Nov. 21, 1950 R. D. COWHERD 2,531,257

VENT CONTROL FOR PROCESSING CONTAINERS

Filed April 25, 1947

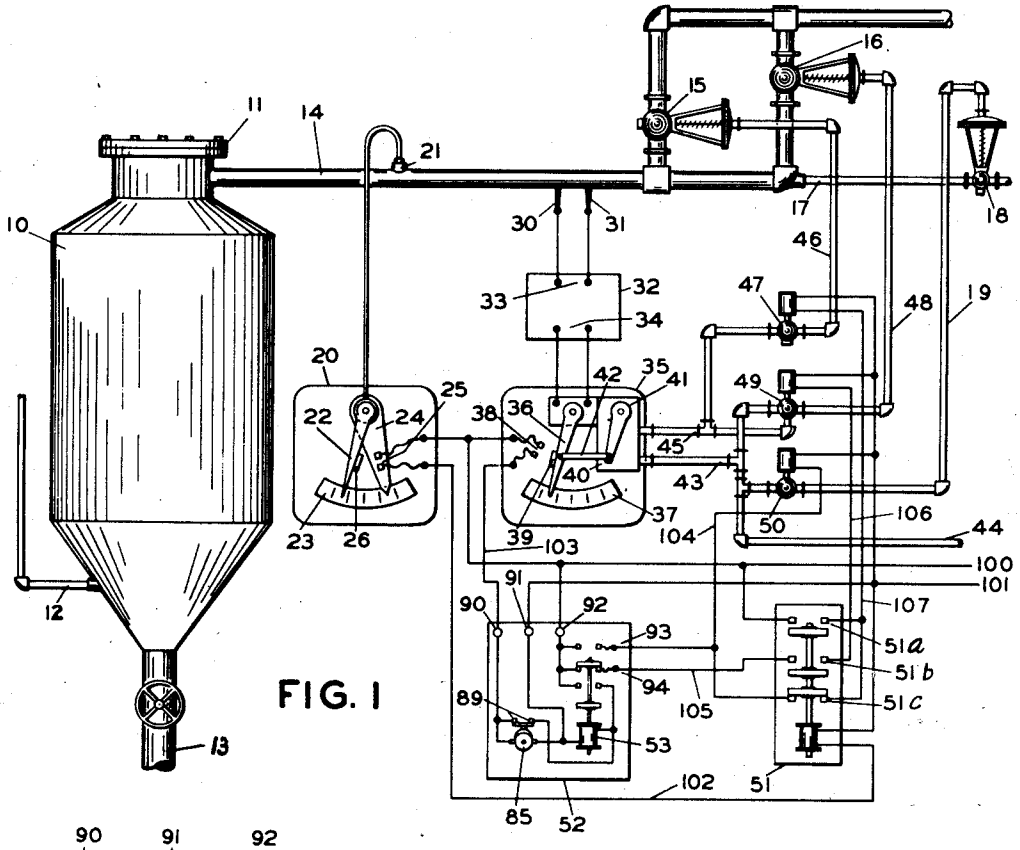


FIG. 1

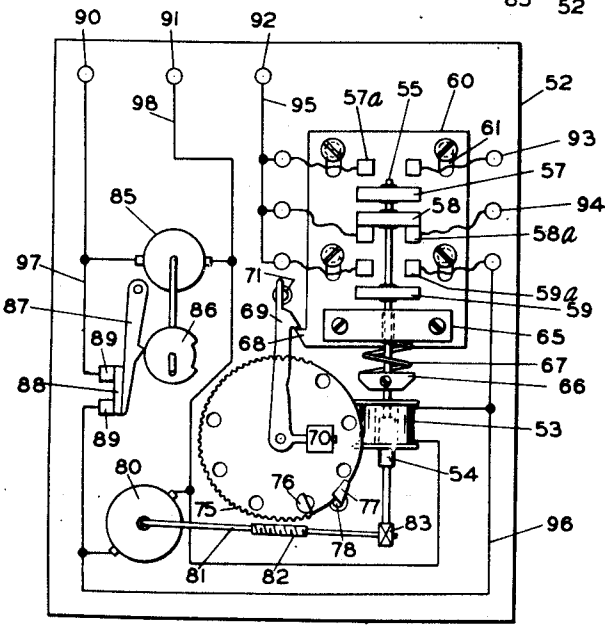


FIG. 2

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Patented Nov. 21, 1950

2,531,257

UNITED STATES PATENT OFFICE

2,531,257

VENT CONTROL FOR PROCESSING CONTAINERS

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Application April 25, 1947, Serial No. 743,925

24 Claims. (Cl. 137—78)

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This invention relates to the automatic control of the venting of fluid from a processing container or a reaction vessel, particularly a pulp digester, in which there is evolved a vapour atmosphere from a multi-component liquid.

In the manufacture of wood pulp it is customary to charge a closed vessel known as a digester with a quantity of wood chips and suitable chemicals and then to set up a reaction by the admission of steam or other heating agent. In the course of this process certain gases are given off; and it is usual to vent these from the top of the digester at such a rate as to maintain saturated steam pressure and temperature values within the digester. During the chemical reaction, the caustic soda saponifies the rosin to form a rosin soap. The reduced surface tension of the solution due to this soap imparts a tendency toward foaming, with the result that some of the solution may be drawn off with the gas being vented from the top of the digester. If extreme foaming or pull-over is present, the chemical content of the digester will be depleted to such an extent as to interfere with the conversion of the wood to pulp.

Automatic control of the rate of venting digester gases is not new. It is customary to equip digesters with instrumentalities which will regulate the rate of gas-off in accordance with the amount of gases other than steam present in the venting medium. The object of such a control is to maintain these reaction gases at a minimum such that the temperature of the reaction will rise with the pressure in a steam table relationship. Another manner of expressing the above is: The rate of venting a digester must be such that the partial pressure of gases other than steam is held to a minimum value. A common means for determining partial pressure of such gaseous mixtures involves the use of a partially filled water thermal system arranged to respond to the thermal potential of the gases, and differentially combined with a pressure measurement taken at the same point. The use of such a combination is recognized in the paper-making industry and in other fields, and may be effected by any one of a number of well known methods, one of which is set forth in U. S. Letters-Patent No. 1,446,097 granted February 20, 1923 to E. Lindbom and C. W. Burroughs. If the gaseous phase of the digester contents is saturated steam, the pressures in the two systems will be identical. If reaction gases other than water vapour are present, the decreased thermal potential due to their partial pressure

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will cause a lower pressure in the water-filled thermal system than the actual pressure in the reaction vessel. The difference between these pressures is a measure of the partial pressure of the gases other than water vapour. Such devices, however, take no cognizance of the condition of the fluid being vented, and will vent the digesting liquor as readily as the reaction gas-steam mixture.

It is recognized also, that there are available various phase discriminating devices, lying in the general category of "steam traps," operating for the most part either on a gravimetric principle or on a basic of relative temperature of a liquid and its vapour; but, as the former require intricate weighing mechanisms and are inherently slow in their action, and as the factor of actual temperature is not necessarily an element in the desired discrimination, such devices are not suited to the objects of the invention.

In my Patent No. 2,411,986, issued December 3, 1946, I have disclosed a method and apparatus for controlling the venting of the products of the reaction, predicated upon the difference between the energy transmitting properties of the liquid, as distinguished from the gaseous components of said products. In the embodiments disclosed in said application, there is applied to the vent pipe from the digester a force tending to cause a flow of energy through the contents of said pipe; and the amount of energy passing through a liquid component of the effluent, as distinguished from that passing through a gaseous component, is utilized to cut off the venting. So long as no liquid appears in the vent pipe, the reaction products are vented freely; but, upon the appearance of said liquid in said pipe, the change in the amount of energy transmitted therethrough causes the venting to be terminated.

My present invention achieves effective regulation of the venting, without reliance upon the different amounts of energy transmitted by the liquid and the gaseous phases of the effluent, and without dependence upon the previously mentioned reaction gas partial pressure control. It is based on my discovery that the electrical conductivity (or resistivity) of the vapour atmosphere evolved by the digester may be employed to regulate the venting of the gases, so as to maintain the desired conditions of saturated steam temperatures and pressures within the digester. I have further found that the electrical resistivity of said vapour phase is a measure of the partial pressure of the non-aqueous vapours in the vapour atmosphere evolved by the react-

ing components of the digester. I have also found that a surge in the non-aqueous composition of the vapour phase is a prior indication of the pull-over of liquor into the vent line. I have further found that the sensitivity of the resistivity measurement of this surge in the non-aqueous vapour phase composition may be utilized to stabilize the process, thus enhancing the relief of the gaseous phase instead of the liquid phase.

Current practice in the operation of pulp digesters recognizes two more or less distinct methods, namely, the direct and the indirect. Each has its advantages and its disadvantages. In the direct method, cooking is accomplished by admitting steam directly to the digester and allowing it to enter into combination with the materials therein. In the indirect method, the heat necessary for the reaction is communicated to the contents of the digester by suitable heat exchangers through which the cooking liquor is circulated. Steam is the usual heat source.

If relief of the gaseous contents of a digester can be effected without pulling over the liquor, operation of the digester is said to be stable. If such relief cannot take place without the loss of liquor the operation is said to be unstable. Between these extremes there may exist various degrees of stability. The hereinbefore discussed distinct methods of cooking pulp are quite different in their stability characteristics; and in any one installation the stability may vary considerably between successive cooks. While the principles of the present invention are suited to the control of digesters operating according to either indirect or direct cooking cycles, or any combination of the two, the advantage is especially apparent in obtaining optimum performance from digesters subject to unstable operation or to the variation between the unstable and stable conditions occuring in the course of a normal cook.

In a process of direct heated digesters, the mixing of steam with the contents of the reaction vessel, causes the process to be subject to unstable venting of reaction gases. The liquid level within the digester is increased due to the condensation of the directly admitted steam. The rising level decreases the foam distance from the vent line so that "pull-over" of the foam and liquid into the vent line is more likely to occur during the venting of the reaction gases. Furthermore, the erratic channeling of steam within the contents of the digester gives rise to pockets of liquor of a higher temperature than that of other portions of the digester. When these pockets of greater heat content equalize, due to excessive internal pressures, violent turbulence of the digester contents may occur, with a resultant pull-over of liquor into the vent line. It will thus be seen that the direct steamed digester is likely to be inherently unstable in its venting characteristics.

The indirectly heated digester has neither of the above-mentioned faults. The use of heat exchangers eliminates any increase in the liquid content of the digester; and the use of circulating pumps minimizes unequal heat distribution. Thus, in the indirectly heated digester, the reaction gases may be freely vented without excessive pull-over. Due to this stability, the gases may be vented at such a rate as to insure that the amount of gases other than steam is a minimum. Under such conditions, the gases will tend to assume saturated steam conditions, and the temperature of the vessel will approach that of the steam equivalent to the digester pressure.

If a directly heated digester were to be vented at the same rate as an indirectly heated digester, liquid pull-over would be abnormal. It is, therefore, necessary to establish a lower continuous venting rate with no pull-over of liquor, rather than a higher rate with liquor pull-over. To effect this result the accent must be removed from the establishment of saturated steam conditions in the vented gases and placed upon the ability of the digester to vent at all. Good practice indicates that over-all operation is much better if the digester is allowed to gas continuously at a low rate rather than intermittently at a high rate.

In the control system disclosed in my Patent No. 2,411,986, it will be observed, that a decrease in the resistivity of the effluent from the digester indicates the pulling over of liquor into the vent line. This may be either in the liquid or the foam condition. At this time, the vent line is closed and steam admitted in such a manner that it purges the electrode of any conducting medium in its path to the digester. After a timed interval, the steam is shut off and the vent opened. If liquor still is in the digester effluent, the process of steam blow-back is repeated. When the effluent is in a gaseous state, the vent is opened and remains so until another pull-over of liquor occurs.

I have now discovered that, not only is the resistivity of the effluent affected by a change in its liquid-gas phase, but that the resistivity of the gaseous phase is directly related to the partial pressure of component gases other than steam; and operating experience with installations embodying the principle has shown that the electrode system used to differentiate between the gaseous and liquid phases may perform not only this function but also that of analyzing the gaseous phase. The electrical resistivity of water vapour in the form of steam is high. As the partial pressure of steam in the mixture of steam and gases other than steam decreases the resistivity of the mixture decreases at a relatively high rate. The electrical resistivity of the gaseous effluent can therefore be utilized as a highly sensitive means for determining the partial pressures of steam and gases other than steam. The sensitivity and speed of response of this method are such as to show that the pull-over of liquor is preceded by a rapid change in the partial pressure of the non-aqueous vapors, thus enabling the approach of the liquor to the venting system to be anticipated, and making possible remedial measures in the form of a decrease in the gas-off rate sufficiently early to prevent the liquor from reaching the venting system.

The sensitive partial pressure change response of the electrical measuring method may be utilized in the control of a digester in two separate and distinct methods of regulation based upon the stability of the process; and a combination of these two may be incorporated into a single control function on either type of digester system.

As hereinbefore pointed out, an indirectly heated digestion process is inherently stable. It is therefore possible to control the steam partial pressure in the following manner: As the partial pressure of the steam decreases the electrical resistivity of the gas stream also decreases. In order to attain saturated conditions in the gas

stream, the vent valve must be opened, eliminating the gases other than steam, so that the steam partial pressure will rise. As the partial pressure increases the resistivity of the gas will also increase, indicating that, since the partial pressure of the steam in the vent gases is approaching conditions corresponding to saturation, the valve should be closed. Neither of these functions is of an on-and-off character. The control setting should be placed at a resistivity value as close to saturated steam conditions as will economically operate the process. As this critical value is attained, the vent valve will be closed. Any decrease in gas resistivity away from the set point will cause the valve to be opened to a corresponding extent, so that the control function becomes one based on deviation from a saturated or near-saturated condition.

The directly heated digestion process, on the other hand, and as previously pointed out, is inherently unstable; and the tendency is to vent liquor rather than gas. If a control function as just described were applied to the venting of such a process, any opening of the gas-off valve, with the corresponding decrease in resistivity of the effluent, would induce further pull-over. It has been found, however, that where an unstable process is involved a decrease in resistivity is a prior index of pull-over of liquor into the vent line, and also that a decrease in the rate of venting will introduce a stabilizing influence; and the present inventon is directed in part to the utilization of these discoveries. By closing the vent valve upon a decrease, and opening it upon an increase, of the electrical resistivity of the gas stream, with reference to that value corresponding to saturated steam conditions, there is established a gas-off rate proportionate to digester stability.

It has been found that, due apparently to non-uniform heat distribution, the first part of the cook in either the direct or the indirect method of digester operation is likely to be of an unstable character. Therefore, without respect to the characteristic of the overall process, it becomes desirable during this period to effect control on a basis of instability, and, as steady conditions are attained, to transfer to that type of control best suited to the system. As the temperature of the effluent when operating under stable conditions is materially higher than that when the operation is unstable, it becomes possible to utilize that temperature as a basis for transition; and, having empirically determined a suitable value corresponding to any selected set of conditions and materials, to cause the control function to be shifted from unstable to stable performance when that temperature is attained. Thus, during the unstable initial stages of the cook, accent will be placed upon the maximum rate of gas-off for the stability present in the process, and after heat distribution has eliminated or decreased the probability of unstable operation, the accent will be placed upon the ability to obtain saturated or near-saturated steam conditions in the vent gases.

In the drawings:

Fig. 1 is a diagrammatic representation of a pulp-digester showing the invention applied to the control of relief of internal pressure by regulating the outflow or products of the reaction.

Fig. 2 is a diagram showing in detail and to an enlarged scale a certain element of the apparatus generally indicated in Fig. 1.

Referring now to the drawings:

The numeral 10 designates a pulp-digester into which mixture of wood chips and suitable chemicals may be charged through an opening in the top which is afterwards sealed by a cover plate 11. A conduit 12 provides for the admission of a suitably regulated flow of steam to the lower part of the digester, and a conduit 13 connected to the bottom of the digester provides means whereby the contents thereof may be discharged to a blow tank at the conclusion of each "cook." A conduit 14 connected near the top of the digester provides for the venting of gaseous products of the internal reaction to the atmosphere, or to a receptacle not shown in the drawings whereby certain valuable constituents of said products may be salvaged. Such venting may be effected through either of two diaphragm valves 15 and 16, connected in a branched section of the conduit 14, which afterwards reunites to provide a connection to said receptacle, or to the atmosphere, as the case may be. The valve 15 is of the "reverse-acting" type, its action being such that increase of pressure applied to its diaphragm top tends to increase the degree of opening of the valve, and vice versa. The valve 16 is of the "direct-acting" type, its action being such that increase of pressure in the diaphragm top tends to close the valve and vice versa.

A pipe 17 provides for the admission of steam or other suitable agent to the conduit 14, whereby the part of the conduit in immediate proximity to the digester may be flushed out and cleared of accumulated liquid or semi-liquid material, and any tendency toward foaming of the digester contents suppressed. A diaphragm valve 18 of the reverse-acting type is inserted in the pipe 17 and has its operating element placed in communication with a conduit 19 whereby air pressure in said conduit will cause said valve to be opened.

A controlling instrument 20, responsive to temperature changes as determined by a suitable bulb 21 inserted in the conduit 14, is provided with a deflectable index or pointer 22 adapted by its position with respect to a graduated scale 23 to provide a measure of the temperature to which the bulb 21 is exposed. Juxtaposed to the pointer 22, and preferably coaxially adjustable with respect thereto, is an arm 24 carrying electric contact elements 25, adapted to be engaged and interconnected by a further contact element 26 carried by the index or pointer 22. The arm 24 being adjustable, the temperature at which the contacts 25 will be interconnected may be set at will to any desired value of temperature as indicated by the position of the arm 24 with respect to the scale 23.

Inserted in the conduit 14, so as to provide intimate electric contact with the contents thereof, are two electrodes 30 and 31, one at least of which must be thoroughly insulated from said conduit. A suitable bridge and amplifier unit 32 is provided with input terminals 33 and output terminals 34, so interrelated by means of a suitable resistance-responsive electrical network that variations in electrical resistance between the terminals 33 will be reproduced in corresponding variations in an electrical potential appearing at the terminals 34. The electrical network within the unit 32 may consist of a transformer energized from a suitable alternating current source, having its primary winding in series with the terminals 33 and its secondary winding connected to the terminals 34 through a rectifier network, as shown in my Patent No. 2,411,986, or it

may be of a more elaborate and refined nature, including any one of a large variety of suitable circuits well known in the art of resistance measurement, and forming no essential part of the present invention.

A controlling instrument 35 includes an index or pointer 36, deflectable in response to changes in the electric potential developed at the terminals 34 of the unit 32, and, by its position with respect to a graduated scale 37, adapted to provide a measure of said potential, and thus of the resistance between the electrodes 30 and 31 in the conduit 14. Positioned within the instrument 35 are electrical contact elements 38 adapted to be engaged and interconnected by a further contact element 39 carried by the index or pointer 36. The contacts 38 are so positioned as to be engaged when said pointer is at a position substantially at the bottom of its scale, corresponding to a relatively low resistance existing between the electrodes 30 and 31.

Included in the instrument 35 is a pneumatic control element 40, which may expediently be of the type fully set forth and disclosed in U. S. Letters Patent No. 1,880,247, granted October 4 1932 to Griggs and Mabey. The unit 40 has a movable arm 41 connected by means of a link 42 to the pointer 36, so that motion of said pointer will correspondingly deflect said arm whereby to control the pressure of air from a conduit 43 connected to source 44, to a variable-pressure conduit 45. The relationship between the control element 40 and the index or pointer 36 is made such that a deflection of the latter in response to an increase in measured resistance will cause the pressure of air in the conduit 45 to be increased, and a deflection of said pointer toward the bottom, or left hand end, of the scale in response to a lowering of said resistance will cause said air pressure to be lowered.

The diaphragm element of the reverse-acting valve 15 is connected to the conduit 45 by means of a conduit 46 having therein a reverse-acting solenoid-actuated valve 47 of the type which will be closed when its electrical winding is energized and open when said winding is deenergized. The diaphragm element of the direct-acting valve 16 is connected through a conduit 48 alternatively to the conduit 45 or to the supply conduit 43 by means of a solenoid-actuated three-way valve 49 arranged that when electrically energized it provides a direct connection between conduits 48 and 45 and when deenergized it provides a direct connection between conduits 48 and 43. The conduit 19, communicating with the diaphragm element of valve 18, is connected to the supply conduit 43 through a direct-acting solenoid valve 50, whereby, when the solenoid is energized, air pressure will be directly applied to the valve 18 to open its parts, and when said solenoid is deenergized the valve 18 will be closed.

While, in practice the bodies of the valves 47 and 50 would probably be of the three-way type, allowing the conduits 46 and 19 respectively to be vented to the atmosphere, whereby quickly to deflate the diaphragms of the valves 15 and 18 when said solenoid valves are closed, these details, for purposes of clarity are omitted from the present specification, as being well understood by those versed in the art of pneumatic control and forming no essential part of this invention.

An electrical relay 51 having two normally open contacts 51*a* and 51*b* and a normally closed contact 51*c*, provides for actuation of the solenoid valves 47, 49 and 50 in a manner presently to be described. A combined timing and interrupter unit 52, shown diagrammatically in detail in Fig. 2, serves to introduce such time elements as are necessary to the control cycle. While the function of the timing element shown in Fig. 2 may be satisfactorily effected by means of a timer such as that fully set forth and described in U. S. Letters Patent No. 2,175,865 granted to C. L. Anderson October 10, 1939, the device is here, for purposes of clarity, shown to a more conventionalized form of reprsentation. A relay assembly comprises a solenoid 53 adapted to actuate a plunger 54 carrying a rod or stem 55 to which are affixed three contact elements 57, 58 and 59. Said contact elements are adapted to engage respectively three corresponding pairs of contact points 57*a*, 58*a* and 59*a*, all insulatedly mounted upon a movable plate 60. Said plate is provided with slotted openings 61 and is attached by means of suitable screws or bolts passing therethrough to the base of the unit 52, in such a manner that the plate may be moved through a limited range in the same sense as the normal direction of operation of the stem 55. The arrangement of the contact elements is such that, when the plate 60 is constrained in its position nearest to the solenoid 53 (by means presently to be described) and said solenoid deenergized, the contacts 57*a* and 59*a* are normally open and the contact 58*a* normally closed. Upon energization of the solenoid 53, the condition of said contacts is reversed, contacts 57*a* and 59*a* being closed and 58*a* opened. The plate 60 is provided with an abutment portion 65, and the stem 55 carries a collar 66 juxtaposed thereto. A compression spring 67 interposed between said abutment and collar tends upon energization of the solenoid 53 to force the plate 60 and contact points carried thereby through a limited distance in the same direction as the motion of the stem 55 and the contact elements carried thereby.

The movable plate 60 is provided with a detent member 68 integral therewith and having a perpendicularly disposed surface adapted to cooperate with a similar and opposed surface on a latch member 69 deflectable through a limited angle about an axis perpendicular to the base plate of the unit 52 and also to the direction of travel of the plate 60, whereby said plate will be restrained from motion in response to the influence of spring 67. At least one of said members is provided with an inclined "rear" surface whereby the plate 60 may freely assume its normal position, the latch yielding to allow the detent to pass until the position of engagement of the cooperating perpendicular surfaces is reached. The latch member 69 is urged toward its position of engagement with the detent 68 by means of a weight or equivalent 70 tending to rotate said latch member about its axis of deflection. A stationary stop 71 limits the excursion of said latch member in the direction of its engaging position, and prevents its fouling the movable plate 60.

Mounted for limited angular rotation about the same axis as the latch member 69 is a worm wheel 75 having through its peripheral portion a number of openings in any one of which may be selectively secured a movable pin 76 adapted upon rotation of said worm wheel in a counter-clockwise sense to engage the latch member 69, deflecting it through a slight angle whereby to release the detent 68. A stop member 77 fixed to the rim of the worm wheel 75 is adapted to engage a stationary abutment 78, whereby to provide a

definite starting point for the worm wheel 75 and to limit its rotation in a clockwise sense when so urged by spring, weight, or equivalent means not shown in the drawing. An electric motor 80 is adapted to rotate a shaft 81 carrying a worm 82 and having one end journalled in a movable bearing 83 carried by the stem 55, whereby when the solenoid 53 is energized the worm 82 will be brought into operative engagement with the worm wheel 75 to rotate the same in a counter-clockwise sense, and when said solenoid is deenergized the worm and worm wheel will be disengaged, whereupon the latter will immediately be returned to its position of repose with the stop 77 engaging the abutment 78.

The interrupter portion of the unit 52 includes an electric motor 85 connected to drive a cam member 86 which engages a movable arm 87 carrying a contact element 88 adapted to provide electrical connection between two stationary contact points 89, the arrangement being such that when the motor 85 is in operation electrical connection between said contact points will be periodically made and interrupted at intervals of the order of several seconds.

The interrupter and timing unit 52 is provided with five terminals, 90, 91, 92, 93, and 94, whereby connection may be made between external circuits and the several electrical elements embodied in the unit 52. The interconnections between said terminals and electrical elements in the unit 52 are as follows: The contact points 57*a*, 58*a* and 59*a* carried by the plate 60 have each one side connected by suitable flexible leads to a common conductor 95 which in turn is connected to the terminal 92. The free member of the contact points 57*a* is connected by a flexible lead to the terminal 93, and that of the contact points 58*a* to the terminal 94. The free member of the contact points 59*a* is connected by a flexible lead to a conductor 96, to which also is connected one terminal of the solenoid 53, one terminal of the motor 80, and one of the contact points 89. The free member of the contact points 89 is connected by means of a conductor 97 to the terminal 90, and to this terminal also is connected one side of the interrupter motor 85. The terminal 91 is connected to a conductor 98 which is common to the free terminals of the motor 85, the motor 80, and the solenoid 53, respectively.

Following are the electrical connections by which the combined interrupter and timing unit 52 is operatively associated with the other elements of the system; A source of electric supply is represented by two conductors 100 and 101. The former conductor is connected to one side of each of the controller contacts 25 and 38, to the terminal 92 of the unit 52, and to one side of the relay contact 51*a*. The other line conductor 101 is connected to the terminal 91 of the unit 52 and to one side of each of the solenoids of the valves 47, 49, and 50, as well as to one side of the actuating winding in the relay 51. The free side of said winding is connected by means of a conductor 102 to the free side of the controller contacts 25. The free side of the controller contacts 38 is connected by means of a conductor 103 to the terminal 90 of the unit 52. Terminal 93 of the unit 52 is connected by a conductor 104 to the free side of solenoid valve 50 and also to one side of relay contacts 51*c*. Terminal 94 of said unit is connected by a conductor 105 to one side of relay contacts 51*b*, whose free side is connected by means of a conductor 106 to the free side of solenoid 49. The free sides of contacts 51*a* and 51*c* are connected by a conductor 107 to that of the solenoid 47.

Before attempting to consider the operation of the control system as a whole, it will be well to study the functioning of the several elements incorporated within the combined timing and interrupter unit 52. Terminal 91 being connected through conductor 101 to one side of the source of electric power supply, it follows that any connection of terminal 90 to conductor 100, representing the other side of said source, will cause the interrupter motor 85 to operate, and that during such intervals as the interrupter contacts 89 are closed, the timer motor 80 and the solenoid 53 will also be energized. So long as the plate 60 and the contact elements carried thereby remain in the position of repose, as shown in Fig. 2, terminal 94 will be connected through relay contacts 58*b* to conductor 95, and thus to line conductor 100. Assume for the moment the interrupter contacts 89 to be closed, and the terminal 90 placed in connection with the line conductor 100, energizing the solenoid 53 and the motor 80. The plunger 54, with the stem 55 and elements carried thereby, will assume their uppermost position. Contacts 57*a* and 59*a* will be closed and contact 58*a* opened. At the same time, the spring 67 will be compressed between the collar 66 and the abutment 65, urging the plate and contact elements carried thereby toward the uppermost position, such motion being prevented, however, by the engagement of the latch member 69 with the detent 68. Also, the worm 82 will be brought into operative engagement with the worm wheel 75, and the motor 80 will cause the same to be driven in such a sense that the pin 76 progressing in a counter-clockwise sense about the axis of rotation of the worm wheel 75 and of the latching member 69, will approach the latter, and, if the motion be not interrupted, will, at the termination of a time interval predetermined by the setting of said pin, engage the latch, causing the same to release the detent 68. Upon release of the detent 68, the plate 60 will be free to respond to the upward influence of the spring 67, and will instantaneously assume its topmost position, as limited by the slots 61, whereupon the condition of the three sets of contacts 57*a*, 58*a*, and 59*a* will be restored to that existing when the winding 53 is not energized.

Consideration may now be given to the performance of the apparatus hereinbefore set forth, when subjected to normal conditions of operation. Upon the line conductors 100 and 101 being energized from a suitable source of electrical supply, and air pressure from the source 44 being applied to the conduit 43, the "normal" disposition of the several elements of the control system will be as follows:

As the electrical resistance of the air initially in the digester outlet 14 is relatively high, the pointer 36 of the instrument 35 will assume a position where the contacts 38 will be open, and where the associated control element 40 will maintain an appreciable regulated control pressure in the conduit 45. At the same time, the temperature to which the bulb 21 is exposed being relatively low, the contacts 25 in the temperature-responsive instrument 20 will stand open, leaving de-energized the winding of the relay 51, so that the contacts 51*a* and 51*b* will stand open and the contact 51*c* closed. The contacts 38 being open, the solenoid 53 and the motor 80 in the timing unit 52 will be de-energized, so that the several elements of said unit

will rest in the positions indicated in Fig. 2, the contacts 58a standing closed, the contacts 57a and 59a standing open, and the contacts 89 being either open or closed, according to the position in which the cam 86, driven by the interrupter motor 85, may previously have come to rest.

The contacts 57a in the timing unit being open, the actuating winding of the solenoid valve 50 will remain de-energized, and that valve will stand in such a position that no air pressure is applied to the actuating element of reverse-acting valve 18, so that the latter will stand closed. As said contact 57a, and also contact 51a of the relay 51, are open, the winding of the reverse-acting solenoid valve 47 will remain de-energized without respect to the position of relay contacts 51c, so that said solenoid valve will stand open, applying to the reverse-acting gas-off valve 15 such pressure as exists in the conduit 45, to maintain it in a correspondingly open position.

The winding of the solenoid valve 49 being de-energized, since contact 51b is open, said valve will stand in a position to maintain communication between conduits 48 and 43, whereby to apply supply air pressure to the direct-acting gas-off valve 16 and maintain the same in a closed position.

Upon the digester 10 being charged, and steam admitted through the conduit 13, a reaction is set up in which there are given off certain gaseous products which tend to accumulate in the upper part of the digester, and will be continuously vented through the valve 15. So long as the digester blows off air from its upper portion, the high electrical resistivity of the escaping gases will cause the controlling elements of the instrument 35 to be maintained in the condition described, and the free venting of the effluent to be continued.

As the non-aqueous gaseous products of chemical reaction within the digester make their appearance in the vent pipe 14, their relatively low resistance, corresponding to an unstable condition of operation, will cause the control element 40 of the instrument 35 to assume its normal function of so regulating the pressure of air admitted to the conduit 45 and through the valve 47 to the gas-off valve 15 that with a decrease of resistivity said valve will approach a closed position, and, with an increase in resistivity, an open position. Thus, there will be established a control function eminently suited, as hereinbefore pointed out, to the operation of the digester under the so-called "unstable" condition.

Upon the occurrence of "wet gas," due to "foaming," or to any condition causing a portion of the liquid contents of the digester to be carried into the conduit 14, said liquid will provide between the electrodes 30 and 31 a path of such relatively low electrical resistance that the pointer 36 in the measuring instrument 35 will rapidly approach the lowest part of its operating range, causing the contacts 38 to be bridged by the contact element 39, thereby providing a connection between the line conductor 100 and the conductor 103 whereby to energize the interrupter motor 85 in the timing device 52. As the motor 85 operates, its contacts 89 will be alternately closed and opened; and upon the first closing of said contacts 89 subsequent to the closing of contacts 38 the relay winding 53 and also the motor 80 will be energized and the worm 82 brought into operative engagement with the worm wheel 75, whereby the latter, under influence of motion transmitted from the motor 80, will be rotated at a predetermined velocity in a counterclockwise sense as seen in the drawing, causing the pin 76 to be steadily advanced toward a position of engagement with the latch member 69 to release the same from the detent 68.

While the upward movement of the plunger 54 and the rod or stem 55, carrying the collar 66 will cause a corresponding upward force to be transmitted through the spring 67 to the abutment portion 65, the restraining action of the latch 69 upon the detent 68 will inhibit upward displacement of the plate 60, so that the contact elements 57a carried thereby will be bridged by the coacting contact element 57, and the contact elements 59a by the contact element 59, while upward displacement of the contact element 58 with respect to coacting contact elements 58a will cause the latter to be electrically separated and the circuit therebetween interrupted.

Closing of the contacts 59a will provide for the winding 53 an energizing circuit alternative to that through the contacts 38 in the instrument 35, so that, after initial energization of the solenoid through said contacts in series with the interrupter contacts 89, both the solenoid 53 and the motor 80 will remain energized irrespective of the positions of said two sets of contacts. As the contacts 51b are open, the opening of contacts 58a in series therewith will produce no result, and the solenoid valve 49 will remain de-energized, so that the gas-off valve 16 will be held closed by air pressure applied through the conduit 48 as hereinbefore set forth. Closing of the contacts 57a will cause the solenoid valve 50 to be energized, applying line pressure to the reverse-acting valve 18, opening the same, and admitting steam through the pipe 17 to the conduit 14 to blow the contents thereof back into the digester, purging said conduit, and also cleaning the electrodes 30 and 31. Closing of the contacts 57a will also cause solenoid valve 47 to be energized through the normally closed relay contacts 51c, thus exhausting the conduit 46, whereby to close the reverse-acting valve 15, so that all the steam admitted through the valve 18 will pass into the digester, instead of being vented to the atmosphere.

Duration of the purging interval is determined by the time required for the pin 76 on the worm-wheel 75 to travel from its initial location to a position of engagement with the latch 69 to release the latter from the detent 68. This interval is pre-established more or less empirically, and may readily be changed to suit specific operating conditions. After the motor 80 has run for a time corresponding to this interval, the detent 68 is released, the plate 60, together with the several contacts carried thereby, under the influence of the spring 67, will be forced abruptly upward, causing the contacts to assume relative positions corresponding to a de-energized state of the soleniod 53, whereupon the purging cycle will be terminated and the regulation of the digester caused to revert to that existing prior to development of the wet-gas condition.

If, during the established time interval of the purging cycle, the wet-gas conditions in the conduit 14 have been eliminated, the resistance between the electrodes 30—31 will have increased sufficiently to cause the contacts 38 to be opened; and, separation of the contacts 59a having opened the locking circuit of the winding 53, that coil, as well as the motor 80, will at once

be de-energized, and the contact elements carried by the stem 55 reset to their normal positions. At the same time, corpression on the spring 67 being relieved, the plate 60 and contact elements borne thereby will follow the plunger 54 to the normal position, while the latch 69, being restored by action of the weight 70 to its position of rest, will re-engage the detent 68, preparing the timing relay for its next cycle of operation.

Should it be that the release of the timing relay finds that the abnormal condition has not been relieved, or that the electrodes have not been cleaned, the contacts 38 will remain closed, so that opening of the locking circuit through the contacts 59*a* will not allow the relay to become de-energized. The reversion to normal regulating conditions, as established by the upward shift of the plate 60 and contact elements borne thereby, will then be but momentary; and upon the first opening of the contacts 89 by action of the cam 86, the relay 53 will be de-energized for a sufficient time to permit the plunger 54 and the stem 55 to reset to their lowest position, disengaging the worm 82 from the worm-wheel 75, and allowing the latter to reset to its normal position of rest with the stop 77 in engagement with the abutment 78, and the latch 69 again to engage the detent 68 upon the plate 60. If the contacts 38 have not separated, the motor 85 will continue in operation; and, upon the first reclosing of the contacts 89, the purging cycle will be established, and repeated as hereinbefore described. This repetition of the purging cycle will be repeated indefinitely until the resistance between the electrodes 30—31 rises above the value corresponding to wet gas in the conduit 14, whereupon the valve 18 will be closed and the system will revert to normal control.

The manner of initiation of the purging cycle and the restoration of normal control having been made clear, it may now be assumed that the "cook" has processed sufficiently far that a "stable" condition is established. This is reflected in an increase in temperature of the vented gases as measured by the instrument 20; and as said temperature attains an empirically determined value established by the setting of the contact arm 24, the electrical contacts 25 will be bridged by the contact piece 22, and controlling electrical circuits correspondingly affected. Closing of the contacts 25 will provide an electrical circuit from the line conductor 100 through the conductor 102 to one side of the winding of the relay 51, whose other side is permanently connected to the line conductor 101, thus causing said relay to be energized, whereby contacts 51*a* and 51*b* will be closed and contact 51*c* opened. Said contact 51*c* being in series with the now-open contacts 57*a* in the timing relay, its opening consequent upon energization of the relay 51 will at the moment produce no effect. The closing of contacts 51*a*, however, will transfer connection of the solenoid valve 47 from one in which the open contacts 57*a* left the circuit incomplete to one in which said valve 47 will be directly energized from the line conductors 100 and 101, whereby said valve will vent the conduit 46 to the atmosphere, removing air pressure from the operating element of the reverse-acting gas-off valve 15, causing the same to revert to a closed position. At the same time, energization of the three-way solenoid valve 49 through contacts 51*b* in series with normally closed contacts 58*a* will cause said valve to assume a position where the operating element of direct-acting gas-off valve 16, instead of being held closed by supply air pressure from the conduit 43, will be placed under regulation of air received from the control element 40 through the conduit 45. Control of the escaping gases will thus be transferred from the reverse-acting valve 15 to the direct-acting valve 16, with a corresponding reversal in the sense of regulation in relation to the resistivity of said gases. Consequently, with an increase in resistivity of the effluent, the gas-off valve 16 will be moved toward closed position, and vice versa. This provides the type of performance which, as hereinbefore pointed out, is best suited to operation under the so-called "stable" condition; and this will be continued so long as the temperature measured by the instrument 20 does not fall below the value for which the contacts in that instrument are set.

In the event of wet gas appearing during stable control, the resulting low resistance between the electrodes 30—31, as hereinbefore set forth, will cause the instrument 35 to close its contacts 38, actuating the timing and interrupter unit 52, and initiating a purging cycle, as previously described. Opening of the relay contacts 58*a* will cause the solenoid valve 49 to be de-energized, providing direct connection between conduits 48 and 43, whereby to supply pressure to the operating element of the direct-acting valve 16, causing said valve to assume a closed position, shutting off escape of gases from the digester. Closing of the contacts 57*a* will cause the solenoid valve 50 to be energized, applying pressure from the supply line to the operating element of reverse-acting valve 18, opening the same, admitting steam to purge the gas-off main 14 and clean the electrodes 30 and 31; and the purging cycle will thenceforth be carried out and terminated in a manner identical to that already set forth for operation of the digester under "unstable" conditions.

The terms and expressions which I have employed are used as terms of description and not of limitation, and I have no intention, in the use of such terms and expressions, of excluding any equivalents of the features shown and described or portions thereof, but recognize that various modifications are possible within the scope of the invention claimed.

I claim:

1. In apparatus for regulating the venting of effluent from a processing container evolving a normally gaseous effluent, means responsive to the electrical resistivity of said gaseous effluent, means for controlling the venting of said effluent, and means controlled by the first mentioned means for impressing a modulated performance upon said controlling means in accordance with the resistivity of said gaseous effluent.

2. In apparatus for regulating the venting of effluent from a processing container evolving a normally gaseous effluent, means responsive to the electrical resistivity of said gaseous effluent, means for controlling the venting of said effluent, and means controlled by the first mentioned means for operating said controlling means to increase said venting in response to increase in resistivitiy of said gaseous effluent and to decrease said venting in response to decrease in said resistivity.

3. In apparatus for regulating the venting of effluent from a processing container evolving a normally gaseous effluent, means responsive to

the electrical resistivity of said gaseous effluent, means for controlling the venting of said effluent, and means controlled by the first mentioned means for operating said controlling means to increase said venting in response to increase in resistivity of said gaseous effluent and to decrease said venting in response to decrease in said resistivity, and means responsive to another characteristic of said effluent for modifying the action of said regulating means in one sense with a change of said characteristic in one direction and rendering said action effective in its original sense with a change of said characteristic in the other direction.

4. In apparatus for regulating the venting of effluent from a processing container evolving a normally gaseous effluent, means for determining the electrical resistivity of said effluent, means for determining the temperature of said effluent, control means actuated in response to changes in said electrical resistivity to regulate the flow of said effluent, and further control means, actuated in response to changes in said temperature, to modify the performance of said first control means in one sense with a change of said temperature beyond a predetermined value in one direction, and to render said performance effective in its original sense with a change of said temperature beyond said value in the other direction.

5. In apparatus for regulating the venting of effluent from a processing container evolving a normally gaseous effluent, means for determining the electrical resistivity of said effluent, means for determining the temperature of said effluent, control means adapted to increase the escape of effluent with an increase in said electrical resistivity and to decrease said escape with a decrease in said resistivity, together with further control means responsive to said temperature-determining means and adapted upon an increase of said temperature above a predetermined value to reverse the characteristic performance of said first control means, and upon a decrease of said temperature below said predetermined value to restore said performance to its original characteristic.

6. In apparatus for regulating the venting of effluent through a conduit extending from a processing container evolving a normally gaseous effluent, means for determining the electrical resistivity of said effluent, means for determining the temperature of said effluent, first and second valves adapted alternatively to discharge effluent from said conduit, control means adapted alternatively to maintain said second valve in a closed condition while regulating said first valve in a sense to be opened with an increase in said resistivity, or to maintain said first valve in a closed position while regulating said second valve in a sense to be closed with an increase in said resistivity, and further control means subject to said temperature-determining means and influencing said first-named control means whereby to select between said two characteristic performances according to the temperature of said effluent.

7. In apparatus for regulating the venting of effluent from a processing container evolving a normally gaseous effluent, means responsive to the electrical resistivity of said gaseous effluent, valve means for controlling the venting of said effluent, and means controlled by the first mentioned means for regulating said valve means to control said venting in accordance with variations in electrical resistivity of said gaseous effluent.

8. In apparatus for regulating the venting of effluent from a processing container evolving a normally gaseous effluent, means responsive to the electrical resistivity of said gaseous effluent, a valve for controlling the venting of said effluent, and means controlled by the first mentioned means for operating said valve to increase said venting as the resistivity of said gaseous effluent increases and for operating said valve to decrease said venting as said resistivity decreases.

9. In apparatus for regulating the venting of effluent from a processing container evolving a normally gaseous effluent, means responsive to the electrical resistivity of said gaseous effluent, a valve for controlling the venting of said effluent, means controlled by the first mentioned means for operating said valve to increase said venting as the resistivity of said gaseous effluent increases and for operating said valve to decrease said venting as said resistivity decreases, a second valve, control means for said second valve for maintaining the latter closed while the first valve is in operation, means responsive to the temperature of said effluent, and control means including connections from said temperature-responsive means activated upon a change in said temperature beyond a predetermined value in one direction to cause closing of said first valve and to place said control means for said second valve under control of said resistivity-responsive means for operating said second valve in the opening direction as said resistivity decreases and in the closing direction as said resistivity increases and, upon a change in said temperature beyond said value in the opposite direction, activated to restore the performance of said valves to the original characteristic.

10. In apparatus for regulating the venting of effluent through a conduit extending from a processing container evolving a normally gaseous effluent; means for determining the resistance of a portion of said effluent, means for determining the temperature of said effluent, control means actuated by said resistance-determining means and operative thereby when the measured resistance is of the order corresponding to a gaseous condition of said effluent, to permit the escape of said effluent to a degree increasing with the measured resistance thereof, and subject to said temperature-determining means upon the increase of said temperature above a predetermined value to reverse its characteristic performance and restrict the escape of said effluent to a degree increasing with the measured resistance thereof and upon decrease of said temperature below said value to restore the performance of said control means to its original characteristic.

11. In apparatus for regulating the venting of effluent from a processing container evolving a normally gaseous effluent, means responsive to the electrical resistivity of said gaseous effluent, means for controlling the venting of said effluent, and means controlled by the first mentioned means for operating said controlling means to decrease the venting as said resistivity increases.

12. In apparatus for regulating the venting of effluent from a conduit of a processing container evolving a normally gaseous effluent, means responsive to the resistivity of said gaseous effluent, means for controlling the extent of venting of said effluent, means controlled by said resistivity-responsive means for operating said vent-con-

trolling means to vary the extent of venting of said effluent, and means rendered active upon said resistivity attaining a predetermined low value corresponding to the presence of liquid in said effluent for causing closure of said vent-controlling means irrespective of the action of said operating means and for re-opening said vent-controlling means upon said resistivity exceeding said low value.

13. In apparatus for regulating the venting of effluent from a conduit of a processing container evolving a normally gaseous effluent, means responsive to the resistivity of said gaseous effluent, means for controlling the extent of venting of said effluent, means controlled by said resistivity-responsive means for operating said vent-controlling means to vary the extent of venting of said effluent, means for admitting a flushing fluid to said conduit to flush the contents thereof, and means rendered active upon the attainment of a predetermined low resistivity value corresponding to the presence of liquid in said effluent for causing opening of said admitting means and closure of said vent controlling means, and for causing closing of said admitting means and opening of said vent controlling means upon said resistivity exceeding said low value.

14. In apparatus for regulating the venting of effluent from a conduit of a processing container evolving a normally gaseous effluent, means responsive to the resistivity of said gaseous effluent, means for controlling the extent of venting of said effluent, means controlled by said resistivity-responsive means for operating said vent-controlling means to vary the extent of venting of said effluent, means responsive to a predetermined low resistivity corresponding to the presence of liquid in said effluent for causing closure of said vent-controlling means irrespective of the action of said operating means timing means, and means controlled by said timing means for causing restoration of said vent-controlling means to the action of said operating means.

15. In apparatus for regulating the venting of effluent from a conduit of a processing container evolving a normally gaseous effluent, means responsive to the resistivity of said gaseous effluent, means for controlling the extent of venting of said effluent, means controlled by said resistivity-responsive means for operating said vent-controlling means to vary the extent of venting of said effluent, means for admitting a flushing fluid to said conduit to flush the contents thereof, means responsive to a predetermined low resistivity corresponding to the presence of liquid in said effluent for causing closure of said vent-controlling means irrespective of said operating means and for causing opening of said admitting means, timing means, and means controlled by said timing means for causing closing of said admitting means and restoration of said vent-controlling means to the action of said operating means.

16. In apparatus for regulating the venting of effluent from a conduit of a processing container evolving a normally gaseous effluent, means responsive to the resistivity of said gaseous effluent, means for controlling the extent of venting of said effluent, means controlled by said resistivity-responsive means for operating said vent-controlling means to vary the extent of venting of said effluent, means for admitting a flushing fluid to said conduit to flush the contents thereof, and means rendered active upon a predetermined low value of effluent resistivity corresponding to the presence of liquid therein for opening said admitting means and for closing said admitting means upon said resistivity exceeding said low value.

17. In apparatus for regulating the venting of effluent from a conduit of a processing container evolving a normally gaseous effluent, means responsive to the resistivity of said gaseous effluent, means for controlling the extent of venting of said effluent, means controlled by said resistivity-responsive means for operating said vent-controlling means to vary the extent of venting of said effluent, means for admitting a flushing fluid to said conduit to flush the contents thereof, means responsive to a predetermined low effluent resistivity corresponding to the presence of liquid therein for opening said admitting means, timing means for maintaining said admitting means open for a predetermined time interval, and means operative upon termination of said interval to effect closing of said admitting means.

18. In apparatus for regulating the venting of effluent from a processing container evolving a normally gaseous effluent, means for continuously determining the electrical resistivity of said gaseous effluent, means for controlling the venting of said effluent, and means controlled by the first-mentioned means for operating said controlling means in accordance with said resistivity.

19. In apparatus for regulating the venting of effluent from a processing container evolving a normally gaseous effluent, means for continuously determining the electrical resistivity of said effluent, means for continuously determining the temperature of said effluent, control means actuated in response to changes in said electrical resistivity to regulate the flow of said effluent, and further control means actuated in response to changes in said temperature beyond a predetermined value in one direction for modifying the performance of the first-mentioned control means in one sense, and in response to changes of said temperature beyond said value in the opposite direction to modify said performance in another sense.

20. In apparatus for regulating the venting of effluent from a processing container evolving a normally gaseous effluent, means responsive to the electrical resistivity of said gaseous effluent, means for controlling the venting of said effluent, and pneumatic means controlled by the first-mentioned means for impressing a modulated performance upon said controlling means in accordance with the resistivity of said gaseous effluent.

21. In apparatus for regulating the venting of effluent from a processing container evolving a normally gaseous effluent, means for continuously determining the electrical resistivity of said effluent, means for controlling the venting of said effluent, and pneumatic means controlled by the first-mentioned means for operating said controlling means in accordance with said resistivity.

22. In apparatus for regulating the venting of effluent through a conduit extending from a processing container evolving a normally gaseous effluent, means for continuously determining the resistivity of a portion of said effluent, means for continuously determining the temperature of said effluent, control means actuated by said resistivity-determining means and operative thereby when the measured resistance is of the order corresponding to a gaseous condition of said ef-

fluent, to permit the escape of said effluent to an extent increasing with the measured resistance thereof, and subject to said temperature-determining means upon the increase of said temperature above a predetermined value to reverse its characteristic performance and restrict the escape of said effluent to a degree decreasing with the measured resistivity thereof and upon decrease of said temperature below said value to restore the performance of said control means to its original characteristic.

23. In apparatus for regulating the venting of effluent from a processing container evolving a normally gaseous effluent, means for determining the electrical resistivity of said effluent, means for determining the temperature of said effluent, control means for providing a modulated regulation upon the flow of said effluent in accordance with the resistivity thereof in its gaseous condition, further control means actuated in response to changes in said temperature beyond a predetermined value in one direction to modify the performance of said first control means in one sense, and in response to changes of said temperature beyond said value in the opposite direction to modify said performance in another sense, means for admitting a flushing fluid to a portion of said container to flush effluent material therefrom, and means brought into action in response to a predetermined low resistivity of said effluent for actuating said admitting means.

24. In apparatus for regulating the venting of effluent from a conduit of a processing container evolving a normally gaseous effluent, means for controlling the extent of venting of said effluent,

means for determining the electrical resistivity of said effluent, means controlled by said resistivity-responsive means for operating said vent-controlling means to vary the extent of venting of said effluent, means for admitting a flushing fluid to said conduit to flush the contents thereof, means responsive to a predetermined low resistivity corresponding to the presence of liquid in said effluent for causing closure of said vent-controlling means irrespective of said operating means and for causing opening of said admitting means, timing means, means controlled by said timing means for causing closing of said admitting means and restoration of said vent controlling means to the action of said operating means, means responsive to the temperature of said effluent, and means controlled by said temperature-responsive means for reversing the action of said vent controlling means, the direction of said reversal depending upon the sense of change in said temperature.

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