Aug. 26, 1930. H. L. PELZER 1,774,291

ART OF CRACKING HYDROCARBON OILS

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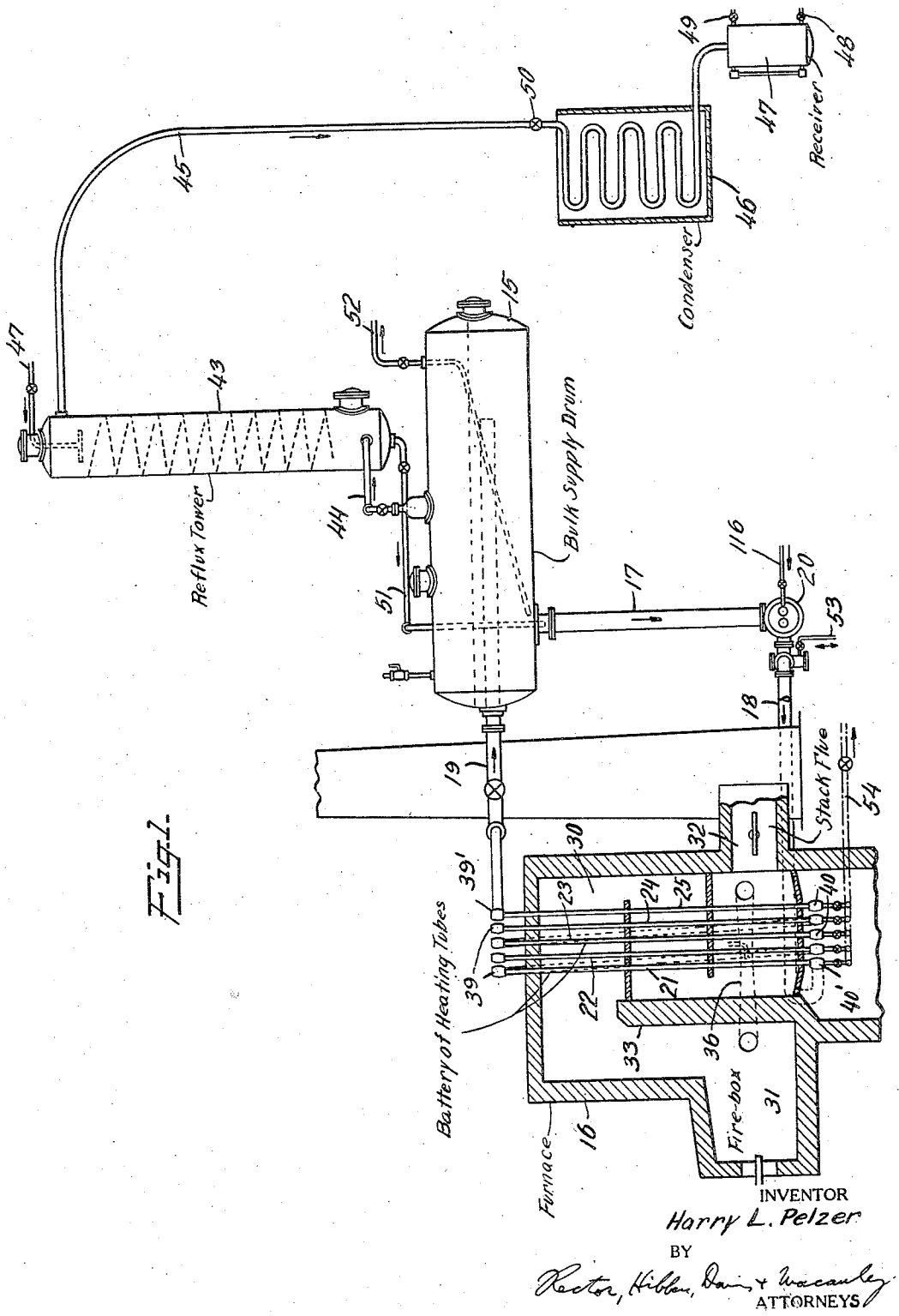


Fig. 1.

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Filed June 7, 1927 6 Sheets-Sheet 2

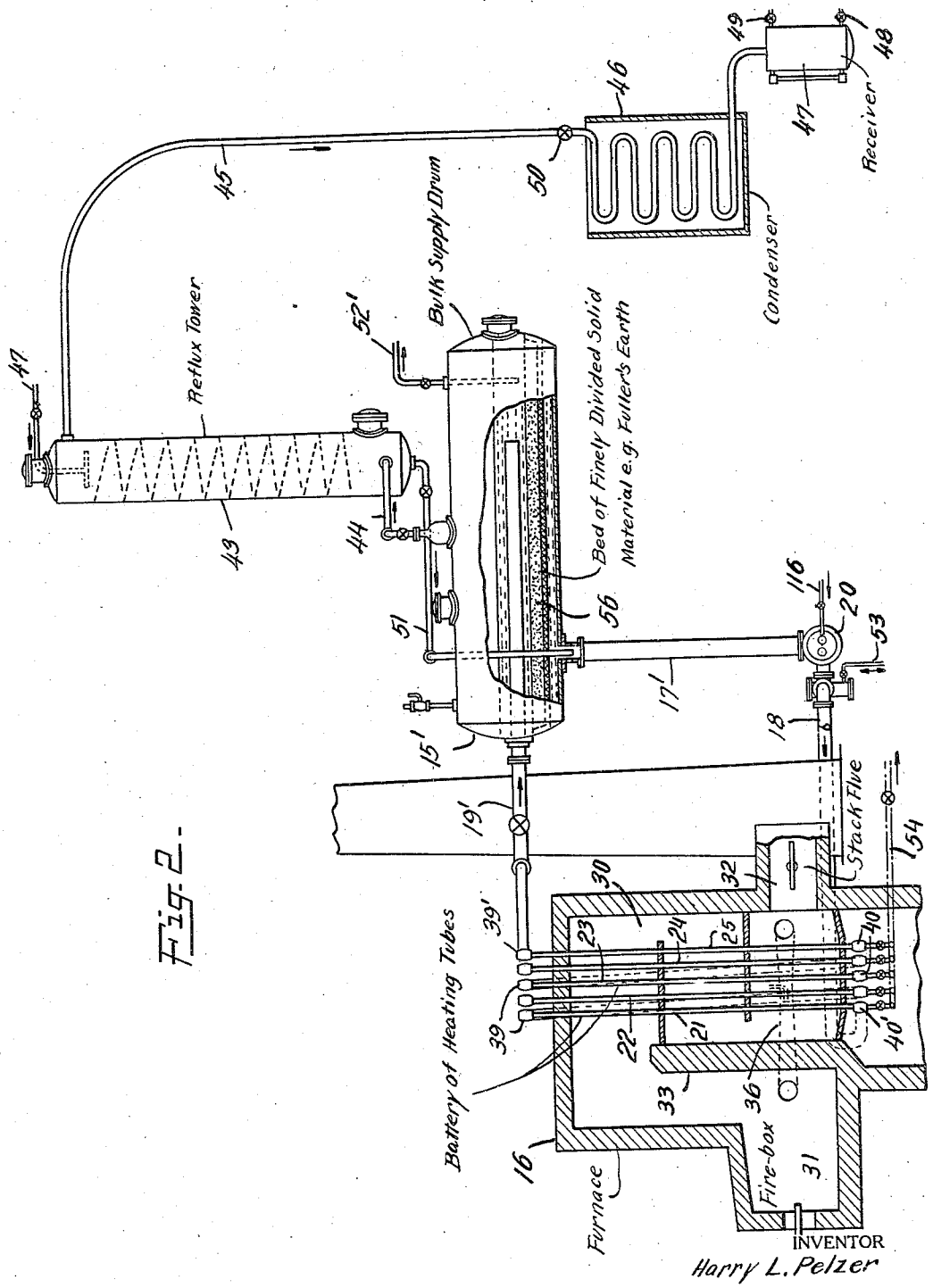


Fig. 2.

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ART OF CRACKING HYDROCARBON OILS

Filed June 7, 1927 6 Sheets-Sheet 3

Fig. 3.

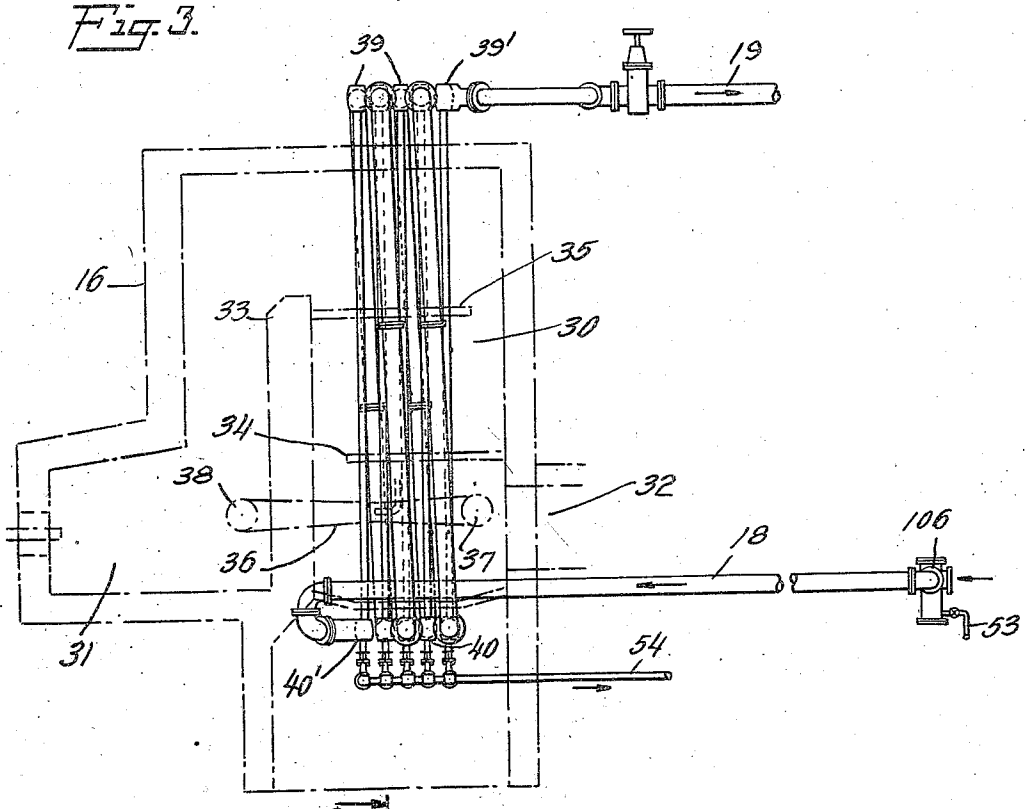
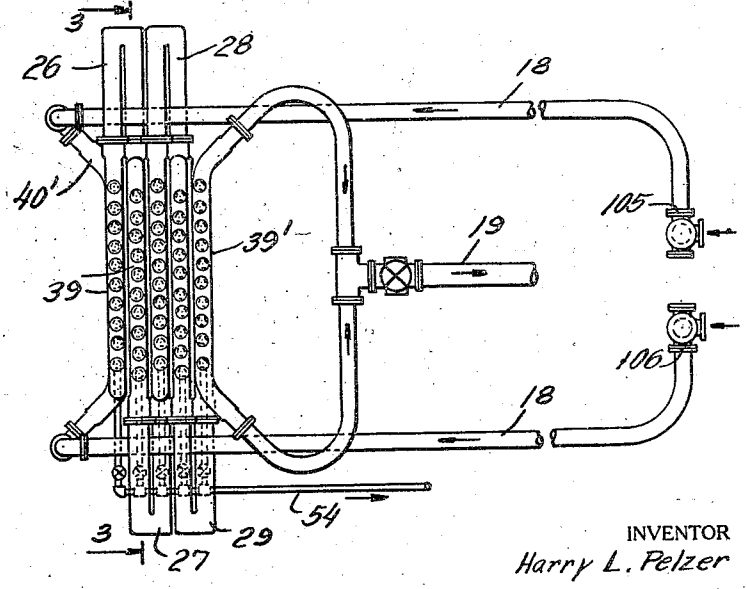


Fig. 4.



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ART OF CRACKING HYDROCARBON OILS

Filed June 7, 1927 6 Sheets-Sheet 4

Fig. 5.

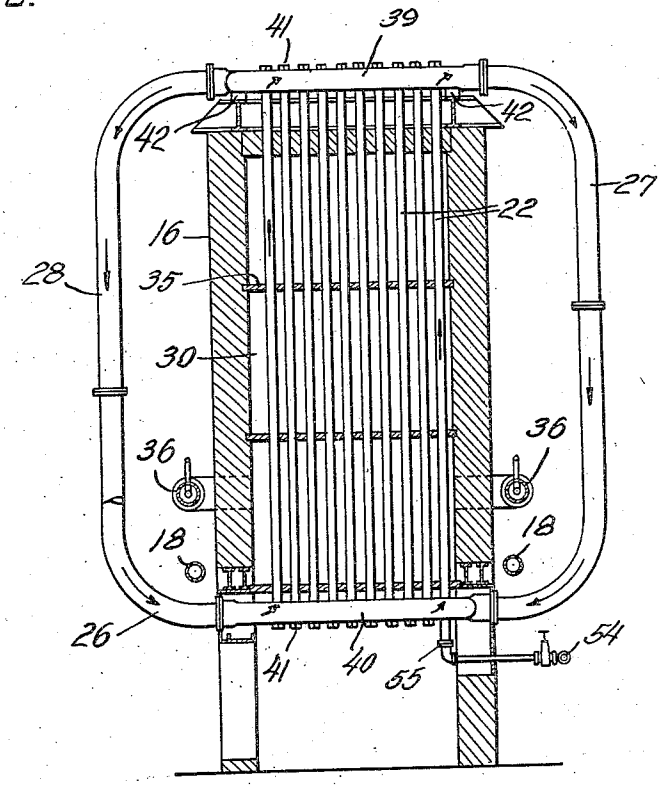


Fig. 7.

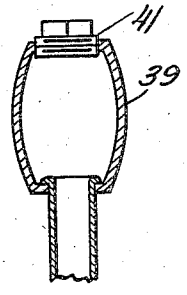
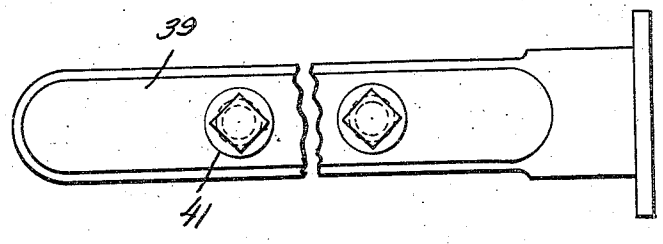


Fig. 6.



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ART OF CRACKING HYDROCARBON OILS

Filed June 7, 1927 6 Sheets-Sheet 5

Fig. 8.

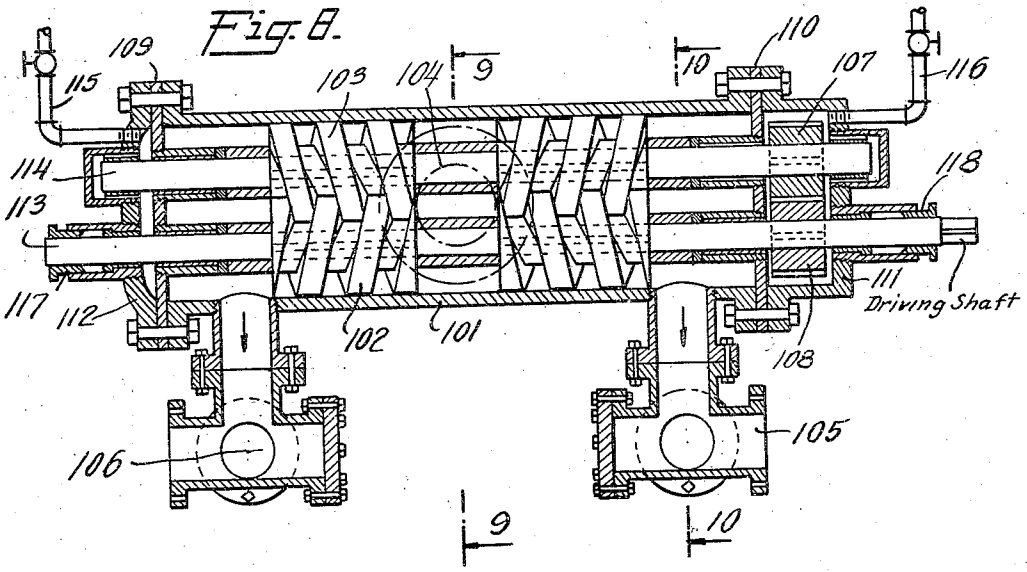


Fig. 9.

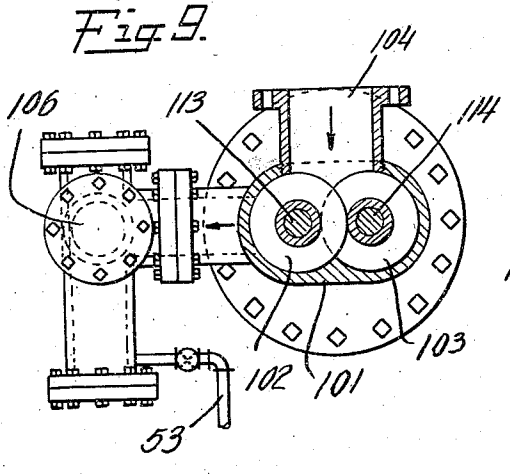
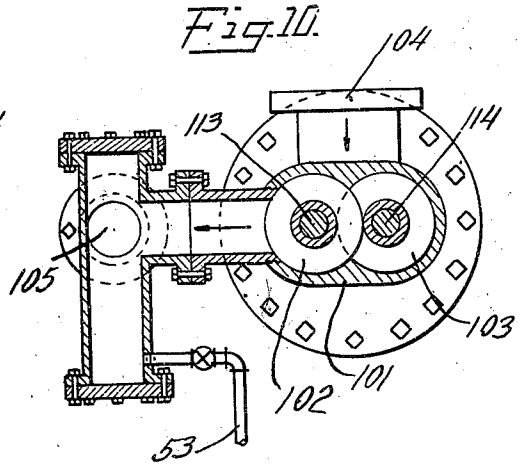


Fig. 10.



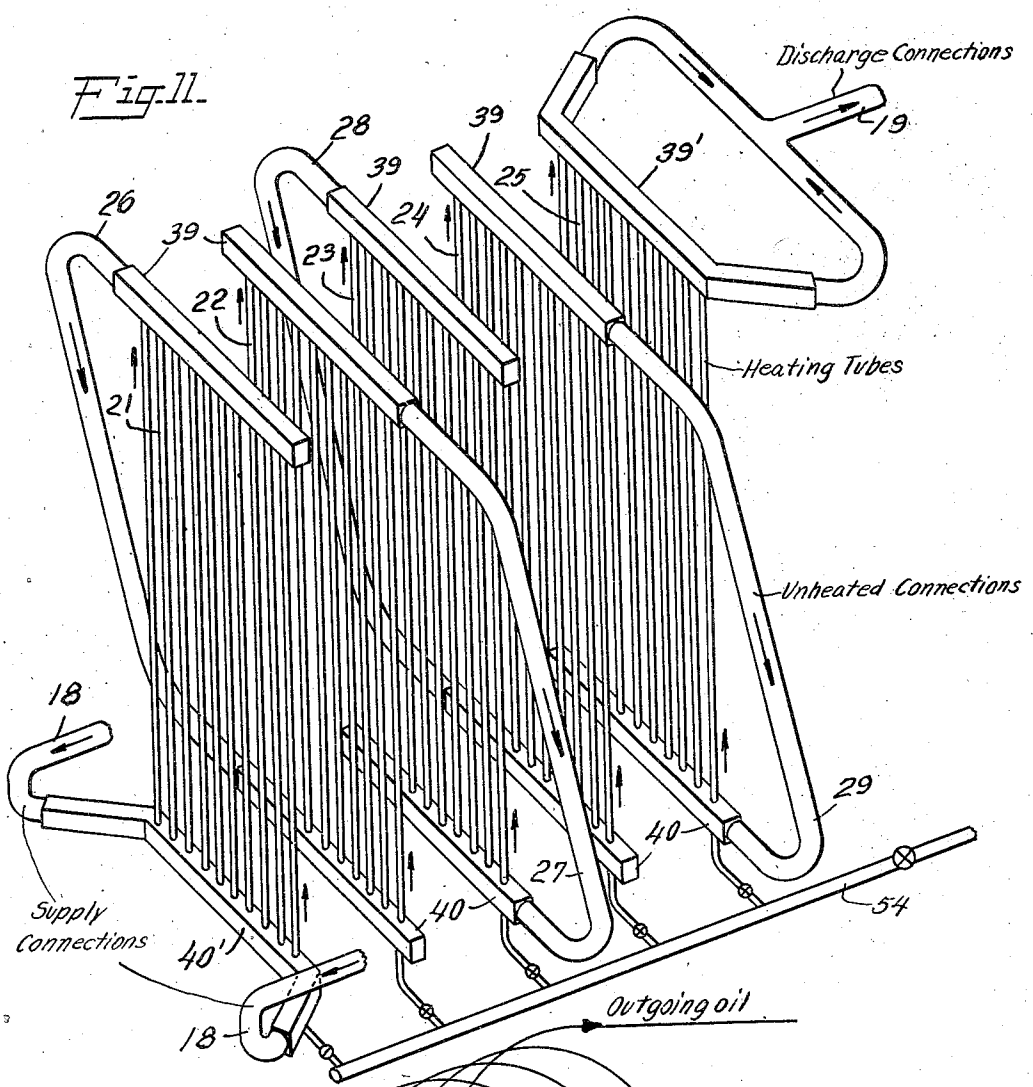
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ART OF CRACKING HYDROCARBON OILS

Filed June 7, 1927 6 Sheets-Sheet 6

Fig. 11.



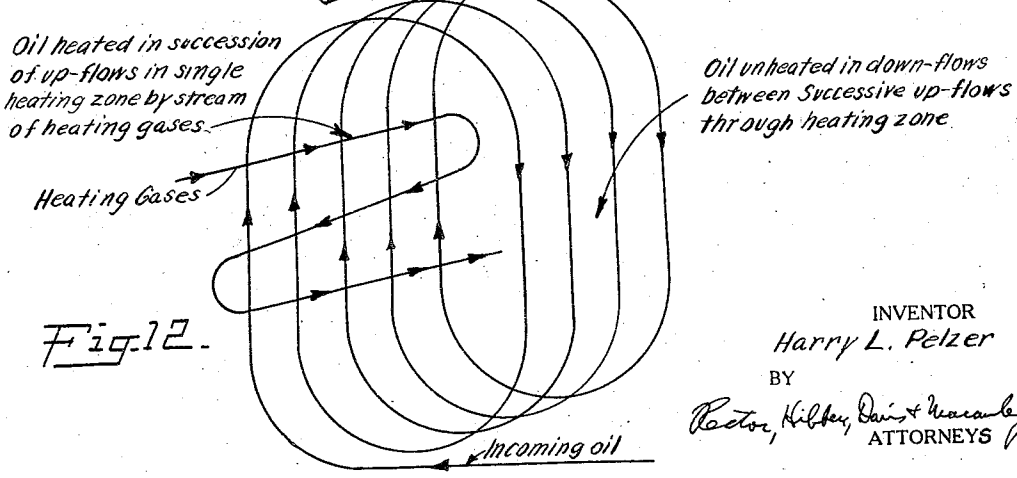


Fig. 12.

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Patented Aug. 26, 1930

1,774,291

UNITED STATES PATENT OFFICE

HARRY L. PELZER, OF HIGHLAND, INDIANA, ASSIGNOR TO SINCLAIR REFINING COMPANY, OF NEW YORK, N. Y., A CORPORATION OF MAINE

ART OF CRACKING HYDROCARBON OILS

Application filed June 7, 1927. Serial No. 197,035.

This invention relates to improvements in the cracking of heavier and higher boiling hydrocarbon oils, such as gas oil, for the production therefrom of lighter and lower boiling hydrocarbon oils, such as gasoline and gasoline-containing cracked distillates. The invention provides an improved pressure still or pressure still system for cracking hydrocarbon oils and an improved heater for heating oil to a cracking temperature, both of which have several important advantages.

In the improved heater of the invention a battery of tubes through which the oil is circulated is arranged in a furnace heating flue through which the heating gases for supplying heat to the oil are passed. This battery of tubes is made up of a succession of banks of vertically arranged tubes, the successive banks of tubes being connected in series by circulating connections connecting the upper end of the first bank with the lower end of the second bank, the upper end of the second bank with the lower end of the third bank, and so on through the series. These circulating connections are arranged externally of the heating flue in which the heating tubes are arranged, although provision may be made to reduce or prevent heat loss from the circulating connections. In operation, oil is supplied to the lower end of the first bank of heating tubes, circulated upwardly therethrough and heated therein by heat exchange with the heating gases, then circulated downwardly from the upper end of the first bank to the lower end of the second bank of heating tubes, circulated upwardly through the second bank and further heated therein, and so on, being discharged from the upper end of the last bank of heating tubes in the heater at a cracking temperature.

The improved pressure still or pressure still system of the invention comprises a bulk supply drum and an oil heater of the type just described with appropriate circulating connections including a suitable forcing means for circulating oil from the bulk supply drum through the several banks of heating tubes in the heater in a succession of passes and then back to the bulk supply drum. In one particularly advantageous form of the invention, a bed of finely divided solid material, such as fuller's earth or ground coke, is arranged in the bulk supply drum below the normal liquid level therein, so as to be submerged in the body of oil in the bulk supply drum during operation, and between the circulating connections from the battery of heating tubes to the bulk supply drum and the circulating connections from the bulk supply drum to the battery of heating tubes, so that oil recirculated through the heating tubes is passed through the bed of finely divided solid material. The finely divided solid material may be of a character exerting a selective absorbent action with respect to more objectionable constituents of the circulating still charge, in operation, or exerting a desulphurizing action, or it may exert simply a mechanical filtering action. In the combined apparatus of the invention, particularly where it includes a bed of finely divided solid material, the forcing means used is advantageously of positive displacement type adapted to maintain a high rate of circulation through the heater.

In the heater, the oil circulating therethrough is heated only while flowing upwardly through the vertically arranged heating tubes. There is thus but a minimum opportunity for deposit in the heating tubes of pitchy and carbonaceous solids and semi-solids formed in the cracking operation and uniformity of heat absorption around the entire circumference of the heating tubes is promoted. At the same time, the heater of the present invention provides for prolonged travel of the oil in the heating zone. The oil travels through the heating zone in a succession of passes in each of which the relation between the circulation of the oil and the flow of the heating gases is the same. In the heater of this invention, the circulating oil is thus passed again and again through the heating zone while the arrangement is such that the heating tubes are afforded a maximum of protection against overheating, general or local.

The improved heater of the invention is of special value and application in connection with operations in which hydrocarbon oils are subjected to relatively severe cracking conditions. Usually, an increase in the production of fixed gases, gases incondensible at ordinary temperatures and pressures, and pitchy or carbonaceous solids or semi-solids accompanies an increase in the severity of the cracking conditions to which an oil is subjected, but in the heater of this invention any difficulties due to an increase in the proportion of fixed gases or pitchy or carbonaceous materials in the oil circulating through the heater, even with prolonged oil travel, are reduced to a minimum. The heater thus has special advantages in the combined pressure still or pressure still system of the invention, where unvaporized oil discharged from the heater containing dissolved or suspended pitchy or carbonaceous solids or semi-solids is recirculated through the heater and where it is desirable to subject the oil to prolonged travel through the heating zone or where it is desirable to subject the oil to more severe cracking conditions.

In the production of motor fuel gasolines, for example, it is frequently desirable to subject the raw oil to be cracked to quite severe cracking conditions, say to temperatures in excess of 800° F. and under pressures up to 300 pounds per square inch or more, to secure products having relatively high critical compression or, as it is sometimes expressed, having anti-knock properties. It will be apparent that the apparatus of the present invention is particularly adapted for this purpose.

The fire-box for supplying hot products of combustion to the heating flue in which the battery of heating tubes is arranged, in the apparatus of the invention, is advantageously arranged to communicate with the upper end of the heating flue and the stack flue for escaping waste heating gases to communicate with the lower end of the heating flue, so that the heating gases pass generally downwardly through the heating flue. Suitable baffles may be arranged in the heating flue to promote or maintain distribution of flow of the heating gases therethrough, as by causing them to pass back and forth across the flue as they travel downwardly therethrough. In the apparatus of the present invention, this arrangement provides for the maintenance of generally countercurrent relation between the heating gases passing through the heating flue and the oil circulating through the heating tubes in each of the successive banks of heating tubes. It is also advantageous to supply the oil entering the heater first to the bank of heating tubes with which the fresh hot products of combustion, or the fresh heating gases, first contact. The several banks of heating tubes are also advantageously each arranged generally transversely to the flow of heating gases through the heating flue. Further to promote the efficiency of heat transfer through the heating tubes and to increase the capacity of the apparatus, to permit realization of high fuel efficiencies, to prevent overheating, particularly local overheating, of the heating tubes, and to promote uniformity of distribution of heat absorption throughout the entire battery of heating tubes, it is advantageous to recirculate through the heating flue together with fresh hot products of combustion, or fresh heating gases of high temperature, a portion of the heating gases escaping from the heating flue in which the heating tubes are arranged. Such recirculation of a portion of the escaping heating gases has special advantages in the apparatus of the present invention where the oil is circulated through the same heating zone in a succession of passes, particularly with respect to the maintenance of a high average temperature differential between the circulating oil and the heating gases in the heating furnace while avoiding overheating of the oil in any part of the battery of heating tubes.

The combined apparatus of the invention, a bulk supply drum with circulating connections to and from an improved heater of the invention and including a bed of finely divided solid material arranged in the bulk supply drum below the normal liquid level therein and between the circulating connections to and from the heater, has several further special advantages. In this general form of apparatus, it is advantageous to maintain a relatively low rate of circulation of the oil through the bed of solid material and a relatively high rate of circulation through the heating tubes. In the apparatus of this invention, a much higher ratio between the average velocity through the heating tubes and the average velocity through the bed of finely divided solid material can be maintained than, for example, in apparatus in which an equivalent number of heating tubes are connected all in parallel. Increased velocity of oil flow through the heating tubes, in the apparatus of the present invention, also further assists in promoting the efficiency of heat transfer to the circulating oil and in improving the capacity of the apparatus, as well as further protecting the heating tubes against overheating, general or local. The bed of finely divided solid material acts to remove more objectionable constituents from the circulating still charge in the operation of the apparatus, suspended pitchy or carbonaceous materials by filtering action and dissolved objectionable constituents by absorption or reaction, so that unvaporized oil recirculat-

ed through the heating tubes is kept relatively more free from constituents which are particularly active in formation of deposits in the heating tubes by passage through the bed of finely divided solid material. After passage through the bed of finely divided solid material, accordingly, the recirculated oil may be subjected to more severe cracking conditions without danger of objectionable deposition in the heating tubes than would be appropriate if the circulating oil had a higher content of pitchy or carbonaceous solid or semi-solid materials or objectionable constituents promoting deposition. In this respect the combined apparatus of the present invention is particularly advantageous, for it provides for removal of such objectionable constituents from the circulating charge before the oil is recirculated through the heating tubes and for prolonged travel of the oil through the heating tubes after the removal of such constituents, and is also particularly adapted to the maintenance of relatively more severe cracking conditions in the apparatus. Here again, the increased ratio between the average velocity through the heating tubes and the average velocity through the bed of finely divided solid material which can be maintained in the apparatus of the present invention assists in improving both the effectiveness of the bed of finely divided solid material and the operation of the battery of heating tubes and of the heating furnace.

The improved pressure still or pressure still system of the invention, particularly including the bed of finely divided material, makes possible improvement both with respect to efficiency and with respect to capacity, and also is particularly adapted for the production of motor fuel products having relatively high critical compression or having anti-knock properties.

The invention will be further described in connection with the accompanying drawings which illustrate, diagrammatically and conventionally, apparatus embodying the invention, but it will be understood that this further description and illustration is intended for exemplification and that the invention is not limited thereto. In the accompanying drawings;

Fig. 1 represents, in elevation and partly in section and with parts broken away, one form of pressure still or pressure still system embodying the invention,

Fig. 2 represents, in elevation and partly in section and with parts broken away, another form of pressure still or pressure still system, including a bed of finely divided solid material, embodying the invention,

Fig. 3 is an elevation, in more detail, of the battery of heating tubes and circulating connections illustrated in the oil heater shown in Figs. 1 and 2, the heating furnace construction being indicated in outlined vertical section,

Fig. 4 is a plan view, in more detail, of the battery of heating tubes and circulating connections illustrated in Figs. 1 and 2,

Fig. 5 is a transverse vertical section through the heating flue of the heating furnace and the battery of heating tubes illustrated in Figs. 1 and 2,

Fig. 6 is a fragmentary detail of one of the headers to which the heating tubes are connected,

Fig. 7 is a fragmentary section through one of these headers showing a connected heating tube,

Fig. 8 is a horizontal section through one form of circulating pump of special value and application in connection with the apparatus of this invention,

Fig. 9 is a section on line 9—9 of Fig. 8,

Fig. 10 is a section on line 10—10 of Fig. 8,

Fig. 11 is a simplified diagrammatic showing of the oil flow through the improved oil heater of the invention, and

Fig. 12 is a further simplified diagrammatic showing of the relation between the flow of oil and the flow of heating gases in the improved oil heater of the invention.

The pressure still or pressure still system illustrated in Fig. 1 comprises a bulk supply drum 15, a battery of heating tubes made up of a series of banks of heating tubes situated in the heating flue of the furnace 16, and circulating connections 17, 18 and 19 including a circulating pump 20 for circulating oil from the bulk supply drum successively through the series of banks of heating tubes and back to the bulk supply drum. The battery of heating tubes comprises a series of banks of vertically arranged heating tubes with connections for circulating oil from the top of the first bank to the bottom of the second bank, from the top of the second bank to the bottom of the third bank, and so on. These connections, connecting the upper ends of the banks of heating tubes, except the last, with the lower ends of the successive banks, are arranged externally of the heating flue in which the battery of heating tubes is arranged. The circulating connections 17 and 18 from the bulk supply drum connect with the lower end of the first bank of heating tubes in the series and the circulating connections 19 to the bulk supply drum connect with the upper end of the last bank of heating tubes in the series.

In operation, a charge of oil is maintained in the bulk supply drum 15, oil from this charge is circulated downwardly through connections 17 and 18 to the lower end of the first bank 21 of heating tubes, upwardly through this bank of heating tubes and heated therein, downwardly through the unheated connections to the

lower end of the second bank 22 of heating tubes, upwardly through this bank of heating tubes and heated therein, downwardly through the unheated connections to the lower end of the third bank 23 of heating tubes, upwardly through this bank of heating tubes and heated therein, downwardly through the unheated connections to the lower end of the fourth bank 24 of heating tubes, upwardly through this bank of heating tubes and heated therein, downwardly through the unheated connections to the lower end of the fifth and last bank 25 of heating tubes, upwardly through this bank of heating tubes and heated therein, and thence back to the bulk supply drum through connections 19. The flow of oil through the battery of oil heating tubes in the heating furnace is illustrated, perhaps more clearly, in Fig. 11. Referring to Fig. 11, the successive banks 21, 22, 23, 24 and 25 of heating tubes are arranged in the heating flue of the furnace and the connections 26, 27, 28 and 29 connecting the successive banks of heating tubes in the series are arranged externally of this heating flue. Oil supplied through connections 18 passes upwardly through each of the banks of heating tubes in the series in succession, being heated while flowing upwardly through the vertically arranged heating tubes in the successive banks but being unheated while flowing downwardly from the top of one bank to the bottom of the next bank, so that the circulating oil is heated only while flowing upwardly through the vertically arranged heating tubes. The oil is then discharged from the top of the last bank of heating tubes in the series through connections 19.

One particularly advantageous form of oil heater embodying the invention, that illustrated in Figs. 1 and 2, is illustrated in more detail in Figs. 3 to 7.

Referring particularly to these figures, the heating furnace is made up of a heating flue 30, a firebox 31 (equipped with suitable means for burning the fuel used to supply heat to the operation) communicating with the upper end of the heating flue, and a stack flue 32 communicating with the lower end of the heating flue. In operation, the hot products of combustion from the firebox pass upwardly from the firebox to the upper end of the heating flue, then downwardly through the heating flue, escaping from the lower end of the heating flue through the stack flue. In the furnace construction illustrated, the bridge wall 33 is arranged to prevent direct radiation from the firebox upon the heating tubes arranged in the heating flue. A battery of heating tubes made up of five banks of ten tubes each are arranged in and extend through the heating flue 30. Baffles 34 and 35 are arranged in the heating flue to cause the heating gases to pass back and forth across the flue as they pass downwardly therethrough. Each of the banks of heating tubes is arranged generally transversely to the flow of heating gases to the heating flue. Oil entering the battery of heating tubes is supplied first to the bank of heating tubes with which the fresh hot products of combustion from the firebox first contact. Steam jet blowers 36 are arranged, on opposite sides of the furnace setting, for withdrawing through openings 37 a portion of the heating gases about to enter the stack flue and returning it through openings 38 to be recirculated through the heating flue in admixture with fresh hot products of combustion from the firebox.

Each bank of heating tubes is made up of a number of tubes connected at opposite ends with an upper header 39 and a lower header 40. Excepting the lower header on the first bank of heating tubes in the series and the upper header on the last bank of heating tubes in the series, these headers are closed at one end and of the general construction illustrated in Figs. 6 and 7. Plugs 41 are provided opposite the ends of each of the heating tubes to permit access for cleaning or to provide for replacement of heating tubes. Supply connections connect with both ends of the lower header 40′ on the first bank of heating tubes and discharge connections connect with both ends of the upper header 39′ on the last bank of heating tubes. This arrangement of the first and last headers is advantageous in promoting uniform distribution of flow across the banks of heating tubes. Circulating connection 26, arranged on the far side of the heater as shown in Fig. 3, connects the upper header 39 on the first bank of heating tubes with the lower header 40 on the second bank of heating tubes. Circulating connection 27, arranged on the near side of the furnace as shown in Fig. 3, connects the upper header 39 on the second bank of heating tubes with the lower header 40 on the third bank of heating tubes. The succeeding banks of heating tubes are connected in a similar manner by circulating connections 28 and 29. These circulating connections, as shown particularly in Fig. 5, are arranged entirely outside of the heating flue 30 in which the heating tubes are situated. These circulating connections, 26, 27, 28 and 29 are thoroughly lagged or heat insulated to prevent heat loss. The bulk supply drum 15 and the circulating connections 17, 18 and 19, as well as the reflux tower illustrated, are also, with advantage, similarly lagged or heat insulated.

In the oil heater illustrated, the several banks of heating tubes, the lower headers 40 and 40′, and the circulating connections 26, 27, 28 and 29 are all suspended from the

upper headers 39 and 39′ which in turn are carried by supports 42 on the furnace setting. Free expansion and contraction of the elements making up the heater with change in temperature is thus provided for. The vertical arrangement of the heating tubes further assists in eliminating any tendency toward sagging of the heating tubes under operating conditions. By arranging all of the heating tubes in the several banks parallel to each other, as in the oil heater illustrated, it is also possible to use a gang cleaner.

One form of circulating pump, or forcing means, particularly adapted for use in conjunction with the apparatus of the invention is illustrated in Figs. 8 to 10. This pump, in so far as it is novel, is the invention of Thomas de Colon Tifft a resident of Chicago, county of Cook and State of Illinois. This pump is of positive displacement type adapted to maintain a high rate of circulation through the oil heater.

In the pump illustrated in Figs. 8 to 10, a stream of oil is drawn in through connection 104, divided, and forced out through connections 105 and 106. The forcing means comprise a pair of driven members 102 and 103 arranged in a closely fitting housing 101. Each end of each driven member is provided with a helical flange intermeshing with and closely fitting a similar but oppositely arranged flange on the other driven member, each of the helical flanges on opposite ends of the same driven member also being arranged in opposition. The driven members 102 and 103 are driven in opposite directions and maintained in fixed relation by means of gears 107 and 108. In operation, successive increments of oil are forced from the central space in the housing 101 between the pairs of intermeshing flanges at the opposite ends of the driven members to the opposite ends of the housing 101 by rotation, in opposite directions, of the driven members 102 and 103. From the end spaces in the housing, the oil is discharged through connections 105 and 106.

The housing 101 is closed at its ends by plates 109 and 110 which are bolted between the housing 101 and end covers 111 and 112. The driven members 102 and 103 are arranged on shafts 113 and 114 which extend through bearings carried by the plates 109 and 110 into the space between these places and the end covers 111 and 112. These bearings fit the shafts 113 and 114 loosely enough to allow for such expansion as takes place under operating conditions. To prevent the escape of hot oil from the interior of the housing 101, oil is supplied to the spaces between the plates 109 and 110 and the end covers 111 and 112 through connections 115 and 116 under pressure sufficient to maintain an inflow of oil through the bearings along the shafts 113 and 114 into the interior of the housing 101. This inflow of oil prevents the escape of hot oil, and also assists in cooling and lubricating the bearings. Operating extensions of the shaft 113 extend through stuffing boxes 117 and 118 for connection to some suitable driving means, such as an electric motor or steam engine. These stuffing boxes also, as well as the gears 107 and 108, are protected against the action of hot oil passing through the pump by the cool oil supplied to the spaces between the plates 109 and 110 and the end covers 111 and 112.

In one advantageous form of construction, the driven members 102 and 103 are machined from iron castings, the shafts 113 and 114 are of cold rolled steel, and the housing 101 and the end covers 111 and 112 are steel forgings. This construction provides for great safety as the entire pump mechanism is thus enclosed within a forged housing. The headers 39, 39′, 40 and 40′ in the oil heater illustrated may also with advantage be machined from unitary steel forgings.

Referring again to the apparatus illustrated in Fig. 1, a reflux tower 43 is arranged above the bulk supply drum 15, vapors of the cracked oil pass from the bulk supply drum 15 through vapor line 44 to the lower end of the reflux tower 43, and vapors remaining uncondensed escape from the upper end of the reflux tower 43 through vapor line 45 to the condenser 46. The reflux tower 43 is provided interiorly with baffles and a connection 47 is arranged for supplying fresh oil to the upper end of the reflux tower 43. The condenser 46 discharges into receiver 47 from which the condensed product is discharged through connections 48 and gases and vapors remaining uncondensed through connection 49. The pressure in the system may be maintained and regulated by means of valve 50 in the vapor line between the reflux tower and the condenser, or by means of suitable valves arranged beyond the condenser, for example in connections 48 and 49. Reflux condensate from the reflux tower 43, together with the unvaporized portion of fresh oil introduced through connection 47, is returned through connection 51 to the oil flowing through circulating connection 17. A connection 52 is provided for discharging tar or pitch-laden oil from the pressure still during operation. A connection 53 is provided for pumping out the still at the end of a run and for initially charging the still at the beginning of a run. To provide for complete draining of the battery of heating tubes, connection 54 is arranged with separate valved connections to each of the lower headers 40 and 40′. As illustrated in Fig. 5, these separate draining lines connecting to the lower head-

ers may open into each of the lower headers through the opening opposite the end tube in each bank of heating tubes. To permit removal of the connections when so made for cleaning, a flanged fitting is provided as shown at 55. Additional fresh oil, in excess of that supplied through connection 47 and in excess of that supplied through connections 115 and 116 for preventing the escape of hot oil and for cooling and lubricating the pump bearings, may be supplied, during operation, through connections 115 and 116 and forced into the pressure still through the pump bearings.

The pressure still or pressure still system, illustrated in Fig. 2, includes a bed 56 of finely divided solid material arranged in the bulk supply drum 15′ below the normal liquid level therein and between the circulating connections 19′ from the battery of heating tubes to the bulk supply drum and the circulating connections 17′ from the bulk supply drum to the battery of heating tubes. In this form of the invention, the unvaporized oil circulating in the pressure still or pressure still system is passed through the bed of finely divided solid material after each passage through the battery of heating tubes and before it is recirculated through the battery of heating tubes. The bed may, for example, be made up of from four to seven tons of fuller's earth of 15—30 mesh or of from two to five tons of coke ground to 15—30 mesh. This form of apparatus has the special advantage of providing for the maintenance of a high ratio between the average velocity through the heating tubes and the average velocity through the bed of finely divided solid material. Likewise, it provides for prolonged or more severe heating of the oil in passage through the battery of heating tubes between successive passes through the bed of finely divided solid material. In the apparatus illustrated in Fig. 2, the same parts described in connection with the apparatus illustrated in Fig. 1 are designated with the same reference characters. It will be noted that, in the apparatus illustrated in Fig. 2, the connection 52′ for discharging tar or pitch-laden oil is arranged for discharge of oil from above the bed 56 of finely divided solid material. The bed of finely divided solid material may be supported on any suitable supporting means adapted to permit free passage of the oil and to retain the finely divided solid material. This support, for example, may be made up of a number of screens of graduated fineness supported between perforated plates.

As an example of operation of the pressure still or pressure still system illustrated in Fig. 2, the still is charged with say 8,000 gallons of cold gas oil, and this still charge gradually brought to the desired cracking conditions of temperature and pressure. The pressure in the system may, for example, be maintained in the neighborhood of from 100 to 300 pounds per square inch, and the temperature maintained at a corresponding value. The temperature of the oil as it is discharged from the last bank of heating tubes in the heating furnace may be somewhat in excess of the temperature corresponding to the pressure at that point, that is the oil may be somewhat superheated as it is discharged from the battery of heating tubes. After the still is brought to operating conditions, fresh oil may be supplied through connection 47 to maintain the desired head temperature at the top of the reflux tower 43, and additional fresh oil may be supplied through connections 115 and 116. The total amount of fresh oil so supplied may amount to as much as 1,500 gallons to 2,500 gallons per hour or more. Likewise, during operation, as much as 500 gallons to 1,500 gallons per hour or more of tar or pitch-laden oil may be discharged through connection 52′. The rate of circulation through the circulating pump 20 may be maintained in the neighborhood of 4,000 gallons per minute. The bed of finely divided solid material is replaced with fresh or regenerated material when it becomes saturated with pitchy or carbonaceous material.

It will be apparent that the improved oil heater of the invention has several advantages for heating oil to a cracking temperature independently of its particularly advantageous application in the combined pressure still or pressure still system of the invention. It is, for example, useful in connection with so-called once through operations in which the oil circulated through the oil heater and heated therein to a cracking temperature comprises only fresh oil or fresh oil admixed with reflux condensate. The oil heater of the invention is, however, particularly advantageous in connection with pressure stills or pressure still systems in which unvaporized oil discharged from the heater is again recirculated therethrough.

In one aspect, the present invention includes or provides an improved method of heating hydrocarbon oils to a cracking temperature in which the oil is circulated in a series of successive passes upwardly through a heating zone, downwardly outside of the heating zone, upwardly through the heating zone, and so on, so that the oil is heated only while circulating upwardly through the heating zone, and the total stream of oil finally discharged from the heating operation at a cracking temperature. In this operation, the direction of circulation of the oil in each of the successive passes through the heating zone is the

same, and the same relation is maintained between the flow of heating gases through the heating zone and the circulation of oil therethrough in each of the successive passes. In this aspect, the improved method also includes passing the heating gases through the heating zone so that heat exchange between the heating gases and the oil occurs first between the heating gases and the oil on its first passage through the heating zone, then between the heating gases and the oil on its second passage through the heating zone, and so on; the maintenance of generally counter-current relation between the flow of heating gases and the circulating oil by passing the heating gases through the heating zone in a generally downward direction; and tempering of the heating gases passing through the heating zone by recirculating through the heating zone a portion of the escaping heating gases. This aspect of the invention, an improved method of heating oil to a cracking temperature, is illustrated diagrammatically in Fig. 12.

I claim:

1. In apparatus for cracking hydrocarbon oils, a bulk supply drum, a battery of heating tubes, and circulating connections between the bulk supply drum and the battery of heating tubes including a forcing means for circulating oil from the bulk supply drum through the battery of heating tubes and back to the bulk supply drum, said battery of heating tubes being arranged in a heating flue and comprising a series of banks of vertically arranged heating tubes and connections between the upper ends of the banks of heating tubes, except the last, in such series and the lower ends of the successive banks, the last mentioned connections being arranged externally of the heating flue in which the heating tubes are arranged.

2. In apparatus for cracking hydrocarbon oils, a bulk supply drum, a battery of heating tubes, and circulating connections between the bulk supply drum and the battery of heating tubes including a forcing means for circulating oil from the bulk supply drum through the battery of heating tubes and back to the bulk supply drum, said battery of heating tubes being arranged in a heating flue and comprising a series of banks of vertically arranged heating tubes and connections between the upper ends of the banks of heating tubes, except the last, in such series and the lower ends of the successive banks, the last mentioned connections being arranged externally of the heating flue in which the heating tubes are arranged, the circulating connections from the bulk supply drum to the battery of heating tubes connecting with the lower end of the first bank of heating tubes in such series and the circulating connections from the battery of heating tubes to the bulk supply drum connecting with the upper end of the last bank of such series.

3. In apparatus for cracking hydrocarbon oils, a bulk supply drum, a battery of heating tubes, and circulating connections between the bulk supply drum and the battery of heating tubes including a forcing means for circulating oil from the bulk supply drum through the battery of heating tubes and back to the bulk supply drum, said battery of heating tubes being arranged in a heating flue and comprising a series of banks of vertically arranged heating tubes and connections between the upper ends of the banks of heating tubes, except the last, in such series and the lower ends of the successive banks, the last mentioned connections being arranged externally of the heating flue in which the heating tubes are arranged, the circulating connections from the bulk supply drum to the battery of heating tubes connecting with the lower end of the first bank of heating tubes in such series and the circulating connections from the battery of heating tubes to the bulk supply drum connecting with the upper end of the last bank of such series, the first bank of heating tubes in such series being arranged to contact first with heating gases passing through the heating flue in which the battery of heating tubes is arranged.

4. In apparatus for cracking hydrocarbon oils, a bulk supply drum, a battery of heating tubes, and circulating connections between the bulk supply drum and the battery of heating tubes including a forcing means for circulating oil from the bulk supply drum through the battery of heating tubes and back to the bulk supply drum, said battery of heating tubes being arranged in a heating flue and comprising a series of banks of vertically arranged heating tubes and connections between the upper ends of the banks of heating tubes, except the last, in such series and the lower ends of the successive banks, the last mentioned connections being arranged externally of the heating flue in which the heating tubes are arranged, a firebox communicating with the upper end of said heating flue and a stack flue communicating with the lower end of said heating flue.

5. In apparatus for cracking hydrocarbon oils, a bulk supply drum, a battery of heating tubes, and circulating connections between the bulk supply drum and the battery of heating tubes including a forcing means for circulating oil from the bulk supply drum through the battery of heating tubes and back to the bulk supply drum, said battery of heating tubes being arranged in a heating flue and comprising a series of banks of vertically arranged heating tubes and

connections between the upper ends of the banks of heating tubes, except the last, in such series and the lower ends of the successive banks, the last mentioned connections being arranged externally of the heating flue in which the heating tubes are arranged, a firebox communicating with one end of said heating flue and a stack flue communicating with the other end, and means for recirculating through the heating flue with fresh hot products of combustion from the firebox a portion of heating gases escaping from the heating flue in which the heating tubes are arranged.

6. In apparatus for cracking hydrocarbon oils, a bulk supply drum, a battery of heating tubes, and circulating connections between the bulk supply drum and the battery of heating tubes including a forcing means for circulating oil from the bulk supply drum through the battery of heating tubes and back to the bulk supply drum, said battery of heating tubes being arranged in a heating flue and comprising a series of banks of vertically arranged heating tubes and connections between the upper ends of the banks of heating tubes, except the last, in such series and the lower ends of the successive banks, the last mentioned connections being arranged externally of the heating flue in which the heating tubes are arranged, each of said banks of heating tubes being arranged transversely to flow of heating gases through said heating flue.

7. In apparatus for cracking hydrocarbon oils, a bulk supply drum, a battery of heating tubes, and circulating connections between the bulk supply drum and the battery of heating tubes including a forcing means for circulating oil from the bulk supply drum through the battery of heating tubes and back to the bulk supply drum, said battery of heating tubes being arranged in a heating flue and comprising a series of banks of vertically arranged heating tubes and connections between the upper ends of the banks of heating tubes, except the last, in such series and the lower ends of the successive banks, the last mentioned connections being arranged externally of the heating flue in which the heating tubes are arranged, and a bed of finely divided solid material arranged in the bulk supply drum below the normal liquid level therein and between the circulating connections from the battery of heating tubes to the bulk supply drum and from the bulk supply drum to the battery of heating tubes.

8. In apparatus for cracking hydrocarbon oils, a bulk supply drum, a battery of heating tubes, and circulating connections between the bulk supply drum and the battery of heating tubes including a forcing means for circulating oil from the bulk supply drum through the battery of heating tubes and back to the bulk supply drum, said battery of heating tubes being arranged in a heating flue and comprising a series of banks of vertically arranged heating tubes and connections between the upper ends of the banks of heating tubes, except the last, in such series and the lower ends of the successive banks, the last mentioned connections being arranged externally of the heating flue in which the heating tubes are arranged, and a bed of finely divided solid material arranged in the bulk supply drum below the normal liquid level therein and between the circulating connections from the battery of heating tubes to the bulk supply drum and from the bulk supply drum to the battery of heating tubes, the circulating connections from the bulk supply drum to the battery of heating tubes connecting with the lower end of the first bank of heating tubes in such series and the circulating connections from the battery of heating tubes to the bulk supply drum connecting with the upper end of the last bank of such series.

9. In apparatus for cracking hydrocarbon oils, a bulk supply drum, a battery of heating tubes, and circulating connections between the bulk supply drum and the battery of heating tubes including a forcing means for circulating oil from the bulk supply drum through the battery of heating tubes and back to the bulk supply drum, said battery of heating tubes being arranged in a heating flue and comprising a series of banks of vertically arranged heating tubes and connections between the upper ends of the banks of heating tubes, except the last, in such series and the lower ends of the successive banks, the last mentioned connections being arranged externally of the heating flue in which the heating tubes are arranged, and a bed of finely divided solid material arranged in the bulk supply drum below the normal liquid level therein and between the circulating connections from the battery of heating tubes to the bulk supply drum and from the bulk supply drum to the battery of heating tubes, the circulating connections from the bulk supply drum to the battery of heating tubes connecting with the lower end of the first bank of heating tubes in such series and the circulating connections from the battery of heating tubes to the bulk supply drum connecting with the upper end of the last bank of such series, the first bank of heating tubes in such series being arranged to contact first with heating gases passing through the heating flue in which the battery of heating tubes is arranged.

10. In apparatus for cracking hydrocarbon oils, a bulk supply drum, a battery of heating tubes, and circulating connections between the bulk supply drum and the battery of heating tubes including a forcing means for circulating oil from the bulk

supply drum through a battery of heating tubes and back to the bulk supply drum, said battery of heating tubes being arranged in a heating flue and comprising a series of banks of vertically arranged heating tubes and connections between the upper ends of the banks of heating tubes, except the last, in such series and the lower ends of the successive banks, the last mentioned connections being arranged externally of the heating flue in which the heating tubes are arranged, and a bed of finely divided solid material arranged in the bulk supply drum below the normal liquid level therein and between the circulating connections from the battery of heating tubes to the bulk supply drum and from the bulk supply drum to the battery of heating tubes, a firebox communicating with the upper end of said heating flue and a stack flue communicating with the lower end of said heating flue.

11. In apparatus for cracking hydrocarbon oils, a bulk supply drum, a battery of heating tubes, and circulating connections between the bulk supply drum and the battery of heating tubes including a forcing means for circulating oil from the bulk supply drum through the battery of heating tubes and back to the bulk supply drum, said battery of heating tubes being arranged in a heating flue and comprising a series of banks of vertically arranged heating tubes and connections between the upper ends of the banks of heating tubes, except the last, in such series and the lower ends of the successive banks, the last mentioned connections being arranged externally of the heating flue in which the heating tubes are arranged, and a bed of finely divided solid material arranged in the bulk supply drum below the normal liquid level therein and between the circulating connections from the battery of heating tubes to the bulk supply drum and from the bulk supply drum to the battery of heating tubes, a firebox communicating with one end of said heating flue and a stack flue communicating with the other end, and means for recirculating through the heating flue with fresh hot products of combustion from the firebox a portion of heating gases escaping from the heating flue in which the heating tubes are arranged.

12. In apparatus for cracking hydrocarbon oils, a bulk supply drum, a battery of heating tubes, and circulating connections between the bulk supply drum and the battery of heating tubes including a forcing means for circulating oil from the bulk supply drum through the battery of heating tubes and back to the bulk supply drum, said battery of heating tubes being arranged in a heating flue and comprising a series of banks of vertically arranged heating tubes and connections between the upper ends of the banks of heating tubes, except the last, in such series and the lower ends of the successive banks, the last mentioned connections being arranged externally of the heating flue in which the heating tubes are arranged, and a bed of finely divided solid material arranged in the bulk supply drum below the normal liquid level therein and between the circulating connections from the battery of heating tubes to the bulk supply drum and from the bulk supply drum to the battery of heating tubes, each of said banks of heating tubes being arranged transversely to flow of heating gases through said heating flue.

13. In apparatus for cracking hydrocarbon oils, an improved oil heater comprising a furnace having a heating flue and a battery of heating tubes arranged in and extending transversely through said heating flue, said battery of heating tubes comprising a closed series of banks of vertically arranged heating tubes and direct connections between the upper ends of the banks of heating tubes, except the last, in such series and the lower ends of the successive banks, the said connections being arranged externally of the heating flue in which the heating tubes are arranged.

14. In apparatus for cracking hydrocarbon oils, an improved oil heater comprising a furnace having a heating flue and a battery of heating tubes arranged in and extending transversely through said heating flue, said battery of heating tubes comprising a closed series of banks of vertically arranged heating tubes and direct connections between the upper ends of the banks of heating tubes, except the last, in such series and the lower ends of the successive banks, the said connections being arranged externally of the heating flue in which the heating tubes are arranged, supply connections connecting with the lower end of the first bank of heating tubes in such series, and discharge connections connecting with the upper end of the last bank of heating tubes in such series.

15. In apparatus for cracking hydrocarbon oils, an improved oil heater comprising a furnace having a heating flue and a battery of heating tubes arranged in and extending transversely through said heating flue, said battery of heating tubes comprising a closed series of banks of vertically arranged heating tubes and direct connections between the upper ends of the banks of heating tubes, except the last, in such series and the lower ends of the successive banks, the said connections being arranged externally of the heating flue in which the heating tubes are arranged, a firebox communicating with the upper end of said heating flue and a stack flue communicating with the lower end of said heating flue.

16. In apparatus for cracking hydrocar-

bon oils, an improved oil heater comprising a furnace having a heating flue and a battery of heating tubes arranged in and extending transversely through said heating flue, said battery of heating tubes comprising a closed series of banks of vertically arranged heating tubes and direct connections between the upper ends of the banks of heating tubes, except the last, in such series and the lower ends of the successive banks, the said connections being arranged externally of the heating flue in which the heating tubes are arranged, a firebox communicating with one end of said heating flue and a stack flue communicating with the other end, and means for recirculating through the heating flue with fresh hot products of combustion from the firebox a portion of heating gases escaping from the heating flue in which the heating tubes are arranged.

17. In apparatus for cracking hydrocarbon oils, an improved oil heater comprising a furnace having a heating flue and a battery of heating tubes arranged in and extending transversely through said heating flue, said battery of heating tubes comprising a closed series of banks of vertically arranged heating tubes and direct connections between the upper ends of the banks of heating tubes, except the last, in such series and the lower ends of the successive banks, the said connections being arranged externally of the heating flue in which the heating tubes are arranged, supply connections connecting with the lower end of the first bank of heating tubes in such series, the first bank of heating tubes in such series being arranged to contact first with heating gases passing through the heating flue in said furnace.

18. In apparatus for cracking hydrocarbon oils, an improved oil heater comprising a furnace having a heating flue and a battery of heating tubes arranged in and extending through said heating flue, said battery of heating tubes comprising a closed series of banks of vertically arranged heating tubes and direct connections between the upper ends of the banks of heating tubes, except the last, in such series and the lower ends of the successive banks, the said connections being arranged externally of the heating flue in which the heating tubes are arranged, each of said banks of heating tubes being arranged transversely to flow of heating gases through said heating flue.

19. A method of heating hydrocarbon oils to a cracking temperature, which comprises supplying a stream of the oil to the heating operation, circulating this stream of oil upwardly through a heating zone, then downwardly outside of said heating zone, then upwardly through said heating zone, and so in a plurality of successive passes through said heating zone in the heating operation, heating the stream of oil to a cracking temperature in said heating zone by indirect heat exchange with heating gases passed transversely to the several paths of said stream of oil through the heating zone, heat being transferred to said stream of oil only while circulating upwardly through said heating zone, and discharging the total stream of oil from the heating operation after the several successive passes through said heating zone and at a cracking temperature.

20. A method of heating hydrocarbon oils to a cracking temperature, which comprises supplying a stream of the oil to the heating operation, circulating this stream of oil in a succession of passes through a heating zone, the direction of circulation of the oil in each of the successive passes through said heating zone being the same, heating the stream of oil to a cracking temperature in said heating zone by indirect heat exchange with heating gases passed transversely to the several paths of said stream of oil through the heating zone, and discharging the total stream of oil from the heating operation after the succession of passes through said heating zone and at a cracking temperature.

21. A method of heating hydrocarbon oils to a cracking temperature, which comprises supplying a stream of the oil to the heating operation, circulating this stream of oil in a succession of passes through a heating zone, the direction of circulation of the oil in each of the successive passes through said heating zone being the same, heating the stream of oil to a cracking temperature in said heating zone by indirect heat exchange with heating gases passed therethrough, the heating gases being passed through said heating zone generally countercurrent to the circulation of the oil therethrough and transversely to the several paths of said stream of oil through the heating zone, and discharging the total stream of oil from the heating operation after the succession of passes through said heating zone and at a cracking temperature.

22. A method of heating hydrocarbon oils to a cracking temperature, which comprises supplying a stream of the oil to the heating operation, circulating this stream of oil upwardly through a heating zone, then downwardly outside of said heating zone, then upwardly through said heating zone, and so on in a plurality of successive passes through said heating zone in the heating operation, passing heating gases transversely to the several paths of said stream of oil through the heating zone first in indirect heat exchanging relation with the oil stream on its first pass through said heating zone, then in indirect heat exchanging relation with the oil stream on its second pass through said heating zone, and

so on, and thereby heating the stream of oil to a cracking temperature in said heating zone, heat being transferred to said stream of oil only while circulating upwardly through said heating zone, and discharging the total stream of oil from the heating operation after the several successive passes through said heating zone and at a cracking temperature.

23. A method of heating hydrocarbon oils to a cracking temperature, which comprises supplying a stream of the oil to the heating operation, circulating this stream of oil upwardly through a heating zone, then downwardly outside of said heating zone, then upwardly through said heating zone, and so on in a plurality of successive passes through said heating zone in the heating operation, passing heating gases downwardly through said heating zone and transversely to the several paths of said stream of oil through the heating zone in indirect heat exchanging relation with the oil circulating therethrough and thereby heating the stream of oil to a cracking temperature in said heating zone, heat being transferred to said stream of oil only while circulating upwardly through said heating zone, and discharging the total stream of oil from the heating operation after the several successive passes through said heating zone and at a cracking temperature.

24. A method of heating hydrocarbon oils to a cracking temperature, which comprises supplying a stream of the oil to the heating operation, circulating this stream of oil upwardly through a heating zone, then downwardly outside of said heating zone, then upwardly through said heating zone, and so on in a plurality of successive passes through said heating zone in the heating operation, passing heating gases downwardly through said heating zone and transversely to the several paths of said stream of oil through the heating zone in indirect heat exchanging relation with the oil circulating therethrough and thereby heating the stream of oil to a cracking temperature in said heating zone, recirculating through said heating zone a portion of the heating gases escaping therefrom, heat being transferred to said stream of oil only while circulating upwardly through said heating zone, and discharging the total stream of oil from the heating operation after the several successive passes through said heating zone and at a cracking temperature.

25. In apparatus for cracking hydrocarbon oils, an improved oil heater comprising a furnace having a heating flue and a battery of heating tubes arranged in and extending through said heating flue, said battery of heating tubes comprising a series of banks of vertically arranged heating tubes and connections between the upper ends of the banks of heating tubes, except the last, in such series and the lower ends of the successive banks, the said connections being arranged externally of the heating flue in which the heating tubes are arranged, each of the said connections having a cross sectional area less than the aggregate cross sectional area of the preceding bank of heating tubes.

In testimony whereof, I have subscribed my name.

HARRY L. PELZER.