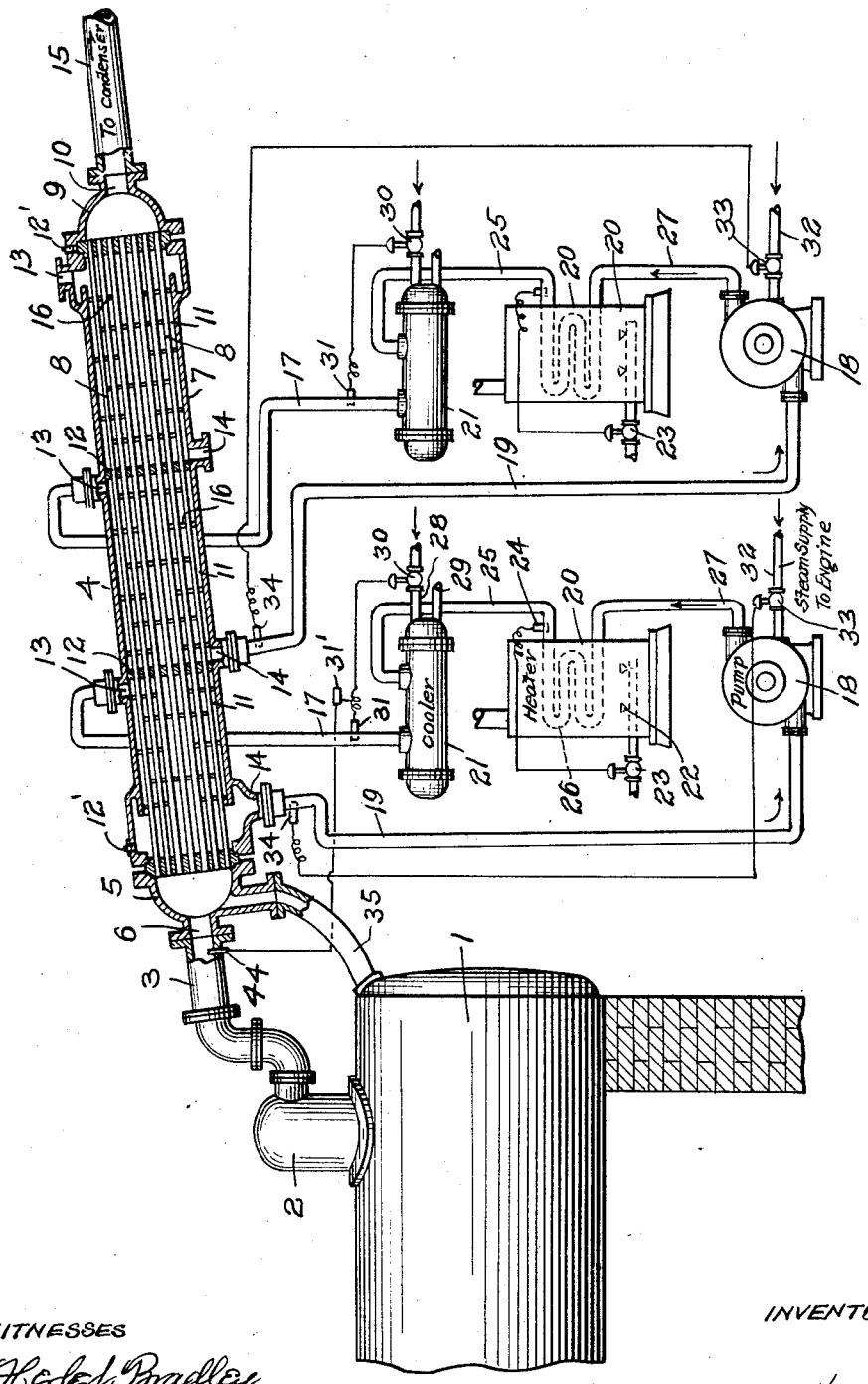
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FRACTIONATING APPARATUS

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WITNESSES

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FRACTIONATING APPARATUS

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This invention relates to apparatus for obtaining substantially complete fractionation of liquids from mixtures, such as binary, or more complex mixtures, containing such liquids.

Various mixtures of liquids are obtained from natural sources, and it is often desirable to separate certain of the liquids contained in the mixture for the purpose of obtaining them in a substantially pure state. While this can ordinarily be accomplished in a laboratory, certain difficulties are encountered when the process of fractionation is attempted on a commercial scale. For example, it is highly desirable to produce motor fuels having certain specific characteristics from mixtures of hydrocarbon liquids which are available in natural sources of supply, and while the theories of fractionation or separation are well understood, it has heretofore been impossible to economically carry out such theories on a commercial scale. As a result, the production of motor fuel having highly desirable characteristics which are obtained by complete fractionation has been so costly as to in effect make the price of such fuel prohibitive when compared with the price of less satisfactory but commercial fuel.

An object of my invention is the production of apparatus which is relatively cheap to build and operate but which may be employed in obtaining substantially complete fractionation of liquids from mixtures available in natural sources of supply or such as result from manufacturing processes.

In the oil refining industry, it is particularly desirable to separate certain hydrocarbon liquids from mixtures containing the same, and one of the objects of the present invention is to produce apparatus which renders it possible to separate certain hydrocarbon liquids, in substantially pure state, from liquid mixtures containing the same. It will, however, be apparent that the apparatus herein illustrated and described may be used in the fractionation of liquids other than those usually classed as hydrocarbons.

In the single sheet of drawings accompanying and forming a part hereof, I have illustrated what I now consider to be the preferred form of apparatus, but it will be apparent to those skilled in the art that various changes and modifications may be made therein without departing from the spirit and scope of the invention as hereinafter more particularly set forth.

The apparatus illustrated includes a still 1, in which a liquid mixture, such as crude oil or naphtha, is vaporized by being subjected to heat. The still is of the usual form employed in distillation processes and is provided with a dome 2 from which the vapors are delivered through piping 3. The delivery end of the piping communicates with a fractionator or heat exchanger 4 which is provided at its inlet end with a head 5 having an inlet port 6 and secured to a cylindrical shell 7. The shell 7 encloses a plurality of tubes or vapor passages 8 which are in open communication at their inlet ends with a chamber formed by the head 5 and which terminates at their outlet ends in a similar chamber formed by a head 9 secured to the shell 7 and provided with an outlet port 10. The interior of the shell is shown divided into a number of fluid circulating chambers 11 by means of diaphragms 12. In the drawings, two such diaphragms are illustrated and the end tubes 8 extend through and are secured in tube sheets 12'. This arrangement of tube sheets and diaphragms provides three liquid circulating chambers 11. Each of these is provided with a liquid inlet port 13 and a liquid discharge port 14. These ports are so connected to liquid circulating systems as to include each chamber 11 in one system.

The fractionator is so formed or located that the tubes 8 are inclined upwardly from their inlet to their delivery ends, and the vapor outlet port 10 of the head 9 or of the fractionator communicates through a pipe 15, with a condenser, of the type usually employed in commercial distillation processes.

The theories of fractionation have been well established, as is exemplified by United States Patent No. 1,171,464 to Rosanoff of Feb. 15, 1916, but it has been impossible to economically carry forward these theories on a commercial scale since the cost of apparatus has been prohibitive and, as a

matter of fact, apparatus heretofore developed has been commercially impractical. One of the features of the present invention is that the heat extraction from the gaseous vapors traversing the fractionator is accomplished gradually, with the result that the vapors are cooled to a predetermined temperature as they traverse the fractionator but at the same time the cooling process is gradual and the temperature of the vapors is gradually reduced from the inlet to the outlet end of the fractionator without being subjected to zones of sudden temperature changes. For this reason, the apparatus may be operated in such a way as to successfully carry forward the theories of complete fractionation wherein the temperature of the mixed vapor is gradually reduced and the condensate occasioned by the reduction in temperature is permitted to flow back to a region of predetermined higher temperature at which it is again vaporized and again carried forward with the vapors moving through the fractionator.

For the purposes of illustration, I have shown three chambers 11 formed within the shell 7 and each forming a part of a separate liquid circulating system. It will be apparent that each such system is adapted to abstract and carry heat away from the gaseous vapors traversing the tubes 8. It will also be apparent that where a relatively large reduction in temperature is necessary to obtain complete fractionation of a particular liquid, from a mixture containing that liquid, a large number of such chambers would have to be employed if the theories, expounded by Rosanoff, are to be satisfied in the fullest degree and if no other means were employed for the purpose of obtaining the gradual reduction in the temperature of the vapors. I, however, avoid the necessity of employing a commercially impractical number of cooling chambers, but at the same time obtain the advantage of the complete fractionation theories, by employing means in connection with each chamber, such that the heat transfer from the vapors, traversing the tubes 8, is controlled and the vapors gradually cooled, even though the circulating liquids delivered to successive chambers 11 vary materially in temperature.

This is accomplished in the illustrated embodiment, by employing a series of baffles 16 in each chamber 11 so arranged as to vary the rate of flow of cooling fluid past different portions of each tube 8 in each chamber and in this way control the rate of heat transfer from the vapors to the fluid so as to minimize or avoid abrupt changes in the temperatures of the vapors as they pass from the region of one circulating system to the region of another.

As shown, the inlet port 13 of each chamber 11 communicates with a pipe 17 forming a part of a circulating system through which cooling fluid, such for example as oil having a high flash point, is delivered by a pump 18. Each outlet port 14 of each chamber 11 communicates with a pipe 19 which in turn communicates with the inlet of the pump 18. In accordance with the theories of complete fractionation and also in accordance with the mode of operation to be employed in connection with the apparatus here disclosed, it is essential that the temperature range in each of the various chambers 11 be maintained at substantially a predetermined temperature. For this reason, I have disclosed means for controlling the temperature of the fluid delivered to each of the chambers 11 in order that the desired determined temperature at the inlet may be maintained. As shown, by way of illustration, I employ a separate heater 20 and cooler 21 in each circulating system, and the heater and cooler are separately controlled by the temperature of the fluid leaving them. As shown diagrammatically, the heater 20 is provided with gas or oil burners 22 and the supply of fuel to these is controlled by a valve 23 which is diagrammatically shown as controlled by a thermostat 24 located in the outlet pipe 25 of the heater. Oil is delivered to the heating coil 26 of the heater through a pipe 27 which communicates with the delivery port of the pump 18. The pipe 25 communicates with the inlet of the cooler 21 which is similar in construction to an ordinary surface condenser and is provided with an inlet 28 and an outlet 29 for cooling fluid, such as ammonia gas, pentane or water.

The flow of cooling fluid is controlled by a valve 30 located in the water inlet piping 28, and this valve is in turn controlled by a thermostat 31 which is located in the piping 17. The outlet to the cooler communicates with the pipe 17 and consequently oil traversing the circulating system is delivered from the cooler direct to the inlet port 13 of the associated chamber 11.

With this arrangement, the circulating oil is delivered at substantially the predetermined temperature to the associated inlet port 13. It will, of course, be apparent that the temperature control is obtained by either the thermostat valve 23 or the valve 30 or by the co-operation of both the heater and the cooler. It will be apparent that the valve 23 may be so arranged as to completely shut off the burners (a pilot flame being employed to relight them) and that the valve 30 may entirely close off the flow of cooling water through the cooler. With such an arrangement, either the cooler or the heater will generally be in operation as such, but at the same time the method of coupling them in the circulating system makes it possible for one to co-operate with the other in producing the desired temperature of the circulating liquid

at the inlet to the associated chamber 11. The effectiveness of the cooler is varied in response to the variations in the temperature of the circulating liquid leaving the cooler, with the result that the cooler responds quickly to any variation in the temperature of the oil and maintains the circulating oil delivered to the fractionator at the desired temperature.

In order to obtain the desired rate of heat transfer from the vapor traversing the tubes 8 to the circulating fluid of each system or to obtain the desired temperature range in each chamber 11, I control the rate of flow of the circulating fluid in each system, in response to the temperature of the fluid as it leaves the associated chamber 11. This is accomplished in the apparatus illustrated by varying the steam supply to the engine or turbine driving the pump 18 in accordance with the temperature of the circulating fluid leaving the port 14 of the associated chamber 11.

For simplicity of illustration, the driving engine of each pump 18 is not shown, but a steam supply piping 32 leading to the engine is shown and is provided with a valve 33 which is controlled by means of a thermostat 34 located in the pipe 19 immediately adjacent to the associated port 14. With this arrangement, the rate of circulation of the cooling fluid, and consequently the rate of heat transfer within each chamber 11, will be controlled by the rise in temperature of the circulating fluid as it traverses the chamber 11 forming a part of its circulating system. It will be apparent that where a fluid such for example as pentane gas is employed as the cooling medium, the pump will not be employed, but the control will be accomplished by means of a thermostatically controlled throttle valve.

It will be apparent that the right-hand chamber 11 illustrated in the drawings will be equipped with a similar system, similarly controlled, but that the thermostatic regulation of each system will be such that the lowest temperature will be maintained in the uppermost or right-hand chamber 11, whereas the highest temperature will be maintained in the chamber 11 located immediately adjacent to the inlet port 6 of the fractionator and progressively decreasing temperatures will be maintained in the intermediate chambers so as to bring the vapors to the desired fractionating temperature but at the same time to avoid subjecting the vapors to temperature shocks or to abrupt changes in temperature.

It will be apparent to those skilled in the art that the temperatures of the circulating fluids delivered to the various chambers 11 of the fractionator may be such as to produce a gradual reduction in the temperature of the vapors traversing the tubes 8 of the fractionator, and that in this way, these vapors may be cooled to any desired temperature to accomplish the substantially complete fractionation of a particular liquid having a definite boiling point, and that this fractionation may be accomplished from mixtures, containing the liquid in question, even though those mixtures are binary or more complex mixtures.

One of the important features of my invention is the method of baffling employed in each of the chambers 11 for the purpose of obtaining the predetermined rate of heat transfer for each unit of length of the tubes 8. In determining this baffling, it is essential to determine the desired temperature for the circulating liquid at the inlet and outlet of the chambers 11. The pitch, i. e. the spacing of the baffles 16 in each chamber is then determined in accordance with the rate of heat transfer that it is desired to obtain from one end of the chamber to the other. For example, if the rate of heat transfer is to be gradually reduced in the direction of the vapor flow in the tubes 8, then in the apparatus illustrated, the baffles would be close together at the vapor inlet end of each chamber 11 and would be spaced further apart as they approach the vapor delivery end of that chamber, it being understood that in the illustration, the flow of circulating liquid is counter-current to that of the vapors traversing the tubes 8. It is, therefore, possible to obtain a proper spacing of the baffles which will provide an increase or a decrease in the temperature increment per unit of length of heat transfer surface of the tubes 8, so as to give the correct and predetermined temperature zones to the vapors passing through the tubes 8 for proper fractionation in accordance with the theories of complete fractionation.

It will, therefore, be apparent that the pitch of the baffles can be determined from the liquid and vapor phase curves of the particular mixtures to be fractionated and that the temperature of the vapors traversing the tubes 8 may be predetermined according to the laws of fractionation by proportioning the inlet temperature of the circulating liquid and the rate of flow of that liquid through the chamber and the baffle pitch. Those skilled in the art will understand that the transfer rate of any particular design of apparatus will vary, but may be empirically determined by known methods, and this transfer rate, together with the other data above mentioned, will then be employed in the determination of the baffle pitch. It will also be apparent that by adopting the proper temperature gradient for any specific mixture to be fractionated, a single chamber may replace the three chambers 11 illustrated in the drawings and the varying pitch of the baffles may be such as to maintain any desired rate of heat transfer per unit of length of tubes 8 so as to give the desired predetermined

temperature of the vapor at every point along the tubes 8, for a complete fulfillment of the laws of fractionation. It will, of course, be apparent that the elimination of the multiplicity of chambers 11 will materially simplify the apparatus, since it will avoid the necessity of employing more than one circulating system and a large number of temperature controls.

In operation, the temperature of the vapors traversing the fractionator is gradually reduced to the predetermined temperature of the circulating liquid entering the vapor delivery end of the fractionator, with the result that condensation is taking place at different points along the tubes 8 and the condensate so formed is draining back into regions of higher temperature, and is being re-vaporized as described. The condensate which does not vaporize at temperatures encountered in the fractionator is returned through the reflux tube 35, and the vapors leaving the fractionator through the port 10 are delivered to a condenser where they are condensed.

In many cases, the temperature of the vapors entering the fractionator through the inlet port 6 varies materially during a run. In order to accomplish true fractionation, it may therefore be desirable to continually vary the temperature of the cooling fluid within the chamber 11 to correspond with variations in the temperature of the vapor entering through the port 6.

In order to accomplish this and also avoid the necessity of manual control, I employ a thermostat 44, diagrammatically shown with the bulb or thermo-couple in the vapor pipe 3. This thermostat controls the operation of the thermostat 31 with the result that a predetermined difference is maintained between the temperature of the vapors entering through the port 6 and the temperature of the cooling fluid delivered to the chamber 11. This is accomplished by so arranging the thermostat 44 that it varies the position of the control or adjusting device 31′ which forms a part of the thermostat 31 and is diagrammatically shown on the drawings.

It will be apparent to those skilled in the art that structure such as illustrated is adapted for use as an independent or integral plant, and that where a continuous supply of circulating fluid is available, as in a refinery employing continuous stills, the use of the separate circulating system may be avoided by employing oil from the stills as the cooling medium.

With such an arrangement, the same general mode of operation would be employed and the thermostats would be similarly placed.

It will also be apparent that the temperature of the incoming cooling medium should be so proportioned with relation to the temperature of the incoming vapors and the known heat transfer rate of the fractionator as to produce temperatures within the vapor passages of the fractionator that correspond with the temperatures necessary for true fractionation and that this may readily be accomplished by adjusting the apparatus herein set forth.

While I have illustrated but one embodiment of my invention, it will be apparent to those skilled in the art that changes and modifications, other than those herein described, may be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

What I claim is:—

1. Apparatus of the character described, comprising a fractionator provided with at least one passage for vapors received from a source of vapor, means for delivering a flow of fluid to said fractionator and in heat transferring relation with said vapor passage, means for delivering the fluid at substantially a predetermined temperature, and means for varying the rate of flow of said fluid at different points along said passage to obtain variable rates of heat transfer from the vapors to the fluid at different points along said passage, to thereby obtain predetermined changes in the temperature increment of the vapors per unit length of the heat transfer surface of said passage.

2. An apparatus of the character described, comprising an unobstructed vapor line receiving vapor at its lower end and delivering vapor at its upper end, a shell surrounding said line and having liquid inlet and outlet ports, a closed circuit including said shell, means for circulating fluid through said circuit in contact with said line, means responsive to the temperature of the fluid at the inlet port of said shell for maintaining the fluid entering the shell at substantially a predetermined temperature, means dependent on the temperature of the fluid after it has received heat from the vapor for controlling said circulating means to vary the rate of fluid flow through said shell, and means within said shell for varying the rate of flow of the liquid past successive portions of said line to control the rate of heat interchange along said line.

3. A fractionator comprising a vapor passage, a shell surrounding said passage and provided with a fluid inlet port and a liquid outlet port, means for circulating a cooling fluid through said shell in contact with said passage, means for maintaining a predetermined temperature of the fluid entering said shell through the inlet port thereof, means dependent on the temperature of the fluid leaving the shell through the outlet port thereof for controlling said circulating means to vary the rate of flow of the fluid traversing the shell and to maintain a predetermined temperature difference between the fluid en-

tering and the fluid leaving the shell, and baffles within the shell for directing the flow of fluid along said passages, and so spaced as to vary the rates of heat transfer per unit lengths of heat transfer surface of said passage along the passage and thereby the temperature increment per unit length of said passage of the vapor traversing the passage.

4. A fractionator of the tube and shell type having an inlet for condensable vapors communicating with one passage thereof and an inlet for cooling fluid communicating with another passage thereof, means including a thermostat subjected to the temperature of the cooling fluid leaving said fractionator for maintaining the fluid entering the fractionator at a predetermined temperature, and a thermostat subjected to the temperature of the vapor entering the fractionator for varying the adjustment of the first mentioned thermostat.

5. Fractionating apparatus, comprising a shell, at least one vapor conveying passage extending therethrough, means for delivering condensable vapors to said passage, said passage extending upwardly from the vapor inlet to the outlet end thereof, means for delivering fluid to the interior of said shell in heat transferring relation to said passage, means for varying the temperature and means for varying the rate of flow of such fluid at different points along said passage to control the rate of heat transfer between the fluid so delivered and the vapors traversing said passage.

In testimony whereof, I have hereunto subscribed my name this 4th day of August, 1926.

E. HUNTINGTON HARRIS.