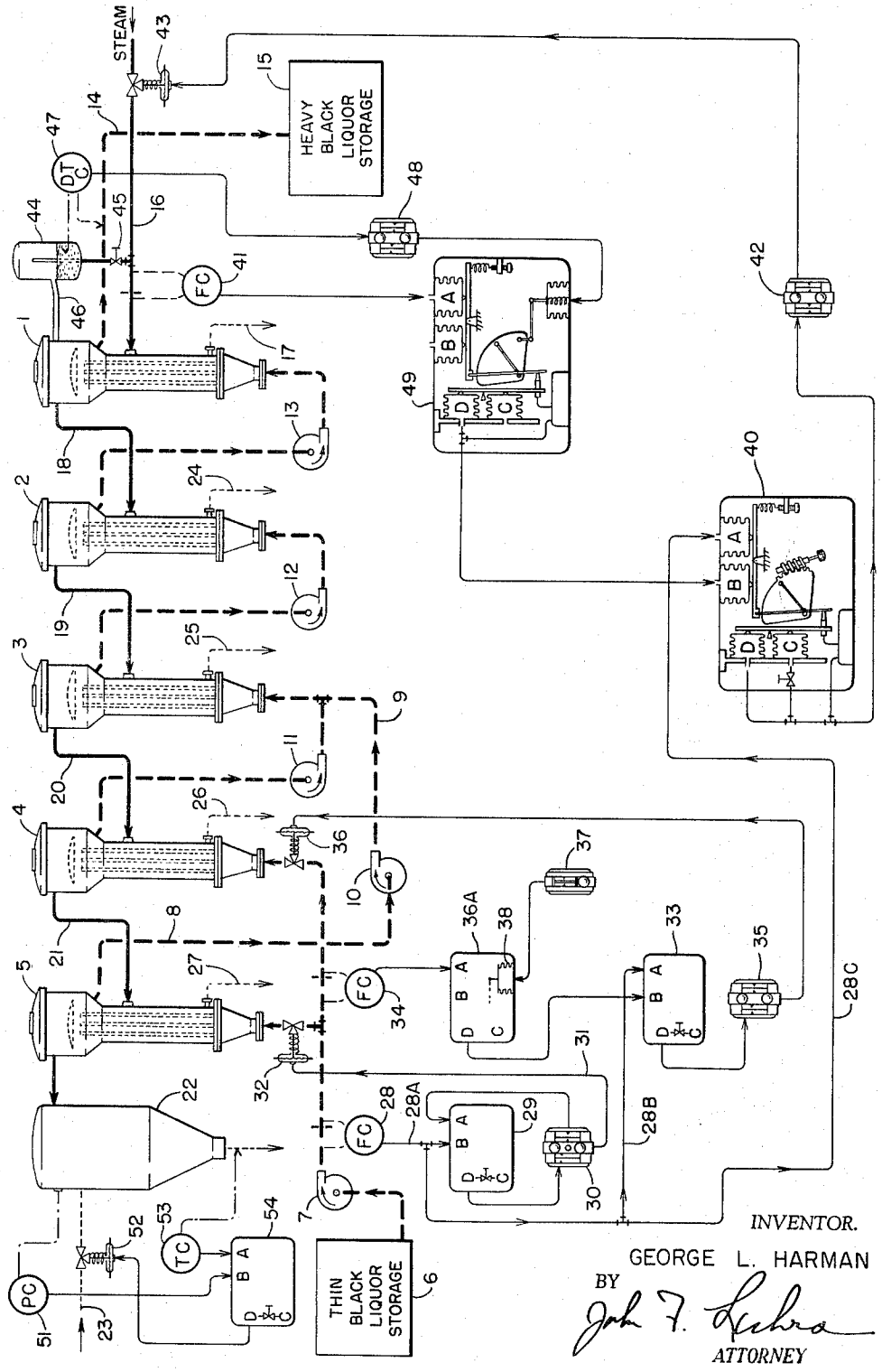
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CONTROL SYSTEM FOR MULTIPLE-EFFECT EVAPORATORS

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CONTROL SYSTEM FOR MULTIPLE-EFFECT EVAPORATORS

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My invention relates to a control system for multiple-effect evaporators used in the pulp industry for the concentration of thin black liquor to thick black liquor.

As well known, if the black liquor was discarded from the process after being washed from the pulp it would be necessary to replace all of the chemicals charged to the digester and the cost of pulp would be prohibitive. Hence, economy dictates the recovery of the chemicals as completely as possible. The first step in the recovery process is the concentration of the thin, or weak as it is sometimes called, black liquor to heavy black liquor suitable for further processing in a direct contact evaporator and recovery furnace.

Liquor received from the washers usually contains from 12 to 15% solids consisting of spent chemicals and the non-cellulose constituents of the wood. After concentration in the evaporator system the solids content is ordinarily in the order of 45 to 55%. Essentially the concentration process in the evaporator system consists in boiling off a considerable portion of the water found in the weak liquor. While such boiling off can be accomplished in a single evaporator economy dictates the use of several evaporators arranged in series or cascade as it may be called. With this arrangement live steam as the heating medium is admitted to the first evaporator in the series and the vapor generated in this evaporator then becomes the steam supply for the next evaporator and so on. The thin black liquor, having the lowest boiling point, is fed to the last evaporator in the series and passes in contra flow relation to the steam through the system. In such a multiple-effect arrangement one pound of steam admitted to the first evaporator will evaporate approximately one pound of water and the pound of vapor so formed will evaporate approximately one pound of water in the second evaporator and so on down the line resulting in a material increase in steam economy over a single evaporator arrangement.

As evaporators or effects are added a point is reached where a working temperature difference between liquor and vapor ceases to exist and the liquor in the evaporator in place of boiling merely simmers. For this reason the effects or evaporators are usually limited to between 5 and 7. In contemporary practice saturated steam is admitted to the first effect at about 15 to 20 p.s.i.g. and the vapor formed in the last effect discharges to a condenser operating at about 25 to 27" of mercury vacuum; the exact vacuum depending upon the temperature and quantity of cooling water available.

While the multiple-effect evaporator system has materially increased the economy of chemical recovery in the pulp industry it has presented a difficult control problem because of the long time constants and small storage capacities involved. Without proper control, changes in liquor feed flow, solids concentration, steam conditions, cleanliness of heat exchanger surfaces and the like result in an output of black liquor of non-uniform concentration. Furthermore because of the long time constants, an evaporator system once upset, may require hours of trial and error adjustment before it is again stabilized. My invention is particularly directed to the solution of the control problems presented by the use of multiple-effect evaporators in the pulp industry for the recovery of chemicals.

In the drawing:

FIG. 1 shows in diagrammatic form my invention applied to a typical multiple-effect evaporator system.

Referring to FIG. 1, I show, for purposes of illustration, a multiple-effect system consisting of evaporators 1–5 inclusive. Thin black liquor is fed to evaporators 4 and 5 in parallel from a storage tank 6 by means of a pump 7. I have shown thin liquor fed to evaporators 4 and 5 in parallel as this represents a practice frequently used and the arrangement further serves to illustrate a feature of my invention as later explained in detail.

The effluent from evaporator 5 is discharged through a pipe 8 and forced into evaporator 3 through pipe 9 by pump 10. The effluent from evaporator 4 is likewise fed to evaporator 3 through pipe 9 by means of a pump 11. The liquor after passing through evaporator 3 is then fed by a pump 12 to evaporator 2, thence fed by a pump 13 to evaporator 1 whence it is discharged through pipe 14 to a heavy black liquor storage tank 15.

Steam as a heating medium is supplied evaporator 1 through a pipe 16 from any suitable source such as the extraction stage of a turbine, pressure reducing valve or the like (not shown) and preferably at constant pressure. As heretofore noted, in contemporary practice steam is supplied the system at about 15 to 20 p.s.i.g. saturated. The condensate of the steam supplied evaporator 1 is discharged through a pipe 17. This condensate may be returned to a steam generator or wasted. As well known in the art the decision to return or waste is frequently automatically determined from a conductivity sensitive control, an increase in conductivity indicating contamination of the condensate by the liquor rendering it unfit for recycling through the steam generator.

The heat of vaporization of the steam fed to evaporator 1 is transferred to the liquor passing therethrough causing the liquor to boil. The vapor so formed is discharged through a pipe 18 to evaporator 2 wherein it forms the heating medium for boiling the liquor passing therethrough. This process is repeated in evaporators 3, 4 and 5, the vapor generated in evaporator 2 discharging through a pipe 19 to evaporator 3, the vapor generated therein discharging through a pipe 20 to evaporator 4, the vapor generated therein discharging through a pipe 21 to evaporator 5. The vapor discharged from evaporator 5 passes to a condenser 22 supplied with water through a pipe 23. Specific mill conditions determine the type of condenser used, that is, whether it is a jet, or barometric as it is sometimes called, or a surface type.

The condensate from the effects 2, 3, 4 and 5 is discharged through pipes 24, 25, 26 and 27 respectively. This condensate may be wasted or reused depending upon mill conditions, due care being taken in regard to contamination by the liquor as outlined with respect to evaporator 1. In some systems the condensate from one effect is flashed to the next succeeding effect improving the economy of operation.

I have purposely illustrated a simplified multiple-effect evaporator system to provide an adequate basis for the description of my invention to follow. As will be apparent to those skilled in the art, ordinarily auxiliary devices and processes are incorporated in a multiple-effect evaporator system such as catchalls in the vapor outflow pipe from each evaporator which serve to refine the separation of vapor from liquor, condensate traps and the like. As such auxiliary devices and processes are not pertinent to an understanding of my invention such have not been illustrated.

The control embodying my invention as shown in FIG. 1 is of the type commonly known as, "pneumatically operated" for the reason that compressed air is used as

the operating medium. However, it will be apparent as the description proceeds that my invention may as readily be incorporated in an electric or hydraulic control. I have chosen to show a pneumatically operated control for the reason that the components making up the system are well known in the art and their operation readily understood.

There is shown in the drawing a constant flow control of the thin liquor feed to the evaporator system with automatic ratioing of the feed among the evaporators, as thin liquor is fed to more than one evaporator. Flow transmitter **28** establishes a pneumatic loading pressure proportional to the total feed of the thin liquor to the system. I have shown this flow transmitter and other transmitters used in my conrol schematically as such transmitters may be any one of several types available.

The loading pressure established by transmitter **28**, proportional to the total feed of thin liquor to the system is introduced through pipe **28A** into the B chamber of a relay **29** having proportional plus reset action. The relay **29** may, for example, be of the type illustrated and described in United States Patent 2,805,678 issued to Michael Panich on Sept. 10, 1957. I have further shown the mechanism of a similar relay **40**, to which reference will be made later, in diagrammatic form.

Into chamber A of relay **29** is introduced a manually adjustable loading pressure which establishes the "set point" of the flow control, that is, establishes the demand rate of feed to the evaporator system. When the loading pressures introduced into chambers A and B are equal or stand in predetermined relation to each other the actual rate of feed will be equal to the demand rate of feed. A convenient means of adjusting the "set point" loading pressure may be provided by a selector station such as shown at **30** being of the type illustrated and described in United States Patent 2,747,595 issued to P. S. Dickey on May 29, 1956.

The output pressure at D of relay **29** changes in proportion to changes in the difference between the loading pressures in chambers A and B and by virtue of the restricted connection to chamber C continues to change at a slow rate so long as the pressures in chambers A and B are unequal or depart from a predetermined relation. Thus the relay **29** is spoken of in the art as a "proportional plus reset type" in that it serves to cause immediate changes proportional to the amount of departure from a desired value and thereafter a continuing change until the actual value is restored to the desired value.

The output pressure at D of relay **29** after passing through selector station **30** is transmitted through a pipe **31** to a diaphragm operated valve **32** regulating the rate of thin liquor feed to evaporator **5**.

The loading pressure established by the transmitter **28** is, as shown, also transmitted through a pipe **28B** to the chamber A of a relay **33** similar to the relay **29**. Into the chamber B of this relay is introduced a loading pressure proportional to the rate of flow of thin liquor to evaporator **4** generated by a flow transmitter **34**. With respect to relay **33** the loading pressure generated by flow transmitter **28** may be considered as establishing the "set point" of the constant flow control regulating the liquor feed to evaporator **4**, as the output pressure established at D of relay **33**, transmitted through selector station **35**, is effective for positioning a diaphragm operated valve **36**.

For any total rate of liquor feed, the ratio between the rates of feed to evaporators **4** and **5** may be adjusted by means of a relay **36A** and a manual loader **37**. The rely **36A** is in general similar to relay **29** but is provided with a bellows **38** for remote adjustment of the proportional band as illustrated and described more particularly in United States Patent 2,743,710 issued to Jack F. Shannon on May 1, 1956. I have further shown the mechanism of a similar relay **49**, to which reference will be made later, in diagrammatic form. More particularly the ratio between the input pressure at A and output pressure at D of relay **36A** is varied in accordance with the loading pressure in a bellows **38** established by manual loader **37**. Thus it will be evident that a one to one ratio between the flows to evaporators **4** and **5** may be established or any other desired ratio established by adjusting the proportionality between the input and output pressures of relay **36A**.

The selector stations **30** and **35** serve primarily as a means of readily transferring the constant flow control I have described from "Automatic" to "Remote Manual" or "Hand" control as it is frequently called. Each selector station is provided with a hand adjustable knob which when the control is on "Remote Manual' establishes the loading pressure for positioning the final control element which with respect to selector station **30** is the valve **32** and with respect to the selector station **35** is the valve **36**.

In accordance with my invention the rate of steam flow to the first effect is maintained in desired proportion to the total rate of liquor feed to the system. To accomplish this I show in the drawing a constant flow control of the steam flow, the set point of which is adjusted from total liquor feed flow. Therein I show the loading pressure established by the transmitter **28** introduced by a pipe **28C** into the A chamber of relay **40** which as previously mentioned is provided with proportional plus reset action. Into the B chamber of this relay the loading pressure generated by a flow transmitter **41**, as modified by relay **49**, is introduced. Thus by virtue of relay **40** the rate of steam flow is maintained in predetermined ratio with the rate of liquor feed. The steam flow constant flow control loop is shown as provided with a selector station **42** and a diaphragm operated flow control valve **43** as the final control element. Changes in feed will effect immediately and proportionate changes in steam flow thereby maintaining the heat input to the system in proportion to liquor feed resulting in an outflow of liquor from the system of uniform concentration. Changes in steam requirements occasioned by changes in liquor input are made before such changes cause an upset in the system.

Further in accordance with my invention the constant steam flow control is "trimmed" or readjusted automatically in accordance with changes in density or concentration of the black liquor outflow from the evaporator system. I show by way of example the concentration or density of the black liquor determined by comparing the boiling temperature of the black liquor to the temperature of boiling water at the pressure of the black liquor. The difference between these two temperatures is a measure of density or concentration of the liquor. Referring to the drawing I therein show a condenser **44** supplied with steam from pipe **16** through an adjustable restriction **45**. The condenser **44** is maintained at the same pressure as the black liquor by a vent pipe **46** connected to the vapor space in evaporator **1**. The arrangement therefore provides a means for maintaining a water sample at saturation temperature at the same pressure as the black liquor in evaporator **1**.

The black liquor leaving evaporator **1** is at boiling temperature, hence a differential temperature device such as shown schematically at **47** responsive to the temperature of the water in condenser **44** and to the temperature of the black liquor in pipe **14** may be utilized to generate a loading pressure proportional to the density of the black liquor. This loading pressure after passing through a selector station **48** serves to adjust the proportional band of relay **49** disposed in the loading line between flow transmitter **41** and relay **40**. Changes in liquor density will thereby cause a change in the proportion between the actual rate of steam flow and loading pressure admitted to chamber B of relay **40**. Thus for a given rate of thin liquor feed a new rate of steam flow will be maintained as required to hold a given density or concentration of the black liquor leaving the system. The

selector station **48** provides a means for manually adjusting the ratio between liquor and steam inputs if desired.

As well known the stability of operation is improved by maintaining a predetermined absolute pressure in condenser **22**, this in some cases may be accomplished by a single element control wherein an absolute pressure meter such as diagrammatically illustrated at **51** establishes a loading pressure proportional to the absolute pressure in the condenser **22** which either directly, or indirectly through a relay to give proportional plus reset action (not shown), controls the rate of flow of cooling water to the condenser by positioning a diaphragm valve **52**.

Certain types of surfaces condensers possess undesirable time lag characteristics. Where such a condenser is used it is desirable to provide a two element control such as I have shown which regulates the flow of cooling water to maintain a predetermined temperature of the cooling water in the condenser. The predetermined temperature is adjusted as required to maintain the desired absolute pressure in the condenser. I have schematically shown such an arrangement in the drawing wherein a temperature transmitter **53** establishes a loading pressure proportional to the temperature of the cooling water in or leaving the condenser and which through a relay **54** provides an output pressure for positioning the valve **52**. The "set point" of this constant temperature control is adjusted as required to maintain a predetermined absolute pressure in the condenser by introducing the loading pressure generated by transmitter **51** into the B chamber of relay **54**, which as shown, is provided with proportional plus reset action.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In a control system for a multiple-effect evaporator system for the concentration of thin black liquor to thick black liquor, comprising in combination; measuring means of the rate of flow of heating medium furnished the system, regulating means of the heating medium furnished the system operated by said measuring means and having an adjustable set point, means measuring the rate of flow of thin black liquor to the system, means operated by said last named means adjusting the set point of said regulating means to maintain a constant ratio between the rates of flow of heating medium and thin black liquor, means determining the concentration of the thick black liquor and means operated by said last named means adjusting the ratio maintained between the rates of flow of heating medium and thin black liquor in a direction tending to maintain a constant concentration of the thick black liquor.

2. In a control system for a multiple-effect evaporator system for the concentration of thin black liquor to thick black liquor composed of several evaporators arranged in cascade by vapor piping in which the water vapor boiled off the liquor in one evaporator acts as the heating medium in the following evaporator and arranged to admit steam as a heating medium to the first evaporator and to admit thin black liquor to the last evaporator whereby the black liquor and steam pass through the system in contra-flow relationship, the combination comprising; means producing a first control signal proportional in magnitude to the rate of flow of steam to the first evaporator, means producing a second control signal proportional in magnitude to the concentration of thick black liquor discharged from the first evaporator, means under the joint control of said signals producing a third control signal proportional in magnitude to the ratio between the magnitudes of said first and second signals, means producing a fourth control signal proportional in magnitude to the rate of flow of thin black liquor to the last evaporator, relay means under the joint control of said third and fourth signals generating a fifth control signal proportional in magnitude to the difference in magnitudes of the third and fourth signals, and regulating means of the rate of flow of steam to the first evaporator under the control of said fifth control signal whereby the rate of flow of steam is maintained in proportion to the rate of flow of thin black liquor and said proportion is changed inversely with changes in the concentration of the thick black liquor.

3. The control system as claimed in claim 2 for a multiple-effect evaporator system wherein thin black liquor is fed to more than one evaporator in parallel which includes means maintaining a predetermined ratio between the flows of thin black liquor to the evaporators.

4. The control system as claimed in claim 2 for a multiple-effect evaporator system wherein the water vapor boiled off the liquor in the last effect is discharged to a condenser in which the vacuum is maintained by cooling water, which includes means regulating the cooling water flow to maintain a predetermined temperature in the condenser and means adjusting the predetermined temperature maintained in accordance with the absolute pressure in the condenser in a direction to maintain the absolute pressure at a predetermined value.

5. The control system as claimed in claim 2 wherein said relay means includes means generating a change in the fifth control signal proportional to the time integral of the magnitude of the difference between said third and fourth control signals.

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