Oct. 6, 1931. A. E. PEW, JR., ET AL 1,825,977

PROCESS OF CRACKING MINERAL OIL

Filed Aug. 18, 1928 2 Sheets-Sheet 1

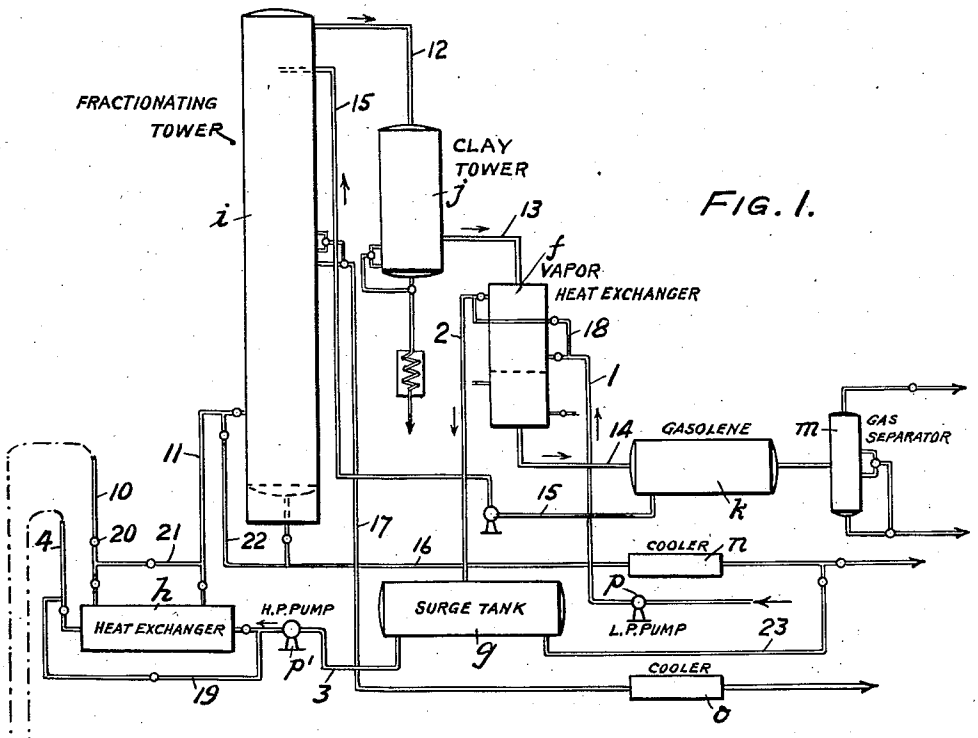
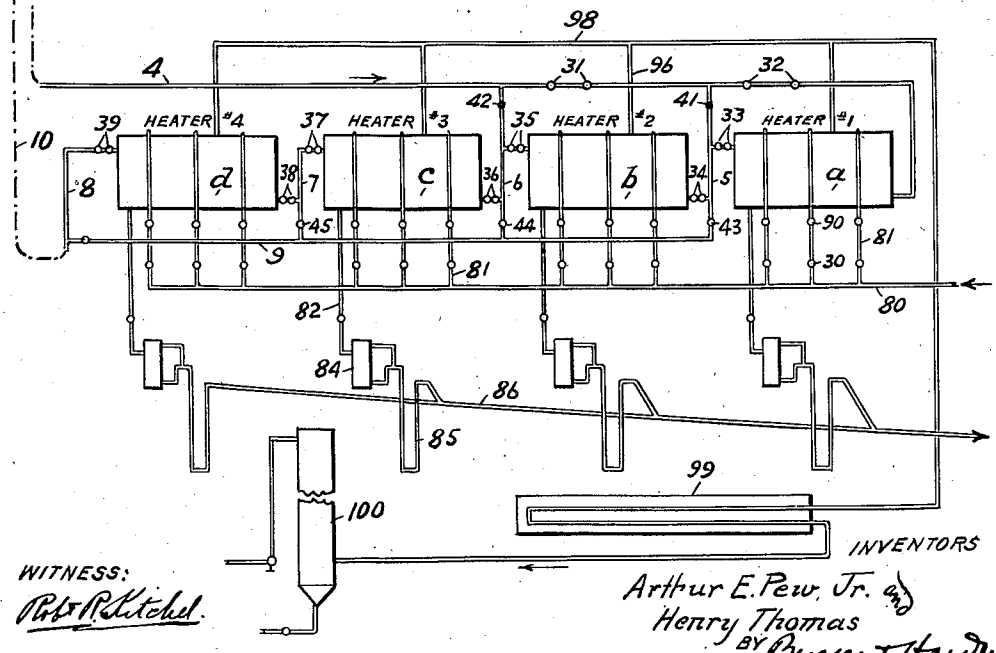


FIG. 1.



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PROCESS OF CRACKING MINERAL OIL

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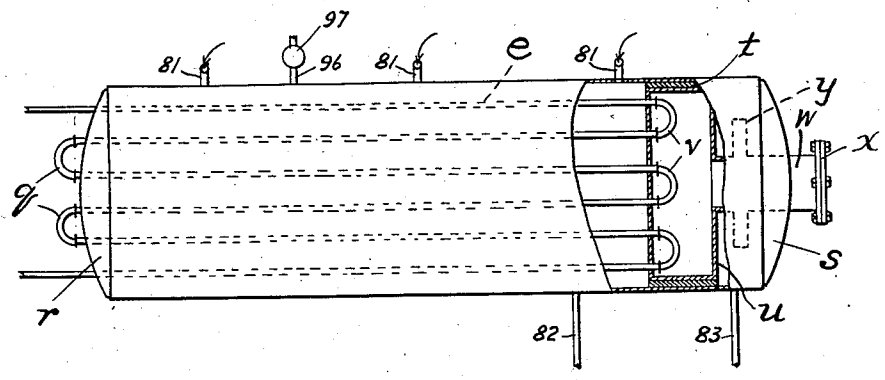


FIG. 3.

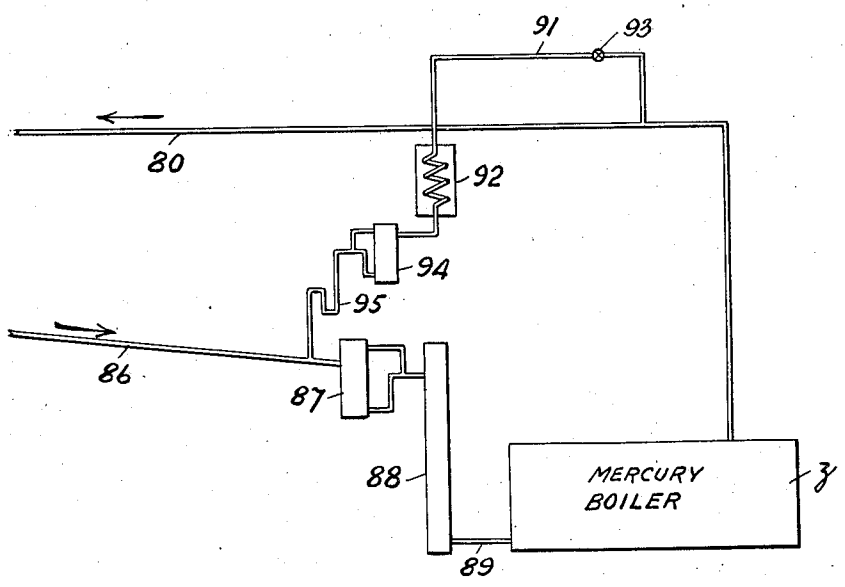


FIG. 2.

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Patented Oct. 6, 1931 1,825,977

UNITED STATES PATENT OFFICE

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PROCESS OF CRACKING MINERAL OIL

Application filed August 18, 1928. Serial No. 300,441.

The object of the invention is to provide a process for cracking higher boiling hydrocarbons to lower boiling hydrocarbons and particularly for cracking gas oil and other constituents of crude petroleum, or the crude itself, to gasoline.

The preferred way of practicing the process embodying the invention involves the use of mercury vapor or some equivalent material as a heating medium. Since the use of mercury vapor as a heating agent, in place of steam, furnace gases or the like, was first disclosed, its adaptability to the heating of mineral oil to effect its cracking was obvious, but the problems involved in its effective, economical and safe adaptation to this use have been such as to preclude its commercial application.

The present invention involves a practical and commercial process that possesses numerous advantages over known cracking systems. By means of the invention many new and useful results are obtained. The invention also involves the useful adaptation of certain discoveries that are unrelated to the use of mercury vapor as a heating medium but which cannot be practically executed except by a precise temperature control which cannot be attained, at least to the degree desired for the most efficient execution of the process, by the use of any heating medium other than one possessing the main characteristics of mercury vapor. By means of said precise temperature control, reliably producing certain temperatures of the stock undergoing decomposition which have been discovered to give the highest yield and the greatest throughput, there can be produced the maximum percentage of gasoline capable of being formed from the charging stock, with a minimum percentage of permanent gases consistent with the gasoline yield, in the shortest possible time. This result is attained with practically no formation of carbon and with the utmost economy of fuel; and the plant itself can be constructed much more economically and can, moreover, be operated continuously.

The process embodying the invention is not dependent for its execution upon any particular apparatus, although the apparatus shown in the drawings and hereinafter described is the best apparatus known to us for practicing the process.

It may also be stated that the use of mercury vapor as a heating medium involves grave danger of serious results due to any rupture of the containing medium for the oil when it is in heat exchange relation with the mercury vapor. No such system can be said to be of practical value, or to possess commercial possibilities, unless adequate safeguards are provided to prevent such results from accidents of this character. The apparatus shown contains every provision required to make the process safe as well as economical and efficient.

In the drawings:

Fig. 1 is a diagram of the entire plant except only certain pipe connections to the mercury boiler.

Fig. 2 is a diagram of the mercury boiler and the pipe connections thereto.

Fig. 3 is a side view, partly in section, of one of the series units of that part of the apparatus in which the cracking is performed.

The cracking apparatus, per se, comprises four tanks *a*, *b*, *c*, and *d*, in each of which is a coil of pipe *e*. The oil to be cracked flows through the coils of any three of the tanks in series. For example, the oil may flow through line 4 and thence through the pipe coil in tank *a*, thence through pipe 5 and through the coil in tank *b*, thence through pipe 6 and through the coil in tank *c* (in which the cracking is completed), and thence through pipe 9 and line 10. The pipes leading to and from the heaters are so arranged that any one of the tanks may be by-passed by the oil stream. In the example given, the tank *d* is by-passed. By proper valve manipulation, either of tanks *a*, *b* and *c* may be by-passed. For example, if tank *a* is by-passed, the oil flows from line 4 into pipe 5, thence through tanks *b* and *c* as above described, and thence through pipe 7, tank *d* and pipe 8 to line 10.

The described arrangement of four tanks of which any three may be in operation simultaneously permits the continuous operation

of the plant. When it is desired to clean out the pipe sections of any coil *e*, it is by-passed and the previously by-passed coil is placed in series with the other two coils.

Mercury vapor from boiler *z* flows through line 80 and thence, in parallel, through branch pipes 81 into the several tanks that are in operation. Mercury vapor enters each tank at the top. Condensed mercury flows out from the bottom of each tank through pipes 82 and 83 into a clean-out 84. This clean-out communicates, top and bottom, with one of the balancing columns of mercury 85, the other balancing column communicating with a line 86 flowing into a clean-out 87, which communicates top and bottom, with a stand pipe 88, the bottom of which connects, through pipe 89, with the liquid mercury space of the boiler.

By throttling more or less the valves 90 on the mercury vapor inflow pipes 81, the pressure of mercury vapor in any given tank may be reduced in varying degree below boiler pressure, thereby making it possible to predetermine the temperature of condensation in each tank independently. The difference between the pressures in the boiler and in a given tank will be taken care of by a corresponding difference in the levels of mercury in the two columns 85. It will thus be understood that by providing a boiler pressure sufficient to give a vapor temperature above the maximum temperature of condensation that may be desired in any of the tanks, any desired temperature of condensation may be established in any of the tanks. Thus extraordinarily exact temperature control is achieved, which is of the utmost importance, as will be explained hereinafter.

In order to limit the maximum boiler pressure, a pipe 91 from the mercury vapor feed or supply line 80 extends through a condenser 92 to a clean-out 94. On pipe 91 is a loaded safety valve 93. The clean-out is connected, top and bottom, with a mercury seal 95, which connects with the mercury condensate return flow line 86.

The described means for maintaining a constant boiler pressure and for governing the pressure in each tank is more particularly described in applications filed by Pew and Thomas May 29, 1926, Ser. Nos. 112,443 and 112,444, which have matured, respectively, into Patents Nos. 1,714,811 and 1,714,812, issued May 28, 1929.

The charging stock is pumped through a line 1, thence through a heat exchanger *f* provided with a water inlet and an outlet (where it exchanges heat with gasoline vapors and partially condenses them, as hereinafter described), thence through a line 2 to a surge tank *g*, thence through a line 3 and, under very high pressure, through a heat exchanger *h* (where it exchanges heat with the cracked stock, as hereinafter described) and thence, through line 4 and successively through the reaction coils of three tanks (e. g., tanks *a*, *b* and *c*), and out through line 10 as hereinbefore described).

The cracked stock outflowing through line 10 flows through the heat exchanger *h* (wherein it exchanges heat with the incoming stock to be cracked) and thence, through pipe 11, into a fractionating tower *i*. The pressure in this tower is so greatly reduced that practically all, or by far the larger part, of the cracked stock is vaporized. The vapors rise in the tower and are cooled and partly condensed by gasoline pumped in through line 15. The amount of gasoline pumped into the upper part of the tower is such as to effect a condensation of fuel oil and gas oil and cool the gasoline to the desired vapor temperature, say about 420° F. The gasoline vapors escaping from the top of tower *i* flow through pipe 12 into and through a tower *j*, in which the vapors are filtered and stabilized and from which they pass, through a pipe 13, into the heat exchanger *f*, where they exchange heat first with incoming cold charging stock and then with water. From the heat exchanger *f* the condensed gasoline and any permanent gases formed in the cracking operation flow, through a pipe 14, into a gasoline accumulator tank *k* and thence to a gas separator *m*, in which a separation of the fixed gases from the liquid gasoline occurs. A regulated proportion of the gasoline flowing into the accumulator tank *k* is pumped through line 15 into the upper part of the tower as above described.

The heavier or fuel oil fractions condensed in fractionating tower *i* are withdrawn through pipe 16 and thence go through cooler *n* to storage. The lighter or gas oil fractions condensed in fractionating tower *i* are withdrawn through pipe 17 and thence go through cooler *o* to storage.

By means of a low presure charging pump *p* in pipe 1, a pressure of (say) 125 pounds per square inch is maintained beyond the pump. Part of the oil may be by-passed around exchanger *f* through a pipe 18, to line 2. Enough oil may be by-passed to give a temperature to the oil entering the surge tank *g* of (say) 280° F.

The high pressure pump *p'* on line 3 may establish a pressure in line 4 of (say) 1200 pounds to the square inch. Part of the charging stock may be by-passed around the heat-exchanger *h* through line 19 to line 4. The proportion of oil by-passed may depend on the extent to which it is desired to reduce the temperature of the cracked stock flowing through the heat exchanger *h* toward the fractionating tower *i*. In practice, it may be desirable to pass all the charging stock through the heat exchanger *h* and use the by-pass 19 only in case of a break in the tubes in

the exchanger. The charging stock may enter line 4 at a temperature of (say) 435° F.

The charging stock may be heated gradually or quickly to the desired cracking temperature in the cracking apparatus per se. The preferred temperatures are hereinafter specified more in detail. For the purpose of discussing the general operation of the plant, it may be assumed that the oil is heated to (say) 865° F. and is then maintained at that temperature until it leaves the last tank through line 10. There is, of course, a great drop in pressure during the flow of the oil through the heat exchanger *h* and the cracking coils. Before the cracked stock reaches the slide valve 20 the pressure may be reduced to (say) 650 pounds per square inch. On the low pressure side of slide valve 20 the pressure may be reduced to (say) 250 pounds per square inch. At the inlet to tower *i* the pressure is further reduced to (say) 100 pounds per square inch, while the pressure in the tower may be 25 pounds to the square inch or lower. Provision is made for by-passing part of the cracked stock or synthetic crude around the heat exchanger *h* through a line 21. By regulating the proportions of the cracked stock passing through the exchanger *h* and the by-pass 21, the temperature of the oil entering the tower *i* may be accurately predetermined. It may enter, for example, at a temperature of 750° F., while the temperature in the tower may be (say) 700° F.

In case it is desired to by-pass the tower *i*, as in starting up or shutting down, the synthetic crude can be diverted through line 22 and line 16 to cooler *n*.

In case of emergency, instead of flowing the fuel oil to storage, it may be diverted through line 23 to the surge tank *g* and recirculated through the cracking system. It is also possible to start the plant more quickly by regulating the water flow through cooler *n* and by-passing oil through lines 22, 16 and 23, thus quickly raising the temperature of the charging stock.

Each coil *e* comprises a large number of pipe sections which are so connected at the ends by curved sections as to form a long continuous coil that may be (say) over seven-tenths of a mile in length. The pipe sections cannot be fixedly secured to the opposite end heads of a simple tank, since provision must be made for the unequal expansion of the tube sections and the tank. It is preferred to construct the tank as shown in Fig. 3.

The tank shown in this figure comprises a shell having circular dished end heads *r* and *s*, and has openings at the top communicating with the mercury vapor inflow pipes 81, and a connection at the top with a pipe 96 on which is a relief valve 97 to relieve internal pressures. The pipe sections forming the coil are, at one end, welded to head *r* from the outside and are connected one to another by headers or return bends *q*, which are removable for cleaning purposes. Inside the tank, near the other end, is welded a ring of steel *t*, which has been machined. A circular box *u*, with flat heads, is inserted inside the steel ring. The other ends of the pipe sections are welded to the inside head of box *u*, and headers or return bends *v* connected adjacent pipe sections and, like headers *q*, are removable. Welded to the other head of box *u* is a pipe *w*, which extends out through head *s* and is welded thereto. At the outer end of pipe *w* are two flanges *x* bolted together to make a tight connection. Installed in pipe *w* is an expansion joint *y* of the well known accordian type.

Mercury vapor fills the space around the tubes composing the coil *e* but cannot penetrate the box *u*. It is thus possible, without hazard, for a man to enter box *u* through pipe *w* and remove the return bends *v* when the tank is not in operation. Mercury vapor, however, will penetrate, through the sliding fit between box *u* and ring *t*, the space between box *u* and end head *s*. Such vapors condense and are withdrawn through pipe 83. The main condensate flows out through line 82.

In case any of the pipe sections of any coil *e* should break, provision should be made to prevent oil vapors from flowing to the boiler either through the mercury vapor line or through the mercury condensate line. A number of provisions are made to insure against this possibility.

As before stated, at the top of each mercury vapor tank is a pipe 96 equipped with a safety valve 97, which is set for any desired pressure, say 125 pounds. The pipes 93 leading from the several tanks connect with a common pipe line 98, which extends through a cooler 99 into a steel tank 100. In case a tube breaks, safety valve 97 opens as soon as the pressure rises to 125 pounds and the mixture of oil vapors and mercury vapor are cooled in cooler 99 to a temperature of (say) 450° F., the mercury and most of the oil being thus liquefied. The liquid mercury, oil and oil vapors then enter tank 100. Due to the difference in the specific gravities of mercury and oil, the mercury collects in the conical bottom and may be drawn off.

The mercury seals 85, hereinbefore described, are of sufficient depth to hold a pressure in excess of 125 pounds and therefore, in event of tube failure, would prevent oil from flowing to the mercury boiler through the mercury condensate return 86. Any liquid oil or oil vapors that would enter pipe 82 would be trapped in the clean-out 84, due to the mercury seal 85.

In the event of tube failure, oil vapors are prevented from flowing to the mercury boiler, by way of the mercury vapor inflow pipe 81

and inflow line 80, by means of the lower valve 30 on pipe 81. This valve is a non-return valve that closes in case the pressure in the tank extends the pressure in line 80. As a double safeguard, the upper valve 90 may be a remote control hand operated valve.

While the above provisions insure against the contamination of the mercury system with oil in case of tube failure, provision is also made to limit the amount of oil that would escape into the tank. To this end valves are installed which automatically isolate any heating tank in which a tube breaks. The valves are arranged in pairs, 31, 32, 33, 34, 35, 36, 37, 38 and 39. Of each pair of valves, one valve is an automatic valve and the other a hand operated valve with remote control for safety; the automatic valve being adapted to close when the pressure drops below a fixed point. Let it be assumed that the plant is operating on units *a*, *c* and *d* and that a break occurs in unit *a*. This would result in an immediate drop in pressure in line 4; and the two automatic valves of the two pairs of valves 31 and 32 would immediately shut, preventing further flow of oil into unit *a*. By suitable connections from these valves to the power shut-off on the high pressure pump *p'*, this pump would stop. The other two valves of the two pairs of valves 31 and 32 would then be closed by hand.

To prevent oil from backing up into the unit in which a break has occurred from the unit immediately in advance, one of the valves of each pair of valves 33, 35, 37 and 39 is made a check valve, the other valves of these pairs being hand operated remote control valves for double safety.

It will thus be clear that in case of a break in any of the coils *e*, the corresponding unit is shut off both at the oil inlet and the oil outlet. The plant can then be restarted by putting in series with the other two units that have been in operation, the unit which theretofore had not been in operation.

Valves 41, 42, 43, 44 and 45 are operated in order to by-pass any unit.

By using mercury vapor as the heating medium in the apparatus described, the temperature of the oil in the several units may be predetermined with extraordinary accuracy. In the first place the heat required to be transferred to the oil to raise it to, or hold it at, a given temperature in any tank may be accurately calculated. The required mercury vapor temperature to effect this required heat transfer by condensation of the mercury vapor may also be accurately calculated, and precisely this required mercury vapor temperature may be established in any tank as hereinbefore described.

Once the oil is raised to the required temperature, the temperature difference between the mercury and the oil is very slight and there is no local overheating of the oil and there will be practically no coke formation if the pressure is maintained high enough to maintain the oil largely in liquid phase. To illustrate the very small temperature difference required to heat the oil in the first described unit through the temperature range 435–865° F. and maintain it at that temperature during the remainder of its flow through that unit, a mercury temperature of 866° F. or thereabouts would be required. To maintain the temperature of the oil at 865° F. during its flow through the other two units, a mercury temperature of about 875° F. would be required. The pressure in pounds absolute of mercury vapor at 875° F. is about 80. Accordingly, the boiler may operate at 80 pounds pressure.

It is well known that the speed of conversion of higher boiling to lower boiling hydrocarbons increases enormously with increase of temperature, the speed of conversion doubling with every 18° F. increase of temperature. Thus the speed of the reaction at 900° F. is over 2000 times the speed of reaction at 700° F. If, however, the oil is heated to above its critical temperature, that is, the temperature at which, regardless of pressure, the oil will be converted into a true gas, the speed of travel of the oil through the coils will be enormously increased. This would so shorten the time of reaction as to more than counterbalance the increased speed of reaction and result in a reduced throughput and a reduced yield of gasoline. Moreover carbon would form rapidly and clog the tubes. The most efficient cracking temperature is therefore just below the critical temperature. It is therefore important to determine the critical temperature of the charging stock before starting the operation of the plant and to raise the temperature of the oil to a temperature just below its critical temperature in the first unit and preferably substantially before it has completed its passage through the first unit. By maintaining the oil just below its critical temperature in the other two units, the oil may be prevented from passing into gas phase, and the two important factors of time and temperature of reaction are so adjusted that when the stock emerges from the last unit it contains the maximum proportion of gasoline which is capable of being produced before the rate of conversion of gasoline into fixed gases begins to exceed the rate of conversion into gasoline of higher boiling hydrocarbons.

While the maintenance of the oil largely in liquid phase is of importance in preventing too rapid a flow of the oil through the cracking apparatus, still the great combined length of the three coils is such as to cause a very rapid flow of oil therethrough. Based on cold oil, this flow would be at the rate of about six feet per second. With the illustrative temperatures and pressures herein

given, the actual flow is approximately at twice this rate. In view of the very small required temperature difference between the heating agent and the oil, the conditions required to prevent carbon formation are almost entirely absent, and if the oil is maintained largely in liquid phase, there is practically no carbon formed, or, at the worst, the amount of carbon formed is little more than infinitesimal. Any minute amounts of carbon that tend to form would, moreover, tend to be washed out of the cracking coils by reason of the high speed of travel of the liquid oil.

We have discovered that notwithstanding the general rule that the critical temperatures of the hydrocarbon constituents of petroleum increase as the boiling points rise, it cannot be assumed that every mixture of hydrocarbon constituents has a critical temperature corresponding to the mean of the critical temperatures of the constituents. We have discovered that in the operation whereby gas oil is cracked into gasoline (and at the same time to some extent into higher boiling fuel oil), the critical temperatures of the mixture actually rises until about the time the production of gasoline reaches its maximum. Thus the critical temperature of the charging stock may be 865° F. and this critical temperature may gradually rise to over 900° F. before the cracked oil is discharged from the last coil of the series. This makes it feasible to so regulate the heat transfer as to cause the temperature of the oil, as it flows through the coils, first rapidly to rise to just below 865° F. and then very slowly to rise so that, at any given point in the oil stream, the temperature of the oil will be just below its critical temperature at that point in its travel. With mercury vapor, and the means for controlling the amount of the heat transfer herein described, it is possible if the process is practiced with the maximum degree of efficiency to predetermine the temperature of the oil at any point in its travel within about one degree F., which has heretofore never been approximated in the oil cracking art. Consequently, while preventing the sudden conversion of the whole body of the oil to a gas, the speed of reaction may be increased to an absolute maximum. This enables the oil to be forced through the coils at a substantially higher speed, with a resultant substantially increased throughput.

While there is specified in certain of the claims herein, as the direct heating agent for the oil, only mercury vapor, it is intended to include, as equivalents, any vaporizable metal, metallic compound, or other substances, such as, possibly, diphenyl oxide, benzo phenone, sulfur, or some possible metal alloy, that is known to or is found to possess the characteristics of mercury vapor that make it particularly adapted to be the purpose of the present invention. In claiming mercury vapor, it is intended to include any substance that may be, in fact, an equivalent. These characteristics principally are: (1) its boiling points, at practicable absolute pressures, correspond to temperatures desirable in oil distillation; (2) it may be brought as a vapor into heat exchange relation with the oil, and, by regulating the pressure, may be caused to condense at the temperature desired and impart its latent heat to the oil; (3) the amount of heat transferable to the oil with each degree of temperature difference between the mercury vapor and the oil is vastly greater than where a hot gas, such as steam or furnace gases, is used as a heating medium; (4) nearly all its heat is usefully expended in heating the oil; (5) avoidance of local overheating due to high temperature differences between the heating medium and the oil; (6) economy in the amount of the heating medium required to vaporize a given amount of oil, thereby making it practicable to avoid the use of an apparatus of huge dimensions.

We have not herein claimed the apparatus herein shown and described, as the same forms the subject-matter of separate applications filed June 26, 1929, Serial No. 373,702 and Serial No. 373,703.

Having now fully described our invention, what we claim and desire to protect by Letters Patent is:

1. The process of cracking mineral oil which comprises first determining the critical temperature of the oil to be subjected to the cracking operation, then heating the oil to just below its critical temperature and thereby subjecting it to cracking, and then, as the critical temperature of the oil rises, raising the temperature of the oil so as to maintain it just below its increased critical temperature.

2. The process of cracking mineral oil which comprises first determining the critical temperature of the oil to be subjected to the cracking operation, then heating the oil to just below its critical temperature and thereby subjecting it to cracking, and then, as the critical temperature of the oil changes, changing the temperature of the oil so as to maintain it just below its changed critical temperature.

3. The process of cracking mineral oil which comprises first determining the critical temperature of the oil to be subjected to the cracking operation, then heating the oil to just below its critical temperaure and thereby subjecting it to cracking, and then, as the critical temperature of the oil rises, raising the temperature of the oil so as to maintain it just below its increased critical temperature until the cracking is substantially completed.

4. The process of cracking mineral oil

which comprises first determining the critical temperature of the oil to be subjected to the cracking operation, then heating the oil to just below its critical temperature and thereby subjecting it to cracking, and then, as the critical temperature of the oil changes, changing the temperature of the oil so as to maintain it just below its changed critical temperature until the cracking is substantially completed.

5. The process of cracking mineral oil which comprises establishing a rapidly flowing stream of oil of great length and small thickness, heating the oil through a range of cracking temperatures, during its flow along a part of the stream, to a temperature just below the critical temperature at which the oil is convertible into a true gas, and as the critical temperature of the oil rises as it flows through a more advanced part of the stream, raising the temperature of the oil so as to maintain it just below its increased critical temperature.

6. The process of cracking mineral oil which comprises establishing a rapidly flowing stream of oil of great length and small thickness, heating the oil through a range of cracking temperature, during its flow along a part of the stream, to a temperature just below the critical temperature at which the oil is convertible into a true gas, and as the critical temperature of the oil changes as it flows through a more advanced part of the stream, changing the temperature of the oil so as to maintain it just below its changed critical temperatures.

7. The process of cracking mineral oil which comprises establishing a rapidly flowing stream of oil of great length and small thickness, heating the oil through a range of cracking temperatures, during its flow along a part of the stream, to a temperature just below the critical temperature at which the oil is convertible into a true gas, and as the critical temperature of the oil rises as it flows through a more advanced part of the stream, raising the temperature of the oil so as to maintain it just below its increased critical temperature until the cracking is substantially completed.

8. The process of cracking mineral oil which comprises establishing a rapidly flowing stream of oil of great length and small thickness, heating the oil through a range of cracking temperatures, during its flow along a part of the stream, to a temperature just below the critical temperature at which the oil is convertible into a true gas, and as the critical temperature of the oil changes as it flows through a more advanced part of the stream, changing the temperature of the oil so as to maintain it just below its changed critical temperature until the cracking is substantially completed.

9. The process of cracking mineral oil which comprises heating a body of liquid mercury under an absolute pressure required to produce mercury vapor at a temperature required to heat the oil as hereinafter specified, flowing the oil in a continuous stream of restricted cross-section, flowing the mercury vapor into a confined space surrounding the oil stream and into heat exchange relation therewith to effect condensation of mercury vapor and such transfer of its latent heat to the oil as will decompose higher boiling constituents thereof into lower boiling products, imposing such superatmospheric pressure on the oil as will maintain it during its decomposition mainly in liquid phase at the temperature hereinafter specified, returning condensed mercury to the body of liquid mercury, and regulating the temperature of the mercury vapor in heat exchange relation with the oil so as to heat the oil rapidly to a temperature close to but just below the critical temperature at which it would be convertible into a true gas, and maintaining the oil at about that temperature during its flow throughout the greater part of the length of the heated stream.

10. The process set forth in claim 9 comprising also flowing the oil in a continuous stream of restricted cross-section through a series of confined spaces in the first of which the temperature of the oil is raised to a temperature close to but just below the critical temperature at which it would be convertible into a true gas, and maintaining the oil close to but just below its critical temperature during its flow through the following confined space or spaces.

11. The process set forth in claim 9 in which the oil, after it is heated to just below its critical temperature, is gradually raised in temperature through a relatively small range as the critical temperature of the oil slowly rises while still maintaining the oil below its critical temperature.

12. The process set forth in claim 9 comprising also flowing the oil in a continuous stream of restricted cross-section through a series of confined spaces in the first of which the temperature of the oil is raised to a temperature close to but just below the critical temperature at which it would be convertible into a true gas, and raising the temperature of the oil through a relatively small range during its flow through the following confined space or spaces as the critical temperature of the oil rises while still maintaining the oil below its critcal temperature.

13. The process of cracking mineral oil which comprises flowing the oil in a continuous stream of restricted cross-section through a series of confined spaces, heating a body of mercury vapor under an absolute pressure required to produce mercury vapor having a temperature exceeding that required in the first of said spaces and not below that re-

quired in the last of said spaces, and maintaining in the first of said spaces a lower mercury temperature than the temperature of the mercury vapor as generated by regulating the rate of flow of mercury vapor thereinto so as to heat the oil flowing therethrough through a wide range of temperature close to but just below the critical temperature at which it is convertible into a true gas.

In testimony of which invention, we have hereunto set our hands, at Marcus Hook, Pennsylvania, on this 13th day of August, 1928.

ARTHUR E. PEW, JR.
HENRY THOMAS.