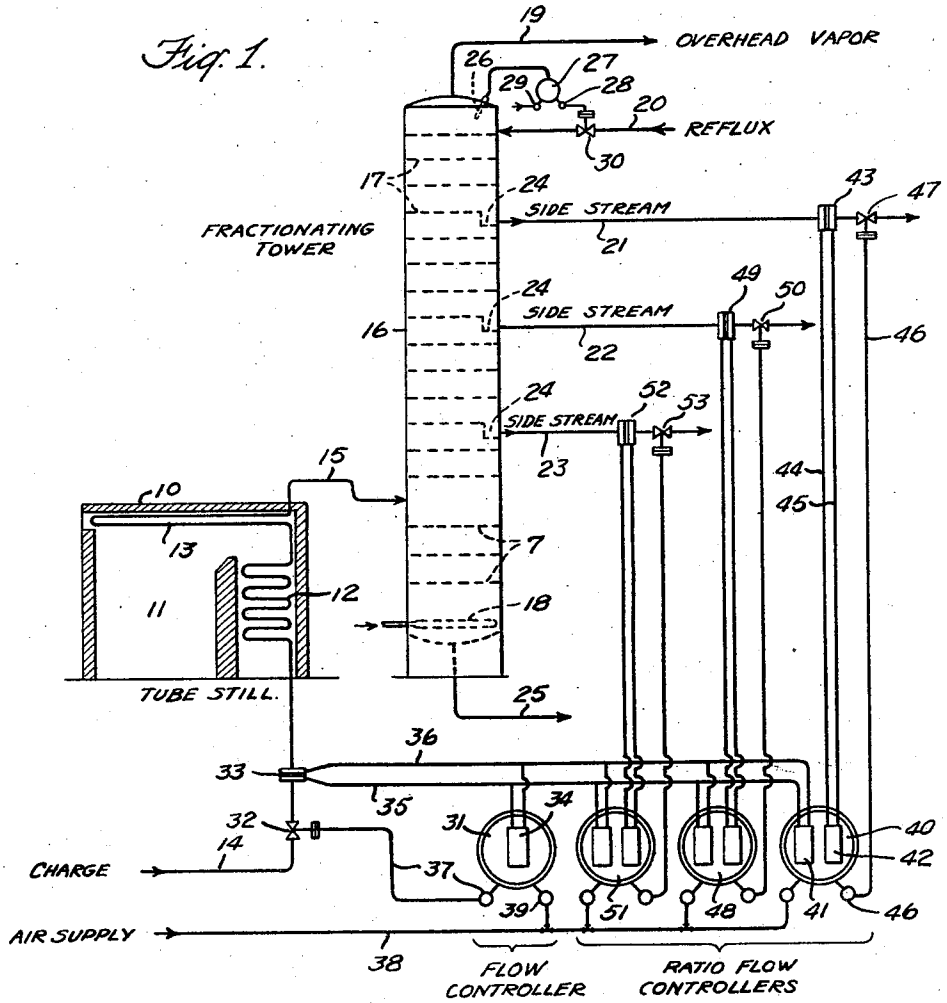
June 24, 1941. C. F. DENNEY 2,246,934

FRACTIONAL DISTILLATION

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Fig. 1.



INVENTOR
COURTLANDT F. DENNEY.
BY
ATTORNEY

June 24, 1941. C. F. DENNEY 2,246,934

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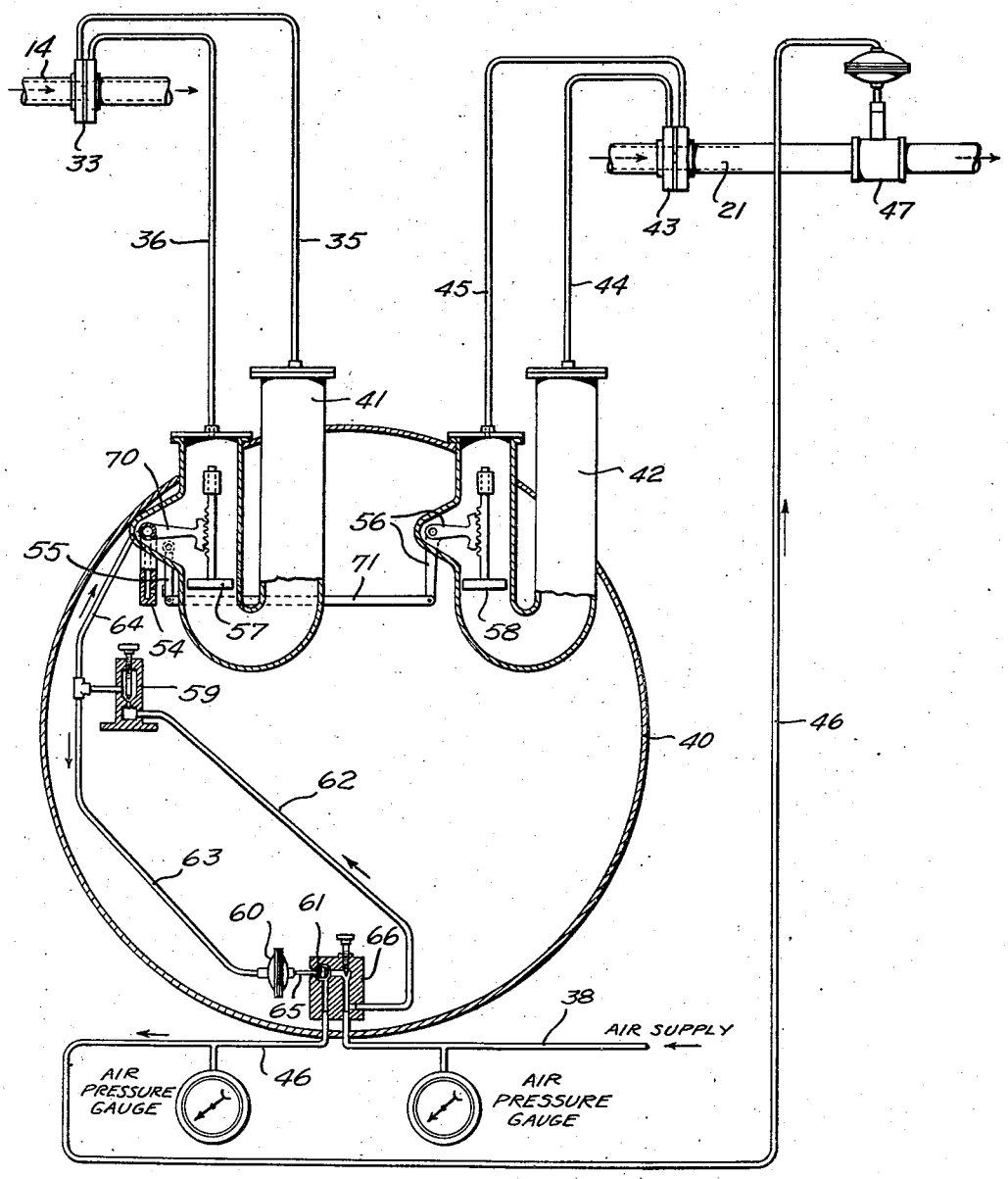


Fig. 2.

INVENTOR
COURTLANDT F. DENNEY
BY
ATTORNEY

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UNITED STATES PATENT OFFICE

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FRACTIONAL DISTILLATION

Courtlandt F. Denney, Westfield, N. J., assignor to Foster Wheeler Corporation, New York, N. Y., a corporation of New York

Application November 26, 1938, Serial No. 242,464

12 Claims. (Cl. 196—132)

This invention relates to the fractional distillation of composite liquids such as hydrocarbon oils and the like, and more particularly pertains to the control of fractions obtained from such liquids.

The present invention provides a method of control, and means for carrying out the method, which will function to maintain side streams or intermediate fractions as definite percentages of the charge regardless of variations in the throughput or of variations in the temperature of the charge or of variations in the steam used in the tower, so long as the charge contains the components of said intermediate fractions in vapor or in vaporizable form under the operating conditions present.

This application is a continuation-in-part of application Serial No. 19,636, filed May 3, 1935.

The nature of the invention will be understood from the following description when considered in connection with the accompanying drawings forming a part thereof and in which:

Fig. 1 is a diagrammatic illustration of a preferred form of apparatus embodying and employing the invention, and

Fig. 2 is an enlarged view showing diagrammatically one of the ratio flow controllers and its connections.

The invention will be disclosed in connection with the control of side streams or intermediate fractions withdrawn or taken off from fractionating towers, with the side streams maintained as definite percentages of the charging stock regardless of variations in quantity or temperature thereof or of the quantities of steam introduced into the tower, but it will be understood that the invention may also be applied to the control of the side streams or intermediate fractions to maintain them as definite percentages of the overhead fraction or of the heaviest fraction or bottoms.

Referring to the drawings, reference character 10 designates a tube still having a furnace 11, a bank of convection tubes 12 and a bank of roof tubes 13. The charging stock is introduced through line 14 and after passing through the tube banks 12 and 13 is conducted through transfer line 15 into the lower portion of a fractionating tower 16 provided with a plurality of superposed bubble trays, or the equivalent, 17. Superheated steam is introduced into the bottom of the tower through a perforated steam coil 18. The lightest fraction is withdrawn overhead in vapor form through line 19 and part of the condensate of the overhead vapors is returned to the top of the tower through line 20 as reflux. Side streams are withdrawn from the tower through lines 21, 22 and 23 and the plates or trays in the tower from which the side streams are withdrawn are provided with suitable pockets or depressions 24. The heaviest fraction or bottoms is withdrawn from the bottom of the tower through line 25. The specifications of the overhead fraction are controlled by a temperature controller preferably of the Foxboro throttling reset type manufactured by the Foxboro Company of Foxboro, Massachusetts, the essential features of which are disclosed in Mason Re. Patent 20,092, granted September 1, 1936. This includes a thermostat 26 responsive to the temperature of the vapors leaving the top of the tower which operates a controller 27 to control the pressure of air delivered to pipe 28 through pipe 29 for operating a motor valve 30 in the reflux line 20. The operation is such that as the temperature tends to increase at the top of the tower, motor valve 30 will operate to permit a greater quantity of reflux to be supplied to the top of the tower and as the temperature at the top of the tower tends to decrease, motor valve 30 will be actuated to restrict the flow of reflux into the tower. By means of this control the percentage of the charge taken overhead is automatically controlled.

The charge is automatically controlled by a rate of flow controller 31 of the Foxboro throttling reset type manufactured by the Foxboro Company of Foxboro, Massachusetts. This device controls the motor valve 32 in the charge line 14 in response to the differential in pressure caused by the flow of the charge across the orifice plate 33 which results in a deflection of the mercury in differential pressure chambers 34, the pressures being transmitted from the orifice plate to the differential chambers through lines 35 and 36. As well understood by those skilled in the art to which this invention relates, the deflection of mercury in the differential chambers 34 moves a float which operates an adjustable flapper to move the latter toward and from a nozzle which controls the flow and pressure of air in air line 37 to operate the motor valve 32, the essential features of which are disclosed in Mason Re. Patent 20,092, granted September 1, 1936. Air is supplied to pipe 37 from a suitable source of air pressure through line 38 to pipe 39 which is connected through the controller to pipe 37.

The side streams are controlled by ratio flow controllers of the Foxboro throttling reset type also manufactured by the Foxboro Company of Foxboro, Massachusetts. These controllers maintain the quantities of the respective side streams withdrawn as definite percentages of the charge irrespective of variations in the quantity or temperature of the charge or of the quantities of steam introduced into the tower, so long as the charge contains the components of the side streams in vapor or in vaporizable form under the operating conditions present. The side

stream withdrawn through pipe 21 is controlled by a ratio flow controller 40 having two sets of differential pressure chambers 41 and 42 respectively, set 41 being connected through lines 35 and 36 to the orifice plate 33 in the charge line 14, and the other set 42 being connected to the orifice plate 43 in side stream draw-off line 21 through lines 44 and 45.

The operation is as follows: Charge to the tube stills flows through line 14 and through the orifice plate 33, thereby producing a differential in pressure between the upstream point at which line 35 is connected to line 14, and the downstream point at which line 36 is connected to line 14, the pressure in line 35 being greater than that in line 36. This pressure differential is transmitted to mercury chamber 41 for the primary stream, in this instance the charge to the still, and mercury chamber 42 for the secondary stream, which in this instance is sidestream 21 from the fractionating tower. This pressure differential results in a relative differential in the levels of mercury in the two arms of the mercury chambers 41 and 42 so that floats 57 and 58 in primary and secondary mercury chambers respectively, are caused to rise and fall as the differential mercury level varies. As float 57 rises in response to an increase in the rate of flow of charge through line 14, air nozzle 54 which is pivoted at its upper end, is caused to move toward the right as viewed in Fig. 2, through the movement of arm 70 with which the air nozzle moves. As the rate of flow through sidestream line 21 increases the differential in pressure set up by orifice plate 43 and transmitted through the connecting lines 44 and 45 to the mercury chamber 42, causes the float 58 to rise and to move bell crank lever 56 counterclockwise. Lever 56 is connected to one end of a link 71, the other end of which is pivotally connected to a flapper 55 which is pivoted at its upper end in close proximity to nozzle 54 so that movement of the flapper will affect the flow of air from the nozzle. As the float 58 rises, the flapper will be moved to the right as seen in Fig. 2.

Assuming a condition of constant flow of the charge through line 14, the nozzle 54 will remain in a fixed position so that if the flow through line 21 tends to increase, flapper 55 will move away from the nozzle. The supply of air provided to the controller through line 38 passes through valve mechanism 66 into line 62, through a controlling valve 59 into line 64 and outward to the atmosphere through nozzle 54. This air is supplied at a constant rate, the rate being adjusted by the throttling valve 59 and when allowed to escape at a constant rate through nozzle 54 maintains a definite pressure in the closed diaphragm 60, which is connected to line 64 by line 63. However, when the position of the flapper valve is changed as indicated above, by movement of the flapper to the right and away from the nozzle, the air escapes more readily through the nozzle opening and consequently the pressure in lines 64 and 63 decreases, which in turn results in a decrease in the pressure in diaphragm 60. The left hand end of diaphragm 60 is fixed in position, the right hand end being connected through rod 65 with valve 61. As valve 61 moves to the left as a result of the collapsing of diaphragm 60, air is admitted into line 46 and to the diaphragm of control valve 47 thereby building up a greater pressure in the diaphragm of control valve 47 and tending to close valve 47, which results in a decrease in the flow of liquid through sidestream line 21.

If, for some reason, the flow of liquid through sidestream line 21 should become less than the desired amount, the differential set up by the flow of the liquid through orifice plate 43 will decrease, float 58 will drop, which will result in the movement of flapper valve 55 to the left and toward nozzle 54 thereby diminishing the ease of escape of air through nozzle 54 and increasing the pressure in lines 64 and 63, which will result in an increase in the pressure in diaphragm 60 and an expansion of the diaphragm, thereby moving stem 65 and valve 61 to the right, decreasing the opening for the passage of air into line 46 and increasing the opening for the escape of air from line 46 to the atmosphere around stem 65. This will reduce the pressure of the air in line 46 and in the diaphragm of control valve 47 which will result in a tendency for valve 47 to open which in turn will allow an increase in the rate of flow of liquid through sidestream line 21.

The foregoing description of the operation is based on the assumption that the flow through charge line 14 is constant. If, however, the flow through line 14 varies, it is necessary that an adjustment be made whereby the flow through sidestream line 21 will be kept proportional to that through charge line 14. This is accomplished automatically by means of the connection of nozzle 54 to float 57 whereby if, for instance, the flow through charge line 14 increases, the differential pressure set up by orifice plate 33 and transmitted to the mercury chamber 41 by lines 35 and 36 will increase, which will cause float 57 to rise and to move nozzle 54 to the right. This movement of nozzle 54, if no other change takes place, will result in a decrease in the opening for the escape of air from the nozzle, and an increase in the pressure in lines 64 and 63, and will cause the diaphragm 60 to expand thereby moving valve stem 65 and valve 61 to the right, which will allow air to escape around the valve stem 65 from the line 46 and will result in an increase in the flow of liquid through sidestream line 21. If the flow of charge through line 14 decreases, the opposite reactions will result and the flow of liquid through sidestream 21 will be decreased. The mechanisms described above are so proportioned and constructed that any change in the flow of liquid through charge line 14 will cause a proportionate change in flow through the sidestream line 21.

In like manner the side stream withdrawn through line 22 is controlled by a similar ratio flow controller 48 which is connected to orifice plate 49 in line 22 and which controls the motor valve 50 in line 22. Also in like manner, the ratio flow controller 51 which is connected to the orfice plate 52 in side stream draw-off line 23 controls the motor valve 53 in line 23.

Flow controller 31 operates the same as ratio flow controller 40 excepting that the nozzle 54 of ratio flow controller 40 is manually set in any desired position so as to obtain constant flow of liquid through line 14 with orifice plate 33 being connected to the flow controller in the same manner that orifice plate 43 is connected to ratio flow controller 40; lines 35 and 36 and mercury chamber 34 function in the same manner as lines 44 and 45 and mercury chamber 42 of the ratio flow controller, and control valve 32 functions in the same manner as control valve 47, being connected to flow controller 31 by line 37 in the same manner as valve 47 is connected

to ratio flow controller 40 by line 46. Thus, if for any reason the flow of charge liquid through line 14 tends to increase, the differential pressure established by orifice plate 33 will increase, the float in mercury chamber 34 will rise and draw the flapper away from the nozzle of flow controller 31 to permit air to escape from the diaphragm which corresponds to diaphragm 60 of the ratio flow controller, which will result in an increase in the pressure in air line 37 and in a partial closing of valve 32, and a reduction in the flow of charge through line 14 until this rate of flow has been restored to the desired amount. Should the rate of flow tend to decrease, the opposite reactions will occur, resulting in a decrease in the pressure of air in line 37 which will open valve 32 and increase the flow of charge through line 14 until the desired rate is again attained.

With this arrangement each of the side streams is automatically maintained at all times as a definite percentage of the charging stock, irrespective of variations in temperature or quantity of the charging stock and independently of variations in the quantity of steam used in the tower, so long as the charge contains the components of the side streams in vapor or in vaporizable form under the operating conditions present.

The following example will serve to illustrate the operation of the method and apparatus herein disclosed. Assume that it is desired to operate a tower for topping crude and producing gasoline as the overhead vapor product and kerosene and gas oil as side streams. Assume also that the laboratory evaluation of the crude shows that it contains 20% of 400 end point gasoline, 15% of kerosene of the desired specifications and 10% of gas oil, when running to the desired specifications on the residue. From previous experience, it is known that the temperature at the top of the fractionating tower will be 280° F. when 400 end point gasoline is being produced. With this temperature determination as a basis, the tower controls can be set as follows: The temperature controller at the top of the tower will be set for 280° F., the kerosene side stream controller will be set to provide 15% of the charge and the gas oil side stream controller will be set to provide 10% of the charge. With these settings the tower will produce products of the specifications which accord with the laboratory evaluation. As long as the temperature of the charge to the fractionating tower is sufficient for the vaporization of the desired products, variations in temperature, quantity of steam used, and throughput will not affect the products produced. The temperature controller at the top of the tower will control the gasoline specifications and in so functioning it is actually controlling the percentage of the charge taken overhead which in the present example is 20%. The ratio flow controller on the kerosene side stream being set for 15% of the charge, will at all times produce the cut corresponding to that fraction lying between 20% and 35% of the charge, that is to say, 15%. The ratio flow controller on the gas oil side stream having been set for 10% of the charge will produce the fraction of the crude lying between 35% and 45%, that is to say, 10%. This example will illustrate the ease with which laboratory evaluations may be transferred to plant operation, while at the same time the limitations inherent in the two prior methods heretofore mentioned will be entirely overcome.

It will be understood that either internal or external stripping sections may be utilized to strip the several side streams withdrawn from the tower, if desired. Where external stripping sections are utilized these may be placed near the ground and the structural steel work to provide access to the tower may be eliminated since all points of control for the unit may be placed in the control room or near the ground. Also, side stream seal loops which ordinarily must be employed, may also be eliminated.

As previously mentioned, one or more of the side streams may be controlled, as herein disclosed, with respect to either the overhead fraction or the bottoms fraction so that the side streams would be automatically maintained in quantity as a definite percentage of the overhead fraction or the bottoms, regardless of variations in the quantity or temperature of the charging stock or the quantity of steam used in the tower, so long as the charge contains the components of the side streams in vapor or in vaporizable form under the operating conditions present.

Although one type of flow controller and ratio flow controller has been disclosed herein, it will be obvious that other controllers of the same or similar character may be employed for the purpose if desired. Such controllers may be actuated by any suitable means which are operated by or in response to mechanically, electrically, hydraulically or pneumatically operated mechanisms or devices.

It will also be understood that variations may be effected in the several steps of the process and in the various parts of the apparatus disclosed without departing from the principles of the invention. Accordingly, the invention is not to be limited except by the scope of the appended claims.

What is claimed is:

1. Apparatus for fractionally distilling hydrocarbon oils and the like comprising a fractionating tower having an inlet through which vaporized oil is introduced into the tower, means in the tower for passing vapors of the oil in contact with reflux, a conduit through which a side stream is withdrawn, a valve for controlling the quantity of the side stream withdrawn from the tower through said conduit, a flow controller for regulating the setting of said valve and operating in response to the rate of flow of fluid through a flow meter in the conduit through which said side stream is withdrawn, another fluid oil conduit connected to the tower, a flow control valve in the other conduit, a flow meter in the other conduit, another flow controller connected to the valve and the flow meter in the other conduit, and connections between the flow controllers, the operation of the first mentioned flow controller being modified in response to the rate of flow of fluid through the other flow meter in the other conduit connected to said tower, which other flow meter also operates to maintain a substantially uniform rate of flow of the stream passing through said other conduit, the combined action of both flow meters resulting in the maintenance of a substantially constant ratio of flow of the two streams irrespective of variations in quantity or temperature of the oil introduced into the tower so long as such oil contains the components of said streams in vapor or in vaporizable form under the operating conditions present.

2. Apparatus for fractionally distilling hydro-

carbon oils and the like comprising a fractionating tower having an inlet through which vaporized oil is introduced into the tower, means in the tower for passing vapors of the oil in contact with reflux, a conduit through which a stream is withdrawn from the tower, a valve for controlling the quantity of the stream withdrawn from the tower through said conduit, a flow controller for regulating the setting of said valve and operating in response to the rate of flow of fluid through a flow meter in the conduit through which said stream is withdrawn, another fluid oil conduit connected to the tower, a flow control valve in the other conduit, a flow meter in the other conduit, another flow controller connected to the valve and the flow meter in the other conduit, and connections between the flow controllers, the operation of the first mentioned flow controller being modified in response to the rate of flow of fluid through the other flow meter in the other conduit connected to said tower, which other flow meter also operates to maintain a substantially uniform rate of flow of the stream passing through said other conduit, the combined action of both flow meters resulting in the maintenance of a substantially constant ratio of flow of the two streams irrespective of variations in quantity or temperature of the oil introduced into the tower so long as such oil contains the components of said streams in vapor or in vaporizable form under the operating conditions present.

3. Apparatus for fractionally distilling hydrocarbon oils and the like comprising a fractionating tower having an inlet through which vaporized oil is introduced into the tower, means in the tower for passing vapors of the oil in contact with reflux, a conduit through which a side stream is withdrawn from the tower, a valve for controlling the quantity of the side stream withdrawn from the tower through said conduit, a flow controller for regulating the setting of said valve and operating in response to the rate of flow of fluid through a flow meter in the conduit through which said side stream is withdrawn, another fluid conduit connected to the tower through which oil is introduced into the tower, a flow control valve in the other conduit, a flow meter in the other conduit, another flow controller connected to the valve and the flow meter in the other conduit, and connections between the flow controllers, the operation of the first mentioned flow controller being modified in response to the rate of flow of fluid through the other flow meter in the conduit through which oil is introduced into the tower, which other flow meter also operates to maintain a substantially uniform rate of flow of the oil into the tower, the combined action of both flow meters resulting in the maintenance of the quantity of the side stream as a definite percentage of the charge oil irrespective of variations in quantity or temperature thereof so long as the charge oil contains the components of said side stream in vapor or in vaporizable form under the operating conditions present.

4. Apparatus for fractionally distilling hydrocarbon oils and the like comprising a fractionating tower having an inlet through which vaporized oil is introduced into the tower, means in the tower for passing vapors of the oil in contact with reflux, a conduit through which a stream is withdrawn from the tower, a valve for controlling the quantity of the stream withdrawn from the tower through said conduit, a flow controller for regulating the setting of said valve and operating in response to the rate of flow of fluid through a flow meter in the conduit through which said stream is withdrawn, another fluid conduit connected to the tower through which oil is introduced into the tower, a flow control valve in the other conduit, a flow meter in the other conduit, another flow controller connected to the valve and the flow meter in the other conduit, and connections between the flow controllers, the operation of the first mentioned flow controller being modified in response to the rate of flow of fluid through the other flow meter in the conduit through which oil is introduced into the tower, which other flow meter also operates to maintain a substantially uniform rate of flow of the oil into the tower, the combined action of both flow meters resulting in the maintenance of the quantity of the said stream as a definite percentage of the charge oil irrespective of variations in quantity or temperature thereof so long as the charge oil contains the components of said stream in vapor or in vaporizable form under the operating conditions present.

5. Apparatus for fractionally distilling hydrocarbon oils and the like comprising a fractionating tower having an inlet through which vaporized oil is introduced into the tower, means in the tower for passing vapors of the oil in contact with reflux, a plurality of conduits connected to the tower through each of which a side stream is withdrawn from the tower, a valve for controlling the quantity of side stream withdrawn through each conduit, a flow controller for regulating the setting of each valve and operating in response to the rate of flow of fluid through a flow meter in the conduit through which the side stream is withdrawn, another fluid oil conduit connected to the tower, a flow control valve in the other conduit, a flow meter in the other conduit, another flow controller connected to the valve and the flow meter in the other conduit, and connections between the flow controllers, the operation of each of the first mentioned flow controllers being modified in response to the rate of flow of fluid through the other flow meter in the other conduit connected to the tower which other flow meter also operates to maintain a substantially uniform rate of flow of the stream passing through said other conduit, the combined action of said flow meters resulting in the maintenance of a substantially constant ratio of flow of each side stream with respect to the flow of the stream in said other conduit irrespective of variations in quantity or temperature of the oil introduced into the tower so long as such oil contains the components of said stream in vapor or in vaporizable form under the operating conditions present.

6. Apparatus for fractionally distilling hydrocarbon oils and the like comprising a fractionating tower having an inlet through which vaporized oil is introduced into the tower, means in the tower for passing vapors of the oil in contact with reflux, a plurality of conduits connected to the tower through each of which a side stream is withdrawn from the tower, a valve for controlling the quantity of side stream withdrawn through each conduit, a flow controller for regulating the setting of each valve and operating in response to the rate of flow of fluid through a flow meter in the conduit through which the side stream is withdrawn, another fluid conduit connected to the tower through

which oil is introduced into the tower, a flow control valve in the other conduit, a flow meter in the other conduit, another flow controller connected to the valve and the flow meter in the other conduit, and connections between the flow controllers, the operation of each of the first mentioned flow controllers being modified in response to the rate of flow of fluid through the other flow meter in the conduit through which oil is introduced into the tower, which other flow meter also operates to maintain a substantially uniform rate of flow of the oil into the tower, the combined action of said flow meters resulting in the maintenance of the quantity of each side stream as a definite percentage of the charge oil irrespective of variations in quantity or temperature thereof so long as the charge oil contains the components of the side streams in vapor or in vaporizable form under the operating conditions present.

7. The method of fractionally distilling hydrocarbon oils and the like which comprises introducing vaporized oil into a fractionating zone, passing vapors of the oil countercurrent to reflux in said zone, withdrawing a side stream from said zone, controlling the quantity of side stream so withdrawn in response to the rate of flow of the side stream from said zone, modifying said controlling action in response to the rate of flow of a fluid stream in another flow path connected with said zone, and controlling the other flow path to maintain a substantially uniform rate of flow of the stream therethrough, the resultant of said controlling actions being operative to maintain a substantially constant ratio of flow of said streams irrespective of variations in quantity or temperature of the oil introduced into said zone so long as such oil contains the components of said side stream in vapor or in vaporizable form under the operating conditions present.

8. The method of fractionally distilling hydrocarbon oils and the like which comprises introducing vaporized oil into a fractionating zone, passing vapors of the oil countercurrent to reflux in said zone, withdrawing a stream from said zone, controlling the quantity of stream so withdrawn in response to the rate of flow of the stream from said zone, modifying said controlling action in response to the rate of flow of a fluid stream in another flow path connected with said zone, and controlling the other flow path to maintain a substantially uniform rate of flow of the stream therethrough, the resultant of said controlling actions being operative to maintain a substantially constant ratio of flow of said streams irrespective of variations in quantity or temperature of the oil introduced into said zone so long as such oil contains the components of said stream in vapor or in vaporizable form under the operating conditions present.

9. The method of fractionally distilling hydrocarbon oils and the like which comprises introducing vaporized oil into a fractionating zone, passing vapors of the oil countercurrent to reflux in said zone, withdrawing a side stream from said zone, controlling the quantity of side stream so withdrawn in response to the rate of flow of the side stream from said zone, modifying said controlling action in response to the rate of flow of oil to said zone, and controlling the flow of oil to said zone to maintain a substantially uniform rate of flow of oil thereto, the resultant of said controlling actions being operative to maintain a substantially constant ratio of flow of said side stream and the oil to said zone irrespective of variations in quantity or temperature of the oil introduced into said zone so long as such oil contains the components of said side stream in vapor or in vaporizable form under the operating conditions present.

10. The method of fractionally distilling hydrocarbon oils and the like which comprises introducing vaporized oil into a fractionating zone, passing vapors of the oil countercurrent to reflux in said zone, withdrawing a stream from said zone, controlling the quantity of stream so withdrawn in response to the rate of flow of the stream from said zone, modifying said controlling action in response to the rate of flow of oil to said zone, and controlling the flow of oil to said zone to maintain a substantially uniform rate of flow of oil thereto, the resultant of said controlling actions being operative to maintain a substantially constant ratio of flow of said stream and the oil to said zone irrespective of variations in quantity or temperature of the oil introduced into said zone so long as such oil contains the components of said streams in vapor or in vaporizable form under the operating conditions present.

11. The method of fractionally distilling hydrocarbon oils and the like which comprises introducing vaporized oil into a fractionating zone, passing vapors of the oil countercurrent to reflux in said zone, withdrawing a plurality of side streams from said zone, controlling the quantity of each side stream so withdrawn in response to the rate of flow of the side stream from said zone, modifying said controlling action of each stream in response to the rate of flow of another fluid stream in another flow path connected with said zone, and controlling the rate of flow in said other flow path to maintain a substantially uniform rate of flow of the stream therethrough, the resultant of said controlling actions being operative to maintain a substantially constant ratio of flow of each side stream with respect to said other stream irrespective of variations in quantity or temperature of the oil introduced into said zone so long as such oil contains the components of the side streams in vapor or in vaporizable form under the operating conditions present.

12. The method of fractionally distilling hydrocarbon oils and the like which comprises introducing vaporized oil into a fractionating zone, passing vapors of the oil countercurrent to reflux in said zone, withdrawing a plurality of side streams from said zone, controlling the quantity of each side stream so withdrawn in response to the rate of flow of the side stream from said zone, modifying said controlling action of each stream in response to the rate of flow of oil to said zone, and controlling the rate of flow of oil to said zone to maintain a substantially uniform rate of flow of oil thereto, the resultant of said controlling actions being operative to maintain a substantially constant ratio of flow of said side streams and the oil to said zone irrespective of variations in quantity or temperature of the oil introduced into said zone so long as such oil contains the components of said side streams in vapor or in vaporizable form under the operating conditions present.

COURTLANDT F. DENNEY.