April 19, 1932. G. W. GRAY 1,854,836

PROCESS AND APPARATUS FOR TOPPING AND CRACKING OILS

Filed May 14, 1929

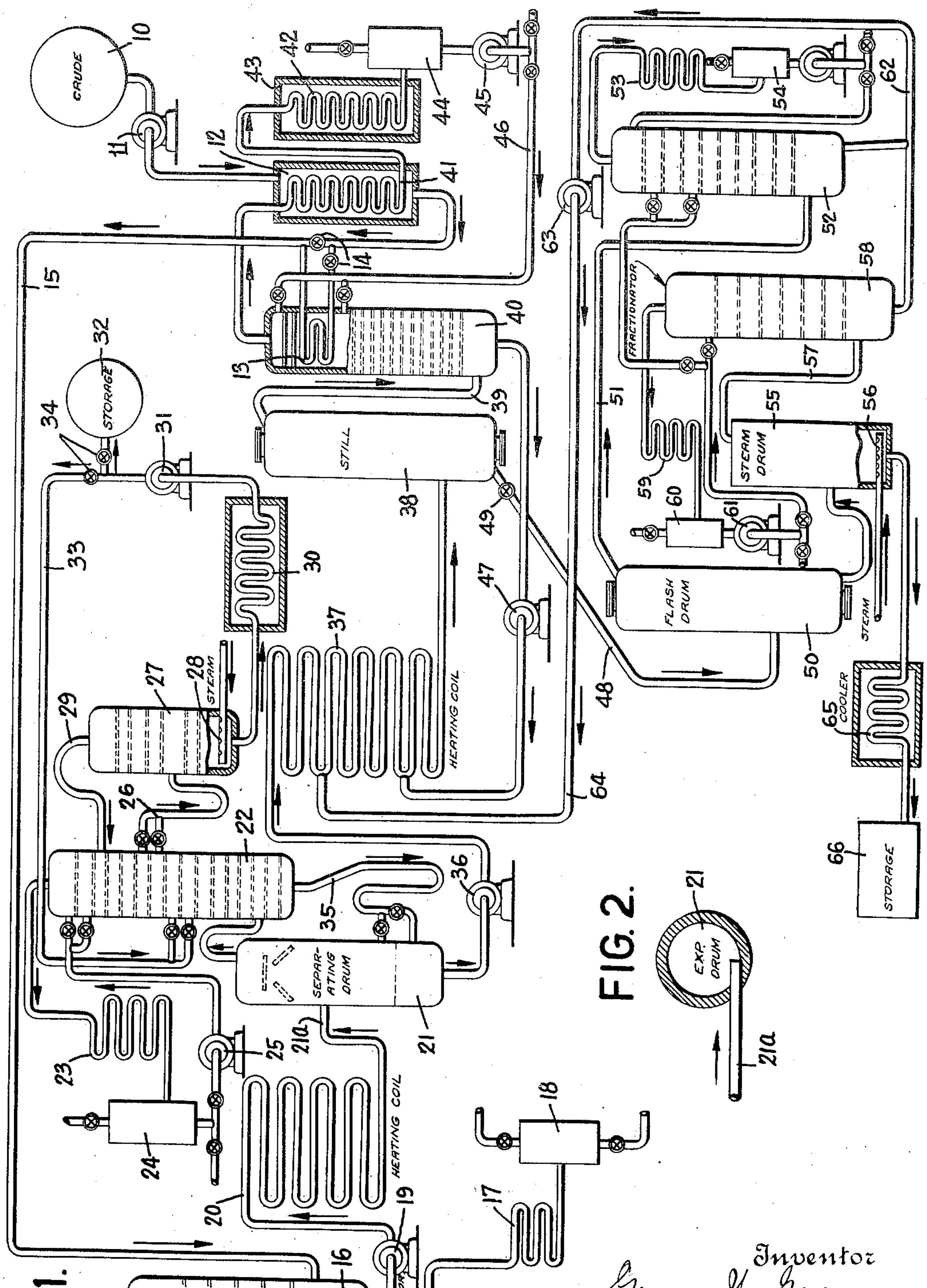

FIG. 1.

FIG. 2.

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Patented Apr. 19, 1932 **1,854,836**

UNITED STATES PATENT OFFICE

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PROCESS AND APPARATUS FOR TOPPING AND CRACKING OILS

Application filed May 14, 1929. Serial No. 362,886.

The present invention relates to a process, and suitable apparatus for carrying out the process, for the conversion of heavy high-boiling oils into lower boiling oils. Its features are particularly applicable to the treatment of natural crude oils, or other heavy oils, which contain relatively light constituents as well as the heavier components. To this end the invention contemplates a combined topping and cracking system in which the lighter constituents of the oil are first removed without being subjected to cracking conditions, while the heavier portions are subsequently passed to and through a cracking system.

A feature of the invention is the method of topping the fresh charge, which is effected in several stages and in such a way as to separate the lighter or vaporized components into their natural gasoline constituents and their kerosene constituents.

While certain phases of the invention are not dependent upon any particular form of cracking system, various novel features have been included in the preferred method of cracking forming a part of the present invention. In general, the cracking system embodies a heating coil wherein the oil is raised to a cracking temperature, preferably between 750° and 950° F., and from which the oil is discharged into a reaction chamber, all operated under a pressure, preferably between 100 and 600 pounds but not necessarily uniform throughout. Provisions may be made for removing vapors and residual oil separately from the reaction chamber, although this is not essential and both may, if desired, be removed together. In either event the invention contemplates the stripping of the heavy oil taken from the cracking system while still hot so as to utilize its heat content in obtaining a maximum yield of vaporizable material to form either the final product or a suitable stock for further cracking. For this purpose the heavy or residual oil is passed to a stripping drum or zone maintained under a materially reduced pressure, preferably as near atmospheric pressure as possible. In this zone a very large percentage of the residual oil will be flashed into vapor. The vapors so formed are fractionated and the heavier portions are returned to the heating coil at an intermediate point. Where the vapors are separately removed from the cracking chamber, separate fractionating means are preferably provided for these vapors and their heavier components are likewise returned to the heating coil at an intermediate point, but preferably at a subsequent point from that at which the fraction from the stripping unit is returned.

Among other features of the invention may be mentioned improvements in methods and apparatus for fractionating the vapors developed at different points in the system. In connection with all phases of the invention, the primary object has been to improve generally a topping and cracking system of the character disclosed and to increase its efficiency in the handling of a relatively large quantity of material and in the production of more of the merchantable products of the reaction and less of the heavy fuel oils and similar constituents, which are more or less of a drug upon the market. Many specific objects and advantages of the invention will become more apparent as the description progresses.

With this brief outline of its primary features, the invention will now be set forth in detail with reference to the accompanying drawings illustrating one form or embodiment of the invention. Of the drawings:

Figure 1 is a diagrammatic showing of suitable apparatus adapted for the conduct of the novel features of the process.

Figure 2 is a sectional view through a separating drum employed in the process.

The complete unit contemplated by the present invention involves three primary systems, namely, the topping, cracking, and residuum stripping systems, all of which are connected and inter-related in such a way as to produce the maximum beneficial results.

Referring now to Figure 1, crude or other heavy oil may be drawn from a suitable storage reservoir 10 by means of a pump 11 and forced through a tank 12 wherein it comes into heat exchange relation with certain vapors generated in the system, as will more clearly appear hereinafter. From the opposite end of the closed tank 12 the oil may be forced through a coil 13 located within and at or near the top of a fractionating column, where the oil comes into further heat exchange with heated vapors and liquid. If desired, the coil 13 may be by-passed altogether or in part by proper manipulation of a pair of valves 14 in the lines indicated. A pipe 15 leading from the coil 13 may serve to convey the heated oil to any suitable form of separator, such as a dephlegmating or fractionating tower, 16 into which it is introduced, preferably near the bottom of the latter. This tower may be of any suitable construction but is preferably provided with a series of bubble trays above the point of entry of the heated oil so that any vapors that may be released will pass successively through the bodies of liquid on the series of trays and any portions not condensed in this way will pass on to a condensing coil 17 and into an accumulator drum or storage tank 18. Any appropriate means may be provided for cooling the coil 17 to condense the vapors. The drum 18 will preferably be provided with valve-controlled outlets for both the liquid condensate and the gases, the latter serving as a means of pressure regulation.

From the bottom of the tower 16 the unvaporized and condensed portions of the initial charge may be withdrawn by a pump 19, which may then pass them to a heating coil 20, of any suitable construction, mounted in any practicable type of furnace. In this coil the temperature of the oil will be raised still further, but preferably not to the point of cracking, and the material will then be passed into a separating or expansion drum 21. In order to bring about a more complete separation between the lighter vaporized components and the heavier liquid components, the transfer line designated 21*a* preferably enters the expansion drum tangentially so as to produce a whirling movement of the heated products. By virtue of the centrifugal action, the liquid will be thrown toward the shell of the drum and the vaporized constituents, which will thus be forced inwardly, will rise to the top of the drum past a series of baffle plates, suitably designed to prevent entrainment of particles of liquid oil, and will pass out at the top of the drum into a fractionating or dephlegmating column 22. The latter may be of any suitable construction but preferably is provided with a series of inter-connected bubble trays. The point of entry of the vapors into the column will preferably be above several of the lowermost trays, although this is not essential. In passing through the column some of the vapors will be condensed and will be refluxed from tray to tray to the bottom, while the lighter constituents will pass on through and out at the top. A suitable vapor line will convey the vapors to a condensing coil 23, which may be cooled in any suitable way, and from which the products are passed to an accumulator drum or storage vessel 24. The latter will preferably be equipped with the usual liquid and gas outlets connected to any desired points of disposition. A pump 25 may serve to draw the condensate from the drum and return it to a point at or near the top of the fractionating column. If desired, several valve-controlled branches may be provided into the column to permit introduction of the condensate at various points near its top.

At or near the midpoint of the column 22 there may be provided a drawoff line 26 having, if desired, a number of valve-controlled branches leading from liquid pockets formed by, or associated with, various trays in the column. This drawoff line may serve to pass an intermediate fraction, in the nature of kerosene or, if desired, light gas oil, to a second fractionating column 27. If desired, this column may be provided near its bottom with a steam spray 28 adapted to aid in the stripping of the lighter components of the fraction handled in the column. A vapor line 29 should be employed to return any of the light vaporized constituents from the column 27 back to the column 22, preferably at a point near the top of the latter. The liquid which collects at the base of the column 27 will preferably be withdrawn, passed through a suitable cooling coil 30, and then forced by a pump 31 either to a suitable storage vessel 32 or (through a line 33, back to the fractionating column 22. The cooling coil 30 may obviously be omitted, if desired, but its use is deemed to be preferable. The point of re-entry of the cooled liquid will preferably be near the middle of the column but slightly below the point at which the liquid is withdrawn by the line 26. Several valved branch lines may be provided, as shown, to permit variation of the point of entry, if desired. In addition to the cooling effect provided at the mid-point of the column by means of the refluxed kerosene, the latter serves to materially improve the color and stability of the material rising to the top of the column by way of washing down the yellowish polymers entrained with the vapors up to this point. A pair of valves 34 may be employed to determine what, if any, of the oil will be returned to the column and what will be sent to storage.

Leading from the base of the column 22 a line 35 may serve to return the condensate which collects there to the base of the expansion drum 21. The return may be made either to a point above or below the liquid level within the drum and for this purpose a pair of valved branch lines may be provided, as shown.

Unvaporized constituents of the initial charge, as well as the condensate of the heavier vapors, may be withdrawn from the expansion drum by means of a pump 36 and passed to the inlet of a second heating coil 37. This coil will constitute the beginning of the cracking system and will preferably serve to heat the oil to a temperature at which cracking takes place at a good rate, as for example between 750° and 950° F. A pressure between 100 and 600 pounds, or even more, may advantageously be employed in the coil. After the oil has been heated to the desired temperature, either with or without a substantial amount of cracking in the coil, it will be passed into a still 38 wherein a relatively large body of oil may be maintained under cracking conditions.

While only a single still has been illustrated in the drawings, it will be understood that a plurality of such stills may be provided and connected in series, or otherwise, to constitute a battery. The heated oil may be passed into one or more of the stills and the latter may be connected by suitable liquid and vapor lines, as desired. The still, or reaction chamber, or battery of such chambers, may either be heat-insulated to prevent any substantial drop in temperature or may be mounted in a furnace so as to receive heat from an outside source to maintain the desired temperature. Vapors evolved in the still may be passed by a vapor line 39 into a fractionating or dephlegmating column 40. The vapors preferably enter near the bottom of the latter and pass to the top. Any suitable contacting means may be provided within the tower, although a plurality of serially connected bubble trays is to be preferred. The vapors in rising through the column will pass the heat exchange coil 13, previously mentioned, and will then pass through one or more additional bubble trays above this coil before emerging from the top of the column and passing to a vapor heat exchange coil 41 mounted within the previously mentioned tank 12. From the coil 41 the mixed condensate and vapors will pass to a coil 42 of a final water-cooled condenser 43 and from there into an accumulator drum or storage receptacle 44.

The arrangement of the heat exchange coil 13 at the top of the fractionating column is such that a desired amount of cooling will be provided at this point and the condensate so formed will be refluxed through the tower to effect the desired temperature gradient throughout. By placing the coil 13 slightly below the top of the tower in advance of the final fractionation of the vapors, a greater heat exchange between the vapors and the fresh charge is effected without disturbing the efficient fractionation of the tower. In lieu of the bubble trays above the coil, the tower may, if desired, be provided with some suitable form of packing, such as rocks or rings, at this point. This packing would then serve effectively to eliminate entrained particles of liquid from the vapors in addition to aiding in the fractionation. Somewhat the same effect, but probably to a less extent, would be brought about by the extra trays.

In the event that insufficient cooling is provided by means of the coil 13, a portion of the final distillate may be returned from the drum 44 to a point near the top of the fractionating column by means of a pump 45 and a line 46. The point of introduction of this returned distillate may either be below the coil 13 or above the trays that are over the coil or partly each way, as desired. If the distillate is returned above the upper trays, it will serve to further wash down the final vapors.

From the base of the column 40 the condensate formed in the process of fractionation may be withdrawn by means of a pump 47 and sent to the heating coil 37. This returned condensate will be at a relatively high temperature and for this reason may be advantageously introduced into the coil 37 at a point relatively near its outlet end. The intermediate point of the coil at which this condensate is introduced may best be selected as that at which the temperature of the condensate coincides with that of the advancing stream of fresh oil.

As the cracking reaction progresses, the oil in the still 38 will gradually become heavier and it will reach the point where it should be withdrawn from the system. If desired, this residual oil may be withdrawn in a continuous stream in such volume as to maintain the proper liquid level in the still, thus representing the difference between the incoming stream of oil and the vapors carried off at the top; otherwise the withdrawal may be made at intermittent periods of sufficient frequency to maintain the proper level in the still. If several stills should be provided in series, as previously suggested, the withdrawal might be effected from any one or more of the stills. An advantage of the intermittent withdrawal is that a larger stream may be withdrawn at a given time and in this way clogging up of the drawoff lines is avoided.

For the purpose of permitting the withdrawal of residual oil, a line 48 controlled by a valve 49 may be connected to the bottom of the still and may serve to pass the oil to a suitable flash drum, or expansion chamber, 50. Preferably the latter will be operated under a materially reduced pressure, which should be as near to atmospheric pressure as possible. If the residual oil is passed intermittently to this drum, its pressure will vary considerably over the period between successive charges but normally the best results are obtainable by maintaining a minimum fluctuation and a minimum pressure. A considerable portion of the residual oil will be vaporized in the chamber 50 under the reduced pressure, due solely to the contained heat of the oil. Vapors so released may be removed from the top of the drum through a line 51 and passed to a fractionating or dephlegmating column 52. This may suitably be either of bubble tray construction or be merely packed with rock, or the like, and may have a vapor line at the top leading to a condensing coil 53 and an accumulator drum or storage tank 54. Cooling of the top of the column may be effected by returning a part of the final distillate from the drum 54, if desired.

In order to effect still further stripping of the volatile constituents from the residual oil, the latter may be passed from the bottom of the drum 50 to a second drum 55, entering the latter preferably at an intermediate point. Here the oil may be subjected to the action of jets of steam supplied through suitable spray nozzles 56 from any suitable source. Vapors released in this drum may be passed through a line 57 to another fractionating column 58, or, if desired, to the same column 52 that receives the vapors from the drum 50. If a separate column is provided, it may suitably be of bubble tray construction, or may be merely packed and may have a vapor line at the top leading to a condensing coil 59, and an accumulator drum or storage vessel 60. A pump 61 may withdraw the liquid from this drum and either pass it to further storage or return it to the top of the column 58 to provide the desired cooling at this point, or pass it to a suitable point in the column 52 or pass a part to each column. If all of the condensate from the drum 60 is employed for the cooling of the columns 52 and 58, the necessity of storing this additional component, which may be in the nature of a light gas oil, will be avoided.

Condensates which collect at the bases of the columns 52 and 58 may be withdrawn into a common line 62 by means of a pump 63 and returned through a line 64 to the heating coil 37. This condensate will preferably enter the coil at an intermediate point somewhat in advance of the point at which the condensate from the column 40 enters the coil. This is for the reason that the condensate from the stripping unit will be somewhat cooler than that from the pressure fractionating tower. It will, of course, be advantageous to introduce it at a point where its temperature corresponds to that of the fresh oil. The final heavy residual fuel oil which remains in the steam drum 55 may be withdrawn continuously or intermittently from the latter and may be passed through a cooler 65 and into a suitable storage vessel 66.

In order that the co-ordination of the various portions of the system may be more readily comprehended, a brief résumé of the preferred mode of operation of the system will now be given.

Crude oil, containing both light and heavy constituents, is withdrawn from the storage tank 10 and passes through the heat exchangers 12 and 13 wherein its temperature may be raised to a point between 300° and 500° F. This heated oil, under relatively low pressure, is then passed to the separating tower 16 where a portion of the lighter gasoline constituents, having an endpoint of, say, between 300° and 400° F., are eliminated. The heavier unvaporized components of the charge are passed through the heating coil 20 still under low pressure, preferably below 75 pounds. Higher pressures may be employed but in that event a reduction valve would normally be placed in the transfer line 21*a*. In the coil 20 the oil will be heated to a temperature preferably between 550° and 700° F. and will then be passed into the expansion drum 21 for further separation. The remaining gasoline constituents, as well as the kerosene constituents, will be eliminated in the overhead product from this drum, whereas the heavier vapor constituents, after condensation, as well as the unvaporized components of the original oil, will be passed by the pump 36 to the pressure cracking system.

The cracking unit is comprised primarily by the heating coil 37 and the still, or series of stills, 38. Preferably a uniform pressure of between 100 pounds and 600 pounds, or higher, will be maintained throughout the pressure cracking system and the pressure fractionating column, although, if desired, pressure drops may be provided between the heating coil and the still and between the still and the fractionating column. Cracking temperatures preferably between 750° and 950° F., or higher, should be maintained at the outlet of the heating coil and as nearly as possible within the still, which may either be fired or heat-insulated. A final distillate of any desired endpoint, preferably within the gasoline range, will be withdrawn from the top of the pressure fractionating column 40, while condensate from the latter will be returned to the heating coil for further cracking. Residual oil from the still 38 will be passed either continuously or intermittently into the flash drum 50, maintained at a materially reduced pressure, preferably only slightly above atmospheric. Unvaporized residual oil will be passed to the second drum 55 where steam may be applied to assist further vaporization. From this steam drum a final residue, consisting of very heavy fuel oil, will be withdrawn and sent to storage. The overhead products from the flash drum 50 and the steam drum 55 will be sent to separate fractionating columns to produce separate final distillates and separate condensates, the latter of which may be joined and returned to the heating coil 37 as good cycle gas oil, or the like, for further cracking. The distillates may be either treated separately or blended and treated together, as by re-running or the like, or, as previously explained, the distillate in the drum 60 may be completely disposed of as a cooling medium for the columns 52 and 58, in which case it will all be ultimately merged with the material passing from the top and bottom of the column 52.

While one admirable form of the invention has been set forth, and suitable apparatus for conducting the novel features of the process has been disclosed, it will be understood that many changes or modifications may be made without departing from the spirit of the present invention. It is desired to be limited only by the scope of the claims which follow:

What I claim is:

1. In a process of the character disclosed the steps comprising introducing a charge of heavy oil at the inlet of a coil, heating the stream of oil to a cracking temperature in transit through the coil, separating the heated oil into vapor and residual components, subjecting the vapors to fractionation to form a light fraction and a heavy fraction, returning the heavy fraction to said coil at an intermediate point, passing said residual oil to a reduced pressure zone where vapors are evolved, subjecting the vapors to fractionation to form a light fraction and a heavy fraction and returning said last named heavy fraction to said coil at a different intermediate point.

2. In a process of the character disclosed the steps comprising passing a stream of oil through a coil under super-atmospheric pressure, heating the oil in transit to a cracking temperature, introducing the heated oil into a reaction chamber, removing generated vapors from said chamber and subjecting them to fractionation, returning the heavier fractions to said coil at an intermediate point, removing heavy oil from said chamber and passing it to a zone of reduced pressure where vapors will be evolved, fractionating said vapors, and returning heavier fractions to said coil at an intermediate point of the latter in advance of that at which said first mentioned fractions are introduced.

3. In apparatus of the class described a heating coil, a reaction chamber in communication therewith, means for forcing oil under pressure through said coil and into said chamber, a low pressure vaporizing drum, means for passing heavy oil from said chamber to said drum to vaporize a portion thereof, a dephlegmator for separating said vapors into a lighter fraction and a heavier fraction, means for withdrawing said heavier fraction from the bottom of the dephlegmator and returning it to said heating coil at an intermediate point thereof, a second dephlegmator for separating vapors evolved in said chamber into a lighter fraction and heavier fraction, and means for withdrawing said heavier fraction from the bottom of said dephlegmator and returning it to said heating coil at an intermediate point subsequent to that at which said first mentioned heavier fraction is returned.

In witness whereof I have hereunto set my hand this 11th day of May, 1929.

GEORGE W. GRAY.