

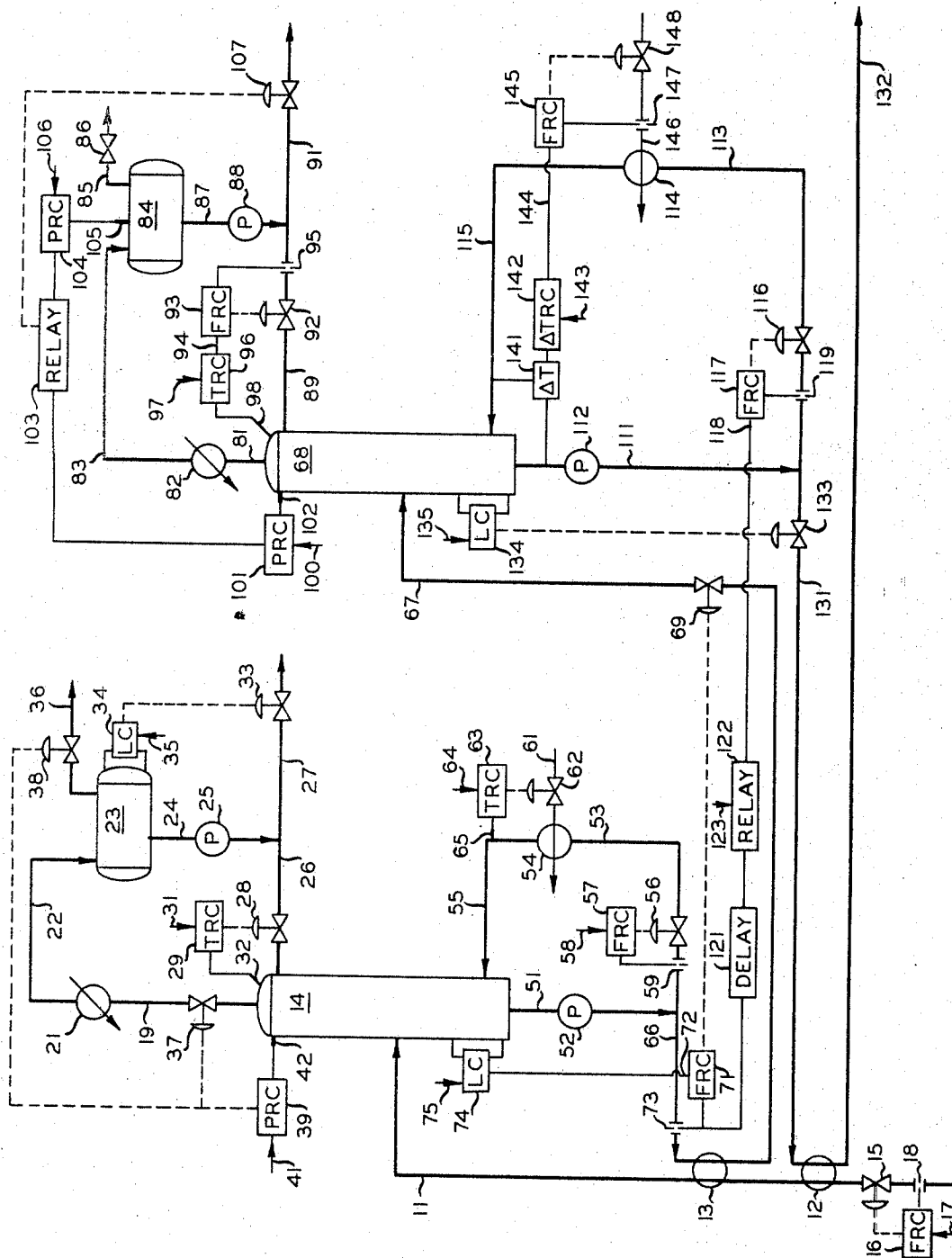
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CONTROL SYSTEM FOR FRACTIONAL DISTILLATION COLUMNS

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CONTROL SYSTEM FOR FRACTIONAL
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8 Claims

ABSTRACT OF THE DISCLOSURE

The flow rate of the overhead stream from a first fractional distillation column and the flow rate of overhead vaporous product from the accumulator are controlled on a split range basis by a pressure controller responsive to column overhead pressure. The kettle product of the first column is utilized as the feed to a second column. The overhead stream from the second column is totally condensed, with the rate of withdrawal of overhead liquid product from the associated accumulator normally being controlled by the overhead pressure of the second column but subject to manipulation by the pressure controller on the accumulator of the second column. A constant differential temperature between the bottom stream and the reboiler effluent for the second column is maintained, with the flow rate of bottom stream through the reboiler being controlled in a ratio relationship with a delayed function of the bottom product flow rate from the first column.

The invention relates to improved control systems for fractional distillation columns. In many of the present systems difficulties have been encountered in that frequently the automatic controls perform at cross purpose with one another. The controlling of column overhead pressure and the controlling of reflux accumulator pressure are examples of conventional control loops whose criteria occasionally conflict. Another example is in the control of heat input rate to a second column whose feed is obtained from a first column at a stream flow rate controlled by a factor in the first column.

Accordingly it is an object of the invention to provide new and improved control systems for fractional distillation columns. Another object of the invention is to provide compatible, interrelated control of the column overhead pressure and accumulator pressure. It is an object of the invention to provide an interrelated control system for two fractional distillation columns connected in series. Another object of the invention is to improve the control of the heat input to a column.

Other objects, aspects and advantages of the invention will be apparent from a study of the specification, the drawing and the appended claims to the invention.

The drawing is a diagrammatic representation of a fractional distillation system incorporating the control techniques of the present invention. A feedstream is passed by way of conduit 11 into and through indirect heat exchangers 12 and 13 into fractional distillation column 14. Valve 15, located in conduit 11, is manipulated by flow recorder controller 16 responsive to a comparison of the desired flow rate represented by the setpoint input 17 and the actual flow rate in conduit 11 as indicated by the pressure drop across orifice 18. An overhead vapor stream is withdrawn from the upper portion of column 14 and passed by way of conduit 19 into and through indirect heat exchanger 21, wherein a portion of the overhead vapor stream is condensed. The resulting partially condensed stream is passed by way of conduit 22 into accumulator 23. A portion of the condensate is withdrawn from accumulator 23 by way of conduit 24 and pump 25. A first portion of the thus withdrawn con-

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densate is passed by way of conduit 26 into an upper portion of column 14 as reflux therefor, while the second portion of the thus withdrawn condensate is passed by way of conduit 27 as an overhead liquid product stream. Valve 28, positioned in conduit 26, is manipulated by temperature recorder controller 29 responsive to a comparison of the desired temperature represented by setpoint 31 and the actual temperature in the top portion of column 14 as indicated by temperature sensor 32. Thus the flow rate of external reflux through conduit 26 is manipulated by controller 29 to maintain the overhead temperature in column 14 substantially equal to the temperature represented by setpoint 31. Valve 33, located in conduit 27, is manipulated by liquid level controller 34 responsive to a comparison of the liquid level setpoint 35 and the actual level of liquid condensate in accumulator 23. The uncondensed portion of the overhead vapor stream is withdrawn from accumulator 23 by way of conduit 36 as an overhead vapor product. Valve 37, located in conduit 19, and valve 38, located in conduit 36, are manipulated by pressure recorder controller 39 responsive to a comparison of the desired pressure in the upper portion of column 14 as represented by the setpoint 41 and the actual pressure in the upper portion of column 14 as indicated by pressure sensor 42. Valves 37 and 38 are biased to provide for a split range operation. This can be accomplished by spring biasing the valves at different values or using different adjustments within the valve positioners, if employed. For example, where controller 39 produces a pneumatic pressure output signal within the range of 3–15 p.s.i., valve 37 can be biased so as to go from fully closed at 3 p.s.i. to fully opened at 9 p.s.i. and remain fully opened at pressures above 9 p.s.i., while valve 38 can be biased to go from fully closed at 9 p.s.i. to fully opened at 15 p.s.i. but remain closed at pressures under 9 p.s.i. Under normal operating conditions, back pressure valve 37 will be fully opened with valve 38 being manipulated by controller 39 to maintain a substantially constant pressure in the upper portion of column 14. This split range control system results in maintaining a maximum reflux accumulator pressure under the prevailing conditions, that is, although the pressure in accumulator 23 will vary, the system will provide for the maximum pressure in accumulator 23 which is possible while maintaining the pressure in the upper portion of column 14 substantially constant. The maintenance of higher pressure in accumulator 23 reduces the overhead vapor product flow rate through conduit 36 by causing a greater portion of the overhead vapor stream in conduit 19 to condense and remain in the liquid phase in accumulator 23 from which it is removed as liquid product stream 27.

A liquid bottom stream is withdrawn from the lower portion of column 14 by way of conduit 51 and pump 52. A first portion of the thus-withdrawn bottom stream is passed by way of conduit 53 into and through indirect heat exchanger 54, which serves as a reboiler for column 14. The reboiled fluid is passed by way of conduit 55 into a lower portion of column 14. Valve 56, located in conduit 53, is manipulated by flow recorder controller 57 responsive to a comparison of the desired flow rate represented by setpoint 58 and the actual flow rate through conduit 53 as indicated by the pressure drop across orifice 59 in conduit 53. A heating fluid is passed through conduit 61 into and through indirect heat exchanger 54. Valve 62, located in conduit 61, is manipulated by temperature recorder controller 63 responsive to a comparison of the desired temperature setpoint 64 and the actual temperature of the reboiled fluid in conduit 55 as indicated by temperature sensor 65. A second portion of the withdrawn bottom stream is passed by way of conduit 66 into and through indirect heat exchanger 13 in indirect heat exchanging re-

lationship with the feed being passed through conduit 11. The resulting partially cooled bottom stream is passed from heat exchanger 13 through conduit 67 into fractional distillation column 68 as the feed thereto. Valve 69, located in conduit 67, is manipulated by flow recorder controller 71 responsive to a comparison of the setpoint 72 on controller 71 and the actual flow rate through conduit 66 as indicated by the pressure drop across an orifice 73 located therein. The setpoint 72 of controller 71 is manipulated by a liquid level controller 74 operatively connected to the kettle section of column 14 in response to a comparison of the desired liquid level represented by setpoint 75 and the actual liquid level in the kettle section.

An overhead vapor stream is withdrawn from an upper portion of column 68 and passed by way of conduit 81 into and through indirect heat exchanger 82, wherein substantially all of the overhead vapor stream is condensed. The resulting condensate is passed by way of conduit 83 into reflux accumulator 84. Accumulator 84 is provided with a vent conduit 85, containing a manually operated valve 86, for venting uncondensed gas from accumulator 84 as required. Liquid condensate is withdrawn from accumulator 84 by way of conduit 87 and pump 88. A portion of the thus withdrawn condensate is passed by way of conduit 89 into an upper portion of column 68 as external reflux therefor. The remaining withdrawn condensate is passed by way of conduit 91 as an overhead liquid product stream. Valve 92, located in conduit 89, is manipulated by flow recorder controller 93 responsive to a comparison of the desired flow rate setpoint 94 and the actual flow rate in conduit 89 as indicated by the pressure drop across an orifice 95 located therein. Setpoint 94 of controller 93 is adjusted by a temperature recorder controller 96 responsive to a comparison of the temperature setpoint 97 with the actual temperature of the overhead of column 68 as indicated by temperature sensor 98. This provides for the manipulation of the external reflux flow rate to maintain the overhead temperature in column 68 substantially constant at the value of temperature represented by setpoint 97. Pressure recorder controller 101 produces an output signal representative of the comparison of the pressure in the upper portion of column 68 as indicated by pressure sensor 102 with the desired overhead pressure setpoint 100. The output signal of controller 101 is applied to one input of low input selector relay 103. Pressure recorder controller 104 produces an output signal which is representative of the comparison of the pressure in the accumulator 84 as indicated by pressure sensor 105 with the desired pressure represented by setpoint 106. The output of controller 104 is applied to a second input of low input selector relay 103. Relay 103 produces an output signal corresponding to the lower of the two input signals thereto. The output signal from relay 103 is utilized to manipulate valve 107 located in overhead liquid product conduit 91. Thus the rate of withdrawal of overhead liquid product through conduit 91 is normally varied to partially flood condenser 82 to maintain the pressure in the upper portion of column 68 at the desired value represented by setpoint 100, unless in so doing the pressure in accumulator 84 drops below its desired setpoint value 106. It is generally desirable to operate column 68 with accumulator 84 exhibiting a positive pressure of at least 0.5 p.s.i.g. If the accumulator pressure should drop below atmospheric pressure, severe structural damage could occur to accumulator 84 as such pressure vessels are not designed to withstand an internal vacuum. A vacuum relief valve open to the atmosphere is frequently provided to prevent negative accumulation pressure, but in many instances air contamination of accumulator liquid would undesirably occur if such a valve were utilized. Furthermore, in systems which provide for the independent regulation of column and accumulator pressures, considerable variations in the composition of the overhead liquid product are frequently encountered. In one such system while regulating from the accumulator pressure, the overhead

pressure varied as much as 4 p.s.i., with each 1 p.s.i. corresponding to an 8 mol percent change in the heavy key component concentration in the overhead liquid product. The present system stabilizes overhead composition while preventing damage to the accumulator due to the accumulator pressure dropping too low.

A liquid bottom stream is withdrawn from column 68 by way of conduit 111 and pump 112. A portion of the thus withdrawn bottom stream is passed by way of conduit 113 into and through indirect heat exchanger 114, which serves as a reboiler for column 68. The thus heated fluid is returned to a lower portion of column 68 by way of conduit 115. Valve 116, located in conduit 113, is manipulated by a flow recorder controller 117 responsive to a comparison of the desired flow rate setpoint 118 and the actual flow rate through conduit 113 as indicated by the pressure drop across an orifice 119 located therein. A signal representative of the flow rate of the bottom product stream from column 14 through conduit 66 as indicated by the pressure drop across an orifice 73 located therein is applied to an input of the delay 121. The resulting delayed signal is applied to one input of the ratio relay 122. A signal 123 representative of the desired ratio of the flow rate of the kettle product from column 14 passing through conduit 66 to the flow rate of bottom material from column 68 being passed to reboiler 114 through conduit 113, is applied to a second input of ratio relay 122. The output of relay 122, which represents the multiplication product of the two input signals, is utilized to adjust the setpoint 118 of flow controller 117. Delay 121 introduces a delay into the flow rate signal corresponding to the delay encountered by the material passing through conduits 66 and 67 in reaching the bottom of column 68 and affecting the inventory and composition of the liquid therein. Thus valve 116 manipulates the flow rate through conduit 113 to maintain such flow rate in the desired ratio relationship with the liquid passing through conduits 66 and 67. A second portion of the bottom stream from column 68 is passed by way of conduit 131 into and through indirect heat exchanger 12 and is then withdrawn from the system by way of conduit 132 as a liquid bottom product stream. Valve 133, located in conduit 131, is manipulated by liquid level controller 134 responsive to a comparison of the desired liquid level setpoint 135 and the actual level of liquid in the kettle section of column 68.

Differential temperature sensor 141 determines the difference between the temperature of the bottom stream in conduit 111 and the reboiled fluids in conduit 115 and transmits a signal representative of the determined difference to an input of differential temperature recorder controller 142. A signal representative of the desired differential temperature is applied as setpoint 143 of controller 142. The output of controller 142 adjusts the setpoint 144 of flow recorder controller 145. A signal representative of the flow rate of heating fluid through conduit 146 to indirect heat exchanger 114 as indicated by the pressure drop across orifice 147 is applied to the measurement input of controller 145. The output of controller 145 manipulates valve 148 to maintain the desired temperature differential between bottom stream 111 and reboiled stream 115. As the result of the operation of the differential temperature control systems associated with the reboiler of column 68, a substantially constant enthalpy difference (B.t.u. per pound) is provided to the reboiling stream, circulated through conduits 111, 113 and 115, by heater 114. Thereby, the total heat input rate to reboil column 68 is directly proportional to the fluid circulation rate, which in turn is manipulated in ratio relationship to the feed rate to column 68. Thereby, the rate of heat input to the reboiler is directly proportional to the column's feed rate and changes of heat input are made in proper dynamic relationship to the feed rate changes by the use of delay 121. While heaters 54 and 114 have been illustrated merely as indirect heat ex-

changers, either or both can be fired furnaces with valves 62 and 148 being in the fuel gas lines to the furnaces.

Thus, by cooperative, compatible and coordinated operation of the several systems for controlling flows, pressures, temperatures and heat input-to-feed ratio, the throughput of feed, purity of products and economy of operation of this two column fractionation unit are substantially improved. Additionally, novel systems for column and reflux accumulator pressure regulation are provided to overcome problems commonly encountered in prior art systems.

Reasonable variations and modifications are possible within the scope of the foregoing disclosure, the drawing and the appended claims to the invention.

I claim:

1. Apparatus comprising a first fractional distillation column, first conduit means connected to an intermediate section of said first fractional distillation column to introduce feed thereto, second conduit means connected to the lower section of said first fractional distillation column to withdraw a bottom stream therefrom, a first condenser, a first accumulator, a third conduit means connected to the upper section of said first fractional distillation column to withdraw an overhead vapor stream therefrom and to pass all the thus withdrawn overhead vapor stream through said first condenser to partially condense said thus withdrawn overhead vapor stream and to pass the thus partially condensed overhead vapor stream into said first accumulator, fourth conduit means communicating between a lower portion of said first accumulator and an upper portion of said first fractional distillation column to pass condensate from said first accumulator to said first fractional distillation column as reflux therefor, fifth conduit means connected to an upper portion of said first accumulator for withdrawing an overhead vaporous product stream therefrom, first valve means operatively positioned in said third conduit means and spring biased at a first value, second valve means operatively positioned in said fifth conduit means and spring biased at a second value different from said first value, a pressure controller having a measurement input, a setpoint and an output signal, means for sensing the pressure in an upper portion of said first fractional distillation column and applying a signal representative thereof to said measurement input of said pressure controller, means for applying said output signal from said pressure controller to said first and second valve means to cause said first valve means to operate between its fully closed position at a low first value of said output signal and its fully opened position at an intermediate second value of said output signal and to cause said second valve means to operate between its fully closed position at said intermediate second value to its fully opened position at a high third value of said output signal to maintain as high a pressure as possible in said accumulator while controlling said sensed pressure in the upper portion of said first fractional distillation column at the desired value represented by said setpoint.

2. Apparatus in accordance with claim 1 wherein said first valve means is located in said third conduit means between first fractional distillation column and said first condenser, and further comprising sixth conduit means communicating with a lower portion of said first accumulator for withdrawing an overhead liquid product stream therefrom.

3. Apparatus in accordance with claim 2 further comprising third valve means operatively positioned in said sixth conduit means, and means for manipulating said third valve means to vary the flow through said sixth conduit means responsive to the liquid level in said first accumulator to maintain said liquid level substantially constant, fourth valve means operatively positioned in said fourth conduit means, and means for manipulating said fourth valve means to vary the flow through said fourth conduit means responsive to the temperature in

an upper portion of said first fractional distillation column to maintain said temperature substantially constant.

4. Apparatus in accordance with claim 1 further comprising a second fractional distillation column, means for heating a portion of said bottom stream from said second conduit means and introducing the resulting heated fluid into a lower portion of said first fractional distillation column, sixth conduit means for passing the remainder of said bottom stream from said second conduit to an intermediate portion of said second fractional distillation column as feed thereto, seventh conduit means connected to a lower portion of said second fractional distillation column to withdraw a second bottom stream therefrom, a second condenser, a second accumulator, eighth conduit means connected to an upper portion of said second fractional distillation column to withdraw a second overhead vaporous stream therefrom and to pass the thus withdrawn second overhead vaporous stream through said second condenser to condense substantially all of said second overhead vaporous stream and to pass the resulting condensate into said second accumulator, ninth conduit means connected between a lower portion of said second accumulator and an upper portion of said second fractional distillation column to pass condensate from said second accumulator to said second fractional distillation column as reflux therefor, tenth conduit means connected to a lower portion of said second accumulator for withdrawing a second overhead liquid product therefrom, a second pressure controller having a measurement input, a setpoint and an output signal, a third pressure controller having a measurement input, a setpoint and an output signal, means for sensing the pressure in an upper portion of said second fractional distillation column and applying a signal representative thereof to said measurement input of said second pressure controller, means for sensing the pressure in said second accumulator and applying a signal representative thereof to said measurement input of said third pressure controller, a low input selector relay having first and second inputs and an output, means for applying said output signal of said second pressure controller to said first input of said relay, means for applying said output signal of said third pressure controller to said second input of said relay, third valve means operatively positioned in said tenth conduit means, and means for manipulating said third valve means responsive to said output of said relay to vary the flow of liquid through said tenth conduit means to control the overhead pressure in said second fractional distillation column while maintaining at least a minimum pressure in said second accumulator.

5. Apparatus in accordance with claim 4 further comprising a heater, eleventh conduit means for passing a portion of said second bottom stream from said seventh conduit means into and through said heater, twelfth conduit means for passing the thus heated fluid from said heater to a lower portion of said second fractional distillation column, thirteenth conduit means for withdrawing the remainder of said second bottom stream from said seventh conduit means as a liquid kettle product stream, means for sensing the temperature of the fluid in said seventh conduit means and for sensing the temperature of the fluid in said twelfth conduit means and establishing a differential temperature signal representative of the difference in the two thus-sensed temperatures, and means for controlling the heat input to the fluid passing from said eleventh conduit means through said heater responsive to said differential temperature signal to maintain the temperature difference substantially constant.

6. Apparatus in accordance with claim 5 further comprising fourth valve means operatively positioned in said eleventh conduit means, means for measuring the flow rate of fluid through said sixth conduit means and for establishing a flow signal representative thereof, delay

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means, a ratio relay having first and second signal inputs and an output signal, means for transmitting said flow signal through said delay means to said first signal input of said ratio relay, means for applying to said second signal input of said ratio relay a signal representative of the desired ratio of the flow rate through said eleventh conduit means to the flow rate through said sixth conduit means, and means for manipulating said fourth valve means responsive to said output signal of said ratio relay.

7. Apparatus in accordance with claim 6 further comprising fifth valve means operatively positioned in said sixth conduit means, and means for manipulating said fifth valve means to vary the flow rate of fluid through said sixth conduit means responsive to the liquid level in the kettle section of said first fractional distillation column.

8. Apparatus in accordance with claim 7 further comprising sixth valve means in said thirteenth conduit means, and means for manipulating said sixth valve

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means responsive to the liquid level in the kettle section of said second fractional distillation column.

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