Oct. 15, 1963 E. D. TOLIN 3,107,293

FRACTIONATION CONTROL

Filed July 29, 1960

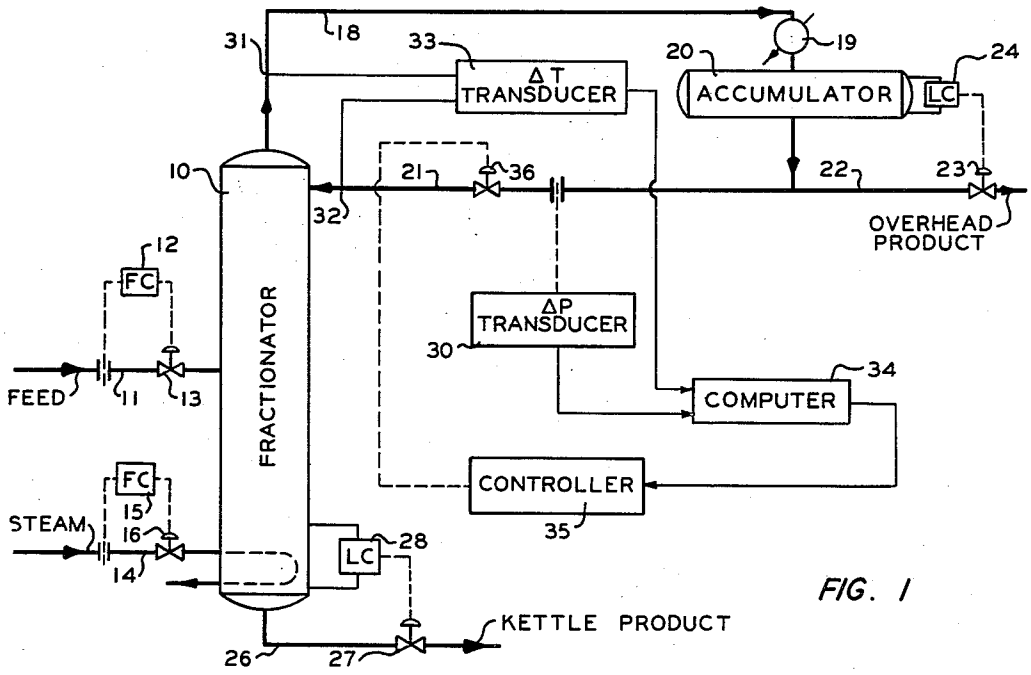


FIG. 1

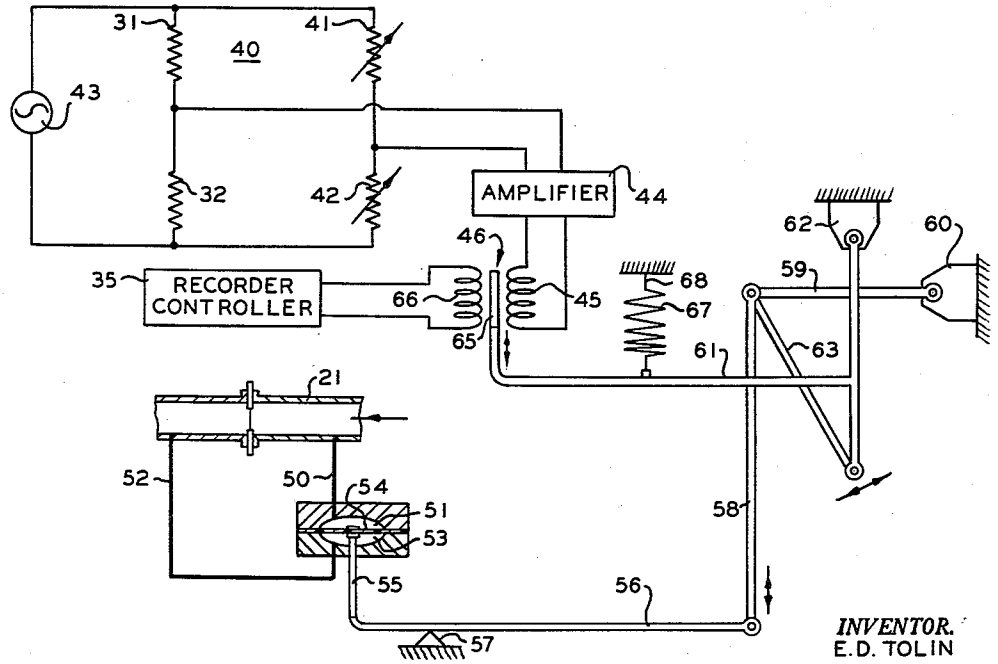


FIG. 2

INVENTOR.
E. D. TOLIN

BY Hudson & Young

ATTORNEYS

United States Patent Office

3,107,293
Patented Oct. 15, 1963

3,107,293

FRACTIONATION CONTROL

Ernest D. Tolin, Bartlesville, Okla., assignor to Phillips Petroleum Company, a corporation of Delaware

Filed July 29, 1960, Ser. No. 46,250
4 Claims. (Cl. 235—151)

This invention relates to the computation of internal reflux in a fractionation column. In another aspect it relates to control systems for fractionation columns which are based on computations of internal reflux.

In recent years an increasing use has been made of fan coolers for condensing overhead vapors from fractionation columns. However, this type of cooler has resulted in a rather serious operating prblem because it is difficult to control the exact amount of cooling provided. Such schemes as fan speed control, variable pitch fan blade control and hot vapor by-pass control have been employed in an attempt to solve this problem, but have not been entirely satisfactory. Sudden atmospheric temperature changes, such as occur during a rainstorm, for example, result in a lowering of the reflux temperature. This causes an increase in the flow of liquid leaving the top tray because more of the vapor which enters this tray is condensed. This results in an increase in overhead product purity at the expense of a decreased overhead product rate.

In accordance with the present invention there is provided a novel system for computing the amount of internal reflux in a fractionation column. Internal reflux constitutes the external reflux returned to the column plus the vapor which is condensed near the top of the fractionation column by the subcooled external reflux. This computation is made from a measurement of the rate of flow of the external reflux and a measurement of the temperature differential between the external reflux returned to the column and a region near the top of the column. An alternating electrical signal is established which is representative of this temperature differential. The alternating signal is applied to the primary winding of a differential transformer having a movable core. The flow of external reflux is measured by a differential pressure transducer connected across an orifice in the external reflux conduit. The output of the differential pressure transducer is applied through a non-linear linkage to adjust the position of the core in the transformer. This multiplies the input signal to the transformer by the flow measurement to establish an output signal, representative of internal reflux, which can be employed to control the operation of the column. This control can be made automatically or by an operator from the information provided.

Accordingly, it is an object of this invention to provide a system for computing the internal reflux in a fractionation column.

Another object is to provide control systems for fractionation columns which utilize computations of the internal reflux in the column.

Other objects, advantages and features of the invention should become apparent from the following detailed description, taken in conjunction with the accompanying drawing in which:

FIGURE 1 is a schematic representation of a fractionation column having the computer and control system of this invention associated therewith.

FIGURE 2 is a schematic circuit drawing of the computer employed in the control system of FIGURE 1.

Referring now to the drawing in detail and to FIGURE 1 in particular, there is shown a conventional fractionation column 10 which contains a number of vapor-liquid contacting trays. A fluid mixture to be separated is introduced into column 10 through a conduit 11 at a predetermined rate which is maintained by a flow controller 12 that adjusts a valve 13. Steam, or other heating medium, is circulated through the lower region of column 10 through a conduit 14 at a predetermined rate which is maintained by a flow controller 15 that adjusts a valve 16.

Vapors are withdrawn from the top of column 10 through a conduit 18 which has a condenser 19 therein. Conduit 18 communicates at its second end with an accumulator 20. A portion of the condensate in accumulator 20 is returned to column 10 as external reflux through a conduit 21. The remainder of the condensate is removed as overhead product through a conduit 22 which has a control valve 23 therein. Valve 23 is adjusted by a liquid level controller 24 to maintain a predetermined level in accumulator 20. A kettle product stream is withdrawn from the bottom of column 10 through a conduit 26 which has a control valve 27 therein. Valve 27 is adjusted by a liquid level controller 28 to maintain a predetermined liquid level in the bottom of column 10.

In order to explain the operation of the internal reflux computer and control system of this invention, an equation which is representative of the internal reflux in a fractionation column will be derived.

The material balance at the top tray of the fractionator can be expressed:

$$R_e+V_1=R_1+V_o \tag{1}$$

where

R_e=mass flow of liquid entering top tray (external reflux)
V_1=mass flow of vapor entering top tray
R_1=mass flow of liquid leaving top tray (internal reflux)
V_o=mass flow of vapor leaving top tray

The heat balance at the top tray can be expressed:

$$R_eh_e+V_1H=R_1h_1+V_oH \tag{2}$$

where

h_e=enthalpy of external reflux
h_1=enthalpy of internal reflux
H=enthalpy of vapor streams (assumed to be equal)

The enthalpy of the vapor streams entering and leaving the top tray can be expressed:

$$H=h_1+\lambda \tag{3}$$

where λ=heat of vaporization of liquid on the tray.

The enthalpy of the external reflux can be expressed:

$$h_e=h_1-C_p\Delta T \tag{4}$$

where

C_p=specific heat of the external reflux stream
ΔT=the difference in temperature between the top tray and external reflux

Equation 3 can be substituted into Equation 2 to eliminate H and rewritten:

$$V_i(h_i+\lambda)-V_o(h_i+\lambda)=R_ih_i-R_eh_e \quad (5)$$

Equation 4 can be substituted into Equation 5 to eliminate h_e and rewritten:

$$(h_i+\lambda)(V_i-V_o)=h_i(R_i-R_e)+R_eC_p\Delta T \quad (6)$$

From Equation 1 it is known:

$$V_i-V_o=R_i-R_e \quad (7)$$

Equation 7 can be substituted into Equation 6 and reduced to obtain:

$$R_i=R_e\left(1+\frac{C_p}{\lambda}\Delta T\right. \quad (8)$$

The computer of this invention solves Equation 8. The term R_e is obtained from a measurement which is representative of the rate of flow through conduit **21**. This is accomplished, for example, by the use of a differential pressure transmitter **30** which establishes an output electrical signal representative of the differential pressure across an orifice in conduit **21**. It is assumed that the temperature of the vapor leaving the top tray of column **10** is equal to the temperature of the liquid on the top tray. The term ΔT is then measured by comparing the vapor temperature with the external reflux temperature. Temperature sensitive resistance elements **31** and **32** are connected to the input of a differential temperature transducer **33**. The output signals from transducers **30** and **33** are applied to the inputs of a computer **34**.

Computer **34** operates in the manner described hereinafter to establish an output signal representative of the internal reflux in the fractionation system. The output signal from computer **34** is employed to adjust the set point of a controller **35**. Controller **35**, in turn, adjusts a control valve **36** in reflux conduit **21**. The control system operates to maintain the computed internal reflux constant at a preselected value. If the computed internal reflux should increase, valve **36** is adjusted to reduce the flow through conduit **21**. If the computed internal reflux should decrease, valve **36** is adjusted to increase the flow through conduit **21**.

Computer **34** is illustrated schematically in FIGURE 2. Temperature sensitive resistance elements **31** and **32** form two adjacent arms of an alternating current bridge network **40**. Variable resistors **41** and **42** form the opposite arms of the bridge. An alternating voltage source **43** is connected across first opposite terminals of the bridge, and the second opposite terminals are connected to the input of an amplifier **44**. The output of amplifier **44** is connected to the primary winding **45** of a differential transformer **46**.

The electrical bridge circuit provides an output signal which is representative of the quantity

$$\left(1+\frac{C_p}{\lambda}\Delta T\right)$$

of Equation 8. Variable resistors **41** and **42** are adjusted so that the output signal of the bridge network is representative of this quantity, the term

$$\frac{C_p}{\lambda}$$

being substantially a constant for any given fluid separation.

As previously described, the term R_e of Equation 8 is representative of the flow of external reflux through conduit **21** of FIGURE 1. A signal representative of this flow is established by transducer **30** which is associated with an orifice in conduit **21**. A first conduit **50** extends from a region upstream of the orifice to a fluid chamber **51**. A second conduit **52** extends from a region downstream of the orifice to a second fluid chamber **53**. Chambers **51** and **53** are separated by a flexible diaphragm **54**. The position of diaphragm **54** is thus representative of the differential pressure across the orifice. This differential pressure is proportional to the square of the rate of flow through conduit **21**.

Diaphragm **54** is connected by a rod **55** to the first end of a lever **56** which rests on a stationary pivot **57**. The second end of lever **56** is pivotally connected to a rod **58** which in turn is pivotally connected to the first end of a rod **59**. The second end of rod **59** is pivotably attached to a stationary support **60**. A T-shaped lever **61** is pivoted at one end to a stationary support **62**. A second end of lever **61** is pivotably attached to a rod **63** which is pivotably attached to the junction between rods **58** and **59**. The third end of lever **61** supports a core **65** which is adapted to be moved with respect to the coils of transformer **46**. The secondary coil **66** of transformer **46** is connected to the input of recorder-controller **35**. This coil preferably is formed of two sections which are connected in opposition so that there is no output signal when the core is centered.

The position of core **65** with respect to the coils of transformer **46** is adjusted by the position of diaphragm **54**. An increase in pressure in chamber **51**, for example, moves diaphragm **54** and rod **55** downwardly. This pivots lever **56** in a counterclockwise direction about support **57** so as to raise rod **58**. This rotates rod **59** in a clockwise direction about support **60** so that lever **61** is rotated in a clockwise direction about support **62**. Such a rotation moves core **65** into the region between the transformer coils so as to increase the mutual inductance of the transformer. The illustrated linkage multiplies the force exerted by non-linear spring **67** until this force is sufficient to balance the pressure differential on diaphragm **54**. Spring **67** is calibrated so that movement of core **65** is a function of the square root of the differential pressure across diaphragm **54**. In this manner, movement of core **65** is a direct function of the rate of flow through conduit **21**.

Differential transformer **46** multiplies the output signal of amplifier **44** by a signal representative of the flow of external reflux so that the signal applied to controller **35** is representative of the internal reflux in accordance with Equation 8. The output signal of controller **35** adjusts valve **36** in FIGURE 1 so as to maintain the computed internal reflux constant at a preselected value.

In view of the foregoing description it should be evident that there is provided in accordance with this invention an improved internal reflux computer which employs electrical and mechanical elements. While the invention has been described in conjunction with a present preferred embodiment, it should be evident that it is not limited thereto.

What is claimed is:

1. Computing apparatus comprising first and second temperature sensing means; means responsive to said first and second temperature sensing means to establish a first alternating electrical signal representative of the difference of the temperatures of said first and second means; a transformer having a primary coil, a secondary coil, and a core movable with respect to said coils; means to establish a second signal representative of the rate of flow of fluid through a conduit; means to apply said first signal to the primary coil of said transformer; and means responsive to said second signal to adjust the position of said core relative to said coils to multiply said first signal by said second signal, the product being the signal induced in said secondary coil.

2. The system of claim 1 wherein said means to establish said first signal comprises first and second temperature sensitive impedance elements, third and fourth impedance elements, a source of alternating current, and means connecting said impedance elements and said source of alternating current in a bridge network to establish a signal representative of the difference in temperature of said first and second elements.

3. The system of claim 1 wherein said means to estab-

lish said second signal comprises an orifice in the conduit, means to establish a third signal representative of the pressure differential across said orifice, and means responsive to said third signal to establish a signal representative of the square root of said third signal.

4. The system of claim 1 wherein said means to establish said second signal comprises an orifice in the conduit, means forming first and second fluid chambers, a diaphragm separating said chambers, means connecting said chambers upstream and downstream of said orifice, respectively, and means connecting said diaphragm to said core so that movement of said diaphragm responsive to

a change in the relative pressures in said chambers results in movement of said core relative to said coils.

References Cited in the file of this patent

UNITED STATES PATENTS

2,439,891	Hornfeck	Apr. 20, 1948
2,636,151	Hornfeck	Apr. 21, 1953

OTHER REFERENCES

Lupfer et al.: "Computer Control of Distillation Reflux," ISA Journal, vol. 6, No. 6, June 1959, pages 34–39.