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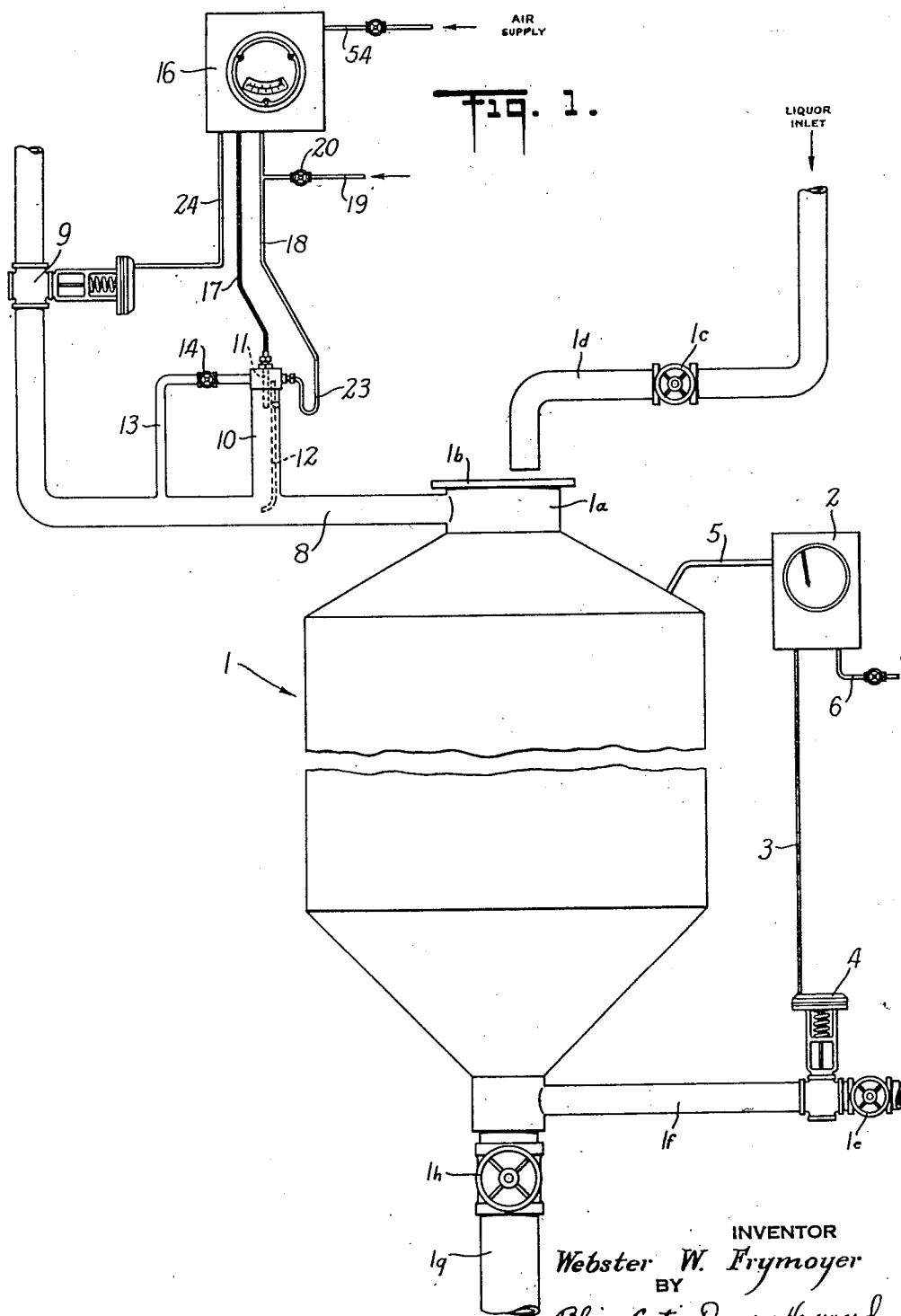
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2,310,415

METHOD OF AND APPARATUS FOR CONTROLLING DIGESTERS

Filed Dec. 1, 1938

3 Sheets-Sheet 1



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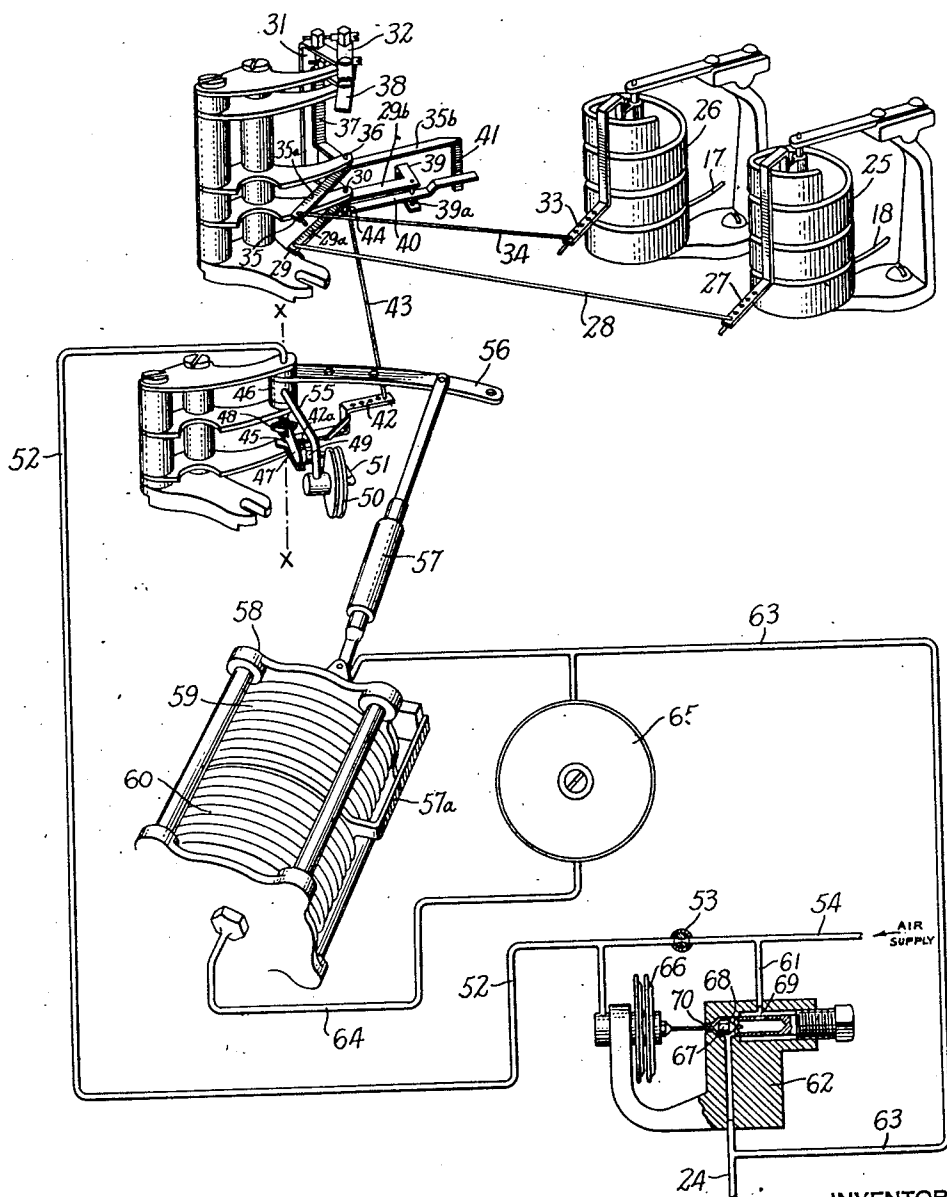
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METHOD OF AND APPARATUS FOR CONTROLLING DIGESTERS

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3 Sheets-Sheet 2

719. 2.



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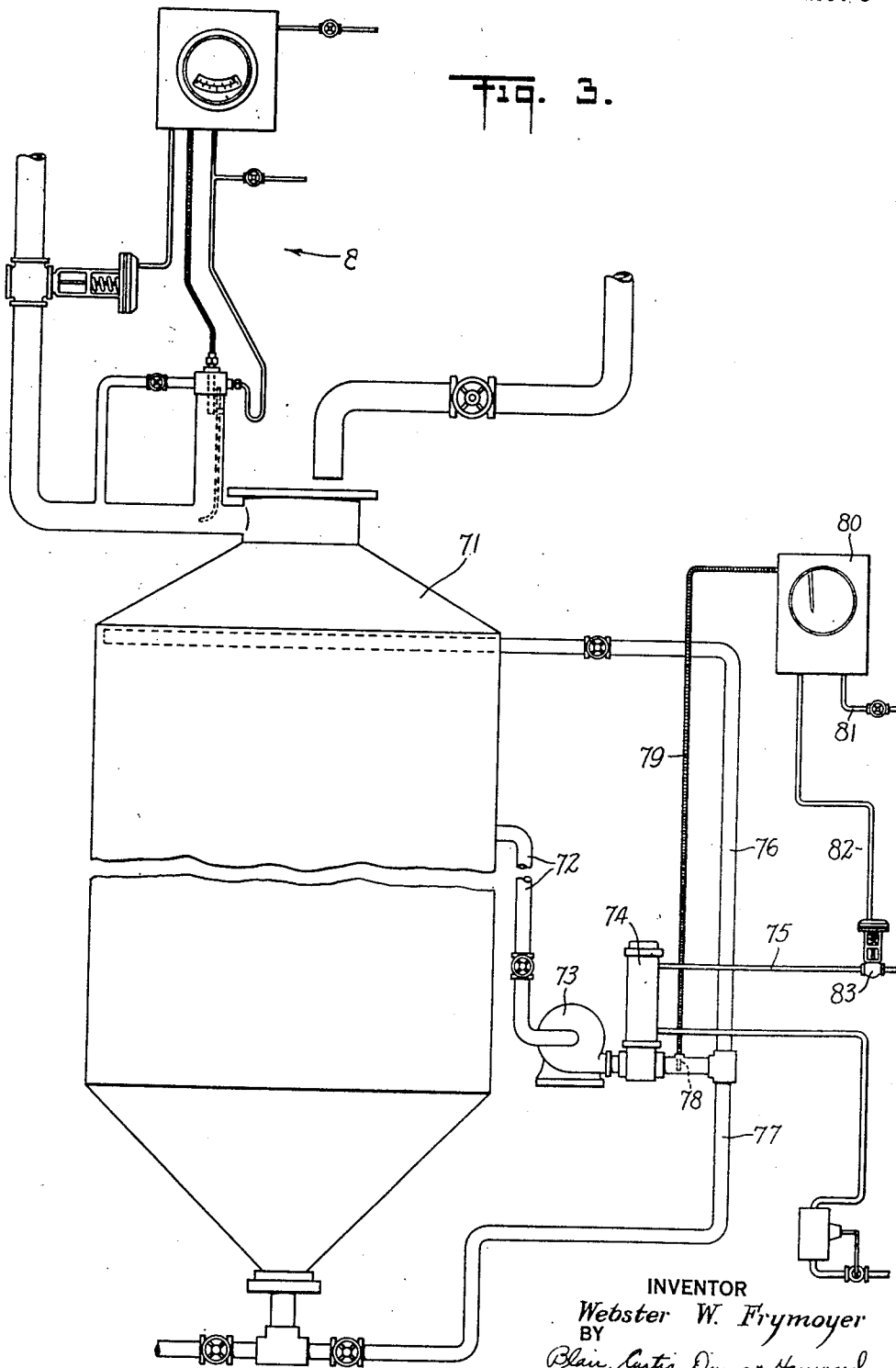
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METHOD OF AND APPARATUS FOR CONTROLLING DIGESTERS

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3 Sheets-Sheet 3

Fig. 3.



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METHOD OF AND APPARATUS FOR
CONTROLLING DIGESTERS

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Application December 1, 1938, Serial No. 243,333

18 Claims. (Cl. 92—7)

This invention relates to a method of and apparatus for automatically maintaining a predetermined relation between a liquid and a vapor in a liquor-vapor system, and more particularly to maintaining such relation in a wood pulp digester. In such a digester it is desirable that the total pressure of the vapor in contact with the liquid be maintained either substantially equal to, or in some predetermined relation to the vapor pressure of the liquid irrespective of variations in the temperature of the system.

In a paper pulp digester, wood in the form of chips is subjected to the action of chemical reagents at elevated temperatures and pressures for a period of hours, the process being known as cooking. At the beginning of the cook, the wood chips are charged into the body of the digester, and sufficient chemical liquor is pumped in to cover the chips. The heating of the digester, usually by steam, may be either direct or indirect, that is, live steam may be admitted at the base of the digester to heat the digester liquor by direct condensation, or the digester liquor may be withdrawn from the body of the digester, pumped through an external heat exchanger and returned to the digester.

In the case of a digester which operates according to the sulphate or soda processes whether directly or indirectly heated, it is desirable that the heating up process be carried out as rapidly as possible. Thus in a directly heated digester it is common practice to open the steam control valve wide at the beginning of the cook. As the temperature of the digester charge rises, the pressure in the digester also rises and automatically checks the rate of the flow of steam to the digester, or in the case of the indirectly heated digester, the increase in temperature of the circulating liquor causes a reduction in the overall heat transfer of the external exchanger.

During the heating up process, a considerable quantity of air present in and around the chips at the start is given off, as well as quantities of turpentine, methyl alcohol, and other volatile materials which are vaporized during the cooking process. It is desirable to remove these non-aqueous vapors as they accumulate in the digester. Unless the air is then removed it tends to form bubbles of air pockets, particularly near the sides of the digester, and these bubbles grow sometimes to relatively larger sizes, forming air pockets and interfering with the circulation of the liquor and the penetration of the liquor into the chips. Unless the total pressure in the vapor space is maintained at as low a value as

practical, these air bubbles do not rise to the surface of the liquor as rapidly as they should, and the resulting pulp contains quantities of uncooked or undercooked chips.

Further, when the air evolved from the digester liquor is removed intermittently, the sudden outrush of vapors tends to cause the liquor to "pull over" into the vapor relief line. I have found that by maintaining in the digester pressures that correspond as closely as practical to the vapor pressure of the digester liquor, air and other non-aqueous vapors are removed in such manner as to reduce substantially the amount of liquor foaming and "pull over" into the relief line.

I have also discovered that by thus removing the non-aqueous gases, circulation of liquor in the digester is improved and that the quantity of incompletely cooked chips, as evidenced by the amount of screenings obtained, is reduced.

In the present embodiment of the invention, the quantity of non-aqueous gases in the vapor space of the digester is, in effect, measured, and relief of the gases from the digester is controlled from this measurement so as to keep venting these gases to establish the desired minimum quantity of them in the digester. In other words, the control operates effectively to maintain a pressure-temperature relationship of the gases above the digester liquor that corresponds to approximately 100% steam.

Apparatus capable of carrying out the method of the present invention is shown in the accompanying drawings, wherein:

Figure 1 shows schematically the application of one embodiment of the invention to a directly heated digester;

Figure 2 is a view largely in perspective showing the details of the control instrument; and

Figure 3 shows schematically the application of one embodiment of the invention to an indirectly heated digester.

Referring to the drawings, and more particularly to Figure 1, a pulp digester of the usual directly heated type is generally indicated at 1. Before the actual cooking starts, wood chips are charged into the top of the digester through a man hole 1a, after which cooking liquor is pumped into the digester through a line 1d and a valve 1c. When the desired quantity of liquor has been pumped into the digester 1, valve 1c is closed, manhole cover 1b is bolted on, and valve 1e near the bottom of the digester is opened to allow steam to pass through the line 1f into the digester to heat the liquor in the

digester 1. When the cooking process is completed, the spent liquors and the cooked pulp are discharged from the digester through the line 1g by opening the valve 1h.

As noted above, as the temperature of the digester liquor rises, the release of vapor therefrom is controlled to cause pressure in the digester to increase, which increasing pressure tends to reduce the rate of flow of steam through the line 1f. If, however, the pressure of the supply steam to valve 1e exceeds the maximum working pressure of the digester, additional means for controlling the steam flow are necessary. In the installation shown in Figure 1, this additional control is provided by the pneumatically operated control instrument 2. The instrument 2 may be of the usual type used for such purposes to control the operation of a valve to supply steam in accordance with pressure desired to be maintained by the steam. Thus, for example, it may be an open-and-shut or a throttling controller of the air-operated type. Although not shown in the drawings, such an instrument would contain a pressure-responsive element (connected to the vapor space of the digester by a line 5) which operates a control valve in the instrument to govern the supply of air from a supply line 6 to a line 3 connected with a diaphragm-operated valve 4. The operation of the instrument, for example, is such that if the pressure in the vapor space of the digester is below the desired value, the pressure-responsive element operates the control valve in the instrument to increase the air pressure in the line 3 and on the diaphragm valve to open the valve further, and if the pressure in the vapor space of the digester exceeds the desired value, the air pressure in the line 3 and on the diaphragm valve is lowered to close the valve. Hence, after the heating up of the digester has been completed the instrument 2 automatically maintains the pressure in the vapor space of the digester 1 at the desired value.

The live steam admitted at the base of the digester flows up into the digester liquor and at the same time air which enters the digester in the chips is released and passes up through the digester. The air and other non-aqueous vapors given off pass to the top of the digester and out a relief line 8 under the control of a valve 9 in the line 8. In the present invention, the relief of these vapors through the line 8 and valve 9 is controlled in such a manner that the tendency is to relieve the gases as rapidly as they are freed in the digester liquor. Since these gases, including the air, are rapidly and continuously removed as they are evolved, circulation in the digester is improved, and the pressure in the vapor space is maintained at a lower average value. Hence, the cook can be brought up to a temperature more rapidly and the average cooking time reduced.

In the present embodiment, this control is obtained by effectively determining the presence of non-aqueous vapors in the relief gases by effectively measuring the temperature of the vapors above the digester liquor, measuring the total pressure of the vapors above the digester liquor, and controlling the release of the vapors to maintain the desired relationship between this temperature and pressure. Thus the presence of non-aqueous vapors would be indicated by a higher total pressure than called for by the effectively measured temperature of the vapors and the control instrument would maintain an open-

ing of the valve tending to release the vapors to remove the non-aqueous vapors and to lower the total pressure. Of course, steam is released along with the non-aqueous vapors, but with the present invention this loss of steam is reduced to a minimum.

In carrying out the above control, the problem is complicated by the fact that the digester liquor contains dissolved chemical reagents so that the vapors in equilibrium with the digester liquor are superheated due to the phenomenon commonly known as "boiling point raising." Furthermore, the concentration of the chemical reagents varies during the cooking process, causing a variation of the degree of superheating in the vapors. Hence, it is desirable that this superheat be removed and that the vapor temperature measured be the initial condensing temperature of the vapors; or, differently stated, the temperature of incipient condensation. The total pressure and the temperature thus determined are then correlated by the control instrument to maintain the desired minimum of non-aqueous vapors present.

In the present embodiment, this initial condensing temperature of the vapors is obtained by providing in the main relief line 8 between the digester 1 and the valve 9 a condensing chamber 10 preferably extending vertically upward from the relief line 8. Positive circulation of vapors from the relief line 8 through the condensing chamber 10 is obtained by the use of a Pitot tube 12 supported within the chamber 10 and having a lower end extending into the line 8 and pointing downstream. Flow of the vapors past the lower end of the Pitot tube 12 causes a reduced pressure therein which is transmitted through the upper end of the chamber 10 to cause the vapors from the line 8 to pass up through chamber 10.

The upper end of the condensing chamber 10 is connected to the main relief line 8 by a pipe 13 containing a valve 14, the function of the pipe 13 being to aid in removing foam which under certain conditions finds its way into the condensing chamber 10.

The flow of the vapors through the condensing chamber produced by the Pitot tube 12 is sufficiently slow to cause the gases in passing through the condensing chamber to lose their superheat through the walls thereof which loss of heat causes incipient condensation of the steam.

In the top of the condensing chamber 10 there is provided a water-filled bulb 11 which by reason of the flow of gases through the condensing chamber is maintained substantially at the initial condensing temperature of the vapors, and hence the water within the bulb exerts a pressure equal to the partial pressure of the water vapor in the vapor mixture.

The bulb 11 is connected by a length of flexible capillary tubing 17 to a pressure-responsive element 26 (see Figure 2) in control instrument 16. A second pressure-responsive element 25 located in the instrument 16 is made responsive to the total pressure of the vapor by a connecting line 18 (best shown in Figure 1) connected to the top of the condensing chamber 10. Water for flushing line 18 and filling a seal 23 in the line 18 is provided through a water supply line 19 which is provided with a shut-off valve 20. Usually this line is flushed after each cook to remove any fibers which may have accumulated at the lower end of line 18.

The operations of these two pressure-responsive

elements 25 and 26 are correlated to maintain a difference between the two pressures at the desired minimum by permitting the escape from the digester of non-aqueous vapors.

In this connection it should be noted that the water-filled bulb is merely the preferred method of measuring the initial condensing temperature of the vapors. It would be possible, for example, to use a mercury-filled bulb or other temperature-sensitive element which produces a mechanical effect that is a linear function of temperature. This effect could then be converted into a second mechanical effect to be correlated with the motion of element 25 by means of a linkage constructed in such a manner as to take into account the well-known logarithmic character of the temperature-vapor pressure relationship of water. However, the water-filled bulb is preferable since it produces directly a mechanical effect which is proportional to the vapor pressure of water at the temperature of the bulb.

The pressure difference as measured by the two responsive elements 25 and 26 in the present embodiment is proportional to the concentration of non-aqueous vapors present in the vapor mixture and, as will be described, the controller operates in response to this difference to release the non-aqueous vapors at a rate which takes into consideration the amount of non-aqueous vapors present in the vapor mixture.

Again referring to Figure 2, the line 18, as noted above, is connected with pressure-responsive element 25, and the capillary 17 is connected with pressure-responsive element 26. Element 25, through lever 27 and link 28, actuates a bell-crank lever 29 pivoted at 30 and comprising the arms 29a and 29b. Connected to, moving with, and partially supporting the bell-crank 29 is an arbor 31 carrying a pen arm 32 which records the digester pressure. The element 26 through lever 33 and link 34 moves a bell-crank lever 35 pivoted at 36 and comprising the arms 35a and 35b. Connected to, moving with, and partially supporting bell-crank 35 is an arbor 37 carrying the pen arm 38 which records the pressure in the bulb 11 as the initial condensing temperature of the vapors leaving the digester. The arm 29b of bell-crank 29 is provided with a yoke 39 which holds a spindle 39a carrying an equalizing lever 40, one end of which is positioned by a tongue 41 extending from the arm 35b of bell-crank lever 35. The other end of the lever 40 is connected to a flapper actuating lever 42 by a link 43 which is connected to the lever 40 at 44. The arrangement of the levers is such that if the pressure and temperature increase or decrease at corresponding rates the lever 40 pivots around the point 44 which does not itself move, and hence the flapper actuating lever 42 remains stationary. In effect, the position of element 26 is always subtracted from that of element 25.

The flapper actuating lever 42 is a bell-crank lever pivoted on the shaft 45 and having an upwardly extending projection 42a against which the flapper 47 bears. A spiral hair spring 48 tends to move the flapper 47 toward the projection 42a. The flapper 47 coacts with a nozzle 49 to create a fluid pressure for controlling the control valve 9 in a manner which will now be described. The operation of the portions of the apparatus now to be described is more completely disclosed in Mason Reissue Patent No. 20,092.

Referring to the lower right-hand portion of Figure 2, air from an air supply line 54 passes through a branch line 61 to a control head 62

and through a restriction 53 and branch line 52 to a nozzle assembly unit comprising the hollow collar 46, a tube 55, bellows 50, tube 51, and nozzle 49. The control head 62 serves to control air pressure existing in line 24 leading to control valve 9, and also the air pressure existing in branch line 63. Control head 62 is provided with a valve chamber 68 containing a double-headed valve 67 which cooperates with a port 69 communicating with branch line 61, and a port 70 communicating with atmosphere. When the valve 68 is in its extreme right-hand position, line 24 is open to atmosphere, and, when valve 67 is in its extreme left-hand position, line 24 receives full line pressure from line 61.

Valve 67 is positioned by the bellows 66 which expand to move the valve to the right with increasing pressure and collapse to move the valve to the left with decreasing pressure. Pressure in the bellows is controlled by the pneumatic control couple comprising the nozzle 49 and the flapper 47, and the pressure in the line 52 is varied by the relative positions of the nozzle and flapper.

When the flapper covers the nozzle opening, a maximum back pressure starts building up in the line 52 and bellows 66. When the flapper is moved away from the nozzle 49, the pressure in the line 52 and bellows 66 starts decreasing.

When the flapper 47 is moved away from the nozzle beyond a certain limited distance, the back pressure in line 52 and bellows 66 decreases to a certain minimum back pressure. For various intermediate relative positions of the nozzle and flapper, the back pressure in line 52 and bellows 66 balances to various values intermediate the maximum and minimum back pressures.

In the present embodiment when the flapper and nozzle are separated beyond approximately a thousandth of an inch, the back pressure in line 52 and bellows 66 decreases to the minimum back pressure above referred to. Thus the range of movement of the flapper with respect to the nozzle, for establishing the said intermediate back pressures, is approximately one thousandth of an inch. Further, these intermediate back pressures bear only an approximately proportional relationship to the intermediate relative positions of the nozzle and flapper within this thousandth of an inch range.

The nozzle 49 and its assembly are positioned by an arcuate lever 56 which is rigidly attached to the hollow collar 46 and which collar and lever pivot about the axis X—X. The lever 56 is connected by a link 57 to a rack 57a supported between two opposing bellows 59 and 60, the opposite ends of which are rigidly supported in a stationary rack 58. The pressure difference within the two bellows positions the rack 57a and consequently the nozzle 49. When equal pressures exist in the bellows 59 and 60, rack 57a assumes a neutral position; but if the throttling bellows 59 has a pressure within higher than the pressure in bellows 60, the rack is shifted downwardly as shown in the drawings an amount corresponding to the pressure difference. If bellows 59 has a pressure within lower than the pressure in bellows 60, the rack is shifted upwardly from its neutral position an amount corresponding to the pressure difference.

As shown in the present embodiment, bellows 59 is connected with bellows 60 through a restriction 65 and a line 64 and the pressure existing in bellows 59 is the same as that existing on the diaphragm motor of valve 9. Further, the

pressure existing in the bellows 59 is transmitted to or from bellows 60 through the restriction 65 which permits only gradual pressure equalization.

When the above-described mechanism is in operation, any movement of the flapper produced by movement of either of the pressure-responsive elements 25 or 26, or, stated in another way, any change in the difference between the pressures existing in the two elements, which would tend to cover or uncover the nozzle 49, affects the pressure in the throttling bellows 59 to move the rack 57a to move the nozzle to a point tangent to the flapper. This "primary reaction" is such that the nozzle is maintained tangent to the flapper by change of the position of the rack 57a and is such that the quantity change in pressure in bellows 59, which this primary reaction tends to produce, is proportional to the change in the difference between the pressures existing in the two elements 25 and 26. In order to avoid confusion in the description below, the difference between the pressures existing in elements 25 and 26 will be denoted by the letter D.

In addition to this "primary reaction" there is a "secondary reaction" produced by the reset bellows 60. Bellows 60 opposes bellows 59 and has a pressure connection therewith through the restriction 65. Thus, a differential pressure between the bellows 59 and 60 tends to produce a rate of change of pressure in the bellows 59 which is directly proportional to the difference of the pressures.

When D remains constant and there is a rate of change of pressure in the bellows 60, the same rate of change of pressure occurs in the bellows 59. This is due to the "primary reaction" which holds the nozzle tangent to the flapper and which requires that a particular differential pressure exist between bellows 59 and 60 so long as D is constant.

For one particular value of D the nozzle will be held tangent to the flapper with zero pressure differential between the bellows 59 and 60; that is, the pressures in the bellows are equal, there is a zero rate of change in both bellows 59 and 60, and the value of the pressure in the two bellows may have any value between zero and a full supply of pressure. This value of D is the control point of the air-operated control mechanism.

A rate of change of pressure in the bellows 60 is produced by a deviation of D from this control value, and the value of the rate of change of pressure in the bellows 60 is proportional to this deviation. The rate of change of the pressure in bellows 60 is positive when D is greater than the desired value, and is negative when D is less than the desired value.

Considering an increase in the value of D as a positive deviation from the control point, the "primary reaction" tends to produce an increased pressure in the bellows 59 for a positive deviation of D and vice versa. Furthermore the "primary reaction" tends to produce a positive rate of change of pressure in bellows 59 for a positive rate of change of D. The "secondary reaction" tends to produce a positive rate of change in pressure in bellows 59 for a positive deviation in D. Hence the aggregate effect of these two reactions is to produce a rate of change of pressure in bellows 59 which is proportional to the algebraic sum of the deviation of D and the rate of change of deviation of D. The pressure

in bellows 59 may be increasing, decreasing, or standing still, dependent upon the rate of change of D and will always have zero rate of change when the control point is reached. Since it is desirable that the flow through relief line 8, which causes changes in the value of D, have the same general characteristics as the pressure in bellows 59, this pressure is used as the operating pressure for the diaphragm motor of the valve 9.

In the foregoing description the apparatus of Figure 2 has been described as responsive to the pressure difference D existing between the elements 25 and 26. The operation of the apparatus as a controller may also be described from another point of view. Considering for the moment the operation of the helical element 25 on the equalizing lever 40 independently of the action of the element 26 on that lever, the element 25 moves in response to the pressure in relief line 8 to adjust the left-hand end of the equalizing lever and the flapper 47 to vary the output pressure of the controller to operate the control valve 9. With element 25 operating in this manner, the control valve 9 will be operated to tend to maintain the pressure in the digester at a value which corresponds to the position of the right-hand end of the equalizing lever 40. Under such circumstances this pressure value, which may be considered as a control point, might be manually adjusted by moving or changing the position of the right-hand end of the equalizing lever 40.

Such an adjustment may be automatically effected by the helical element 26 which, operating through the linkage described above, continuously positions the right-hand end of the equalizing lever 40 and hence may be said to continuously adjust the control point of a pressure controller. The helical element 26 is responsive to the temperature within the chamber 10 and hence the apparatus may be described as a pressure controller having a control point which is continuously adjusted in response to changes in the value of the initial condensing temperature of the vapors within the digester.

During the cook, the amount of air and other non-aqueous vapors given off varies to a considerable extent. At the start of the cooking, the amount of air given off is the largest, but this rapidly drops to a lower value which holds approximately constant for a while until it rises again and then falls off to a minimum during the latter part of the cook. The instrument operates to maintain the valve open sufficient to maintain the differential desired between the responsive elements 25 and 26 at approximately the control point in the manner described above.

From the above description it may be seen that the present invention provides a means for maintaining a predetermined relation between a liquid and a vapor in a liquid-vapor system. The difference between the vapor pressure of the liquid and the total pressure is used as a control variable to reestablish the desired relation between liquid and vapor upon departure therefrom. Thus in a paper pulp digester it is possible to continuously remove the air from the vapor space of the digester as it is given off, thus permitting more rapid and uniform penetration of the cooking liquor into the chips. Since the air is not held back in the vapor space in the digester, the flow of steam to the digester is not retarded by excessive pressures in the vapor space due to air, and the temperature of the

digester liquor may be brought rapidly to the desired condition. Furthermore, the continuous removal of air in the early stages of the cook eliminates the necessity for removing relatively large volumes of vapor at later stages of the cook and reduces foaming and entrainment problems. With a digester control, as above described, the pressure in the vapor space of the digester is kept substantially at the pressure corresponding to the temperature of the liquor in the digester, which, in turn, is maintained by the instrument 2.

In the modification just described, the controller is adapted to a directly heated digester; and, in the embodiment now to be described, the controller is adapted to an indirectly heated digester. Referring now to Figure 3, there is indicated at 71 a digester which operates much the same as the digester shown in Figure 1 except that the heating of the liquor takes place outside of the body of the digester. Digester liquor is withdrawn from the digester through the line 72 by the pump 73 and passes through a tubular heat exchanger 74 which is supplied with steam through the line 75.

After leaving the heat exchanger 74, the liquor divides, one portion passing through the line 76 to the top of the digester 71 and the other portion passing through line 77 to the bottom of the digester. The flow of steam to the heat exchanger 74 is controlled in response to the temperature of the outlet liquor. At the liquor outlet of the heat exchanger there is located a temperature-sensitive bulb 78 which is connected by a length of flexible tubing 79 to a control instrument 80. The operation of control instrument 80 is generally similar to that of the instrument 2 of Figure 1, except that the instrument 80 contains a temperature-responsive element rather than a pressure-responsive element. The instrument 80 serves to control the flow of air from a supply line 81 through the connecting pipe 82 to a diaphragm valve 83, the pressure in the line 82 being varied in response to the temperature of the outlet liquor. The instrument 80 controls the flow of steam to the heat exchanger 74 in such a manner as to maintain the temperature of the circulating liquid substantially at the desired value and to prevent excessive heating of the liquor.

The digester 71 is provided with a vapor relief controller, generally indicated at 84, which operates in the same manner as the controller shown in Figure 1. In the case of an indirectly heated digester, such as the digester 71, there is an additional reason for using a condensing chamber. The circulating liquor returned to the digester through the line 76 is heated to a higher temperature than the liquor within the digester, and hence as it enters the digester it forms a quantity of superheated vapors therein. Thus, in the indirectly heated digester there are two sources of superheat which it is desirable to remove; superheat due to the "boiling point raising" caused by the dissolved solids in the digester liquor and superheat due to the increased temperature of the recirculated liquor.

The controller in Figure 2 operates on the indirectly heated type of digester to perform the same operation and obtain the same result as on the directly heated digester. It relieves the non-aqueous gases as they are given off and thus serves to aid in the circulation of the cooking liquor and in the cooking of the pulp.

I claim:

1. The method of automatically maintaining the pressure in the vapor space of a digester at a value which is a predetermined function of the mean temperature of the digester liquor, which comprises, measuring the vapor pressure of water at the initial condensing temperature of vapors in said vapor space, measuring the total pressure in the vapor space of the said digester, continuously subtracting the value of the said vapor pressure from the value of the said total pressure to obtain a difference, and regulating the removal of vapors from said vapor space in response to variations in the value of said difference.

2. Method of controlling the gas release from a pulp cooking digester, comprising, continually releasing air from the vapor space of the digester in accordance with the difference between the total pressure in the digester and the vapor pressure of water at the initial condensing temperature of the gases in said vapor space.

3. The method of controlling the pressure in a pulp cooking digester wherein the heating is accomplished by admission of steam directly into the body of the said digester, which comprises continually releasing gases from the said digester in accordance with the difference between the total pressure in the said digester and the vapor pressure of water at the initial condensing temperature of the gases in the digester.

4. Method of controlling the pressure in a pulp cooking digester wherein the digester liquors are removed from the digester, passed through an external heater and returned to the digester, which comprises continually releasing gases from the top of the said digester in accordance with the difference between the total vapor pressure in the digester and the vapor pressure of water at the initial condensing temperature of the gases in the digester.

5. The method of automatically maintaining the pressure in the vapor space of the digester at a value which is a predetermined function of the mean temperature of the digester liquor, which comprises controlling the total pressure in the vapor space by means of a pressure controller and continuously adjusting the said pressure controller to cause it to control the pressure at a value which is proportional to the vapor pressure of water at the initial condensing temperature of the vapors in said vapor space.

6. The method of automatically maintaining the pressure in the vapor space of a digester at a value which is a predetermined function of the mean temperature of the digester liquor, which comprises, removing heat from the vapor to produce a condition of incipient condensation, measuring the vapor pressure of water at the temperature of the vapors in this condition, measuring the total pressure in the vapor space of the said digester, continuously subtracting the value of the said vapor pressure from the value of the said total pressure to obtain a difference, and regulating the removal of vapors from said vapor space in response to variations in the value of said difference.

7. The method of controlling the removal of non-aqueous gases from the vapor space of a digester through a pressure relief line, which comprises removing from a portion of the vapors passing through the said relief line enough heat to cause incipient condensation, measuring the vapor pressure of water at the temperature of said portion of vapors, continuously subtracting said vapor pressure value from the total pressure of vapor in the said relief line to obtain a differ-

ence, and regulating the flow of vapors through said relief line in response to variations in the value of the said difference.

8. In apparatus for automatically maintaining the pressure in the vapor space of a digester at a value which is a predetermined function of the mean temperature of the digester liquor, the combination of, means for measuring the vapor pressure of water at the initial condensing temperature of the vapors in said vapor space, means for measuring the total pressure in the vapor space of the said digester, means for continuously subtracting the value of said vapor pressure from the value of the said total pressure to obtain a difference, and means for regulating the release of vapors from the vapor space of the said digester in response to variations in the value of the said difference.

9. In apparatus for controlling the removal of non-aqueous gases from the vapor space of a digester through a pressure relief line, the combination of, a condensing chamber connected to the said relief line, means responsive to the temperature within the said condensing chamber, means responsive to the pressure in the said relief line, means for continuously subtracting the position of the said temperature-responsive means from the position of said pressure-responsive means to obtain a difference, and means for regulating the flow of vapors through said relief line in response to variations in the value of said difference.

10. In apparatus for controlling the removal of non-aqueous gases from the vapor space of a digester through a vapor relief line, the combination of, a condensing chamber connected to the said relief line, temperature-sensitive means located within the said condensing chamber, means for causing a continuous flow of vapor past the said temperature-sensitive means, means responsive to the pressure in the said relief line, means for continuously subtracting the value indicated by said temperature-sensitive means from the value indicated by said pressure-responsive means to obtain a difference, and means for regulating the flow of vapors through the said relief line in response to variations in the value of said difference.

11. In apparatus for controlling the removal of non-aqueous gases from the vapor space of a digester through a pressure relief line, the combination of, a condensing chamber connected to the said relief line, a water-filled thermal system having a temperature responsive bulb located in the said condensing chamber, said thermal system indicating values which are a function of the temperature in said condensing chamber, means for causing a continuous flow of vapor past the said bulb, means responsive to the pressure of said relief line, means for continuously subtracting the value indicated by said thermal system from the value indicated by said pressure-responsive means to obtain a difference, means responsive to said difference for establishing a fluid pressure value which is at all times a function of said difference, and means responsive to the said fluid pressure value for controlling the flow of vapors through the said relief line.

12. The method of continuously measuring the amount of gas or foreign non-condensing vapor present in a vapor atmosphere of a multicomponent liquid, said vapor atmosphere being in equilibrium with said liquid and including as a principal constituent the vapor of the principal constituent of said liquid, which comprises, meas-

uring the total pressure of said atmosphere, measuring the vapor pressure of the principal constituent of said liquid at the initial condensing temperature of said atmosphere, and subtracting the value of said vapor pressure from the value of said total pressure to obtain a value proportional to the quantity of gas and foreign non-condensing vapors present in said atmosphere.

13. The method of continuously measuring the amount of gas or foreign non-condensing vapor present in a vapor atmosphere of a multicomponent liquid, said vapor atmosphere being in equilibrium with said liquid and including as a principal constituent the vapor of the principal constituent of said liquid, which comprises, measuring the total pressure of said atmosphere, continuously removing heat from a portion of said atmosphere to lower the temperature of said portion to the temperature of incipient condensation, measuring the vapor pressure of the principal constituent of said liquid at said temperature of incipient condensation, and subtracting the value of said vapor pressure from the value of said total pressure to obtain a value proportional to the quantity of gas and foreign non-condensing vapors present in said atmosphere.

14. Apparatus for automatically controlling the removal of gas or foreign non-condensing vapor from the vapor atmosphere over a multicomponent liquid, said vapor atmosphere being in equilibrium with said liquid and including as a principal constituent the vapor of the principal constituent of said liquid, which comprises, in combination, means for measuring the total pressure of said atmosphere, means for measuring the vapor pressure of the principal constituent of said liquid at the initial condensing temperature of said atmosphere, means for continuously subtracting the value of said vapor pressure from the value of said total pressure to obtain a differential value proportional to the quantity of gas and foreign non-condensing vapors present in said atmosphere, and means for regulating the removal of gas and foreign non-condensing vapors present in said atmosphere in response to said differential value.

15. Apparatus for regulating the removal of non-aqueous vapors and gases from the vapor space of a digester in response to variations in the quantity of said non-aqueous vapors present in said vapor space, comprising, in combination, means for measuring the total pressure in said digester, means for measuring the initial condensing temperature of said vapors, a first element positioned in proportional correspondence with the value of said total pressure, a second element positioned in proportional correspondence with the value of the vapor pressure of water at said initial condensing temperature of said vapors, and control means for controlling the flow of vapors from said digester in response to variations in the difference between the position of said first element and the position of said second element.

16. The method of continuously measuring the amount of gas or foreign non-condensing vapor present in a vapor atmosphere in equilibrium with a multi-component liquid, said vapor atmosphere including as a principal constituent the vapor of the principal constituent of said liquid, which comprises measuring the total pressure of said atmosphere, removing heat from a portion of said atmosphere to lower its temperature to a point where said atmosphere is saturated with respect to said principal constituent, effectively

measuring the partial pressure of said principal constituent at said saturation temperature, and subtracting the value of said partial pressure from the value of said total pressure to obtain a value proportional to the quantity of gas or foreign non-condensing vapors present in said atmosphere.

17. The method of continuously measuring the amount of non-aqueous gases and vapors in the vapor space of a digester which comprises continuously removing a portion of the vapors from said vapor space, cooling said removed vapors to their initial condensing temperature, effectively measuring the partial pressure of water vapor in said vapors at that temperature, measuring the total pressure in said vapor space, and subtract-

ing the value of said partial pressure from the value of said total pressure to obtain a value proportional to the quantity of non-aqueous gases in said vapor space.

5 18. In a method of regulating the relief of gases from a paper pulp digester, the steps of measuring the total gas pressure within said digester, removing heat from a portion of said gases to reduce the temperature of said portion of gases to a condition of incipient condensation, measuring the temperature of said portion of gases at said condition of incipient condensation, and regulating the relief of gas from said digester in response to variations in said measured pressure and in said measured temperature.

15 WEBSTER W. FRYMOYER.

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CERTIFICATE OF CORRECTION.

Patent No. 2,310,415.

February 9, 1943.

WEBSTER W. FRYMOYER.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 1, first column, line 5, after the word "such" insert --a--; line 49, for "bubbles of" read --bubbles or--; page 5, second column, line 16, claim 2, strike out "the vapor space of" and insert the same after "from" in line 14, same claim; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 31st day of August, A. D. 1943.

(Seal)

Henry Van Arsdale,
Acting Commissioner of Patents.