

March 6, 1934.

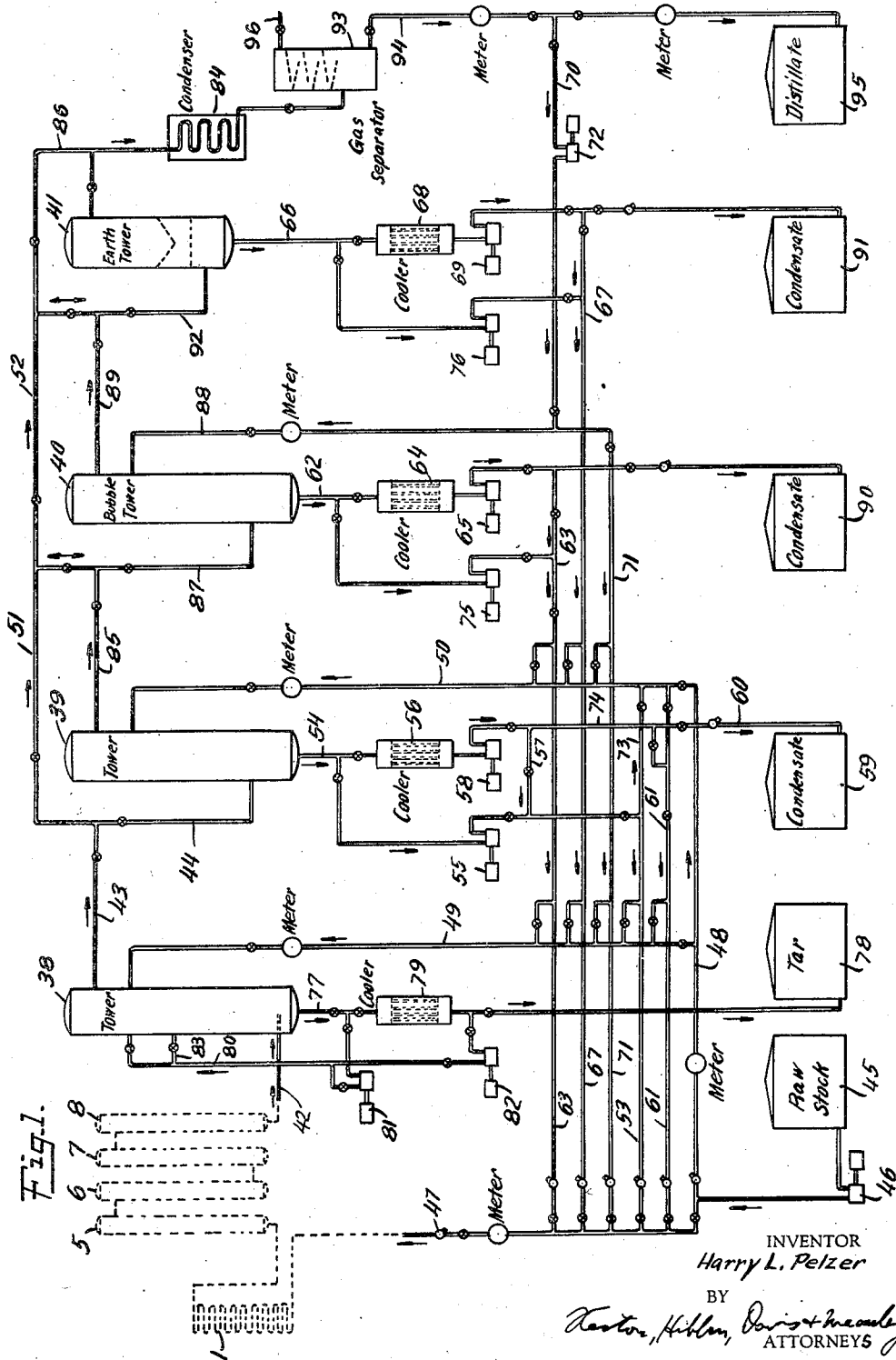
H. L. PELZER

1,949,655

ART OF CRACKING HYDROCARBONS

Filed June 13, 1927

4 Sheets-Sheet 1



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4 Sheets-Sheet 2

Fig. 1A.

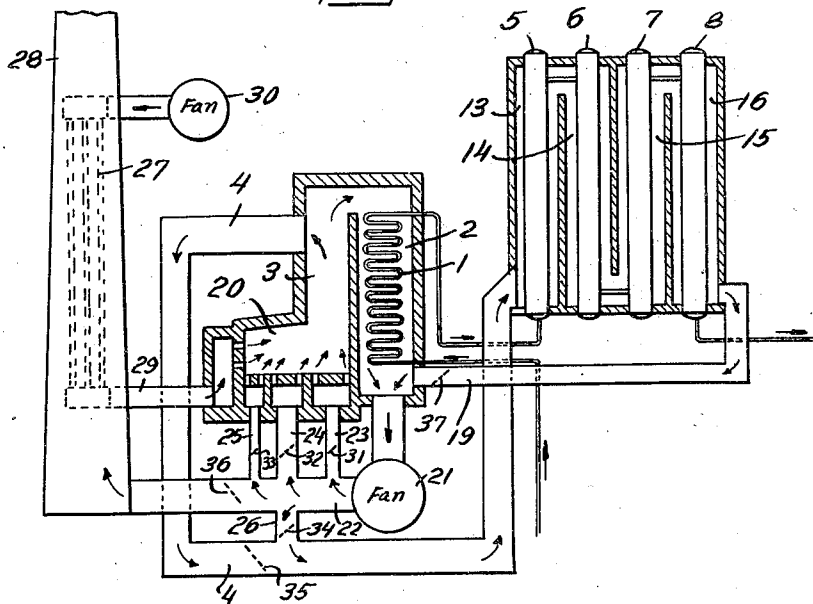
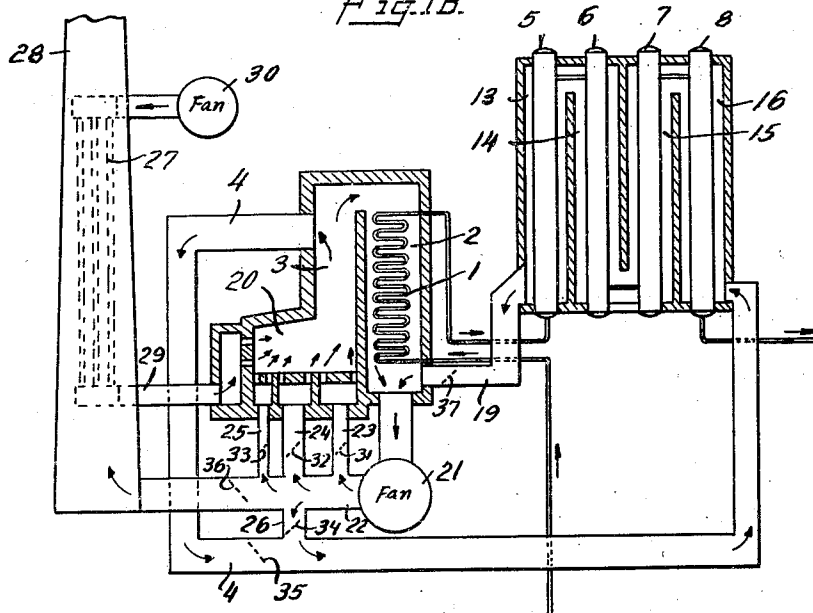


Fig. 1B.



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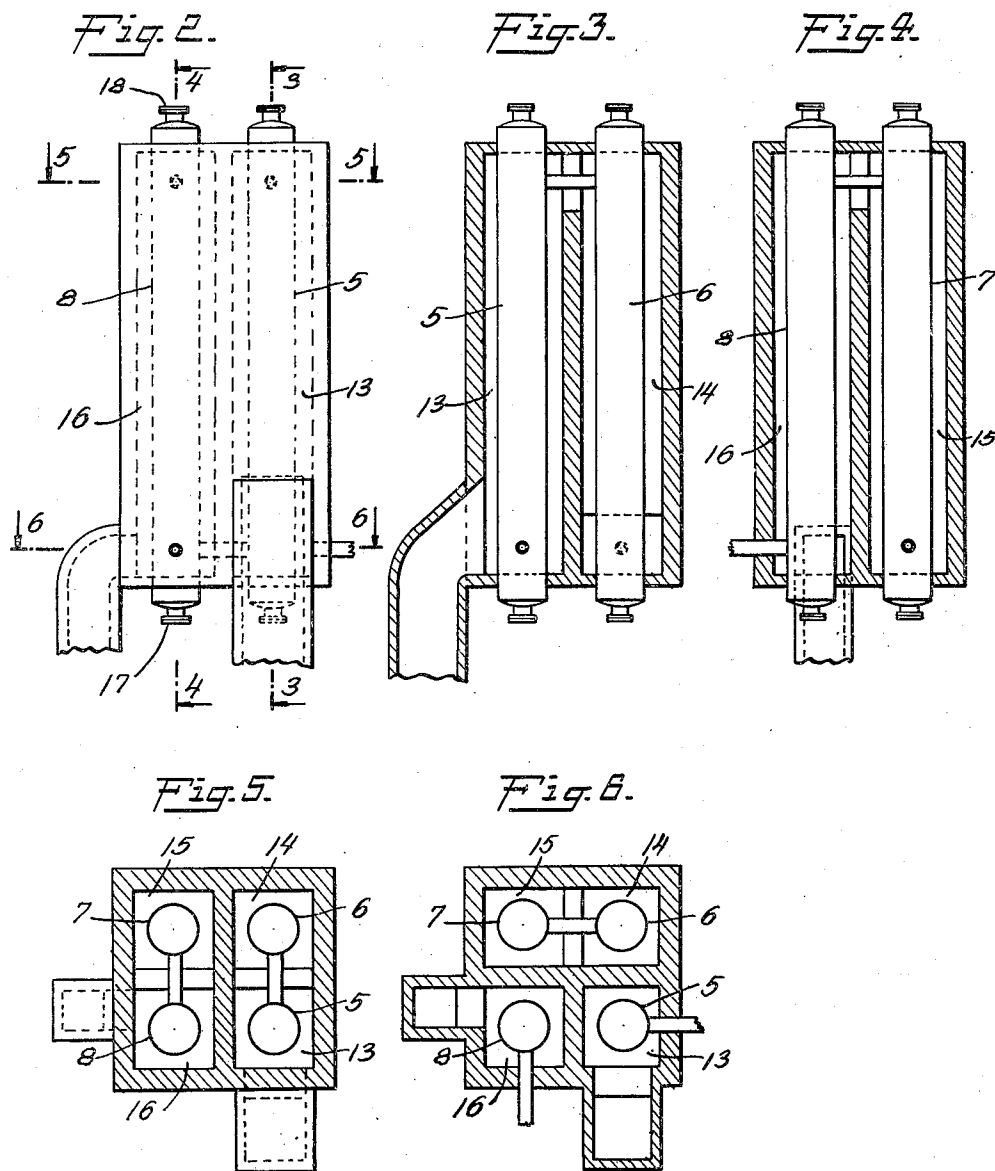
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4 Sheets-Sheet 4

Fig. 7.

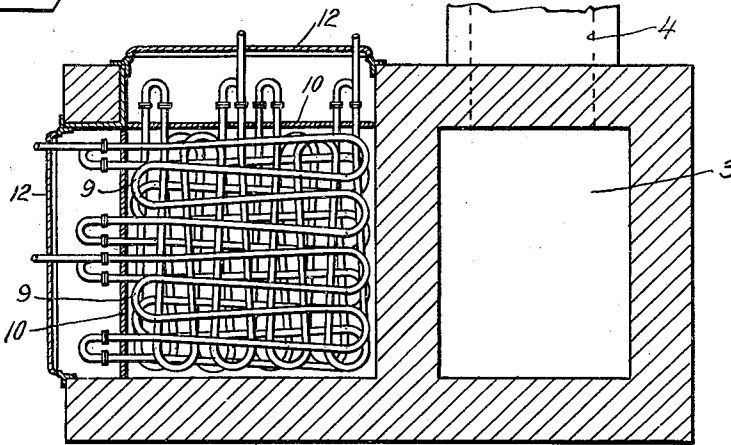
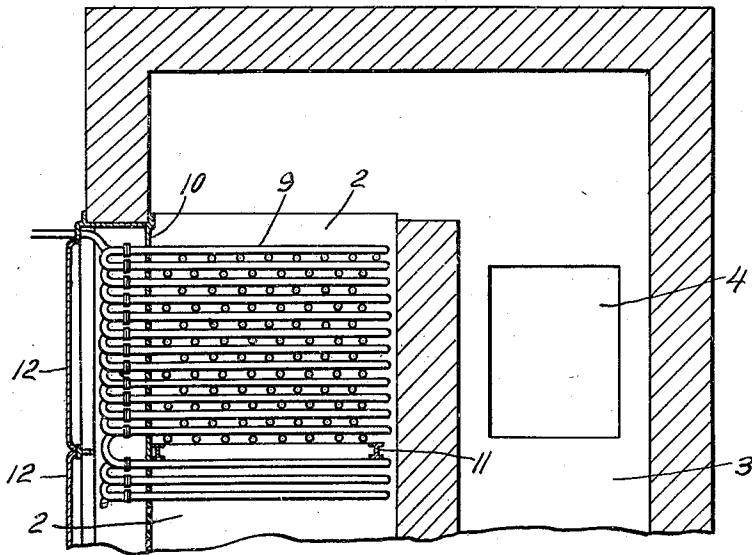


Fig. 8.



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UNITED STATES PATENT OFFICE

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ART OF CRACKING HYDROCARBONS

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Application June 13, 1927, Serial No. 198,621

22 Claims. (Cl. 196—61)

This invention relates to improvements in the cracking of heavier and higher boiling hydrocarbon oils for the production of lighter and lower boiling hydrocarbon oils. In particular, the invention relates to improvements in such operations where the heavier or higher boiling oil is cracked while in the vapor phase.

The invention is of special value and application in the production of gasolines or motor fuels having a relatively high critical compression or having anti-knock properties when burned in the usual type of internal-combustion gasoline engine.

Certain oils, such as kerosene and light gas oil, are more refractory with reference to cracking than are other heavier or higher boiling oils, such as heavier gas oil, and usually must be subjected to more intense or more severe cracking conditions for effective cracking than is necessary with such less refractory oils. The products of operations in which more intense or more severe cracking conditions are maintained include, if the conditions are appropriate, constituents of special value as components of motor fuels. Such more intense or more severe cracking conditions, however, tend to promote objectionable over-cracking with excessive formation of gases in-condensable at ordinary temperatures and pressures and excessive formation of carbon and tarry matter.

The products of a cracking operation are closely related to the temperature to which the oil is subjected and to the time during which the oil is subjected to the cracking temperature, both as to the amount of lighter or lower boiling constituents produced and as to the character of such constituents. In the production of a cracked oil for use as or in a motor fuel of relatively high critical compression, it is advantageous to subject the heavier or higher boiling oil to a high cracking temperature for a substantial period of time. With many of the more refractory stocks, such as mentioned above, the more advantageous range of cracking temperatures lies above the critical temperature of the stock so that the operation must be carried out substantially in the vapor phase. With heavier or higher boiling and less refractory stocks the more advantageous range of cracking temperatures may not exceed the critical temperature of the stock, but even in such cases the pressures necessary to maintain any substantial part of the stock in liquid phase are usually extremely high.

In carrying out my present invention, the heavier or higher boiling oil is maintained in

the vapor phase, substantially completely, throughout the cracking operation proper. Small amounts of tarry matter or carbonaceous matter formed during the cracking operation or very small amounts of very heavy constituents of the stock may be carried in the oil-vapor mixture as a fog or mist, but the predominating proportion of the oil is in the vapor phase.

Several difficulties are involved in heating oil in the vapor phase to a high cracking temperature and more difficulties are involved in maintaining it at a high cracking temperature, among which may be mentioned difficulties involved in efficient and effective heat transfer and in excessive formation of gases and carbon and tarry matter. This invention provides several improvements which assist in eliminating or minimizing such difficulties.

The invention also includes improvements in the complete operation and in the handling and treatment of the products of the cracking operation proper and of the stocks supplied to the operation. The invention includes improvements in both method and apparatus.

According to the present invention, a stream of the stock to be cracked is heated and vaporized, the vapors are then heated to a high cracking temperature, and the hot vapors are then maintained at a cracking temperature for a substantial period of time. The stock may be heated and vaporized and the vapors then heated to a high cracking temperature in a continuous heating conduit or a series of conduits arranged in a single heating furnace, or the stock may be vaporized in one operation and the vapors from this operation heated to an appropriate cracking temperature in a separate operation. To promote efficient and effective heat transfer, the vapors are heated to a high cracking temperature by heat exchange with heating gases at a substantially higher temperature. After being brought to an appropriate cracking temperature, the vapors are maintained at a cracking temperature by heat exchange or by being maintained in heat exchanging relation with heating gases at a temperature not substantially higher than that of the vapors, to avoid or reduce excessive formation of gases and carbon and tarry matter. The heating of the oil vapors to a high cracking temperature and the maintenance of the hot vapors at a cracking temperature, are moreover, combined in a particularly advantageous way in accordance with the invention.

Digestion of the vapors for a substantial period of time at a cracking temperature, in accordance

with the invention, improves the yield of lighter and lower boiling constituents and also assists in repressing the formation of constituents not suitable or desirable as components of the product, such as tarry matter and unstable oil constituents. The heat supplied during the digesting operation may advantageously be just sufficient to compensate for the heat absorbed by the cracking and that dissipated by radiation losses and the like. The temperature of the vapors during the digesting operation may be somewhat higher or somewhat lower as an average than that at which the vapors are supplied to the digesting operation. Generally counter-current or generally concurrent flow relations may be maintained between the heating gases and oil vapors which are in heat exchanging relation during the digesting operation. The cracking temperature may be maintained substantially the same throughout the digesting operation, or the cracking temperature may be reduced somewhat during or toward the end of the digesting operation. Each of these modes of operation has certain advantages.

The cracked vapors discharged from the digesting operation may be subjected to suitable refluxing or fractionating operations, and, before final condensation, the vapors may be subjected to refining treatment. The vapors, for example, may be subjected to a fractionating operation or to a refluxing operation for separation of heavier and higher boiling constituents suitable for further treatment in the cracking operation. Such reflux condensate may be returned while hot to the cracking operation together with fresh stock, or it may be cooled and then returned with fresh stock. Likewise, fresh stock exclusively may be supplied to the cracking operation. The vapors may also be subjected to a suitable fractionating operation for the direct production of a product of the desired boiling range.

Before the vapors from the digesting operation are subjected to such refluxing, fractionating or treating operations, it is advantageous to subject the vapors to a scrubbing treatment for the separation of any tarry or carbonaceous matter mechanically carried with the vapors, for example, with fresh stock or with condensate from some subsequent refluxing or fractionating operation or with mixtures of such stocks. The supply of such scrubbing agents may be regulated so that the scrubbing agent is vaporized substantially completely to pass on with the vapors from the cracking operation, or, where the stock supplied to the operation, or part of it, contains tarry or carbonaceous matter, such stock may be supplied to the scrubbing treatment for the separation of such tarry or carbonaceous matter therein together with tarry and carbonaceous matter carried by the vapors from the cracking operation. The vapors from the digesting operation may also be passed through a body of collected tar constituents to promote the removal of mechanically entrained tarry or carbonaceous matter. Such tarry or carbonaceous matter is advantageously separated from the vapors, or from stock supplied to the scrubbing treatment, and withdrawn without again being supplied to the cracking operation; as it might be, for example, if the vapors from the digesting operation were directly subjected to a refluxing operation from which condensate was returned to the cracking operation.

Stocks containing tarry or carbonaceous constituents may also be supplied to such scrubbing

treatment for separation therefrom of such constituents together with the tarry or carbonaceous matter separated from the vapors from the cracking operation proper. Raw stock containing tarry or carbonaceous matter, for example, may be introduced into the scrubbing treatment and the balance of the stock vaporized therein leaving behind such tarry or carbonaceous matter, this raw stock at the same time serving as a scrubbing agent. The vaporized part of the stock, or such portions of it as are appropriate to be supplied to the cracking operation proper, may then be condensed in some subsequent fractionating or refluxing operation from which condensate is returned to the cracking operation proper. Crude petroleum or topped crude oil, for example, may be supplied to the scrubbing operation and tar-free components of the crude oil supplied to the cracking operation proper as a condensate from some subsequent fractionating or refluxing operation.

The invention also provides for close control of the boiling range of the stock supplied to the cracking operation proper. The stock supplied to the cracking operation proper may be fractionated, as part of the complete operation, so that the stock forced through the heating and vaporizing and digesting operations is of advantageous character. The boiling range of the stock supplied to the cracking operation proper, including raw stock as well as refluxed stock, may thus be made wide or narrow and within such limits as may be desired. Raw stock may be supplied to one or more of the refluxing or fractionating operations, heavier components may be separated and discharged from the operation, components appropriate to be supplied to the cracking operation proper may be separated in one or more of the refluxing or fractionating operations, in a refluxing or fractionating operation subsequent to any in which heavier components are separated, and lighter components may be stripped from the stock without being supplied to the cracking operation proper. Similar components of the vapors from the cracking operation proper may be handled in the same way in the same refluxing or fractionating operations. Condensates from subsequent fractionating operations. For example, may be returned to preceding refluxing or fractionating operations for stripping of lighter components therefrom, and at the same time may serve as refluxing or condensing mediums. A heart cut from crude petroleum or from a topped crude oil, for example, may be supplied to the cracking operation proper by introducing the crude oil into the scrubbing treatment and condensing from the resulting vaporized fraction the intermediate components comprising the heart cut in a subsequent refluxing or fractionating operation and returning this condensate to the cracking operation proper. The stock so supplied to the cracking operation proper may include in admixture similar components condensed from the vapors from the cracking operation proper. By stripping stocks supplied to the cracking operation proper of light components, such as those desirable as components of the cracked product, overcracking of such components is avoided.

The cracked product is advantageously subjected to refining treatment before condensation so that the vapors forming the product are subjected to treatment while fresh from the cracking operation. The process heat, or part of it, may thus also be utilized for effecting or promoting

ing the refining treatment. The vapors, for example, may be passed through a body of fuller's earth or similar absorbent earth or clay while still at elevated temperature. The cracked product
 5 may thus be stabilized, chemically and physically, as part of the complete operation by direct fractionation and treatment. A part of the vapors may be condensed in the refining treatment and such condensate may include heavy polymerized constituents. This condensate may be re-
 10 turned to preceding refluxing or fractionating operations. If this condensate includes polymerized constituents of a tarry character or tending to form tarry constituents, it may be supplied
 15 to the scrubbing treatment for separation of such constituents therein.

The heat for the heating and vaporizing operations and the digesting operation may be supplied by heating gases from a common fire-box; the present invention provides a particularly advantageous apparatus and operation for so supplying the heat required by the cracking operation. The heating gases may be supplied to the heating operation at a temperature initially substantially higher than that at which the oil vapors are discharged from the heating operation and the heating gases may be supplied to the digesting operation at a temperature intermediate this initial temperature and the temperature at which the heating gases escape from the heating operation. The heating gases, for example, may be supplied to the heating operation and to the digesting operation from a common fire-box and the heating gases supplied to the digesting operation tempered to a lower temperature than that at which the heating gases enter the heating operation. This tempering may be effected by admixing with the heating gases from the fire-box a portion of the heating gases escaping from the heating operation or from the digesting operation or from both of these operations. The heating gases supplied to the heating operation from the common firebox may also be tempered, to a lesser degree, by admixing therewith a portion of the heating gases escaping from the heating operation or from the digesting operation or a mixture of the heating gases escaping from both operations. Remaining heating gases escaping from either the heating operation or the digesting operation or both may be utilized to pre-heat air for combustion in the firebox. However, separate heating furnaces may be used for the heating operation and the digesting operation. Where such separate heating furnaces are used, the heating gases supplied to each operation may also be tempered, as just described, by admixing therewith heating gases escaping from either or both of the operations.

Further features and advantages of the invention will be apparent as the description proceeds.

The invention will be further described in connection with the accompanying drawings which illustrate, in a diagrammatic and conventional manner, an apparatus embodying the invention and adapted for the practice of the invention, but it is intended and will be understood that this further description and illustration are for the purpose of exemplification and that the invention is not limited thereto.

In the accompanying drawings:

Fig. 1 represents, partly in elevation and partly in section, and partly by diagram only, one arrangement of apparatus embodying the invention and adapted for the practice of the invention,

Fig. 1A shows, in elevation and partly in sec-

tion, one form of heating furnace and digesting apparatus embodying the invention and adapted for the practice of the invention,

Fig. 1B shows, in elevation and partly in section, another form of heating furnace and digesting apparatus embodying the invention and adapted for the practice of the invention,

Fig. 2 shows, in elevation, one arrangement of the digesting chambers,

Figs. 3 and 4 are sections along line 3—3 and line 4—4 respectively of Fig. 2,

Figs. 5 and 6 are sections along line 5—5 and line 6—6 respectively of Fig. 2,

Fig. 7 is a plan view in section of one particularly advantageous form of heating element, and

Fig. 8 is a fragmentary view in elevation and partly in section of the heating element shown in Fig. 7.

Referring to the drawings, and particularly to Fig. 1, a stream of the stock to be cracked is heated and vaporized and the vapors are then heated to a high cracking temperature in the heating conduit 1 arranged in a heating flue in the heating furnace and the hot vapors discharged from this heating conduit are maintained at a cracking temperature for a substantial period of time while flowing in succession through the drums, or digesting chambers, 5, 6, 7 and 8.

The heating conduit 1 may comprise a tube or a bank of tubes through which the stock passes but once. This heating conduit is arranged in a furnace structure comprising a firebox 20, a heating flue 2 and an uptake flue 3 connecting the firebox with the upper end of the heating flue 2. Branch flue 4 communicating with the upper end of the uptake flue 3 is arranged for conducting heating gases from the uptake flue to the heating flues 13, 14, 15 and 16 in which the drums 5, 6, 7 and 8 are arranged. Heating gases escape from the heating flues 13, 14, 15 and 16 through the heating flue 2. The flow of heating gases through the heating flues 13, 14, 15 and 16 may be concurrent with the flow of oil vapors through the drums 5, 6, 7 and 8, as in the apparatus illustrated in Fig. 1A, or may be countercurrent, as in the apparatus illustrated in Fig. 1B. Where concurrent flow is maintained between the heating gases and the oil vapors in the digesting operation, the cracking temperature maintained during the digesting operation may be allowed to decrease somewhat during or toward the end of the operation, and this may assist in causing more unstable unsaturated constituents to react to form a more stable product. The maintenance of substantially the same cracking temperature throughout the digesting operation, however, may assist in minimizing any difficulties due to the formation of carbonaceous deposits in the digesting chambers.

A circulating fan 21 is arranged for withdrawing heating gases from the lower end of the heating flue 2 and from the heating flues surrounding the drums 5, 6, 7 and 8 through flue 19 and for supplying these relatively cool heating gases to the main 22. Branch flues 23, 24 and 25 are arranged to permit discharge from the main 22 into the firebox 20 through suitably arranged openings of part of the relatively cool heating gases for tempering the hot products of combustion from the firebox before the mixture of heating gases contacts with surfaces through which heat is transferred to oil or oil vapors and for protecting the refractory linings of the firebox and the uptake flue. Branch flue 26 is arranged to permit discharge from the main 22 into the flue 4 of part of

the relatively cool heating gases discharged by fan 21 for tempering or further tempering the heating gases supplied to the heating flues 13, 14, 15 and 16 in which the drums 5, 6, 7 and 8 are arranged. Heating gases not discharged through flues 23, 24, 25 and 26 are discharged through the heat exchanger 27, which may be arranged in a stack 28, for preheating air supplied to the firebox 20 for combustion of fuel therein. Preheated air from the heat exchanger 27 is supplied to the firebox 1 through flue 29. Gas or oil may be used as fuel, for example, and suitable burners therefor are arranged in the openings between the chamber in front of the firebox 20. A fan 30 may be arranged to effect or assist the supply of preheated air to the firebox. Suitable dampers 31, 32, 33, 34, 35, 36 and 37, are arranged in the various flues to assist in controlling the flow of heating gases.

In the apparatus illustrated, in both Figs. 1A and 1B, the flow of heating gases through the heating flue 2 and the flow of oil or oil vapors through the heating conduit 1 arranged therein are generally countercurrent, the heating gases passing downwardly through the heating flue and the oil or oil vapors passing in a generally upward direction through the heating conduit. The flow of heating gases through the heating flues 13, 14, 15 and 16 in which the digesting drums are arranged may be generally concurrent to the flow of oil vapors through the digesting drums 5, 6, 7 and 8, as in the apparatus illustrated in Fig. 1A, or generally countercurrent to the flow of oil vapors through the digesting drums 5, 6, 7 and 8, as in the apparatus illustrated in Fig. 1B. In the heating conduit 1, the oil or oil vapors is thus brought into heat exchanging relation with the heating gases first while the heating gases are at highest temperature and while the oil or oil vapors is at highest temperature and just before it is discharged from the heating conduit.

The apparatus illustrated, in both Fig. 1A and Fig. 1B, referring particularly to the arrangement shown for heating the heating conduit 1 in the heating flue 2 and the drums in the heating flues 13, 14, 15 and 16, is exceptionally flexible and affords accurate and independent control of the temperatures of the heating gases passed over the heating conduit and these drums and also provides for tempering of the heating gases passed over both the heating conduit and the drums in a particularly advantageous manner. The fan 30 is advantageous but not essential, as the flow of both air and heating gases can be effected by the fan 21 arranged as shown and the flow controlled by suitable dampers. Where fan 21 is arranged as shown a stack may be dispensed with or a very short stack may be used. The use of a fan as shown at 30 permits the maintenance of a more balanced draft, as compared to operation where such a fan is not used. With fan 30, leakage of excess air inwardly through the walls of the furnace setting may be avoided by operating with maintenance of substantially the same or a slightly higher pressure within the firebox than the prevailing atmospheric pressure.

One particularly advantageous form of heating element is shown in Figs. 7 and 8. This element comprises a group of heating coils made up of a number of heating units. These units are formed from a single pipe or tube bent to form a plurality of substantially straight sections connected by bends of relatively large radius. In the heating element shown, adjacent straight sections are farthest apart at the connecting

bend and are closest together at the other end. Provision is thus made for considerable tube length, a large number of straight sections, even though bends of very large radius are used. The end tubes of each unit extend beyond the extremities of the bends connecting the intermediate portions and are provided with flanges at the extended ends. The heating tubes are arranged in tiers transversely within the heating flue and the tubes in adjacent rows are disposed with their axes generally perpendicular to each other. The end tubes of each unit project beyond the plates 10 forming the inner wall of the heating flue proper so that the flanged connections between consecutive units of a coil are not directly subjected to the heating gases. Supporting members 11 are arranged transversely within the heating flue at suitable intervals to divide the coil or coils into sections opposite doors 12 arranged in the outer wall of the furnace structure so that any heating unit may be readily removed for cleaning, repair or replacement. Instead of being mounted directly over each other the heating units in alternate tiers are advantageously offset and connected serially by flanged return bends arranged at the required angle. By this staggered arrangement of alternate rows and transverse position of adjacent rows a compact heating element is obtained and efficient baffling of the heating gases is provided for by the tubes themselves while at the same time a free opening for the passage of the heating gases is provided and undue resistance to flow of the heating gases is avoided. The heating units may be connected serially to form a single continuous coil or they may be connected serially in groups to form a plurality of continuous coils of substantially equal length throughout each of which corresponding conditions will be maintained. This form of heating element can be cleaned of any deposited carbonaceous matter by burning out with air or a mixture of steam and air.

One particularly advantageous arrangement of the drum in which the digesting operation is carried out is shown in Figs. 2 to 6 inclusive. The digesting drums 5, 6, 7 and 8 are vertically arranged in the heating flues 13, 14, 15 and 16 respectively. These drums are connected in series and the connections are arranged so that the vapors are required to pass through substantially the entire length of each drum. Man-holes 17 and 18 are arranged to provide access to the interior of each drum for cleaning, inspection or repair. The flues in which the drums are arranged are similarly connected. These flues are advantageously arranged in the form of a square as shown in Figs. 5 and 6. This arrangement provides a maximum length of travel of the heating gases passing through the flues in contact with the external surfaces of the drums and also provides a minimum of external heat radiating surface, at least two walls of each flue being common with the walls of other flues in the series.

The tower 38 may be provided interiorly with baffles, best in its upper part. The tower 39 may be of any construction suitable for refluxing or fractionating the vapors. For example, it may be an ordinary baffle tower. The tower 40 may be of any construction suitable for accurate fractionation of the vapors. For example, it may be an ordinary bubble tower. The tower 41 is of any suitable construction adapted to hold a body of a refining agent, such as fuller's earth

or a treated clay, and to provide for passage of the vapors therethrough. These towers, particularly towers 38, 39 and 40, may with advantage be thoroughly lagged or thermally insulated to prevent or reduce heat loss.

In carrying out the invention in the apparatus illustrated, a stream of oil is heated and vaporized and the vapors are heated to a high cracking temperature in the heating conduit 1 arranged in the heating flue 2, the hot vapors discharged from the heating conduit are maintained at a cracking temperature for a substantial period of time while flowing through the drums 5, 6, 7 and 8, and the vapors discharged from the drums are passed in succession through towers 38 and 39 by means of connections 42, 43 and 44. The vapors from tower 38 may also pass directly to tower 40 or tower 41 through by-pass connections 51 or 51 and 52. Raw stock from tank 45 is supplied by means of pump 46 directly to the heating conduit, through connections 47, or, where the vapors from the digesting operation are subjected to a refluxing operation in tower 39, to the upper part of tower 39 and there introduced into direct contact with the vapors flowing therethrough, through connections 48 and 50, or to the upper part of tower 38 and there introduced into direct contact with the vapors flowing therethrough through connections 48 and 49, or the fresh stock may be supplied in part directly to the heating conduit and in part to either or both of towers 38 and 39. Where the vapors are subjected to a refluxing operation in tower 39, the condensate therefrom, together with any admixed unvaporized portions of stock introduced into the upper end of the tower, may be returned to the heating conduit, in whole or in part, through connection 53. This condensate or condensate mixture may be so returned hot or cold or at an intermediate temperature.

The scrubbing treatment effected in tower 38 and the refluxing or fractionating operations carried out in towers 39 and 40 may be effected or controlled by the regulated introduction of stocks or mixtures of stocks of appropriate character and at appropriate temperature. The fresh stock supplied to the cracking operation may be introduced into one or more of these towers to assist in effecting or controlling the scrubbing or refluxing or fractionating operation carried out therein, and at the same time may be preheated and subjected to fractionating treatment for the separation of components heavier or lighter than desired to be supplied to the cracking operation proper. Similarly, the condensates or condensate mixtures from tower 39 or tower 40 or both of these towers may be reintroduced into either or both of these towers to assist in effecting or controlling the refluxing or fractionating operations carried out therein, and at the same time components of these condensates or condensate mixtures heavier or lighter than desired to be supplied to the cracking operation proper may similarly be separated therefrom. Either or both of towers 39 or 40 may be operated as a refluxing or as a fractionating tower, that is all or part of the condensate or condensate mixture produced in either tower may be supplied to the cracking operation proper or may be discharged from the operation.

Where the vapors from tower 38, including vapors from the cracking operation proper and any vaporized components of stock introduced into tower 38, are subjected to a refluxing operation in tower 39, this refluxing may be controlled

by supplying raw stock through connections 48 and 50 and by regulating the rate at which raw stock is so supplied. Reflux condensate, together with any admixed unvaporized raw stock, discharged from tower 39 through connection 54 may be supplied to the heating conduit 1 directly through connection 53 by means of hot oil pump 55. Part of this hot oil mixture may be supplied to the upper part of tower 38 through connection 49. Part of the raw stock supplied to the operation may also be supplied to the upper part of tower 38 through connections 48 and 49. Condensate, together with any admixed unvaporized raw stock, discharged from tower 39, may be passed through cooler 56, in whole or in part, and then supplied, in whole or in part, to the heating conduit 1 through connections 57 and 53 by means of pump 58. Part of this condensate or condensate mixture, or all of it where the vapors from tower 38 are subjected to a fractionating operation rather than a refluxing operation in tower 39, may be so cooled and then discharged to tank 59 through connection 60. Part of such cooled condensate or condensate mixture may be supplied to the upper part of tower 38 through connections 61 and 49. The operation in tower 38 may thus be controlled or effected by the condensate mixture discharged from tower 39 through connection 54 either while hot or after cooling. For example, such of this oil mixture as is returned to the heating conduit 1 may be returned directly while hot and another part of the oil mixture may be introduced into the upper part of tower 38 after cooling. Where condensate or condensate mixture is not returned from either tower 39 or tower 40 to the heating conduit 1, all of the raw stock may be supplied directly to the heating conduit through connection 47, or where condensate or condensate mixture from either tower 39 or 40 is returned to the heating conduit the raw stock, or part of it, may be supplied to tower 38 through connections 48 and 49. Where raw stock is not introduced into the upper part of tower 39, or where the amount introduced is insufficient to effect the desired condensation, the operation in this tower may be effected or controlled with advantage by introduction of condensate or part of the condensate from tower 40 or 41, or by introduction of part of the final product, or by introduction of mixtures of these oils. For example, cooled condensate from tower 40 may be introduced into the upper part of tower 39 through connections 62, 63 and 50 and cooler 64 by means of pump 65; or condensate from tower 41 may be introduced into the upper part of tower 39 through connections 66, 67 and 50 and cooler 68 by means of pump 69; or part of the final condensate may be introduced into the upper part of tower 39 through connections 70, 71 and 50 by means of pump 72. Likewise, part of the oil mixture discharged from tower 39 through connection 54 may be returned to the upper part of the tower, after cooling or partial cooling, through connections 57, 73 and 50 or through connections 74 and 50 by means of pump 58, to assist in effecting or controlling the operation in the tower. The condensate mixture, or part of it, from tower 40 may be introduced hot into the upper end of tower 38 or tower 39 through connection 63 by means of hot oil pump 75, and the condensate mixture, or part of it, from tower 41 may similarly be introduced into the upper end of tower 38 or tower 39 through connection 67 by means of hot oil pump 76.

In tower 38, the hot vapors discharged from the

digesting drums 5, 6, 7 and 8 through connection 42 are subjected to treatment for the separation of any tarry or carbonaceous matter mechanically carried with the vapors. This material usually separates as a heavy residue or tar which is fluid while hot. Connection 77 is provided for the discharge of such fluid tars or residues from tower 38 to tank 78. Except for reintroduction into tower 38 as a scrubbing medium, this material is not returned to the system. Cooler 79 may be provided in connection 77 to cool the tar or residue to a temperature below its ignition point when exposed to air. It is advantageous to maintain a body of this hot tar or residue in the lower part of tower 38 and to discharge the hot vapors from the digesting drums into this liquid body below its surface. The operation in tower 38 may be controlled or effected as has been described; by the introduction of raw stock into the upper part of the tower through connections 48 and 49, or by the introduction of condensate or condensate mixture from one or more of the towers 39, 40 and 41, or by introduction of mixtures of these stocks. The supply of such oil mixtures, that is raw stock or condensate or condensate mixtures from subsequent refluxing or fractionating or refining operation, or mixtures thereof, is advantageously regulated so that substantially all of the oil mixture introduced is vaporized and escapes with the vapors from the digesting operation through connection 43. Where fresh stock initially containing tarry or carbonaceous matter is to be cracked, it may with advantage be supplied to tower 38 through connection 49 to separate such constituents with the tar and residue collected in tower 38 before the fresh stock is supplied to the heating conduit 1, the vaporized components of the raw stock, or those desired to be supplied to the heating conduit, then being condensed in tower 39 or tower 40 and supplied to the heating conduit as condensate or one or the other of these towers. To assist or to effect the scrubbing treatment carried out in tower 38, a part of the tar or residue discharged through connection 77 may be reintroduced into the tower through connection 80. This reintroduced tar or residue may be returned hot by means of pump 81 or after cooling by means of pump 82. In such operation, where fresh stock or condensate or condensate mixtures from one or more of the subsequent refluxing or fractionating or refining operations or mixtures thereof is also introduced into tower 38, such reintroduced tar or residue is advantageously introduced into tower 38 at a point lower than that at which such other stock is introduced, for example, through connection 83.

Where the cracked product is subsequently to be redistilled, the vapors escaping uncondensed from tower 39 may be discharged directly to condenser 84 through connections 85, 52 and 86 and condensed as a crude cracked product. Where it is desired to produce directly, for redistillation, a low end point product, the vapors from tower 39 are passed through connections 85 and 87 to tower 40. This tower may, for example, be a bubble tower of any standard construction. The fractionation of the vapors therein may be effected or controlled by returning a part of the final condensate and introducing it into the upper part of the tower through connections 70 and 88 by means of pump 72. Constituents heavier or higher boiling than desired as components of the final product are condensed in this tower and discharged through connection 62 while the vapors remaining uncondensed escape through con-

nection 89. These vapors may be passed directly to the condenser 84 through connections 89 and 86. As previously explained, the condensate or part of the condensate from tower 40 may be used to assist in effecting or controlling the operation in tower 38 or in tower 39. Storage tank 90 is provided for condensate from tower 40.

The products obtained from vapor phase cracking operations generally contain a relatively large percentage of unstable unsaturated constituents and, with most stocks, undesirable sulphur compounds which are not desirable as components of motor fuels. The removal of such objectionable constituents by ordinary refining methods involves several difficulties. Such cracked products may with advantage be treated with fuller's earth or treated clay or similar absorbent material while in the vapor phase. In the apparatus illustrated, the vapors escaping from tower 39, with or without intermediate fractionating in tower 40, may be subjected to treatment with such absorbent material in the tower 41. In this tower, the vapors are passed upwardly while still at elevated temperature through a body of fuller's earth or the like suitably supported in the tower. Part of the objectionable constituents is absorbed and part collects as a condensate in the lower part of the tower. This condensate may be discharged through connection 66 and cooler 68 to the tank 91. Where this condensate or part of this condensate is supplied to the upper part of tower 39, as previously described, heavier or higher boiling constituents thereof may be returned to the heating conduit 1 with condensate from tower 39 or with condensate from tower 40. If the condensate from tower 41 includes polymerized constituents of a tarry character or tending to form tarry constituents, it may be introduced into tower 38 through connections 66, 67 and 49 for separation of such constituents with the tar or residue separated in tower 38. Where the cracked product is subsequently to be redistilled, and in particular where such redistillation is in conjunction with the redistillation of other light oils or distillates of such character as not to require any different further refining treatment than the cracked fraction, the vapors from tower 39 may be passed directly to tower 41 through connections 85, 52 and 92. By passing the vapors from tower 39 through both the fractionating or refluxing tower 40 and the treating tower 41, however, only the lighter vapors are subjected to the treating operation and the capacity of the treating tower is accordingly increased.

The cracked product is condensed in condenser 84 and the condensate is separated from gases and any vapors remaining uncondensed in separator and receiver 93. This separator and receiver is advantageously provided with baffles, as illustrated, above the point of discharge of the connection from the condenser 84, to promote a clean separation between condensate and the gases and vapors remaining uncondensed. The condensate is discharged through connection 94, for example to tank 95, and the gases and uncondensed vapors are discharged through connection 96. The gas-vapor mixture discharged through connection 96 may be subjected to any suitable treatment for the recovery of condensable constituents, for example, it may be subjected to a scrubbing operation with an absorbent oil and the absorbed constituents distilled from the oil.

The several towers 38, 39 and 40 may be combined in operation to control the boiling range of the stock supplied to the heating conduit 1.

The towers through which the vapors from the digesting operation are passed, for example, are advantageously operated to prevent the return to the heating conduit of any very light components, particularly those suitable as components of the desired product. Condensate or condensate mixture from tower 40, for example, may with advantage be reintroduced into tower 38 or tower 39 to be revaporized and recondensed to strip from it any such light components, the heavier components being condensed and returned to the heating conduit in the condensate from tower 39. Tower 39 may be operated as a fractionating tower rather than as a reflux tower to separate from raw stock or condensates or condensate mixtures introduced into it components heavier than desired to be returned to the heating conduit 1, and the vaporized stock then condensed in tower 40 and returned to the heating conduit from this tower through connections 62 and 63. Crude petroleum, for example, may be introduced into tower 38, the tar free components of the crude oil vaporized in this tower, and these vaporized components condensed in tower 39 or 40 and returned to the heating conduit 1 in the condensate from either or both of these towers. At the same time, lighter components of the crude oil may be separated and discharged from the operation. For example, the operation of tower 39 may be regulated so that only those components desired to be supplied to the heating conduit are condensed therein and the lighter components may then be discharged from the operation in condensate from tower 40 or with the final condensate. A heart cut from crude petroleum or from a topped crude oil may thus be supplied to the heating conduit 1 by introducing the crude oil into tower 38 and condensing from the resulting vaporized fraction the intermediate components comprising the heart cut in tower 39 and supplying this condensate to the heating conduit. The condensate or condensate mixture, or part of it, may be returned from any one or more of the towers 39, 40 and 41 to the heating conduit 1 either while hot or after cooling; from tower 39 through connection 53 by means of pump 55 or pump 58, from tower 40 through connection 63 by means of pump 75 or pump 65, and from tower 41 through connection 67 by means of pump 76 or pump 69.

It will be appreciated that one raw stock or raw stock mixture or several separate raw stocks or raw stock mixtures can be handled advantageously in carrying out the present invention. For example, a gas oil or a light gas oil stock may be supplied to the heating conduit 1 or in part to the heating conduit 1 and in part to tower 39 and a crude oil or topped crude oil supplied to tower 38 in the same operation. Similarly, a gas oil or a light gas oil may be supplied to the heating conduit 1 or in part to the heating conduit 1 and in part to the tower 39 and a naphtha cut containing gasoline components may be supplied to the tower 39 together with such part of the gas oil or light gas oil as is supplied thereto in the same operation. In this respect, the invention provides for advantageous handling of stocks of different character and for separation of those components advantageously supplied to the heating conduit 1 from one or several such stocks all as part of the complete operation.

The conditions of temperature, and pressure maintained in the various steps of the operation may vary widely with the character of the oil treated and with the character of the product de-

sired. The pressure under which oil is supplied to the heating conduit 1 and the pressure maintained throughout the entire system are advantageously just sufficient to maintain flow through the apparatus. Higher pressures, however, may be employed.

An example will serve to illustrate one advantageous mode of operation of the invention. In a run in which the fresh stock was introduced into the tower 39 and the admixed condensate and unvaporized fresh stock supplied to the heating conduit from this tower, oil was supplied to the heating conduit through connection 47 at the rate of 715 gallons per hour. This stream of oil was heated and vaporized and the vapors were superheated to a temperature of about 1100° F. as the vapors were discharged from the heating conduit to the digesting drums. The temperature of the heating gases entering the top of the heating flue 2 was maintained at about 1575° F. The temperature of the heating gases entering the series of flues in which the digesting drums are arranged was maintained at about 1260° F. (Fig. 1A). The temperature of the hot oil vapors as discharged from the digesting drums was about 970° F. and that of the heating gases entering flue 19 was about 965° F. The temperature of the heating gases passing through the fan 21 slightly exceeded 900° F. The air passing through the heat exchanger 27 was preheated to about 550° F. and the temperature of the waste heating gases escaping from the heat exchanger 27 was about 350° F. The oil entering the heating conduit was at a temperature averaging about 425° F. and it was supplied under a pressure of about 80 pounds per square inch. A light gas oil stock at a temperature of about 36° F. was supplied to the upper end of tower 39 at a rate of about 410 gallons per hour. A part of the oil mixture from the lower end of this tower was cooled to about 70° F. and reintroduced into the upper part of the tower at a rate of about 105 gallons per hour. The temperature at the top of this tower was maintained at about 360° F. and the pressure at the top of this tower averaged about 0.82 inches of mercury. A part of the oil mixture from the lower end of tower 39 was also introduced into the upper part of tower 38 at a temperature of about 425° F. and at a rate of about 250 gallons per hour. The temperature at the top of tower 38 was maintained at about 512° F. and the pressure at the top of this tower averaged about 5.5 inches of mercury. Heavy tar was discharged from the bottom of tower 38 at a rate of about 70 gallons per hour. A pool of this tar was maintained in the lower part of the tower and the vapors from the digesting drums were discharged through the pool. The condensate from the vapors discharged from tower 39 amounted to about 285 gallons per hour, and from this crude cracked product about 131 gallons per hour of 420° F. end point gasoline were obtained on redistillation. The oil mixture supplied to the upper part of the tower 38 and to the heating conduit from tower 39 was supplied while at substantially the temperature at which it left the tower and without cooling. A substantial quantity of gases was produced, these gases including hydrogen, methane, ethylene, propylene, butylene, amylene and other light hydrocarbons.

In another run, the fresh stock was supplied directly to the heating conduit 1, the fresh stock being preheated to about 350° F., and that part of the condensate from tower 39 not supplied to the operation in tower 38 and reintroduced into tower

39 was run to storage through a cooler, or heat exchanger. The condensation in tower 39 was effected and controlled by cooling or reintroducing a part of the condensate from that tower and by introducing into the upper part of the tower a part of the condensed cracked product. The fresh stock was supplied to the heating conduit at a rate somewhat in excess of 700 gallons per hour. Otherwise about the same conditions were maintained; the temperature of the oil vapors passing from the heating conduit to the digesting drums and from the latter to the tower 38 was maintained at about the same values and the head temperatures of the two towers 38 and 39 were maintained at about the same values.

In still another run, the operation was carried out as just described except that the fresh stock was supplied to the heating conduit without being preheated at a temperature of about 60° F.

In the foregoing examples, it will be understood that the temperatures, pressures and rates of flow given are averages of operations lasting for periods upwards of ten days.

The invention is of general application in the cracking of heavier and higher boiling hydrocarbon oils, such as gas oils and kerosenes, for the production of lighter and lower boiling hydrocarbon oils, such as gasoline and gasoline-containing fractions, and it includes many features of general application in the cracking of hydrocarbon oils. As I have noted, however, it is of special value and application in the production of oils or oil constituents having a relatively high critical compression. The cracked products, or fractions of the cracked products, of the invention may be used as motor fuels or they may be blended with other motor fuels of lower critical compression to provide a composite product of higher critical compression.

I claim:

1. A method of cracking hydrocarbon oils, comprising flowing a stream of the oil through a heating operation and heating it in the vapor phase to a high cracking temperature therein and then through a digesting operation in which the hot vapors discharged from the heating operation are maintained at a cracking temperature for a substantial period of time, heating the oil in the heating operation by heat exchange with heating gases maintained in generally countercurrent flow with respect to the stream of oil, and maintaining the temperature of the oil in the digesting operation by heat exchange with heating gases of initially higher temperature than the temperature of the heating gases which have passed in heat exchange with the oil in said first mentioned heating operation maintained in generally concurrent flow with respect to the stream of oil.

2. A method of cracking hydrocarbon oils, comprising flowing a stream of the oil through a heating operation and heating it in the vapor phase to a high cracking temperature therein by heat exchange with heating gases and then through a digesting operation in which the hot vapors discharged from the heating operation are maintained at a cracking temperature for a substantial period of time by being maintained in heat exchanging relation with heating gases, separately supplying heating gases to both operations from a common firebox, tempering the heating gases supplied to the heating operation and further tempering the heating gases supplied to the digesting operation.

3. A method of cracking hydrocarbon oils,

comprising flowing a stream of the oil through a heating operation and heating it in the vapor phase to a high cracking temperature therein by heat exchange with heating gases and then through a digesting operation in which the hot vapors discharged from the heating operation are maintained at a cracking temperature for a substantial period of time by being maintained in heat exchanging relation with heating gases, supplying heating gases to the heating operation at a temperature initially substantially higher than that at which the vapors are discharged from the heating operation, and supplying heating gases to the digesting operation at a temperature lower than that at which the heating gases are supplied to the heating operation but higher than that at which the heating gases are discharged from the heating operation.

4. A method of cracking hydrocarbon oils, comprising flowing a stream of the oil through a heating operation and heating it in the vapor phase to a high cracking temperature therein by heat exchange with heating gases and then through a digesting operation in which the hot vapors discharged from the heating operation are maintained at a cracking temperature for a substantial period of time by being maintained in heat exchanging relation with heating gases, separately supplying heating gases to both operations from a common firebox and tempering the heating gases supplied to the digesting operation with heating gases discharged from the heating operation.

5. A method of cracking hydrocarbon oils, comprising flowing a stream of the oil through a heating operation and heating it in the vapor phase to a high cracking temperature therein by heat exchange with heating gases and then through a digesting operation in which the hot vapors discharged from the heating operation are maintained at a cracking temperature for a substantial period of time by being maintained in heat exchanging relation with heating gases, separately supplying heating gases to both operations from a common firebox and tempering the heating gases supplied to the digesting operation with heating gases discharged from the heating operation and the digesting operation.

6. A method of cracking hydrocarbon oils, comprising flowing a stream of the oil through a heating operation and heating it in the vapor phase to a high cracking temperature therein by heat exchange with heating gases and then through a digesting operation in which the hot vapors discharged from the heating operation are maintained at a cracking temperature for a substantial period of time by being maintained in heat exchanging relation with heating gases, separately supplying heating gases to both operations from a common firebox and tempering the heating gases supplied to the digesting operation with heating gases discharged from the digesting operation.

7. A method of cracking hydrocarbon oils, comprising flowing a stream of the oil through a heating operation and heating it in the vapor phase to a high cracking temperature therein by heat exchange with heating gases and then through a digesting operation in which the hot vapors discharged from the heating operation are maintained at a cracking temperature for a substantial period of time by being maintained in heat exchanging relation with heating gases, supplying the heating gases to both operations

from a common firebox, tempering the heating gases supplied to the heating operation with heating gases discharged from the heating operation and separately tempering the heating gases supplied to the digesting operation to a lower temperature than that at which the tempered heating gases are supplied to the heating operation with heating gases discharged from the heating operation.

8. A method of cracking hydrocarbon oils, comprising flowing a stream of the oil through a heating operation and heating it in the vapor phase to a high cracking temperature therein by heat exchange with heating gases and then through a digesting operation in which the hot vapors discharged from the heating operation are maintained at a cracking temperature for a substantial period of time by being maintained in heat exchanging relation with heating gases, supplying the heating gases to both operations from a common firebox, tempering the heating gases supplied to the digesting operation from the firebox with heating gases discharged from the heating and digesting operations and tempering the heating gases supplied to the heating operation from the firebox with heating gases discharged from the heating and digesting operations.

9. A method of cracking hydrocarbon oils, comprising flowing a stream of oil through a heating operation and heating it in the vapor phase to a high cracking temperature therein by heat exchange with heating gases and then through a digesting operation in which the hot vapors discharged from the heating operation are maintained at a cracking temperature for a substantial period of time by being maintained in heat exchanging relation with heating gases, separately tempering the heating gases supplied to the heating operation and the heating gases supplied to the digesting operation with heating gases which have once passed in heat exchanging relation with the oil.

10. A method of cracking hydrocarbon oils, comprising flowing a stream of oil through a heating operation and heating it in the vapor phase to a high cracking temperature therein by heat exchange with heating gases and then through a digesting operation in which the hot vapors discharged from the heating operation are maintained at a cracking temperature for a substantial period of time by being maintained in heat exchanging relation with heating gases, separately tempering the heating gases supplied to the heating operation and the heating gases supplied to the digesting operation with heating gases which have once passed in heat exchanging relation with the oil and preheating air for the combustion by which the heating gases are supplied by heat exchange with heating gases discharged from the heating operation and the digesting operation.

11. A method of cracking hydrocarbon oils, comprising flowing a stream of oil through a heating operation, a digesting operation, a tar separating operation and a refluxing operation in succession, heating the oil in vapor phase, to a high cracking temperature in the heating operation, maintaining the hot vapors discharged from the heating operation at a cracking temperature for a substantial period of time in the digesting operation, scrubbing the vapors with a liquid and thereby separating tar from the hot vapors discharged from the digesting operation in the tar separating operation, introducing fresh

stock to the refluxing operation in direct contact with the vapors therein to condense a part of the vapors and preheat the fresh stock, returning reflux condensate and admixed preheated fresh stock to the heating operation, and discharging the separated tar from the tar separating operation without permitting it to return to the said heating operation.

12. In a vapor phase cracking operation, passing the hot vapors from the cracking operation proper in succession through a tar separating operation and a refluxing operation, preheating fresh stock by heat exchange with the vapors in the refluxing operation and supplying preheated fresh stock to the tar separating operation whereby substantially all of the preheated fresh stock supplied to the tar separating operation is vaporized and tar is precipitated from the cracked vapors, discharging the separated tarry matter from the tar separating operation, and supplying reflux condensate together with a part of the preheated fresh stock from the refluxing operation to the cracking operation.

13. In a vapor phase cracking operation, passing the hot vapors from the cracking operation proper successively through a tar separating operation, a refluxing operation and a fractionating operation, reintroducing condensate from the fractionating operation into the tar separating operation, returning reflux condensate from the refluxing operation to the cracking operation proper, and discharging vapors including vapors of lighter components of the condensate reintroduced from the fractionating operation into the tar separating operation from the fractionating operation.

14. An apparatus for cracking hydrocarbon oils in the vapor phase, comprising a heating conduit and a digestion chamber of larger cross section than said heating conduit, means for forcing a stream of oil in succession through the heating conduit and the digestion chamber, means for heating oil in vapor phase to a high cracking temperature in the heating conduit, means for maintaining oil at a cracking temperature in the digestion chamber, a tar separator and a fractionating condenser and connections for passing vapors from the digestion chamber in succession through the tar separator and the fractionating condenser, means for reintroducing into the tar separator condensate from the fractionating condenser, means for discharging tar from the tar separator without permitting its return to the said heating conduit, and means for supplying fresh stock to the system.

15. An apparatus for cracking hydrocarbon oils, comprising a firebox, an oil heating conduit arranged in a heating flue, a digestion chamber arranged in a second heating flue, flues separately connecting the firebox with each of the heating flues, and means for repassing through the second heating flue together with fresh hot products of combustion from the firebox heating gases which have passed through the heating flues.

16. An apparatus for cracking hydrocarbon oils, comprising a firebox, an oil heating conduit arranged in a heating flue and a digestion chamber arranged in a second heating flue, flues separately connecting the firebox with each of the heating flues, means for admixing with hot products of combustion entering both heating flues from the firebox heating gases which have passed through one of the heating flues, and separate means for admixing additional amounts of such heating gases which have passed through one of

the heating flues with the heating gases entering the second heating flue.

17. An apparatus for cracking hydrocarbon oils, comprising an oil heating conduit arranged in a heating flue and a digestion chamber arranged in a second heating flue, a firebox and flues connecting it with each of the heating flues, circulating means and flues connecting the suction side thereof to each of the heating flues, a waste flue connected to the discharge side of the circulating means, and a flue directly connecting the discharge side of the circulating means and the second heating flue.

18. An apparatus for cracking hydrocarbon oils, comprising an oil heating conduit arranged in a heating flue and a digestion chamber arranged in a second heating flue, a firebox and flues connecting it with each of the heating flues, circulating means and flues connecting the suction side thereof to each of the heating flues, a waste flue connected to the discharge side of the circulating means, a flue connected to the discharge side of the circulating means communicating with the firebox, and a flue directly connecting the discharge side of the circulating means and the second heating flue.

19. A method of cracking hydrocarbon oils, which comprises flowing a stream of the oil through a heating conduit and heating it in the vapor phase to a high cracking temperature therein by heat exchange with heating gases of substantially higher temperature and maintaining the hot vapors discharged from the heating conduit at a cracking temperature for a substantial period of time by maintaining them in heat exchanging relation with heating gases of temperature approximately the same as that of the vapors, said last mentioned heating gases comprising at least a part of said first mentioned heating gases and heating gases other than said first mentioned heating gases.

20. In a vapor phase cracking operation, passing the hot vapors from the cracking operation proper in succession through a tar separating operation and a fractionating operation, con-

densing heavier constituents of the vapors in the fractionating operation, scrubbing the vapors in the tar separating operation with liquid condensate from the fractionating operation, and discharging from the system without again subjecting it to a cracking temperature tar as precipitated in the tar separating operation free from components suitable for further cracking.

21. A method of cracking hydrocarbon oils, comprising flowing a stream of the oil through a heating operation and heating it in the vapor phase to a high cracking temperature therein and then through a digesting operation in which the hot vapors discharged from the heating operation are maintained at a cracking temperature for a substantial period of time, heating the oil in the heating operation by heat exchange with heating gases maintained in generally counter-current flow with respect to the stream of oil, and maintaining the temperature of the oil in the digesting operation by heat exchange with a mixture of heating gases including heating gases other than the first mentioned heating gases maintained in generally counter-current flow with respect to the stream of oil, the temperature of the heating gas mixture supplied to the digesting operation being initially lower than the temperature of the heating gases supplied to the first said heating operation.

22. In a vapor phase cracking operation, passing the hot vapors from the cracking operation proper successively through a tar separating operation, a refluxing operation and a fractionating operation, scrubbing the vapors with a liquid in the tar separating operation and discharging separated tarry matter from the tar separating operation, reintroducing condensate from the fractionating operation into the refluxing operation whereby the reintroduced condensate is stripped of light components, discharging vapors including the vapors of such light components from the fractionating operation, and returning reflux condensate from the refluxing operation to the cracking operation proper.

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