maximum potential cracked gasoline yield obtainable from any given charging stock, and the closeness of approach to that maximum will depend upon the efficiency of the individual cracking system. Considering the matter of heat transfer rates from the heating medium to the oil, the tube-and-tank type cracking unit involves first the transfer of heat from hot combustion gases to the cracking tube wall, and it is well understood that the unit heat transfer rates from gas to metal are low. In the usual cracking tube banks, the gas to metal heat transfer rates ordinarily lie between 3.0 and 4.5 B. t. u./sq. ft./deg. F./hr. in the convection section, and between 7.5 and 13.5 B. t. u./sq. ft./deg. F./hr. in the radiant section. At the oil side of the tubes, the unit heat transfer rates are higher, ranging from 25 to 150 B. t. u./sq. ft./deg. F./hr., although the latter is exceptionally high and can be maintained only during short time tests.

The oil is pumped through the tubes (still speaking of the usual tube-and-tank type unit) and is maintained under pressure sufficient to partially suppress vaporization of the low boiling fractions formed in the cracking tubes. However, extremely high pressures, and pressures greater than are utilized in any of the present commercial systems, would be required to hold gasoline fractions in the liquid phase. Consequently, the cracking tubes contain and are completely filled with a mixture of oil and vapor flowing in a turbulent stream in which neither the liquid nor vapor body is confined to any predetermined zone. While fairly high conversion ratios are obtainable in cracking tubes as described, particularly when aided by recirculation of residue, conditions in the tubes not only present a close approach to the theoretical maximum conversion, but actually cause unnecessary recracking of a substantial portion of the cracked gasoline vapors, with resultant production of excessive fixed gases and carbon.

These conditions arise largely as a result of the fact that some of the vapors, when generated at the wall of the tube, form a constantly present oil enveloping gas film held under cracking pressure between the tube and the oil and through which any cracking heat transfer must occur, and also due to the fact that the cracked vapors, once formed, must remain held in the hot oil stream for several minutes and throughout the remaining length of the cracking tubes, instead of being immediately released to a vapor zone maintained below the cracking temperature. There results a comparatively low heat transfer rate from tube to oil, and recracking of some of the vaporized cracked gasoline fractions due to the vapors being continuously held under high pressures and temperatures and in contact with the tube wall solution. Concomitantly, fixed gas forms as the gasoline fractions recrack, and heavy carbon deposits form on the tube walls. The faults

thus encountered may be summarized, at least in part, as lowered heat transfer rates, loss of gasoline fractions through fixed gas production, and excessive carbon formation.

In accordance with the invention, I propose to remedy these faults by changing the oil and vapor conditions within the tubes, and to materially raise the heat transfer rate at the inner surface of the tube and preferably at the outer surface as well. Instead of filling the tube with oil, I pass the oil in a film-like stream wetting the entire inner surface of the tube and surrounding a vapor space. By virtue of certain conditions in the oil film stream hereinafter explained in detail, there is established, instead of the usual comparatively low metal-to-oil heat transfer rate seldom even approaching 150 B. t. u./sq. ft./deg. F./hr., a boiling heat transfer rate, heretofore unattainable to my knowledge in oil cracking processes, of at least 2000 B. t. u./sq. ft./deg. F./hr. Additionally, and also by virtue of the filmed condition of the oil, almost instantly upon their formation at the tube surface, the cracked gasoline vapors are released through the film into a subcracking temperature vapor zone to prevent recracking of the vapors. In rapidly removing the vapors from a high temperature cracking to a low temperature subcracking zone, recracking and undue fixed gas formation is prevented. The carbon that necessarily forms during the cracking reaction, is promptly and continuously picked up and removed in the oil film stream. While confined to a defined zone not occupied by the oil, the cracked vapors released through the oil film are maintained in contact with the oil in being caused to flow through the tube counter-current to the oil film stream.

In order to obtain higher heat transfer rates at the outside surface of the tubes and also to facilitate more exact temperature control, I preferably heat the tubes by circulating a high heat conductive molten metal or salt in contact with them. And while I prefer, for various reasons, to use lead as the tube heating medium, it will be understood that conditions permitting, other metals or salts may be used instead. By thus exteriorly heating the tubes with molten lead, I obtain instead of the usual low gas-to-metal heat transfer rates seldom exceeding 14 B. t. u./sq. ft./deg. F./hr., a metal-to-metal transfer rate, under average conditions, of around 4000 B. t. u./sq. ft./deg. F./hr.

The invention is characterized by the fact that temperature, pressure and conditions in the oil stream which go to influence the cracking operation are capable of close control, the outside tube temperature may be regulated with exactness, and the film velocity and thickness controlled within close limits by regulating the vapor density or pressure and the rate of vapor flow within and counter-current to the oil film stream.

While thus far and for convenience of discussion I have referred to certain general aspects of the invention as applied to apparatus in which the oil is passed in a film stream within an exteriorly heated tube, it will be understood that in its broad aspects, the invention is not limited to the use of cracking tubes or any other particular form of cracking apparatus, but applies broadly to any form of apparatus for carrying out the method as defined in the claims. Preferably, however, I prefer to utilize as the cracking unit proper, an oil film heater comprising one or more vertically extending tubes.

The above mentioned and various additional features and objects will be understood to best advantage and without further preliminary discussion, from the following detailed description of a preferred, though typical, system embodying the invention. Throughout the description, reference is had to the accompanying drawings, in which:

Figure 1 is a diagrammatic view in flow sheet form showing a typical refining and cracking system embodying the invention;

Fig. 2 is an enlarged sectional detail showing the oil filming heater or cracking unit;

Fig. 3 is a fragmentary enlarged section on line **3—3** of Fig. 4, showing one of the oil filming nipples;

Fig. 4 is a section on line **4—4** of Fig. 3.

Fig. 5 is a flow diagram of the lead circulating system; and

Fig. 6 is a diagrammatic view illustrating the probable conditions existing in the oil films being subjected to cracking and vaporization in the cracking unit.

The invention may be most clearly described by first following through the flow sheet of Fig. 1, and then by taking up specifically and more in detail certain parts of the system with which the invention is more particularly concerned. The characteristics of the charging stock supplied from tank **10**, may be predetermined in accordance with the products desired, and operating conditions within the system. Any water contained in the charging stock may be preliminarily freed by first forcing the charging stock by pump **11** via line **12** through vapor cooler **13**, line **14***a* and the tubes in the convection section **23** of preheater retort **15**, and thence through line **16** into water vapor separator **17**. The latter consists of a tank having a constant liquid level float control **18**, and vent line **19**, the flow of water vapor through which is controlled by a suitable float operated valve **20**. The charging stock is then passed under pressure by pump **21** through line **22**, convection and radiant tube sections **23** and **24** of retort **15**, and thence via line **25** into the top of dephlegmator **26**. In the event the charging stock is substantially dry, water vapor separator **17** may of course be dispensed with.

Retort **15** is heated by hot waste gases from the lead retort, hereinafter described, and introduced through passage **27**, any additional heat required to preheat the oil to desired temperatures being supplied by burner **28** which may be controlled by a suitable regulator, not shown, in accordance with the outlet temperature of the oil leaving the radiant tube section **24**. The waste gases from the oil preheater retort pass through an air preheater **29** counter-current to an air stream to be used as combustion air in both the oil and lead retorts, and forced through the system by fan **30**. Passage **31**, receiving the preheated air from heater **29**, communicates with passages **32** and **33** leading to the oil preheater and lead retort burners.

The preheated charging stock in line **25** enters the dephlegmator through a valve **34** controlled by float operated regulator **35** acting to maintain the oil in the lower section of the dephlegmator at a constant predetermined level. The oil introduced into the top of the dephlegmator passes downwardly over trays **26***a*, or other suitable liquid-vapor contact media, in thorough admixture and intimate contact with vapors being discharged from line **36** into the dephlegmator at a point below trays **26***a*. As will later appear, these vapors consist mainly of cracked and the

lighter product fractions, for example gasoline and kerosene, although they will also carry substantial quantities of heavier fractions extending perhaps through the gas oil range. The charging stock reflux in the dephlegmator serves to condense and absorb all such heavier fractions as it may be desired to return to the cracking cycle, and also to retain in the system the latent heat of the heavier fractions given up through condensation.

Under some circumstances, depending upon temperatures and other operating conditions in the system, if all the charging stock were to be passed down through the dephlegmator, the resulting temperature of the oil in the base thereof may become excessively high and may reach the point at which undesirable preliminary cracking will occur. In order to anticipate this possibility, I provide a by-pass line **38** leading from a point in advance of valve **34** into the base of the dephlegmator, and carrying a valve **39** which is controlled in accordance with the temperature of the oil body in the bottom of the dephlegmator. Valve **39** permits a sufficient portion of the comparatively cooler charging stock to by-pass directly into the base of the dephlegmator, and to keep the temperature of the oil body therein from exceeding a predetermined maximum. In the event the remaining portion of the charging stock stream is insufficient to provide the necessary amount of reflux for the dephlegmator, make-up reflux may be supplied by returning to the dephlegmator some of the final condensate through line **40**.

From dephlegmator **26**, the preheated charging stock passes through line **41** to pump **42** and is forced by the latter through line **43** to the top of the oil film heater or cracking unit generally indicated at **44**. The latter is hereinafter described in detail, and it will suffice to observe at this point that the charging stock is passed downwardly through the oil film heater and subjected to cracking and vaporization, the vapors being released through line **36** to the dephlegmator, and the unvaporized residuum being discharged through line **45** to separating cylinder **46**, the residuum being introduced tangentially into the latter at some suitable point below the oil level L. The residuum is maintained at a constant level L by means of a float controlled regulator **47** operatively connected to valve **48** in the feed line **41**. Line **41** connects with the separating cylinder via line **41***a* below the point at which line **45** discharges into the cylinder but at a substantial distance above its base. Assuming pump **42** to operate at a constant capacity rate, regulator **47** and valve **48** act to maintain a predetermined oil level in the separating chamber by increasing or decreasing the pump supply through line **41** as the flow of residuum from the separator to the pump respectively decreases or increases.

Pump **42** thus normally feeds to the oil film heater, a mixture comprising preheated charging stock and residuum from separating cylinder **46**. Cylinder **46** is provided primarily for the purpose of allowing carbon or other solid bodies to settle and separate out of the oil, and in general practice, the separating cylinder need not have a specially large capacity with the view to maintaining the residuum under pressure and at substantially the temperature at which it leaves the oil film heater, for any long period of time. Cylinder **46** is primarily a carbon and oil separator and need only be sufficiently large to hold the residuum long enough (say five minutes) to permit the necessary proportion of the suspended carbon to settle out. Carbon settling to the base of the separating cylinder may be withdrawn along with some of the residuum, through line **50** and passed through cooler **51** to storage or a coking still.

Insofar as disposition of the residuum in the separating cylinder is concerned, the system may operate in several different manners. For example, it may be desired to crack the charging stock to produce a high gasoline yield and still produce a residuum conforming to free carbon specifications for fuel oil. Under such conditions, pump **42** will continuously circulate a mixture of charging stock and residuum from the separator through the cracking zone in the oil film heater **44**. The cracked gasoline vapors formed per pass of charging stock and residuum through the cracking zone may, for example, be within 10 to 15% of the feed, depending upon the characteristics of the charging stock, and depending upon the permissible percentage of free carbon in the product fuel oil which comprises that portion of the residuum not recirculated through the cracking zone, and being withdrawn through line **50**.

The pressure on the unit in this case will be such as to permit all gasoline, kerosene and substantially all the gas oil fractions to vaporize. The latter however will be condensed within the dephlegmator, combined with the charging stock, and returned to the cracking cycle, the recirculated resdiuum being drawn from the separator at a point between the liquid level and the residuum outlet at the base. In the oil body below outlet **41***a*, suspended carbon particles settle out and accumulate until the residuum draw-off through line **50** will meet required specifications. Assuming a constant proportionate rate of feed of charging stock and residuum to the oil film heater, the desired fuel oil residuum specification can be met by changing the pressure in the system, by varying the cracking temperature in the oil film heater, or by a combination of both.

Assuming it to be desired to operate the system on a non-residuum cycle, that is one in which the end products are gasoline and coke, either of two methods may be employed: Instead of recirculating residuum to the oil film heater, all the residuum may be withdrawn from the separator, taken to a separate coking still (not shown), and run to coke, the vapors from the coking still being separately condensed or returned to the cracking cycle with the fresh feed. As an alternative, all the residuum within the separator may be recirculated through the oil film heater and the carbon and coke permitted to accumulate in the bottom of the separating cylinder, to be withdrawn continuously or intermittently removed by suitable means.

The oil film heater, detailed in Figs. 2 to 4, comprises a vertically extending shell **53** containing a plurality of open oil cracking tubes **54** whose lower ends extend through tube sheet **53***a* and whose upper ends extend through the top closure **53***b* of the shell and tube sheet **55** forming the bottom of an oil distributing head **56**. Heating fluid, preferably molten lead, is fed into the bottom of shell **53** through inlet **57** and is discharged from the upper end of the shell through outlet **58**. In addition to flowing in a general path longitudinally of the tubes, and countercurrent to the down flowing oil film streams therein, the molten lead is also caused to flow transversely of the tubes and in reverse directions by a system of baffles

59. Except for its lower portion 53c which connects with line 45 leading to the separating cylinder, shell 53 is encased within the lead retort combustion gas passage 60 and is thus exteriorly heated.

The oil distributer head 56 comprises a shell 61 having a feed oil 62 connecting with line 43 and discharging into a tray 63 positioned directly above oil filming nipples 64, see Fig. 3, attached to the upper ends of cracking tubes 54. The oil fed into tray 63 drains through apertures 65 into the base 61a of the distributer head, and thence flows through a plurality of non-radial slots 66, see Fig. 4, in the oil filming nipples. By virtue of the arrangement of these slots, the oil passing through them is given a swirling motion and is caused to flow spirally in a film-like stream down the inside surfaces of the cracking tubes. Giving the oil film stream a spiral motion within the tubes increases the heat transfer rates between the tubes and oil film, the time of exposure of the oil to cracking temperatures, and the effectiveness of the oil stream in removing carbon particles from the tube wall.

Sections 54a of the tubes directly below the distributer head are not heated for the reason that it is desired first to cause the oil film to be established and the inner tube surface to be completely wetted before the oil enters the cracking zone, that is, the lower portions of the tubes within shell 53 contacted by the molten lead. Additionally, it is desired to avoid contact between the molten lead and tube sheet 55 so as not to crack the oil and deposit carbon within the distributer head.

A fragmentary section of one of the cracking tubes and the probable conditions within the oil film adjacent the wall of the tube are diagrammatically shown in Fig. 6. The oil film 68, surrounding a central vapor space 69 within the tube, may be regarded as comprising sections or layers 68a, 68b and 68c, in each of which the oil molecules are subjected to different and distinctly important conditions. In layer 68a contacting the wall of the tube, the downward velocity of the oil molecules is substantially zero, and the heat transfer through this layer is by conduction and also by convection, depending upon the molecule vibration rate induced by heating to high temperatures and vaporizing the oil molecules. In layer 68b, the oil flows in a downwardly spiralling path, and in layer 68c, at the oil-vapor interface, the oil molecules are given a turbulent, upwardly turning motion, as shown by the arrows, due to the upward velocity of the oil vapors in space 69. The arrows at 70 indicate the probable path of a reformed low boiling point molecule resulting from cracking and vaporization within the tube contacting layer 68a.

The oil molecules within layers 68a quickly approach the temperature of the tube wall and when that temperature is above 950° F., cracking of the heavier oil molecules and formation of low boiling point molecules occurs almost instantaneously. As a result of their instantaneous vaporization, the reformed molecules create turbulence within layer 68a, lower the resistance of the layer to heat flow, and set up a boiling condition at the metal surface of the tube wall. Thus instead of the usual metal-to-oil heat transfer rate, I obtain a boiling heat transfer rate many times greater.

In order to obtain this boiling heat transfer rate, it is essential that there be space available into which the molecule vaporizing at the metal surface can immediately escape, and that as little resistance as possible be offered to escape of the vaporized molecule into the vapor space. In the present instance, the vaporized molecules have only to traverse the oil film 68 in order to reach the vapor space 69, and it will be readily apparent that the oil film will offer no appreciable resistance to escape of the vaporized molecules. As the resistance to vapor escape from the heating surface decreases, the rapidity of vapor release and turbulence within the oil film increases, as does also the conduction of heat throughout the film. It is important to observe that instantly upon their formation, the cracked gasoline molecules pass into the lower temperature vapor zone 69, thus rendering it impossible for these molecules to become reheated and recracked with resultant formation of waste fixed gas and carbon.

The rate and condition of oil flow through the tubes is such that the inner surfaces are wetted throughout their lengths, thereby establishing a necessary condition for obtaining boiling heat transfer rates. Carbon released in the molecular reformation is picked up and washed from the tube surface by the oil film stream and carried to the separating chamber by the residual oil leaving the bottoms of the tubes.

The oil film and vapor within each tube flow counter-currently, with resultant heat transfer at the oil-vapor interface. Due to the motion of the oil particles in film layer 68c, there results an intimate admixture of such particles with those in the adjacent layer 68b, and a transfer of heat from 68c to 68b such as to rapidly elevate the oil film temperature throughout. Thus the oil film receives heat from both the oil-metal and oil-vapor interfaces while the high temperature cracked vapors are being projected through the film. By reason of the oil film and vapor stream counter flow, a certain amount of recycling or rectification occurs within the tubes themselves, some of the heavy vapor fractions being condensed through contact with the colder oil, particularly in the upper tube portions.

As previously stated, the vapors leave the oil film heater through line 36 and the heavier ends are removed in dephlegmator 26. The uncondensed vapors, mainly gasoline and kerosene, then flow through line 73 and coolers 13 and 14, and the condensate and uncondensed gases through lines 75 and 76 to gas trap 77. From the latter, the fixed gases are released through float controlled valve 78 in line 79, and the pressure distillate through line 80. Any suitable back pressure (the cracking pressure) may be maintained in the system by adjusting valve 81 in the pressure distillate discharge line 80. Referring again to Fig. 1, a vapor line 83 leading from separator 46 connects with a vapor by-pass line 84 connecting with the base 53c of the oil film heater shell, and with outlet vapor line 36. Depending upon desired operating conditions within the oil film heater, all or any selected portion of the vapors released from the residuum in the separator may be returned through lines 83 and 84 to the base of shell 53, circulated up through the cracking tubes and combined with the vapors being formed therein. The proportion of the vapors circulated from the separator to the oil film heater and those passed directly to vapor line 36, may be controlled by valve 86 in line 84.

The downward velocity of the oil film streams in the tubes is controllable by regulating the upward velocity of the contacting vapors, and therefore the resistance to flow of the oil streams. The

vapor velocity, in turn, is controllable either by adjusting by-pass valve 86, by adjusting the final pressure control valve 81 to vary the specific vapor volume, or by a combination of both. Through ability to regulate the oil film stream velocity, I am able to control the time of oil contact with the heating surfaces. By prolonging the time of contact, the maximum yield of distillate may be obtained by one pass of the charging stock through the tubes, or by shortening the time of contact and repeatedly recirculating the unvaporized residuum, with make-up charging stock, through the tubes.

The lead heating and circulating system comprises a retort 88 having a combustion chamber 89 and passages 90 and 91 which conduct a portion of the hot gases into passage 92 and in contact with the oil film heater shell 53. The combustion gas flow past heater shell 53 is controlled by a damper 93 which in turn may be regulated by any suitable means in accordance with the outlet lead temperature in line 94 connecting with the oil film heater lead outlet 58, see Fig. 2. Molten lead is circulated by a pump 95 via line 96 through the retort heating coils 97 in which the lead is heated to a temperature of from 1000 to 1200° F., or above, depending upon the characteristics of the charging stock and operating conditions. The molten lead then flows through line 98 and inlet 57 into the lower portion of the oil film heater shell, passes upwardly in contact with the cracking tubes and discharges through outlet line 94 into a drum 99 located within combustion gas passage 91. Pump 95 takes suction from the lead receiving drum 99 through line 100. It will be noted that all the lead circulating lines are contained within the hot combustion gas passages of the retort, thereby minimizing heat losses from the lead stream and providing effectively for its maintenance at the necessary high temperatures.

While it will not be necessary to describe pump 95 and the lead circulating system in full detail, as these matters are more particularly treated in my copending application on Molten metal pump, Ser. No. 726,652, filed on even date herewith, for the sake of completeness in describing the present system as a whole, I will refer briefly to certain aspects of the lead circulating system and its general mode of operation.

Referring now to Fig. 5, which diagrammatically illustrates the lead circulating system, all the lead for the system is initially charged into drum 99. After the lead has become molten, inert gas supplied under suitable pressure by pump 108 through line 109, is admitted to the drum above the lead level through the line 101 and under control of pressure regulator valve 102. The gas pressure in drum 99 is increased until the molten lead has become elevated through line 100 into the lower portion of the pump 95 and through pipe 102a into float chamber 102b to a predetermined level 103. At the same time, the molten lead fills the retort heating coil 97 and rises within the lower portion of shell 53 to a corresponding level. Valve 104 is then opened to admit inert gas through line 105 into gas chamber 106 of the float reservoir and under control of float operated valve 107. The inert gas admitted to the float chamber and through pipe 110 into the barrel of pump 95, prevents the molten lead from rising above level 103 and into the upper bearing 111 of pump shaft 112 being driven by motor 113. Additional gas is admitted through valve 102 to drum 99 to elevate the lead through line 98 to the top of the oil film heater and to completely fill the latter above level 103. By opening vent valve 115 in line 116, gas or air may be expelled from the system as the latter fills with the molten lead. The valve controlled vent also serves as a means for determining when the lead has reached the high point in the system. After the entire lead circulating system is filled with molten lead, valve 115 is closed and circulating pump 95 started into operation. In shutting down the lead circuit, it is only necessary to stop the pump, release the inert gas pressure and allow all the lead to drain back into drum 99.

I claim:

1. The method that includes, passing a film-like stream composed exclusively of oil cracking stock, downwardly over a vertically extending heating wall, said film-like stream being of uniform thickness excepting as its thickness is affected by diminution of the oil by vaporization, heating said wall to a temperature sufficient to crack and vaporize oil in that portion of the stream immediately adjacent one surface of said wall, uniformly releasing the oil vapors directly through the stream from the points at which said vapors are formed, into a vapor zone adjacent the exposed surface thereof, passing the vapors in a path counter-current to said oil stream, and regulating the rate of oil flow in said stream by varying the counter-current vapor velocity by controllably imposing a variable back pressure on said vapors.

2. The method of converting hydrocarbon oils comprising passing the oil downwardly over the inner surface of an internally unobstructed vertically oriented and substantially cylindrical heating tube of small diameter as compared with its length, in a film-like stream of progressively increasing temperature in its direction of flow, thereby leaving an unobstructed central vapor space surrounded by said film-like stream, circulating a stream of molten metal in contact with the outer surface of said tube and thereby heating the outer surface of the tube from the outside only, to a temperature causing oil in that portion of the stream immediately adjacent said inner surface of the tube to crack and liberate cracked vapors into said central vapor space, and subjecting vapors to condensation and recycling within the tube by passing them upwardly through said space in direct contact with the surrounding and relatively cooler portion of the oil-film stream in the upper portion of said tube.

3. The method of converting hydrocarbon oils comprising passing the oil downwardly over the inner surface of an internally unobstructed vertically oriented and substantially cylindrical heating tube of small diameter as compared with its length, in a film-like stream of progressively increasing temperature in its direction of flow, thereby leaving an unobstructed central vapor space surrounded by said film-like stream, circulating a stream of molten metal in contact with the outer surface of said tube and thereby heating the outer surface of the tube from the outside only, to a temperature causing oil in that portion of the stream immediately adjacent said inner surface of the tube to crack and liberate cracked vapors into said central vapor space, subjecting vapors to condensation and recycling within the tube by passing them upwardly through said space in direct contact with the surrounding and relatively cooler portion of the

oil-film stream in the upper portion of said tube, withdrawing unvaporized residuum from said tube, and returning at least a portion of said residuum to the upper portion of said oil stream.

4. The method of converting hydrocarbon oils comprising passing the oil downwardly over the inner surface of an internally unobstructed vertically oriented and substantially cylindrical heating tube of small diameter as compared with its length, in a film-like stream of progressively increasing temperature in its direction of flow, thereby leaving an unobstructed central vapor space surrounded by said film-like stream, heating the outer surface of said tube from the outside only, to a temperature causing oil in that portion of the stream immediately adjacent said inner surface of the tube to crack and liberate cracked vapors into said central vapor space, subjecting vapors to condensation and recycling within the tube by passing them upwardly through said space in direct contact with the surrounding and relatively cooler portion of the oil-film stream in the upper portion of said tube, and regulating the rate of oil flow in said stream by varying the counter-current vapor velocity.

5. The method of converting hydrocarbon oils comprising passing the oil downwardly over the inner surface of an internally unobstructed vertically oriented and substantially cylindrical heating tube of small diameter as compared with its length, in a film-like stream of progressively increasing temperature in its direction of flow, thereby leaving an unobstructed central vapor space surrounded by said film-like stream, heating the outer surface of said tube from the outside only, to a temperature causing oil in that portion of the stream immediately adjacent said inner surface of the tube to crack and liberate cracked vapors into said central vapor space, subjecting vapors to condensation and recycling within the tube by passing them upwardly through said space in direct contact with the surrounding and relatively cooler portion of the oil-film stream in the upper portion of said tube, and regulating the rate of oil flow in said stream by varying the counter-current vapor velocity by controllably imposing a variable back pressure on said vapors.

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