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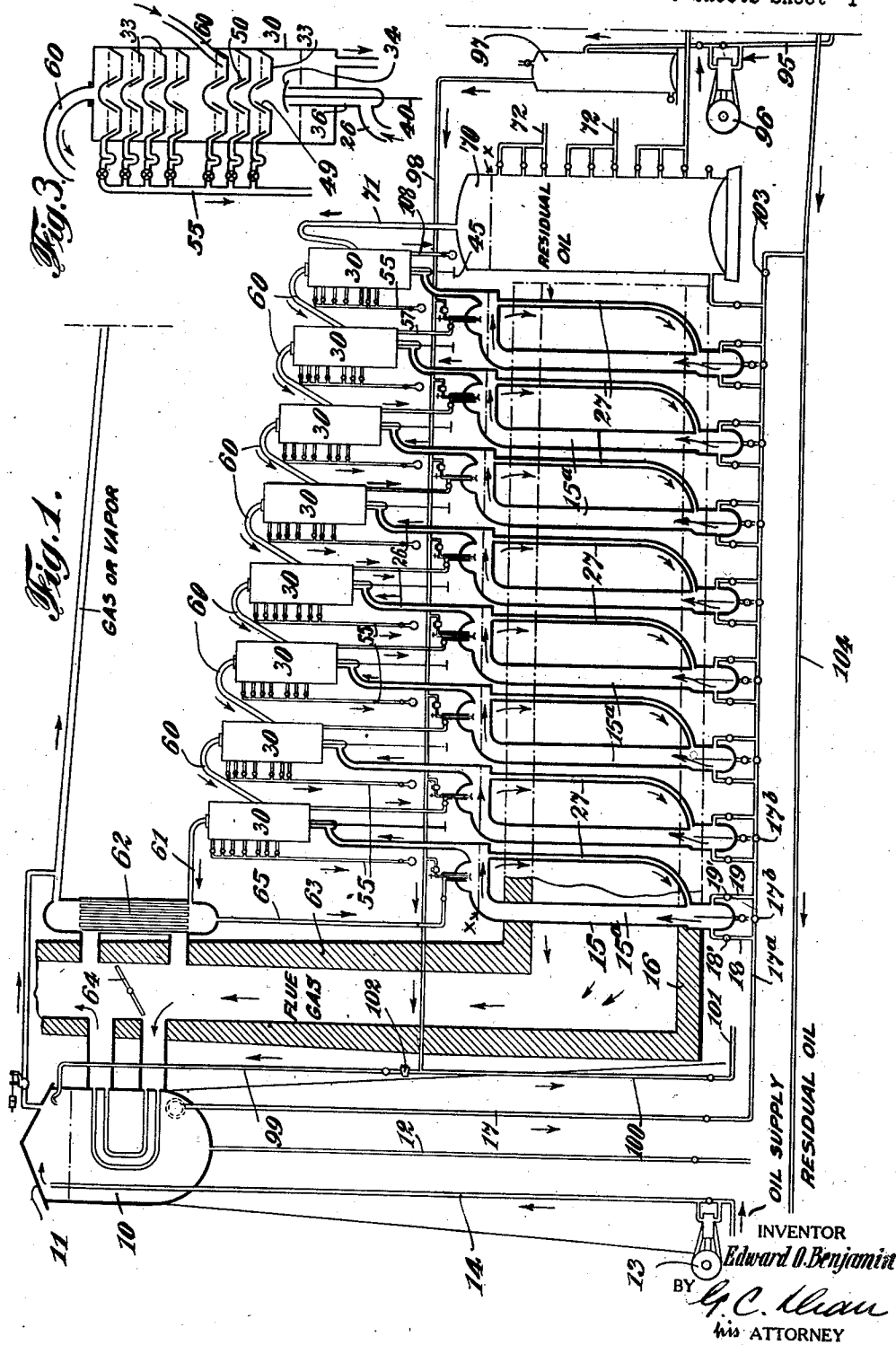
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DISTILLING APPARATUS AND METHOD

Filed July 28, 1924

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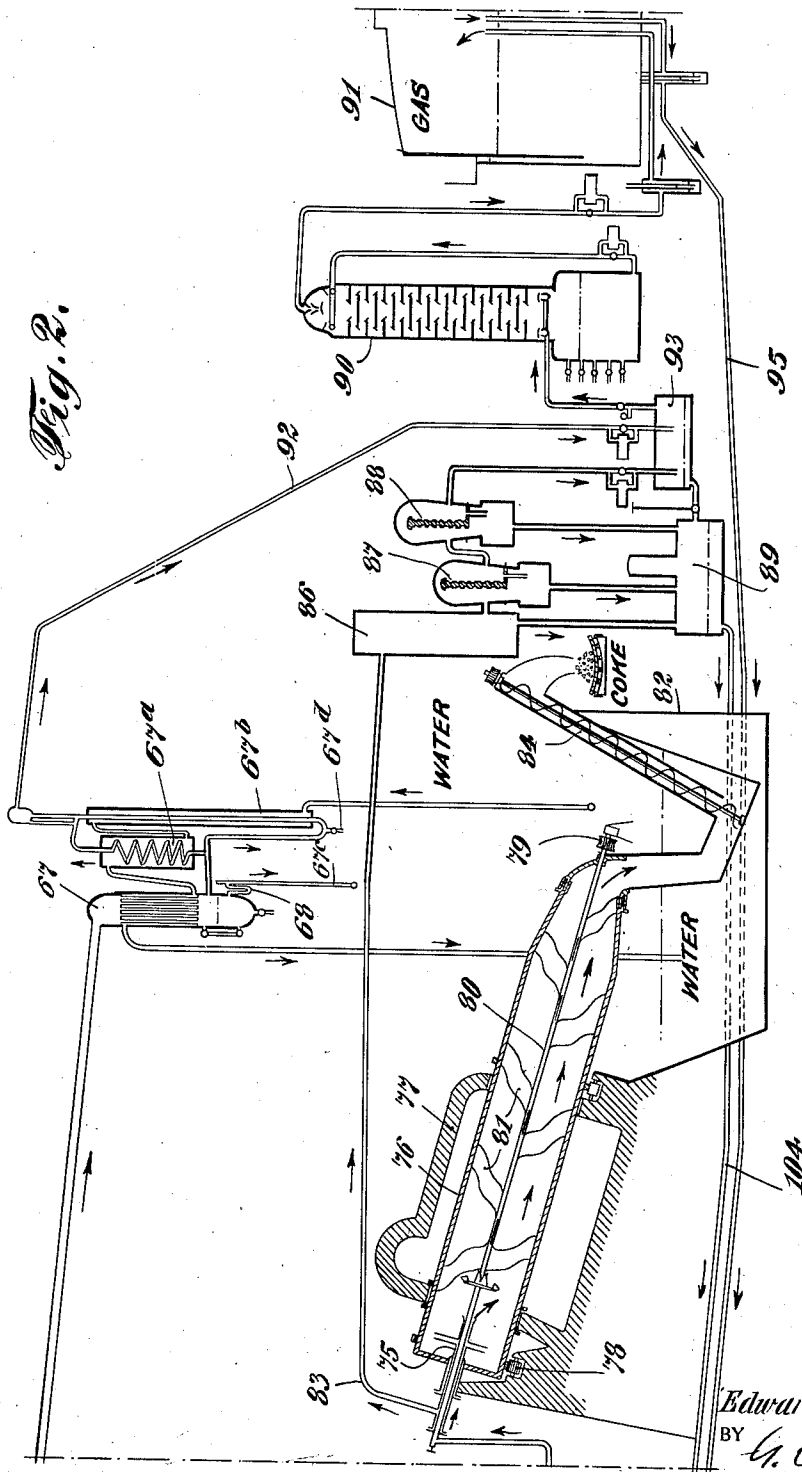
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DISTILLING APPARATUS AND METHOD

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Fig. 2.



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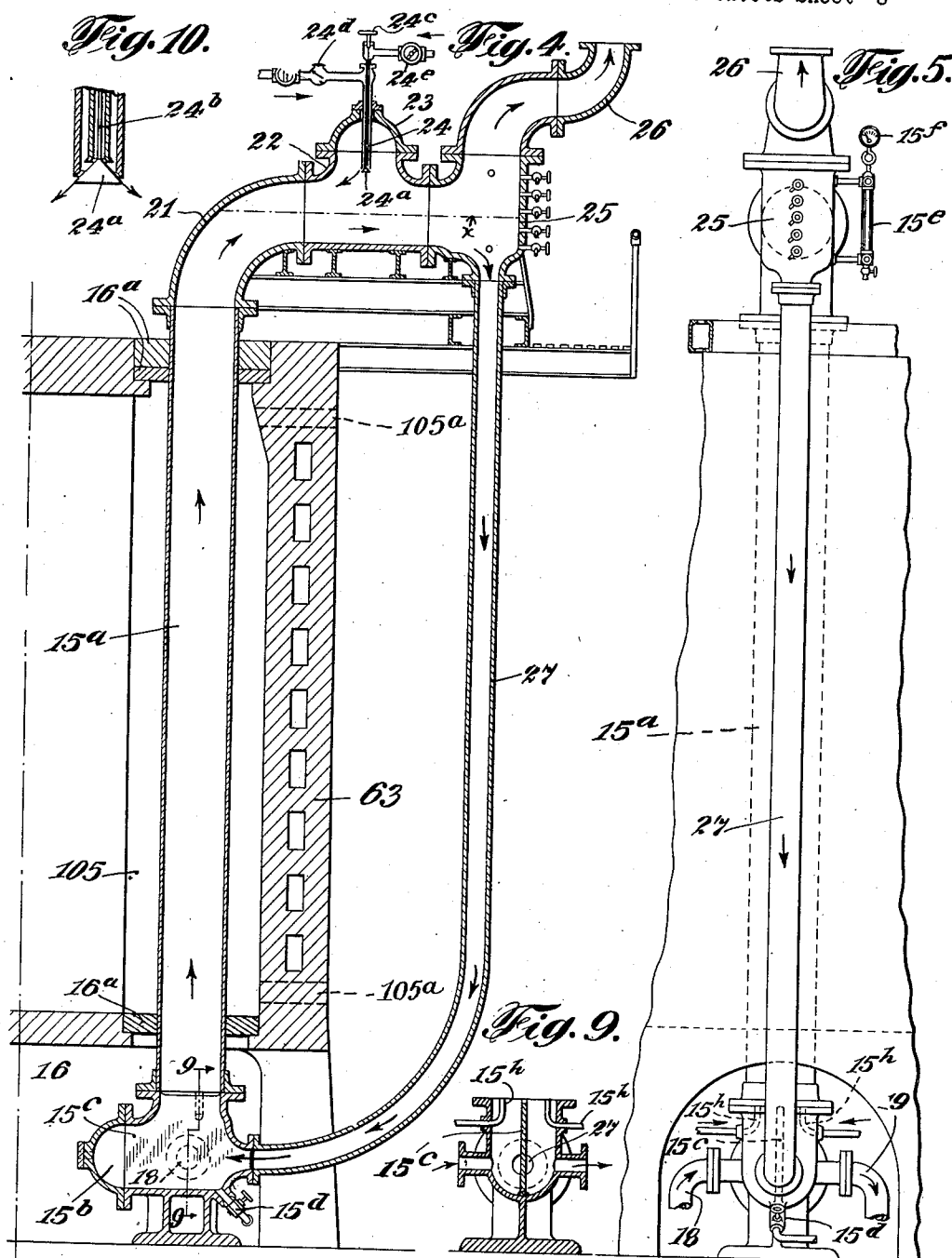
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DISTILLING APPARATUS AND METHOD

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5 Sheets-Sheet 3



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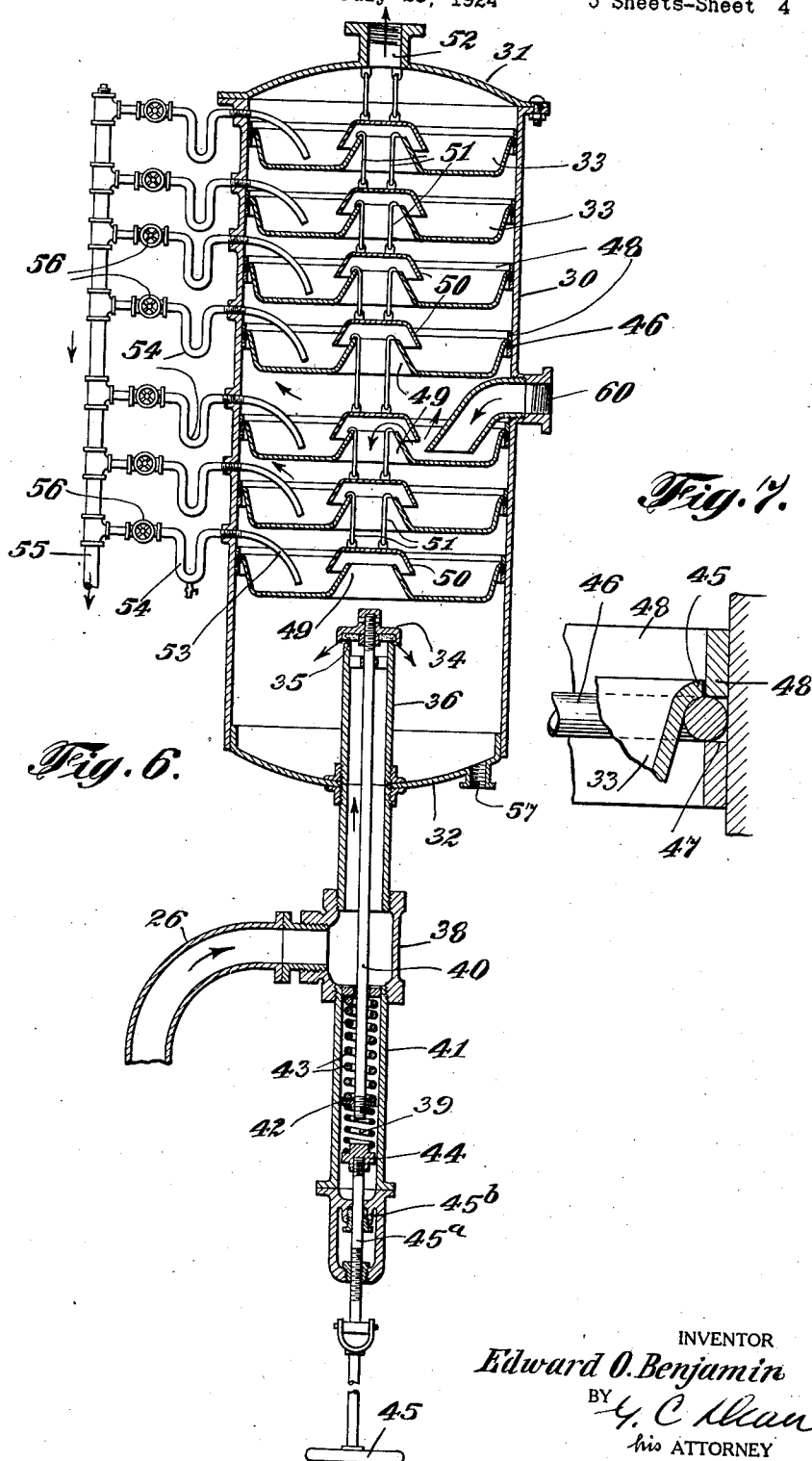
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DISTILLING APPARATUS AND METHOD

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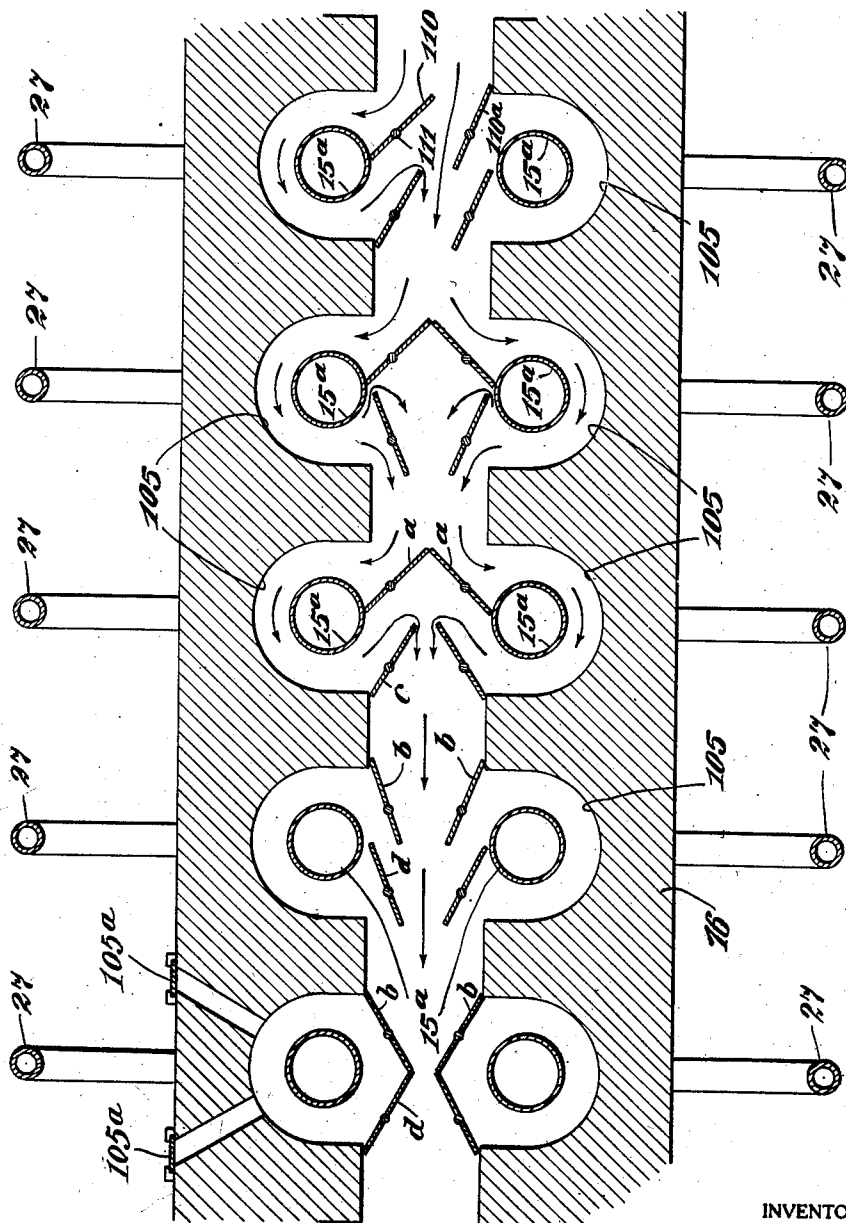
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DISTILLING APPARATUS AND METHOD

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Fig. 8.



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DISTILLING APPARATUS AND METHOD

Application filed July 28, 1924. Serial No. 728,543.

My present invention is shown in a form particularly adapted for fractional distillation and cracking of crude petroleum to recover the various constituent fractions including various grades of petroleum ethers, gasoline, etc., but it will be evident that the invention is equally applicable to petroleum from which the more volatile constituents have been "skimmed" and also for more accurate separation of fractional products of distillation or skimming; also that with obvious changes either of design or temperatures and pressures of operation, the apparatus may be employed for fractional distillation of any fluid or even of solids suspended in a fluid medium.

As applied to mineral oils, it is a continuous process, the oil to be distilled being continuously fed into the system and the final products such as separated distillates, fixed fuel gases, residuum, coke, etc., being continuously withdrawn.

The process may be carried on at a low operating cost and with but slight heat losses. No sediment, coke or other encrustations are formed in the active parts of the apparatus and when cleaning becomes necessary, the units may be cleaned one at a time and the operation of the remaining units need not be interrupted. By use of the process, sharp fractions are obtained and the yield is relatively high.

The apparatus which I prefer to employ for carrying out the process may be installed at a comparatively low cost. The replacement parts are few and inexpensive and perfect control of temperatures and pressures at all points are assured.

As applied to the refining of mineral oils, notable features of the invention are as follows:

Oil from the usual storage tanks is pumped to an elevated reservoir which is preferably sealed and kept under pressure higher than that of the highest pressure retort to be supplied thereby. From the reservoir the oil passes through a series of retorts each of successively lower internal pressure and higher temperature than that of the preceding retort, thus "upsetting the equilibrium of con-

stant boiling point," as will be explained below. The flow through the successive retorts may be controlled by adjustable valves which are preferably differential automatic valves adapted to operate on a pressure drop which may be adjusted to suit the conditions. The distillate from each retort passes to a separate condenser column, preferably through an adjustable relief valve of the automatic type, an important feature being that all the condensers are maintained at pressures very much less than the internal pressures of their respective retorts, whereby the hot vapors escaping from the respective retorts are abruptly and greatly expanded, thereby greatly lowering their temperatures and facilitating maximum condensation with minimum heat evolution, so that problems of cooling or refrigeration of condensers are simplified and practically eliminated.

The condensers are each at a considerably lower temperature and pressure than the retorts with which they are associated, and the condensers corresponding to the respective retorts are in a reversed order as regards internal pressures. In other words, the condenser into which the first low temperature and high pressure retort delivers is maintained at a comparatively low pressure, while the successive condensers into which the progressively higher temperature, lower pressure retorts deliver have progressively higher pressures. This causes the flow of gases and vapors through the successive condensers to be in an opposite direction to the oil flow through the retorts. Thus, in the direction of the gas flow, there is a graduated drop in pressure and temperature in the successive condensing columns. Thus the uncondensed vapors continue to flow in the direction of lower pressure and temperature until each particular constituent reaches the particular condenser where it finds conditions necessary for its liquefaction.

One feature of the invention involves providing each condenser with a plurality of separator pans for collecting the various grades of condensate and from which the condensate is continuously withdrawn. The vapors entering the condenser from the lower

end are caused to successively flow through each of these pans until they either condense or pass from the top of the condenser back to the next adjacent lower pressure cooler condenser which they enter midway, or at least above the lowermost of the series of pans therein. The gas which is thus circulating through the apparatus promotes fine separation of the fractions by picking up higher fractions that may be held in solution in lower fraction pans and causing the same to be precipitated in pans where the temperature is lower.

A certain amount of uncondensable gas is necessarily produced in carrying out the process, and I prefer to utilize this gas as a medium for performing several useful functions. It may be used for applying the desired pressures in the storage tanks, retorts and condensers, for injecting dephlegmated distillates into the retorts, for removing vapors from the retorts and carrying them through the successive condensing columns and finally as a fuel for firing the retorts. Preferably, the gas, after traveling through the system and having the vapors removed by cooling and compression, is washed to remove the water soluble constituents and then stored in a gasometer from which it may be withdrawn and used as needed.

Preferably, after the crude oil has been passed through the series of retorts and separated by the above described refining process, the residue which remains in the last retort is deposited in a settling tank from which the residuum may be withdrawn and sprayed under pressure into a highly heated rotating coking kiln, in which the temperature is sufficiently high to cause destructive distillation of the residuum, the products being coke, various hydrocarbons from the heavy tars, to the light oils, gases, etc. In accordance with certain features of the invention, the coke may be removed from the kiln by scrapers, and the vapors and gases may be removed and condensed. The liquid separations from this kiln cracking process are preferably delivered back to the crude oil storage tank and again go through the process of refining. The settling tank in addition to the residuum will contain lighter grade constituents which may be tapped off for further refining and worked into paraffin wax, lubricating oils, etc.

It is to be understood that so far as the present invention is concerned, the particular number of retorts and condensers and collector pans depend entirely upon the desired fineness of separation, the number of final products desired and the nature of the material being treated. In the case of the example shown, the offtakes of any or all the pans in each condensing column may be closed so that undesirable condensates will be caused to overflow as dephlegmates or refluxes, while

the properly graded fractional distillates are being separately withdrawn from the upper pans of each column. With eight condensers each having the three lower pans overflowing and five of the upper pans discharging, forty distinct refined separations may be had.

Other important features have to do with cracking. "Cracking in the liquid phase" occurs in the ordinary distilling retorts, but in the retorts with which I am familiar, the conditions are such that encrustations are formed on the walls, which then become very hot. These encrustations break away and suddenly expose the liquid to a very high temperature areas of the wall so that the cracking is apt to be too violent, and too large a fraction of the cracked product is in the form of permanent fuel gases, instead of the much more valuable gasoline product. This I avoid by designing the retorts with a closed conduit circuit for continuous flow of the liquid being distilled in the retort. To this end the retort proper is in the form of a tall column of rather small cross section, thereby exposing relatively great surface area to the furnace heat. Connecting the top and the bottom of this column is an exterior unheated, or at least much cooler, conduit for downflow of the liquid. Preferably, the downflow conduit is of even smaller cross section than the main retort whereby the downflow forced by boiling in the main retort column is of much higher velocity than the upflow in the main retort due to said boiling. This counteracts tendency to deposit encrustations on the relatively cool walls of the downflow conduit. In retorts where the liquid is particularly viscous, as will usually be the case with the higher temperature retorts near the end of the series, I provide at the base of the main retort column, powerful upwardly directed jets whereby fixed fuel gases or steam may be discharged at high pressure.

Either or both of these expedients serve to maintain a high speed circulation very unfavorable to deposit of encrustations on the walls; hence the inner wall temperature of the main retort column is not very much above that of the liquid so that cracking in the liquid phase is conducted at the closely regulated temperature of the bare wall of the retort and is favorable to maximum production of gasoline. There is no encrustation to break off and expose hot spots tending to produce fixed gases.

An incidental feature for this close temperature regulation of the walls of the retort is location of the retorts in niches out of the direct path of flow of flue gases and flames from the furnace and providing independently adjustable deflectors affording effective control of flow of the heating medium into or away from the niche or recess occupied by each individual retort.

Another feature of my invention is "cracking in the vapor phase", which is conducted under most favorable conditions. The heavier liquid, more or less contaminated with mechanically carried off particles of the crude oil, tends to collect in the bottom of the respective condensers, because in general that particular condenser will be at a temperature far below the condensing point of said heavier contaminated liquid (as likewise it is above the condensing point of liquid lighter than those intended to be separated out therein). This undesirable condensate in the bottom and sometimes in some of the lower pans of each condenser is injected, as a spray, into the next retort which is of predetermined, higher temperature than the retort from which said liquid was evaporated. This sudden spraying of the liquid into such retort of predetermined, higher temperature than the boiling point of the liquid so sprayed, results in cracking of a portion of said liquid under conditions calculated to produce maximum production of gasoline. Naturally, the portion of the liquid not so cracked distills off into the next condenser, is sprayed into the retort of the next higher temperature and so on, step by step, being thus subjected to cracking conditions at progressively higher temperatures, and part of it being cracked in each retort, until a remnant is finally condensed in the bottom of the condenser of the retort of highest temperature whence it may be withdrawn for further treatment or for use as fuel.

The liquid for spraying into and cracking in the first or lowest temperature retort is derived from a condenser which receives the vapor escaping from the top of the condenser of the first or coolest retort, which, as we have explained, is the last condenser from which also escapes the uncondensed product from all individual retort condensers of the series.

The above described spraying back of the condensate is of extraordinary importance in an entirely different relation. That is to say, the cruder petroleum, particularly in the first retorts of the series, frequently and usually proves extremely troublesome by reason of its tendency to emulsify and produce voluminous foam on the surface of the liquid in the retort, larger or smaller bubbles of which are apt to be carried by the draft or even to push their own way through the outlet valve, thereby contaminating with crude oil the liquid in the condenser and such contamination may and sometimes does extend to or even through the topmost pan of said condenser. The liquid which is cut back into the retort and sprayed onto the foam, is extraordinarily effective in suppressing the latter, because of its high velocity mechanical impacts on the bubbles and more especially because, being a thinner more volatile liquid, it

weakens the surface tension of the bubble films, thereby breaking the bubbles and so keeping down the foam.

It is important to note that in regulating the operation of the plant, an important objective is to utilize the distilling capacity of all of the retorts so that the amount of distillate discharged from each will be nearly the same. Hence, while each is always of lower pressure and higher temperature than the preceding retort of the series, and while the pressure differences between retorts may be more or less the same, the temperature differences may be much less for the cooler retorts at the beginning of the series than for the hotter retorts toward the end of the series. The liquid being distilled may contain a very large percentage of one grade of distillate while very deficient in some other grade. In such case, two or more adjacent retorts may be run at only sufficient differences of pressure and temperature, to insure continued flow of the supply of oil being treated.

In a particular case, the pressure maintained in the elevated storage tank may be 125 pounds, the pressure in the successive retorts being respectively 115, 110, 105, 100, 95, 90, 85 and 80 pounds above atmosphere. The temperatures, however, could be, say, 300 degrees centigrade in the first retort and say 660 degrees in the eighth, but they are not necessarily graduated proportionally for the intermediate retorts and, in general, the temperature differences between several of the first retorts of the series will be much less than the difference in temperature between adjacent retorts toward the end of the series.

The expansion drop from the first retort to its condenser may be from, say, 115 pounds in the retort to, say, 40 pounds in the condenser, and the drops for the remaining retorts to their condensers will be less, the 80 pounds pressure in the last retort dropping to, say, 61 pounds in its condenser. The gas pressure line for maintaining pressure on the supply tank and for injecting the cut-back condensate into the retorts may be, say, 300 pounds. The effective spray-pressure will be regulated by reducing valves and may be, say, 15 pounds above the internal pressure of the retort into which the spray is discharged.

The above and other features of my invention may be more fully understood from the following description in connection with the accompanying drawings, in which

Fig. 1 is a somewhat diagrammatic view, mainly an elevation of a portion of the apparatus;

Fig. 2 is a similar view of the remainder of the apparatus, the dotted lines in Figs. 1 and 2 indicating the line of separation;

Fig. 3 is a diagrammatic view of one of the condensing columns;

Fig. 4 is a longitudinal sectional view through one of the retorts;

Fig. 5 is an edge view of Fig. 4;

Fig. 6 is a longitudinal sectional view through one of the condenser units;

Fig. 7 is an enlarged detail view showing the manner of supporting the separator pans; and

Fig. 8 is a view in transverse section through the firebox or flue indicating the damper arrangement which controls the temperatures of the successive retorts.

Fig. 9 is a sectional detail on the line 9—9 of Fig. 4.

Fig. 10 is a sectional detail of one of the injectors.

In Fig. 1, the elevated tank 10, sealed by a cover 11, serves as the immediate source for supply for pressure feed of the crude oil, the oil being pumped from ordinary storage tanks (not shown) through a pipe line 14 into said tank 10 until the level has been raised and the air between the oil surface and the top of the tank has been compressed to the desired extent. A pump 13 may be utilized to lift the oil into the tank and sediment may be drained from the bottom of the tank through a drain pipe 12.

The retorts 15 are substantially identical and each includes a relatively large vertical portion 15a which is disposed within a firebox or flue 16 and directly exposed to the flames and flue gases from a source of heat (not shown). Oil from the tank 10 flows down through a pipe 17 and across a main supply pipe 17a for the retorts. The supply pipe is provided adjacent each retort with a cut-off valve 17b which is normally maintained in closed position during operation so that the oil flows serially through the retorts by way of pipes 18 and 19 connecting the retorts with the main supply pipe 17a at opposite sides of the valves 17b. The pipe 18 is the inflow pipe to the chamber at the lower end of the retort and pipe 19 is the discharge pipe from such chamber. Valves 18' and 19' in the pipes 18 and 19 respectively serve to control the inter-retort flow of oil. In order that pressure differences may be maintained in the retorts I preferably use a differential pressure valve at 19' which may be manually regulated so as to automatically maintain a desired pressure differential between two adjacent retorts. Valves 17b, 18', 19', are so arranged that any retort may be by-passed for purposes of cleaning or repair. Baffle plates 15c in the chambers 15b baffle direct flow of oil between the inlet and outlet ports, and the lower ends of the chambers serve as sediment collecting pockets which may be drained by cocks 15d.

Vertical pipe 15a connects at its upper end with header comprising an elbow or other suitable coupling member 21, which in turn is connected to a spray head 22 having a

dome 23 into which a spray nozzle 24 discharges. Spray head 22 connects with a second coupling member 25 which is in open communication at its upper end with a pipe 26 leading to one of the condensers and at its lower end with a reduced, elongated substantially, vertical pipe 27. The header 21, 22, 25, is of ample capacity to provide for considerable variation in the liquid level at *z*. The pipe 27 is arranged exteriorly of the flue and provides a relatively cooler passage for the downflow of oil back to the lower end of the retort. The oil circulation produced by convection currents is up through the hot retort pipe 15a, coupling 21, across through the spray head 22 and coupling 25 and down through the cooler pipe 27. Vapors distilled in the retort or mechanically entrained in the gases escape through the pipe 26. Because of the reduced flow-section area of the pipe 27, a rapid downflow is assured, thereby preventing the retort circulation from becoming clogged by encrustation of solid matter formed by the evaporation and cracking process which occurs in the retort and thus also preventing the formation of a great amount of gas which would occur if the liquid were suddenly exposed to the hot wall of the retort. The inter-retort flow is entirely independent of the oil circulation which occurs in each retort and is preferably regulated by adjusting the differential pressure valves 19'. Level and pressure gauges 15e, 15f are preferably associated with the upper end of each retort. If the oil is unusually heavy, it may tend to sluggish circulation and to the formation of large bubbles in the upflow pipe which tend to explode at the oil surface and drive crude liquid up into the condenser. In such case I may employ one or more gas injectors 15h (Fig. 9) discharging into the lower end of the upflow pipe. These injectors effectively prevent the formation of large bubbles and promote a more rapid circulation of heavy oil. The injectors are not essential to successful operation under ordinary conditions, but may be brought into service when unusual conditions such as above described occur. They are frequently found desirable in connection with the higher temperature retorts for introducing oils, gases or other reagents for treatment of the mixture, as in cases where it becomes too heavy and sticky.

The only sections of the retorts which are directly exposed to flame and flue gases are the vertical upflow pipes 15a and in case these pipes burn out, I provide means for facilitating their rapid removal and replacement. Preferably they are mounted in magnesium, asbestos or fire clay 16a (Fig. 4) removably cemented into the roof and floor of the heating furnace 16. The cement may be broken away and blocks quickly dismounted to permit withdrawal of a damaged pipe 15a

through the roof and the insertion of a new pipe.

The condenser unit, seen most clearly in Fig. 6, is preferably in the nature of an air cooled fractionating column 30 formed with upper and lower heads 31, 32 and supporting in superposed spaced relationship, a number of separator pans 33. Vapor escaping to these through the pipe 26 is controlled by an expansion valve 34 which operates to maintain desired pressure in the retort. The expansion valve may be of any appropriate construction, and for illustrative purposes I have disclosed a poppet valve held against a seat 35 formed at the top of a standpipe 36 which projects through the lower head 32 of the condensing column and is suitably coupled at 38 to the pipe 26. The vapor pressure necessary to displace the valve 34 may be predetermined by adjusting the tension of spring 39. Stem 40 of the expansion valve projects into a housing 41 below the coupling member 38 and carries a head 42 oppositely acted upon by expansion springs 39 and 43. Spring 43 normally tends to seat the valve while the relatively weaker spring 39 normally tends to unseat the valve. A spring tension adjusting member 44, manually controlled by a hand wheel 45, may be utilized to decrease or increase the pressure on the spring 39 and consequently render more or less vapor pressure necessary for lifting the valve 34. The connection between 44 and hand wheel 45 may comprise a threaded rod 45a working in a stuffing box 45b at the lower end of a pipe 41 screwed into coupling 38 and serving as a housing for the springs and the valve stem. The sudden expansion of the vapor escaping from the valve into the relatively low pressure condenser greatly lowers its temperature, so that air cooling is sufficient to take care of the remnant of heat absorbed by condensing from vapor to liquid.

The separator pans 33 preferably have flanged edges 45 supported upon split locking rings 46 which are sprung into annular grooves 47 between bands 48 secured within the condensing column. The extreme overall diameters of the pans are slightly less than the internal diameter of the fixed bands 48 and the material of the locking ring 46 is thicker than the depth of groove 47, preferably about twice as thick. Thus the pans and split rings may be successively removed through the top of the condenser when the cover 31 is removed. As shown in Fig. 7, the depending side wall of the pan locks the ring in its groove. Obviously, other expedients might be resorted to for supporting the pans. Each pan is provided with a central tapered passageway 49 for the upflow of vapor and gas, which upon flowing through one of the openings 49 is directed back into the pan and caused to bubble up through the liquid in the pan by a hood or deflector 50,

supported on hangers 51, which depend from the edge of the flange defining the central opening of the pan above. At the top of the condensing column there is provided an outlet 52 for the escape of uncondensed vapors and uncondensable gases. Pipes 53 provided with traps 54 are used in carrying off the condensate from the separator pans and deliver the same to a take-off conduit 55. Valves 56 in each of the pipes 53 regulate offtake of oil flow therethrough. The traps 54 may be of glass or valves 56 may be three-way valves so that the condensate, particularly of the lower pans, may be examined for quality and if this is below grade, the pan outlet may be closed by valve 56. Such pan will then overflow into the dephlegmated liquid in the base of the condenser until such pan has been washed clean enough to yield a standard product.

The successive retorts are maintained at successively higher temperatures and the dephlegmated and rejected distillate from one condenser is delivered back to the next retort through one of the spray nozzles 24. The spray nozzles are preferably in the form of injectors, the injecting medium used being gas produced in the process. The method of producing, compressing and utilizing this gas will be more fully described hereafter. The injection of rejected distillate from one condenser into the next higher temperature retort serves to dissolve the foam on the liquid surface in the retort and assist in the circulation above mentioned. The spray nozzles preferably include concentric pipes for the gas and oil and a conical deflector 24a (Fig. 10) arranged at the discharge end of the pipes may be raised or lowered by a stem 24b operated by a handwheel 24c to control the force and fineness of the spray and the area of oil surface over which the injected cut-back oil is sprayed. Lowering of this deflector will give a large discharge annulus resulting in a coarser spray of less force and vice versa. A reducing valve 24d in the gas line and a cut-off valve 24e in the oil line to the injector are also employed. Thus spraying the distillate into a retort where the temperature is higher, and the pressure is lower, than in the retort from which the distillate was boiled off results in immediate gasifying of a substantial percentage of said distillate, and such vaporized portion is subjected to cracking in the vapor phase while the liquid remainder of the cut-back distillate, is redistilled along with the other liquid in said retort.

The relative pressures and resulting flow through the series of condensers are just the reverse of those in the retort series. The inlet pop valve 34, of the condenser into which the last and highest temperature retort delivers, is set for the highest pressure condenser so that the flow of uncondensed va-

pors and gases from one condenser to another is countercurrent to the inter-retort flow of oil. The outlet 52 of each condenser discharges through conduit 60 into one of the lower pans 33 of the next condenser near the bottom of said pan. This affords a liquid sealed trap through which uncondensed vapor and gas forces its way into a lower pressure condenser. It bubbles up through all of the upper separatory pans. Thus the pressure at the outlet for each pan is normally lower than that of the preceding, by an amount equal to the flow resistance plus the depth pressures against which the gases must be forced to reach the successive bubble outlets.

The gases and vapors from each condenser are thus subjected to the successively lower temperatures and pressures of the five successive pans of all the successive condensers through which they must pass to reach the outlet at the end of the series. The fixed gases not only deposit condensed vapors but also tend to evaporate and carry along fractions held by solution in pans too hot for them to condense in. Such fractions are thus washed along from pan to pan until they condense and come to rest in a pan where the temperature and pressure are too low for reevaporation thereof. Thus the heavy oils of higher boiling point are trapped first and the grades are trapped out successively each in its own pan where it first finds a temperature and pressure below its own boiling point.

From the last condenser of lowest boiling point (associated with the first retort) gas and vapor are carried through a pipe 61 to a heat interchanger 62 receiving heat from the flue gases. This heat interchanger may be conveniently supported upon a chimney 63 rising from the end of flue 16 and heat from the chimney may be directed to the interchanger by the use of a damper 64. In the interchanger sudden expansion of the gases causes precipitation of much of the vapor carried thereby. Liquid condensate from the heat interchanger is cut back through a pipe 65 to the spray head in the first retort, as described above. Uncondensed vapors and gases pass from the heat interchanger to a cooling system including a pair of water cooled condensers 67, 67a and a barometric trap 67b in all of which some condensation takes place and from which condensate is tapped and carried back to storage through pipes 67c, 67d. Liquid collecting in the lower end of this condenser may be tapped off through a trapped outlet 68 and cut back either to the storage tank or to one of the retorts. Rejected condensate from the highest temperature retort is preferably carried off by a pipe 108 and used for fuel oil instead of being cut back to the system. Low grade unevaporated oil from the

last high temperature retort is discharged into a settling tank 70, maintained at slightly lower temperature. Volatile products from the settling tank 70 pass through pipe 71 into the condenser of highest boiling point. This tank is provided with a number of off-takes 72, arranged at different elevations. The lighter grade oils removed through the upper off-takes may be further refined and worked into paraffin, wax, lubricating oils, etc.

The residuum from the bottom of the settling tank is sprayed through an injector nozzle 75 into a rotating coking kiln 76. This kiln preferably has bearings in the walls of a firebox 77 and is inclined so that the products of coking may be gravitationally fed toward the outlet end. Means are provided at 78 for rotating the kiln and at 79 for oppositely rotating a central shaft 80 carrying a plurality of scrapers 81 for removing the products of coking from the kiln walls. The temperature in the kiln is sufficiently high to cause destructive distillation and cracking of the residuum, the products being coke, various hydrocarbons from the heavy tars, greases and oil, coke oils and motor fuels to gases, including methane (CH_4) and hydrogen. The coke scraped from the walls of the kiln is fed to the lower end thereof and dropped into a well 82 containing water. The overflow cooling water from the cooling system 67, 67a, 67b, may be conveniently utilized to supply the well. The hot coke on contact with the water forms sufficient steam to afford back pressure on the joint between rotating and non-rotating parts at the lower end of the kiln, thereby preventing inlet of air at this point.

The contact of the steam and the heated coke produces water gas, thus adding to the fuel gases generated in the kiln and affording pressure thereon for carrying oil vapors from the kiln through an upper outlet pipe 83. Wet coke is removed from the well by a screw elevator 84 which carries the same to a storage bin. Gases from the pipe 83 are delivered to a tank 86, where partial condensation takes place. Uncondensed vapors are successively sprayed against a series of cooled plates 87, 88, the condensate from the tank 86 and the liquids precipitated on the plates draining into a collecting tank 89 from which the liquid may be pumped back into the system. The gases after passing the plates 87, 88, pass to a tank 93 and are pumped into a washing tower 90, in which final cooling and removal of water soluble constituents takes place and from which the gases are carried to a gasometer 91. Uncondensed gases from the cooling system 67, 67a, 67b, are also delivered through a pipe 92 to the tank 93, from which they are pumped to the

washing tower 90 and subsequently to the gasometer 91.

The gasometer 91 serves as a storage tank from which fuel gas may be withdrawn for firing the retorts and kiln. Gas may also be withdrawn through a pipe 95, compressed by a suitable compressor 96 to a pressure of approximately 300 pounds and stored in a high pressure tank 97. Leading from the tank 97 is a main high pressure gas line 98 tapped by the various gas pipes to the injectors 24, these latter pipes being equipped with the aforementioned reducing valves. Branch pipes 99 and 100 from the supply pipe 98 lead respectively to the upper end of the tank 10 and to a pipe line 101 for supplying the small agitating injectors. The gas pressure in the pipe 99 is controlled by a suitable reducing valve 102 and serves to supplement the pressure of the system caused by the gravity head and maintain the oil in tank 10 under the desired pressure. If it is desired to re-run the product from the last retort instead of passing it to the settling tank, it is carried directly back to storage through a pipe 104. This pipe is normally cut off from the retorts by a valve 103 and serves to convey liquid from the collecting tank 89 back to the main source of supply.

Figure 8 is a fragmentary view of a preferred arrangement wherein two batteries of retorts are arranged within the flue. A double bank of retorts, and preferably a double set of fractionating columns, are ordinarily used in connection with a single flue for supplying heat to the two complete sets of distilling apparatus. The inner walls of the flue are provided with opposed vertical recesses or niches 105 which accommodate the vertical upflow pipe 15a of the two sets of retorts. The upflow pipes are thus partially encircled by the hot flue walls and the portions of the pipes which are not directly exposed to radiation from the walls are in position to be exposed directly to the flue gases. In order to control the distribution of heat to the various retorts so that proper temperatures may be maintained, I prefer to employ a system of dampers or deflectors 110. The dampers are so arranged that they may cause deflection of the flue gases into the niches and completely around the upflow pipes; they may be set to entirely protect the upflow pipes from the direct heat from the gases or they may be adjusted to numerous intermediate positions to finely and accurately control the impingement of the gases on the pipes.

I have not attempted to indicate an arrangement of successive dampers such as would be used on a series of retorts in actual use but have simply shown some of the characteristic positions to which my dampers may be adjusted.

Preferably the dampers 110 are in the form

of deflecting blades or plates carried upon rotatable vertical shafts 111. Preferably also two of the dampers are employed in connection with each up-flow pipe 15, one to control the entrance and the other the exit of the annular passage between the pipe and the walls of the recess in which it is located. The shafts 111 are disposed within the flue directly in front of the entrances to the niches. The larger damper 110 associated with each retort has the blade arranged eccentrically on the shaft 111 so that it presents a wider portion 110a toward the inlet end of the flue. Characteristic positions of the larger dampers are indicated at *a* and *b*. At *a* it will be noted that the damper is swung so that its shorter side engages with the up-flow pipe and its longer side extends to the middle of the flue. When two of the dampers are thus arranged they completely block the flue passage and direct all of the flue gases in a divided path around the up-flow pipes in two oppositely facing niches. When the larger dampers are in their other extreme position *b* their longer sides engage with the wall of the flue and the dampers serve to effectively screen the retorts from the direct action from the flue gases, such gases passing through the center of the flue as indicated by the arrows. The characteristic positions of the smaller dampers are indicated at *c* and *d*. In position *c* the smaller dampers engage with the wall of the flue and when the larger dampers are in position *a* the smaller ones serve to complete the deflection of the flue gases entirely around an up-flow pipe. In other words, the flue gases having passed around the retorts are directed back toward the entrance of the flue by the smaller dampers so that when the two dampers associated with a single retort are in positions *a*, *c*, the retort is heated to the greatest possible extent. The other illustrated position *d* of the smaller dampers is a neutral position, the ends of the dampers engaging with neither the retorts nor the flue walls. The particular effect of this position is determined largely by the position of the larger dampers. When the latter are in position *b* the neutral position *d* of the small dampers has a tendency to prevent any direct contact of the flue gases with the retorts. With the large dampers in position *a* the neutral position of the smaller dampers serves to divide the stream of flue gases, passing some of them entirely around the retorts and permitting a portion of the gases to escape down the flue after having passed approximately three-fourths of the way around the retorts. Quite obviously numerous combinations of damper arrangements may be resorted to other than the combinations shown.

Another important feature of the damper arrangement is that they may be set to completely close in the niche of any desired re-

tort or retorts, as indicated for the last or fifth pair of retorts of the series. In this same connection, I have shown how inlet ducts 105a, for fresh air may be arranged extending through the walls of the flues to cool a niche and retort which has thus been cut off, thereby putting them in condition for repairs, etc.

It will be recognized that the feature of distilling in a series of retorts wherein each successive retort is at a lower pressure as well as higher temperature than the preceding, is of great advantage in fractional distillation. It is a well known fact that in distilling mixtures of liquids of different boiling points, there is a critical percentage mixture of the liquids for each particular pressure where the two liquids have an intimate relation analogous to that of alloys of quasi-chemical combination, in which condition the composite liquid has a definite boiling point which is not that of either of the liquids, at which boiling point the two liquids are vaporized as one, that is to say, both liquids boil off in a vapor containing the same proportion as does the liquid. Continuous boiling of liquids of different boiling points naturally tends to bring them to this equilibrium of constant boiling point. In the practice of my method there is this same tendency, but before the equilibrium condition is reached for the pressure in any one of the retorts, the material is discharged into a retort of lower pressure and higher temperature, thereby upsetting the equilibrium of constant boiling point. Therefore, the more volatile liquid will again be boiled off selectively the mixture again approaching nearer and nearer to the equilibrium condition for that retort and pressure, whereupon the liquid will pass to another retort of still lower pressure and still higher temperature, and so on through the series of retorts.

While my present invention is shown as including apparatus and methods suitable for fractional distillation and cracking of crude petroleum to recover the various constituent fractions, including grades of benzine, gasoline, naptha, etc., it will be evident that it is equally applicable to petroleum from which the more volatile constituents have been distilled and also that they may be employed for cracking or fractional distillation of higher grade oils. For these reasons, it will be understood that the term "oil" is used in the specification and claims hereof as a word of identification for certain classes of liquids to which the various features of my methods may prove applicable.

I claim:

1. A process of refining oil, which includes passing the oil successively through a series of retorts in each of which the oil is maintained at temperatures higher and pressures lower than in the preceding retort, conduct-

ing off vapors from each retort, separately condensing constituents of such vapors, segregating the lighter condensate and feeding heavier condensate into a retort of higher temperature and lower pressure than that of the retort from which it was derived by injector action of higher pressure gases, the differences both in the pressures and in the temperatures being substantial and continuously maintained during normal operation, for the purpose described.

2. A process of refining oil, which includes passing the oil successively through a series of heated retorts in each of which the oil is maintained at pressures lower than those of the preceding retort, permitting escape of vapors from each retort, separately condensing fractions of such vapors and spraying heavier condensate back to a retort of lower pressure than that of the retort from which it was derived by injector action of higher pressure gases.

3. A process of refining oil, which includes passing the liquid oil successively through a series of retorts in each of which the oil is maintained at temperatures higher and pressures lower than in the preceding retort, carrying off vapors from each retort separately and condensing such vapors, and returning uncondensed gases to the vapor space of each retort separately, the differences in the pressures being substantial and continuously maintained during normal operation for the purpose described.

4. A process of refining oil, which includes passing the oil successively through a series of retorts in each of which the oil is maintained at temperatures higher and pressures lower than in the preceding retort, condensing fractions of such vapors and spraying the heavier condensate so condensed into a succeeding retort over the surface of the oil therein by injector action of higher pressure gases, for the purpose described.

5. A process of refining oil, which includes successively passing the oil through a series of retorts in each of which the oil is maintained at boiling points higher and pressures lower than those maintained in the preceding retort, carrying off vapors from each retort and fractionally condensing such vapors, segregating the lighter condensate and spraying heavier condensate so condensed from one retort into the retort of next higher temperature by injection action of higher pressure gases.

6. A process of refining oil, which includes passing the oil successively through a series of retorts in each of which the oil is maintained at temperatures higher and pressures lower than those of the preceding retort, carrying off vapors from each retort condensing such vapors, producing a rapid oil circulation in each retort independent of the inter-

retort circulation, and returning uncondensed gases to the vapor space of each retort separately, the differences in the pressures being substantial and continuously maintained during normal operation for the purpose described.

7. A process of refining oil, which includes passing liquid oil successively through a series of retorts in each of which the oil is maintained at higher temperature and lower pressure than in the preceding retort of the series, permitting the escape of vapors from each retort and fractionally condensing such vapors, and returning uncondensed gases to the vapor space of each retort separately, the differences in the pressures being substantial and continuously maintained during normal operation for the purpose described.

8. A process of refining oil, which consists in controlling flow of the oil through a series of retorts which are maintained at successively higher temperatures and lower internal pressures, maintaining a relatively rapid circulation of oil by convection currents in each retort independent of the inter-retort flow, by providing a separate, relatively cool down-flow path from the upper to the lower portion thereof, carrying off vapors from each retort and condensing such vapors.

9. A process of refining oil which consists in flowing the oil through a series of retorts maintained at successively higher temperatures and lower pressures, passing the vaporized oil from each retort into an associated condenser and maintaining intercondenser vapor flow in a reverse direction to the oil flow through the retorts, the differences both in the pressures and in the temperatures being substantial and continuously maintained during normal operation, for the purpose described.

10. A series of retorts, each retort having inlet and outlet ports therein adjacent its lower end, heated up-flow and externally cooled down-flow pipes for liquid circulation, a vapor take-off at the upper end of the retort and pressure operated means for regulating the escape of vapor from the retort, successive retorts of the series having their respective escape means set for successively lower pressures.

11. A retort having inlet and outlet ports therein adjacent its lower end, up-flow and down-flow pipes for liquid circulation and a vapor take-off at the upper end of the retort, pressure operated means for regulating the escape of vapor from the retort, a gas operated injector nozzle at the upper end of the retort for injecting liquid into the retort.

12. A retort having inlet and outlet ports therein adjacent its lower end providing a sediment collecting pocket below and between them, a substantially vertical heated up-flow pipe connected with the lower end

of the retort and an unheated down-flow pipe of much smaller cross-section than the up-flow pipe delivering to the lower end of the retort.

13. A retort having inlet and outlet ports therein adjacent its lower end providing a sediment collecting pocket below and between them, a substantially vertical heated up-flow pipe connected with the lower end of the retort and an unheated down-flow pipe of much smaller cross-section than the up-flow pipe delivering to the lower end of the retort, and a baffle plate arranged between the inlet and outlet ports in the lower end of the retort.

14. Apparatus for refining oil comprising in combination a connected series of retorts maintained at successively higher temperatures by regulable external heating means and at lower pressures by separately adjustable pressure relief means for each retort, a condenser associated with each retort and into which vapors are boiled off from the retorts, means for serially connecting the condensers and for so regulating condenser pressures that the intercondenser vapor flow is in a reverse direction to the inter-retort oil flow, the differences both in the pressures and in the temperatures being substantial and continuously maintained during normal operation, for the purpose described.

15. Apparatus for refining oil, including in combination a connected series of retorts maintained at successively higher temperatures by regulable external heating means and at lower pressures by separately adjustable pressure relief means for each retort, a condenser associated with each retort and into which vapors are boiled off from the retorts, means for serially connecting the condensers and for so regulating condenser pressures that the intercondenser vapor flow is in a reverse direction to the inter-retort oil flow, and means for delivering the lower grade of condensate from each condenser directly back to the retorts, the differences both in the pressures and in the temperatures being substantial and continuously maintained during normal operation, for the purpose described.

16. Apparatus for refining oil, including in combination a connected series of retorts maintained at successively higher temperatures by regulable external heating means and at lower pressures by separately adjustable pressure relief means for each retort, a condenser associated with each retort and into which vapors are boiled off from the retorts, means for serially connecting the condensers and for so regulating condenser pressures that the inter-condenser vapor flow is in a reverse direction to the inter-retort oil flow, and means for spraying the lower grade condensate from each condenser back into a retort of higher temperature.

17. Apparatus for refining oil, including in combination a connected series of retorts maintained at successively higher temperatures by regulable external heating means and at lower pressures by separately adjustable pressure relief means for each retort, a condenser associated with each retort and into which vapors are boiled off from the retorts, means for serially connecting the condensers and for so regulating condenser pressures that the inter-condenser vapor flow is in a reverse direction to the inter-retort oil flow, and means for ensuring oil circulation in each retort independently of the inter-retort circulation, the differences both in the pressures and in the temperatures being substantial and continuously maintained during normal operation, for the purpose described.

18. A process of refining oil, which includes flowing the oil into a retort, boiling off vapor, fractionally condensing such vapor and spraying only the heavier fractions of the condensate by injector action of higher pressure gases into a similar retort maintained at a higher temperature but lower pressure to effect cracking of such condensate.

19. A process of refining oil which includes flowing the oil into a retort, boiling off vapor, fractionally condensing such vapor and discharging only the heavier fractions of the condensate through the vapor above the liquid in another retort maintained at a higher temperature but lower pressure to effect cracking of such condensate, boiling off the vapors from the second retort and condensing part of them and passing part of them back to the condenser of said first retort.

20. A process of refining oil, which includes flowing the oil into successive retorts and in each retort boiling off vapor, fractionally condensing the vapor, injecting only the heavier fractions of the condensate by injector action of higher pressure gases under pressure into a retort maintained at a higher temperature and lower pressure than the first retort to effect cracking of said condensate, the differences both in the pressures and in the temperatures being substantial and continuously maintained during normal operation, for the purpose described.

21. A process of refining oil, including flowing the oil into successive retorts, fractionally condensing vapors generated in each retort, and injecting only the heavier fractions of the condensate into a succeeding retort maintained at a higher temperature and lower pressure than the first retort by injector action of higher pressure gases whereby to effect rapid cracking of such condensate, the differences both in the pressures and in the temperatures being substantial and continuously maintained during normal operation, for the purpose described.

22. Apparatus of the class described, in-

cluding a series of retorts, means for maintaining the retorts at progressively higher temperatures conjoined with progressively lower pressures for the higher temperatures, a fractionating condensing column into which vapors from a lower temperature retort are delivered and condensed, an injector for spraying heavier condensate into a higher temperature retort by injector action of higher pressure gases to effect cracking of such condensate.

23. Apparatus of the class described, including a series of retorts, means for maintaining the retorts at progressively higher temperatures conjoined with progressively lower pressures for the higher temperatures, a fractionating condensing column into which vapors from a lower temperature retort are delivered and condensed, means for spraying heavier condensate on the surface of the liquid in a succeeding retort by injector action of higher pressure gases to cut the foam on the surface and to crack such condensate.

24. Apparatus of the class described, including a series of retorts, means for maintaining the several retorts at progressively different pressures, a fractionating condensing column into which vapors from a high pressure retort are delivered and condensed and means for mixing the heavier fraction of such condensate with uncondensed gases, and ejecting the mixture into a lower pressure retort to effect cracking of the condensate.

25. A process of refining oil which includes flowing the oil through a series of retorts maintained at successively higher temperatures and lower pressures, boiling off vapors from each retort into an associated fractional condenser maintained at considerably lower pressures and temperatures than its retort, cutting back heavier condensate from each condenser to a retort which is maintained at a slightly higher temperature than the boiling point of such condensate by an injector spray operated by higher pressure gases.

26. A process of refining oil which includes flowing the oil through a series of retorts maintained at successively higher temperatures and lower pressures, boiling off vapors from each retort into an associated fractional condenser maintained at considerably lower pressures and temperatures than its retort, cutting back heavier condensate from each condenser to a retort which is maintained at a slightly higher temperature than the boiling point of such condensate and maintaining intercondenser vapor flow in a direction countercurrent to the direction of inter-retort oil flow.

Signed at New York city, in the county of New York and State of New York, this 25th day of July, A. D. 1924.

EDWARD O. BENJAMIN.