

Jan. 1, 1963

J. W. SMALLING
APPARATUS FOR CONTROLLING THE LOADING
OF A FRACTIONATION COLUMN
Original Filed Feb. 8, 1956

3,071,520

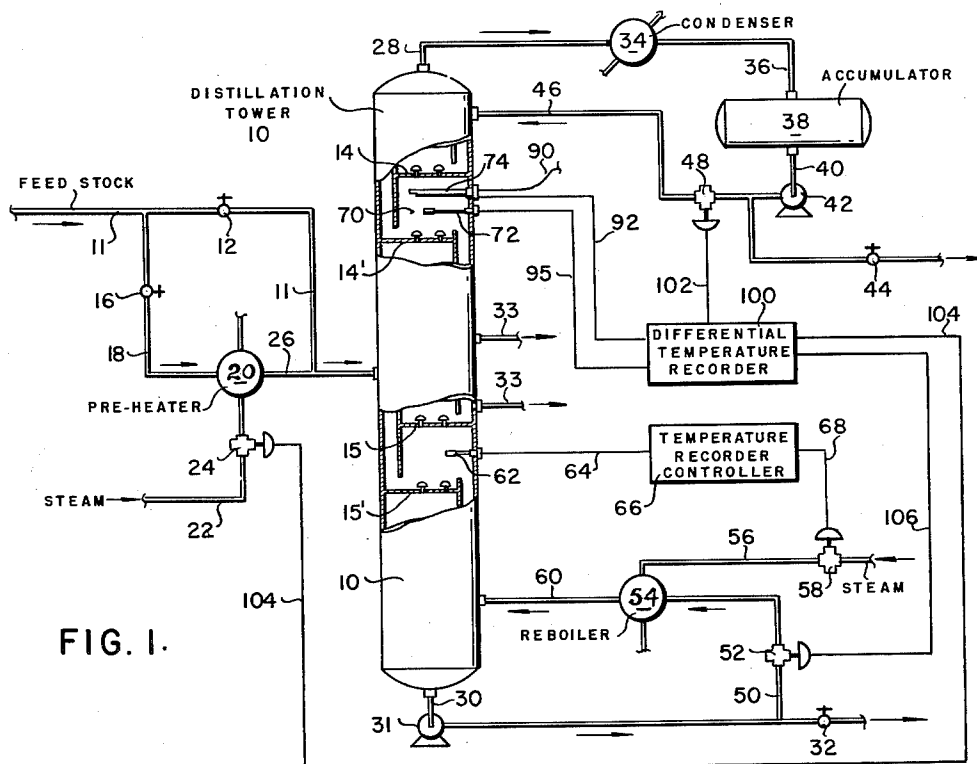


FIG. 1.

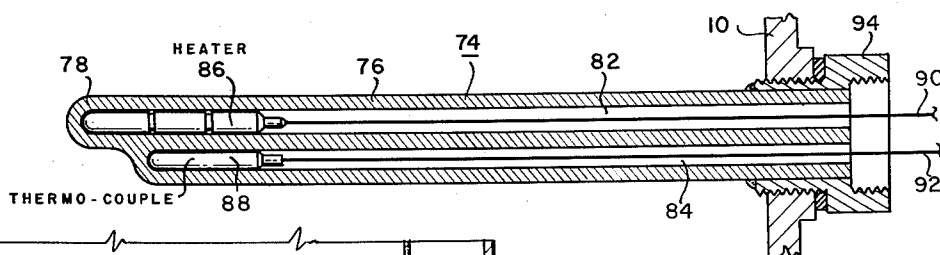


FIG. 3.

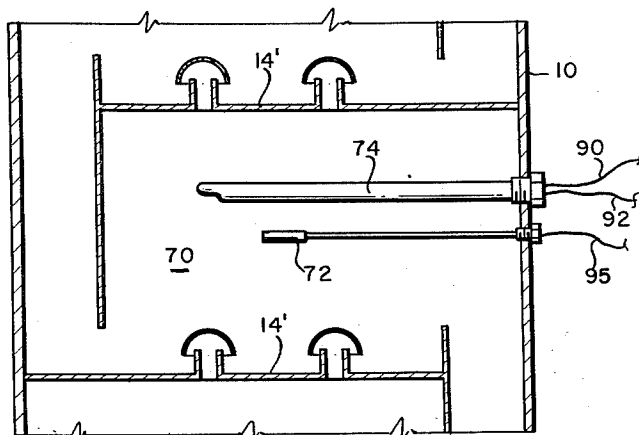


FIG. 2.

INVENTOR.
JACK W. SMALLING,
BY *Carl G. Ries*
ATTORNEY.

1

3,071,520

APPARATUS FOR CONTROLLING THE LOADING OF A FRACTIONATION COLUMN

Jack W. Smalling, Baytown, Tex., assignor, by mesne assignments, to Esso Research and Engineering Company, Elizabeth, N.J., a corporation of Delaware

Original application Feb. 8, 1956, Ser. No. 564,239, now Patent No. 2,994,643, dated Aug. 1, 1961. Divided and this application July 6, 1959, Ser. No. 825,241
8 Claims. (Cl. 202-160)

This invention relates to apparatus for controlling the operation of a fractionating column. More particularly, the present invention is directed to a method and apparatus for obtaining a signal constituting a measure of the heat transfer capacity of material in the vapor space between two adjacent fractionating plates of a fractionating column and for regulating the loading of said fractionating column in response to the thus obtained signal.

This application is a division of copending Smalling application Serial No. 564,239, filed February 8, 1956, and now U.S. Patent No. 2,994,643, and entitled "Method and Apparatus for Controlling Fractionating Columns."

The operation of a fractionating column (i.e., tower) containing suitable fractionating plates such as bubble cap trays, etc., presents a serious problem in that it is necessary to provide for satisfactory fractionating conditions under loading conditions which will prevent flooding of the tower. In the operation of a distillation column a liquid material to be fractionated, such as a mixture of petroleum hydrocarbons, is introduced into a column for fractionation. Fractionation is accomplished through the provision of a plurality of fractionation plates adapted to hold liquid feed stock components and provided with means for passing vaporized feed stock components there-through. The liquid components flow downwardly through the column and the vaporized components ascend upwardly through the column. The rate of ascent of the vaporized material is a function of the load on the tower. When the loading of a tower is increased, the rate of vapor ascent is also increased. Further, the vapor will carry an increased number of liquid droplets as the rate increases. If too great a load is placed upon the tower, the vaporized material will ascend at a rate sufficiently rapid to cause excessive frothing and/or entrainment of the liquefied material on the fractionating plates. Further increase in loading results in exceeding the liquid handling capacity of the tray. When this happens, flooding of the tower occurs. In order to obtain the most efficient fractionation of a liquid feed stock, it is normally desirable to operate the fractionating column under loading conditions which approximate but are short of flooding conditions. It is desirable, therefore, to regulate the operation of the fractionating tower so as to provide for satisfactory fractionation at optimum loading conditions and at the same time to prevent flooding of the fractionating column.

An object of this invention is the provision of means for determining the heat transfer capacity of material in the vapor space between a pair of fractionating plates in a fractionating column.

A still further object is the provision of apparatus useful in obtaining a measure of heat transfer capacity.

These and other objects are attained, in general, by providing an exposed temperature detector and a positively heated enclosed temperature detector in the vapor space between two adjacent fractionating plates in a fractionating column, providing means for obtaining a signal constituting a measure of the temperature differential between the temperatures detected by the said detectors, whereby a measure of the heat transfer capacity of the material in said vapor space is obtained and by providing

2

means for regulating the loading of the fractionating column in response to said signal.

The manner in which these and other objects are attained will be more clearly apparent from the following description and the accompanying drawings wherein:

FIG. 1 is a schematic flow sheet illustrating a preferred apparatus and method for fractionating a liquid feed stock in accordance with the present invention;

FIG. 2 is a side elevational view in section of a portion of a fractionating column constructed in accordance with the present invention; and

FIG. 3 is a side elevational view, in section, of one form of an enclosed positively heated temperature detecting element useful in the determination of heat transfer capacity.

Turning now to FIG. 1, there is shown a feed line 11 controlled by suitable means, such as a valve 12, for delivering a feed stock to be fractionated to a distillation column 10 containing suitable fractionating means such as a plurality of bubble cap plates; two of such plates being schematically shown in FIG. 1 and designated by the numerals 14 and 14'. The feed stock may be derived from any suitable source such as, for example, a storage tank (not shown), a preceding distillation column (not shown), etc. It is frequently desirable to preheat the feed stock and, when such is the case, the valve 12 may be closed and a valve 16 in a branch line 18 leading to a preheater 20 may be opened. The preheater 20, which may be of any suitable construction, is provided with suitable means for heating a feed stock charged thereto. Thus, for example, there may be provided for this purpose a steam line 22 controlled by suitable means such as an electrically and/or pneumatically controlled valve 24 for regulating steam input to the preheater. The feed stock, after being preheated in this or similar fashion, is passed from the preheater 20 through a return line 26 to the feed line 11.

Feed rate may be controlled, for example, through suitable manipulation of the valve 12 when the feed stock is not to be preheated or through suitable manipulation of the valve 16 when a preheating step is to be employed. It is generally desirable to maintain a substantially constant feed rate although, in some instances, the feed rate may be changed to bring about a change in fractionation and/or loading. However, a substantial change in feed rate is normally required to affect significantly loading conditions.

Within the distillation tower 10 the feed stock is fractionated to provide at least a vaporized overhead fraction discharged therefrom through an overhead line 28 and a bottoms fraction discharged therefrom through a bottoms line 30 containing a pump 31 and controlled by a valve 32. If desired, the feed stock may be fractionated in a manner to provide, in addition, one or more side stream fractions discharged from the distillation tower through suitable side delivery lines 33.

Means are provided for establishing the desired fractionating conditions in the distillation tower 10 in order that the feed stock may be separated into desired components. Thus, for example, in order to provide for reflux, the overhead discharge line 28 may be connected with a suitable condenser 34 for condensing the vaporized overhead components of the feed stock; the condensed liquid being discharged from the condenser 34 through a line 36 leading to a suitable accumulator 38. A discharge line 40 containing a pump 42 and controlled by a valve 44 leads from the accumulator 38. There is also provided a reflux line 46 controlled by suitable means such as an electrically and/or pneumatically operated valve 48 whereby a desired portion of the condensed overhead may be returned to the tower 10 as reflux.

Means of any suitable construction are also provided for regulating the temperature or pressure conditions in the distillation column 10, or both. Thus, by way of illustration, the bottoms discharge line 30 may be provided with a branch line 50 regulated by suitable control means such as an electrically and/or pneumatically operated valve 52 for charging a portion of the bottoms fraction to a reboiler 54 of any desired construction; such as a reboiler provided with a steam line 56 regulated by suitable control means such as an electrically or pneumatically operated valve 58. The reheated portion of the bottoms fraction is reintroduced into the distillation tower 10 adjacent the bottom thereof by way of a line 60 leading thereto from the reboiler 54. Reheating is preferably controlled through regulation of the valve 58 in the steam line 56. With this construction, therefore, it is possible to positively select fractionating conditions such as feed rate, feed stock temperature, reflux rate, reboiler rate and/or the degree of heating of the reboiled fraction, etc., whereby the tower operating conditions necessary for satisfactory separation may be provided.

It is normally desirable to control automatically fractionating conditions through the provision of suitable control means so that satisfactory separation may be obtained during continuous operations. By way of illustration, a suitable temperature detector such as a thermocouple 62 may be located in the vapor space between adjacent selected plates 15 and 15' at any suitable point in the distillation tower. Generally, the thermocouple 62 will be located with respect to the fraction of primary interest in the portion of the tower wherein the greatest change occurs in the composition of the material being fractionated. Thus, if it is desired to obtain a bottoms fraction of positively controlled composition, the thermocouple 62 will be placed in the bottom portion of the tower 10 and preferably above a plate in such bottoms portion which reflects the greatest change in composition occurring with respect to the material being fractionated; such as, for example, at a point intermediate the feed line 11 and the reboiler return line 60. It will be understood that if it is desired to primarily control the composition of the overhead fraction, the control thermocouple 62 will normally be located in the upper portion of the tower 10. There is provided an electrical lead 64 leading from the thermocouple 62 to a suitable control mechanism such as a temperature recorder controller 66 of any desired construction wherein the temperature detected by the thermocouple 62 may be registered. The controller 66 is preferably provided with output means for transmitting a signal to control a process variable when the temperature varies significantly from a predetermined optimum value. Thus, a signal may be transmitted through a lead 68 leading from the temperature recorder controller 66 to a process control valve 58 in the steam line 56 leading to the reboiler 54. As a result, the amount of steam introduced into the reboiler 54 may be increased or decreased as required thereby to provide for the maintenance of an optimum fractionating condition in the distillation tower 10. It will be understood, of course, that the signal through lead 68 may be used to control another fractionation variable by means such as the valve 52 in the bottoms reboiler line 50, the valve 48 in the reflux line 46, the valve 24 in the preheater steam line 22, etc. It should also be understood that two or more such variables may be simultaneously controlled. However, with respect to fractionation control, satisfactory results are normally obtained through the control of a single process variable; particularly when the process variable to be controlled primarily affects the portion of the distillation tower 10 wherein the thermocouple 62 is located (i.e., through control of reboiler steam rate when the thermocouple 62 is in the bottom portion of the tower 10, as shown in FIG. 1).

In accordance with the present invention, means are

also provided for detecting or controlling, or both, the heat transfer capacity of the material in the vapor space above a plate in the portion of the tower 10 most susceptible to flooding, which portion is normally different from the portion of the tower wherein maximum composition change occurs; frequently being remotely spaced therefrom in a different portion of the distillation column. The heat transfer capacity of the material in such vapor space is a measure of the load on the tower.

The loading of a distillation tower, such as the tower 10, is dependent upon a multiplicity of factors, any one or a combination of which, may be regulated in order to control the loading thereof. These factors are, in general, the same factors that may be regulated to control fractionating conditions. However, control of tower loading is conducted for another purpose, namely, the regulation of load in response to periodic and frequently unanticipated changes such as changes in the composition of the feed stock, the temperature and/or amount of steam supplied to a tower preheater and/or reboiler, etc. Thus, for a distillation tower 10 of a given design, loading may be regulated, for example, by control of the rate at which the feed stock is charged thereto through the feed line 11, by regulation of the temperature thereof, by control of the rate at which reflux is returned to the tower 10 by the reflux line 46, by control of the rate of return of and/or the temperature of the reheated bottoms fraction returned to the tower 10 through the line 60.

In accordance with the present invention, the loading of the tower 10 is determined by measuring the heat transfer capacity of the material in the vapor space between two adjacent fractionating plates; such plates being in the portion of the tower 10 most susceptible to flooding. Thus, for example, such means may be provided in the vapor space 70 between the plates 14 and 14' for obtaining a measure of the heat transfer capacity of the material in such vapor space 70. For this purpose there is provided an exposed thermocouple 72 of any conventional construction for detecting the ambient temperature of the material in the vapor space 70. There is also provided in accordance with the present invention an enclosed positively heated temperature detector element 74 which is useful in obtaining the desired measurement of heat transfer capacity.

With reference to FIG. 3, it will be seen that the detector 74 comprises an elongated housing 76 terminating in an enclosed dual chambered tip section 78. The housing 76 is provided with means permitting access to the chambers such as, for example, an opening 82 and an opening 84 communicating, respectively, with each of the chambers in the tip section 78. Suitable heating means such as an electrical resistance heater 86 of any suitable construction is positioned in one of the chambers of the tip member 78 and a temperature detector such as a thermocouple 88 is positioned in the other chamber. An electrical lead 90 is passed through the opening 82 in the housing 76 and connected with the heater 86 for transmitting an electrical current therethrough. In similar fashion an electrical lead 92 is passed through the opening 84 and connected with the thermocouple 88. Suitable means such as a bushing 94 fixed to the other end of the housing 76 is provided for securing the detector 74 in the side wall of the distillation tower 10.

With respect to this showing, it will be noted that the openings 82 and 84 have cross-sectional configurations identical with the chambers in the tip member 78 with which they communicate. As a consequence, the heater 86 or the thermocouple 88, or both, may be withdrawn from the tip member 78 through the passageways 82 and 84 for inspection and/or replacement without removing the detector 74 from the distillation tower 10. While the detector 74 illustrated in FIG. 3 constitutes a preferred construction, it will be understood that the detector 74 may be of any suitable construction provided, however, that a dual chambered tip is provided at the

end thereof for the reception of suitable heating means and a suitable temperature detector.

Returning now to FIGS. 1 and 2, the lead 90 is connected with a suitable means (not shown) for transmitting an electrical current therethrough in order to actuate the heating element 86 in the detector 74. The lead 92 and a lead 95 from the exposed thermocouple 72 are connected with suitable electrical means 100 for registering the temperatures detected by the thermocouples 72 and 74. There may be employed for this purpose apparatus of any suitable construction known to those skilled in the art such as a temperature indicator-recorder, a temperature recorder-controller, etc. The electrical means 100 is preferably a differential temperature recorder of a construction such that there may be derived an output signal constituting a measure of the difference between the temperatures detected by the thermocouples 72 and 74 whereby the output signal provides a measure of the heat transfer capacity of the material in the vapor space 70. However, if desired, the temperatures detected by the thermocouples 72 and 74 may be independently registered, recorded, displayed, etc.

When the electrical means 100 comprises a differential temperature recorder-controller, such recorder-controller is provided with suitable electrical leads for one or more of the process control means for the distillation column 10, whereby the output signal from the recorder-controller 100 may be transmitted thereto. Thus, for example, the controller 100 may be provided with a lead 102 leading to the electrically or pneumatically actuatable valve 48 in the reflux line 46. A lead 104 may supplementarily or alternately be provided for interconnecting the controller 100 with the electrically or pneumatically actuatable valve 24 in the steam line 22 leading to the preheater 20. In similar fashion there may be provided a lead 106 interconnecting the controller 100 with the electrically or pneumatically actuatable valve 52 in the branch line 50 leading to the reboiler 54 or a lead (not shown) interconnecting the controller 100 with the electrically or pneumatically actuatable valve 58 in the steam line 56 leading to the reboiler 54.

It will be understood, of course, that any one, or a combination of two or more of the valves 24, 48, 52, and 58 may be interconnected with the controller 100 in the described fashion; which valve may be the same or different from the valve regulated by the fractionation controller 66. However, it is generally preferable to interconnect the loading controller 100 with only one of the process variables and, still more preferably, to interconnect the loading controller 100 with a process variable which is primarily effective for controlling conditions in the portion of the tower 10 in which the detectors 72 and 74 are located. Thus, when the detectors 72 and 74 are positioned in the upper portion of the tower 10, it is preferable that the loading controller 100 be interconnected with a process variable which primarily affects conditions in the upper portion of the tower 10, such as the valve 48 controlling reflux rate.

In a situation wherein fractionation capacity is responsive to vapor rate, the signal should control reboiler heat input (that is, detectors 72 and 74 would be located in the bottom portion of the tower and the controller 100 would be interconnected with the valve 58). In this situation, a thermocouple 62 in the upper portion of tower 10 would be electrically interconnected with valve 48 for controlling reflux rate.

In operation, the ambient temperature of the material in the vapor space 70 between the selected plates 14 and 14' will be detected by the thermocouple 72. The temperature of the detector 74 will normally be above the temperature of the detector 72 due to the positive input of heat. For example, the heater 86 in the detector 74 may be operated so as to provide an input of about 5 to about 50 watts of electrical energy per square inch

of area of the tip 78. The energy input should preferably be such that under conditions of normal operation at optimum vapor loading there is about a 20° to 50° F. difference in temperature between ambient tray temperature and the temperature of the tip member 78.

In the controller 100 electrical signals constituting measures of the temperature of the detector 72 and the detector 74 may be separately obtained or, preferably, a single electrical signal constituting a measure of the difference in the temperatures detected by the members 72 and 74 is obtained, which signal is also a measure of heat transfer capacity.

During normal distillation operations, when a flooded condition does not exist, the material in the space 70 between the selected fractionating plates 14 and 14' will consist essentially of small droplets of liquid from the tray and vaporized feed stock components. However, if the load on the tower 10 is increased, the ascending vapors in the space 70 will carry additional entrained liquid components of the feed stock. The heat transfer capacity of the liquid components will be substantially greater than the heat transfer capacity of the vaporized components and, as a consequence, as liquid components are entrained in the ascending vapors, such liquid components will be brought into contact with the tip member 78 of the detector 74 whereby more efficient transfer of the heat from the tip 78 to the material in the vapor space will be obtained. As a consequence, the temperature of the tip 78 will be lowered. When flooding conditions exist the temperature will be substantially equal to the temperature detected by the member 72. From this it is seen that the difference between the temperatures detected by the members 72 and 74 constitutes a measure of the loading of the tower 10. Loading of the tower 10 is regulated in accordance with the present invention in response to a signal such as a signal constituting a measure of this temperature difference.

If the operating variable to be controlled is, for example, reflux rate, the electrical signal constituting a measure of the temperature differential is transmitted through the lead 102 to the electrical actuating means for the valve 48 in the reflux line 46. If the thus obtained signal is indicative of too small a temperature differential, indicating that flooding conditions have been or are being approached, the valve 48 is actuated to decrease the reflux rate. On the other hand, if the signal is indicative of too wide a differential, valve 48 will be actuated to increase the reflux rate to the distillation column 10. As a consequence, an optimum reflux rate may be maintained at all times whereby the loading of the tower 10 may be maintained at any desired level without adversely affecting fractionating conditions.

As has been previously indicated, any one or a combination of two or more of the electrically or pneumatically actuatable valves 16, 24, 48, 52, and 58 may be regulated by means of the differential temperature recorder-controller 100 in the indicated manner in order to control the loading of the tower 10.

It is seen, therefore, that in accordance with the present invention fractionating conditions within the distillation tower 10 are controlled by suitable means such as the temperature recorder-controller 66 in order that a desired separation of the feed stock into suitable fractions may be obtained. There is also provided, in accordance with the present invention, suitable means such as the temperature detectors 72 and 74 and the differential temperature recorder-controller 100 for sensing the heat transfer capacity of material in the vapor space between two adjacent fractionating plates and for regulating a distillation process variable in response to heat transfer capacity in order to provide or maintain a desired loading in the tower 10 whereby the desired fractionation may be obtained and whereby the approach of a flooding condition in the tower 10 may be detected and properly compensated for.

As adduced from the foregoing, it is preferred in the practice of the present invention to detect heat transfer capacity in the vapor space above a plate located in the portion of the distillation column most susceptible to flooding and to regulate the loading of the tower in response to the detected heat transfer capacity by control of a distillation process variable which primarily controls distillation conditions in the portion of the distillation tower wherein the heat transfer capacity is detected. It is also preferable in practicing the method of the present invention to detect distillation temperatures in the portion of the tower wherein the greatest change in the composition of the material being fractionated occurs and to regulate fractionation in response to the detected temperature by control of a process variable which primarily controls distillation conditions in the portion of the tower wherein temperature is detected.

By way of example, the thermocouple 62 may be located in a distillation column 10 in the portion of the column wherein the greatest change occurs in the composition of the material being fractionated. The thermocouple 62 is interconnected with a process control variable which primarily affects the portion of the distillation tower 10 wherein the thermocouple 62 is located. Thus, for example, in the embodiment in FIG. 1 wherein the thermocouple 62 is in the lower portion of the distillation tower 10 the process variable that is preferably controlled is the reboiler steam rate.

The temperature detectors 72 and 74 of the present invention are located in the vapor space above a plate in the portion of the distillation tower 10 which is most susceptible to flooding. This portion of the tower will normally be different from the portion of the tower wherein maximum composition change occurs. The temperature detectors 72 and 74 are electrically coupled in the described manner with a process control variable which is primarily effective for controlling conditions in the portion of the distillation tower 10 wherein the detectors 72 and 74 are located. Thus, in the example shown in FIG. 1 wherein detectors 72 and 74 are in the upper portion of the tower, the process control variable that is preferably controlled is reflux rate.

What is claimed is:

1. In a fractionating device including a tower having spaced fractionating plates therein, the improvement which comprises loading detection means including a first temperature detector and a second temperature detector both in the vapor space between two adjacent of said plates, means for positively heating said first detector to a temperature higher than that of said second detector and means coupled to said detectors for measuring the detected temperatures.

2. In a fractionating device including a tower having spaced fractionating plates therein, the improvement which comprises means for detecting the loading in said tower, said means comprising both an exposed thermocouple and an enclosed temperature detector in the vapor space between two adjacent fractionating plates, said temperature detector comprising a housing having an

opening extending therethrough, a dual chambered heating element fixed to one end of said housing, electrical heating means in one of said chambers, electrical temperature detecting means in the other of said chambers, separate electrical conducting means for said heating means and said temperature detecting means connected therewith and passing from said chamber through said opening in said housing, and means connected with said thermocouple and said electrical conducting means for said temperature detecting means for obtaining an electrical signal constituting a measure of the temperature differential therebetween.

3. In a fractionating tower having spaced apart liquid-vapor contact means, a first temperature detecting means and a second temperature detecting means both in the vapor space between adjacent contact means, means for heating said first detecting means to a temperature higher than said second detecting means, means responsive to said first and second detecting means for generating a signal proportional to the temperature difference between said first and said second detecting means, and means responsive to said signal for controlling the loading of said tower.

4. An apparatus in accordance with claim 3 wherein the liquid-vapor contact means are bubble cap trays.

5. An apparatus in accordance with claim 3 further comprising reflux means, and wherein said means responsive to said first and second temperature detector means comprises a control valve for varying the reflux rate.

6. In a fractionating system comprising a tower having spaced apart liquid-vapor contact means therein, liquid feed preheater means, reflux means for said tower, and reboiler means for said tower, a control system comprising a first and a second temperature detecting means between adjacent contact means, means for heating said first detecting means, means responsive to said first and second detecting means for generating a signal proportional to the temperature difference between said first and said second detecting means, and means responsive to said signal for controlling said preheater means.

7. An apparatus in accordance with claim 6 wherein said means responsive to said signal controls said reflux means.

8. An apparatus in accordance with claim 6 wherein said means responsive to said signal controls said reboiler means.

References Cited in the file of this patent

UNITED STATES PATENTS

1,261,086	Wilson	Apr. 2, 1918
1,699,143	Hill	June 15, 1929
1,822,989	Feussner	Sept. 15, 1931
2,570,451	Hottenroth	Oct. 9, 1951
2,580,016	Gilbert	Dec. 25, 1951
2,684,326	Boyd	July 20, 1954
2,728,225	Skibitzke	Dec. 27, 1955
2,843,714	Stanton	July 15, 1958
2,904,518	Shea	Sept. 15, 1959