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C. B. SPANGENBERG

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MOISTURE RESPONSIVE SYSTEM

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FIG. 1

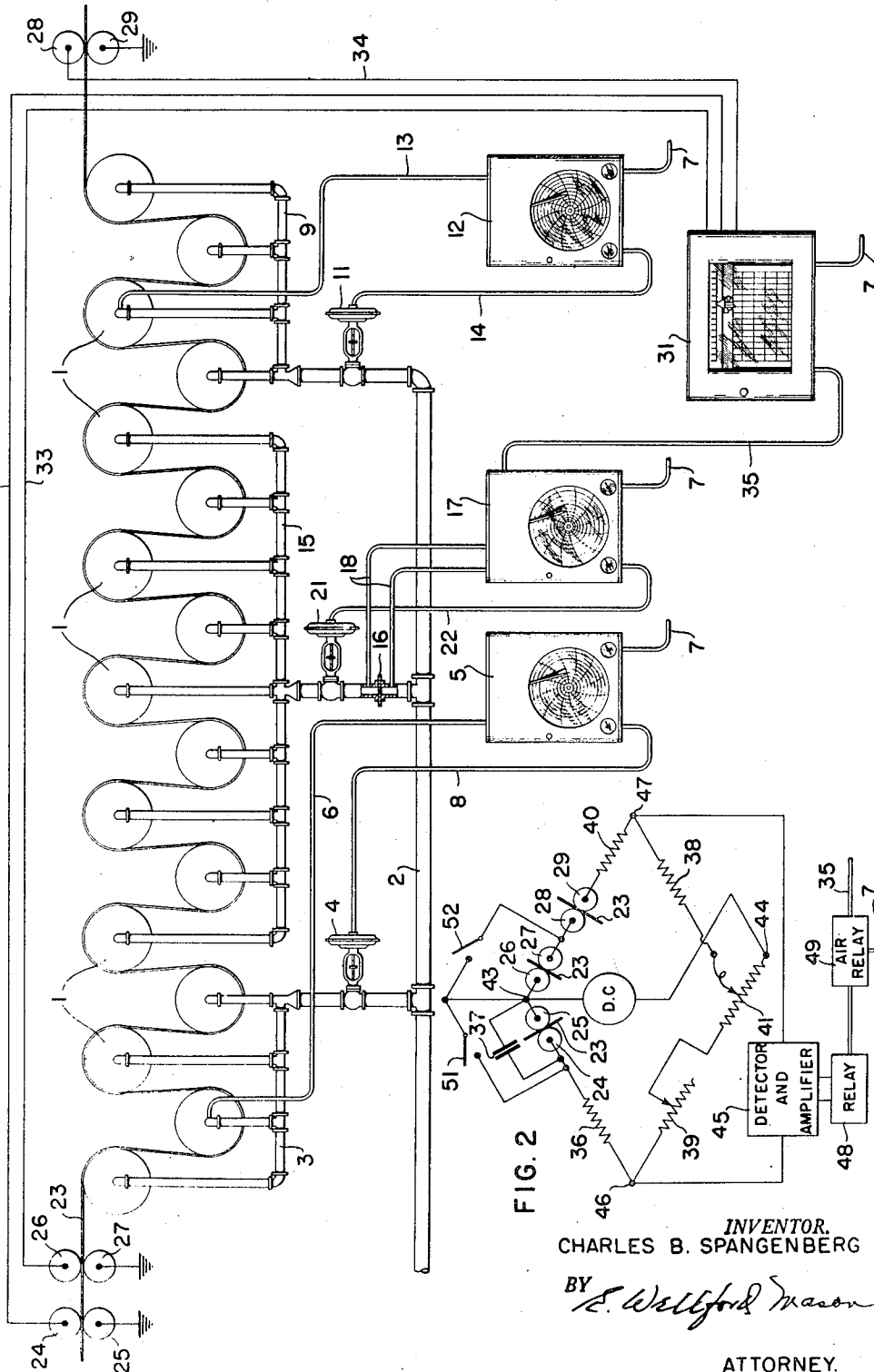


FIG. 2

INVENTOR.  
CHARLES B. SPANGENBERG

BY *E. W. Mason*

ATTORNEY.

## UNITED STATES PATENT OFFICE

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## MOISTURE RESPONSIVE SYSTEM

Charles B. Spangenberg, Chicago, Ill., assignor,  
by mesne assignments, to Minneapolis-Honey-  
well Regulator Company, Minneapolis, Minn., a  
corporation of Delaware

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The present invention relates to drying machines, and more particularly to means to effect the control of a paper drying machine so that the web of paper passing thereover may be maintained at a predetermined, constant moisture content.

In the control of drying machines it is customary to divide the drying drums into groups or sections and control the supply of drying medium, such as steam, to each section individually. Many ways of accomplishing the control of these machines have been devised, but none of them can effectively handle unusual and rapid fluctuations in the moisture content of the web of paper as it enters the drying machine. It is an object of the invention to provide a control system for a drying machine that will operate to maintain constant the moisture content of a web of material passing therethrough. It is a further object of the invention to provide a control system for a drying machine that will take into effect the sudden changes in the moisture content of a web of material as it enters the machine.

In carrying out the present invention means is provided which is responsive to the variations in moisture content of the web as it enters the drying machine, but whose effect is only temporary. This means that when any variation in the moisture content of the web occurs the machine will be adjusted to take care of this variation as the web is passing through it. Since the adjustment is temporary its effects will die out by the time that the portion of the web having the variation has passed through the machine. In addition to the above mentioned responsive means, there is provided another means which is responsive to the moisture content of the web as it leaves the machine. This latter means acts to adjust continuously the drying effect of the machine for any sustained change in the web moisture content.

The various features of novelty which characterize this invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, however, its advantages and specific objects obtained with its use, reference should be had to the accompanying drawings and descriptive matter in which is illustrated and described a preferred embodiment of the invention.

In the drawings:

Figure 1 is a diagrammatic representation of a paper drying machine and the control system therefor, and

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Figure 2 is a diagrammatic representation of the manner in which the various moisture detecting elements are connected in a moisture responsive electrical circuit.

As is shown in Figure 1 of the drawing, the machine consists of a large number of rolls 1 over which the web to be dried passes. These rolls take the form of hollow cylinders which are suitably mounted on bearings and are driven at the same speed by any suitable type of driving means. It is customary to divide these rolls into groups or sections which are individually controlled in response to some condition of the drum that can be measured. As is shown herein the drums are divided into three sections, a wet end section on the left, an intermediate section, and a dry end section on the right.

The drums of the wet end section are supplied with steam through a header 3 that is common to this group of drums only. Steam from the main supply pipe 2 passes through a valve 4 which is adjusted in accordance with the temperature of these drums. As is shown herein, there is provided a temperature controller 5 of conventional type which is actuated in response to the temperature of one of the drums. Accordingly a temperature responsive element such as a thermometer bulb that is placed in one of the drums is connected by capillary tubing 6 with the control instrument 5. This instrument is supplied with air under a constant pressure through a pipe 7 and regulates the air in accordance with the temperature of the drums. The regulated air is applied through a pipe 8 to the valve 4 to thereby adjust the opening of this valve in such a manner that the temperature of the drums supplied by the header 3 is maintained at some constant, predetermined value.

In like manner the drums on the dry end section are supplied with steam through a header 9 that in turn receives its steam from the main supply pipe 2. The supply of steam to header 9 is controlled by a valve 11 in response to the temperature of the drums as measured by a temperature controller 12. The temperature of one of the drums in the dry end section is measured by a conventional thermometer bulb and is connected with the instrument 12 through a capillary 13. This instrument also adjusts air from a suitably regulated source which may be the source that supplied air to instrument 5 and applies this adjusted air to the control valve 11. In this manner the temperature of the drums of the dry end section of the machine is also maintained at a predetermined constant value. While the con-

trollers 5 and 12 have been described as temperature controllers it is obvious that they can also be pressure controllers and be responsive to the pressure of the steam in selected drums of the wet and dry end sections respectively. In this case tubes 6 and 13 would be pressure lines instead of capillary tubes forming part of a thermometer system. The pressure could be controlled instead of temperature since the pressure of steam bears a definite relation with the temperature of the steam.

The drums forming the intermediate section, which is the largest group of drums and supply most of the drying action, are supplied by a header 15 that is in turn supplied with steam from the main pipe 2 through a valve 21. In this case it is desirable to control the flow of steam to the drums and to adjust the control point of the flow controller in accordance with the moisture content of the web passing over the machine. To this end there is provided an orifice 16 in the connecting pipe between pipes 2 and 15. A flow controller 17 which is responsive to the flow through this pipe is connected by pressure taps 18 to opposite sides of orifice 16. This instrument is supplied with air at a constant pressure and serves to adjust this air in accordance with the amount of steam passing through orifice 16 and applies the adjusted air pressure through a pipe 22 to adjust valve 21 in a manner to keep the flow constant. The control point of this controller is adjusted in accordance with web moisture in a manner described below.

The paper web to be dried is indicated at 23 and it is intended that the paper should be coming from some paper forming machine and passing from the left to the right through the successive sections of the drying machine. Just prior to the time that the paper enters the drying machine it passes a first moisture responsive device consisting of rollers 24 and 25 the latter of which is grounded and a second moisture responsive device comprising a second pair of rollers 28 and 29, the latter of which is grounded. These rollers are connected in an electrical circuit to be described below, which circuit is responsive to the moisture content of the web as it enters and leaves the drying machines. The moisture responsive instrument of which the above mentioned circuit forms a part is located in an instrument casing 31. This instrument acts in response to moisture variations in the web to adjust a supply of air from the suitably regulated source 7 and applies the adjusted air through a pipe 35 to adjust the control point of flow controller 17. From the above it will be seen that the temperature of the drums in the dry end and the wet end of the drying machine are maintained at a constant value and are therefore intended to both stabilize the temperature of the web and to remove a small amount of moisture therefrom. The main drying effect of the machine, however, is obtained by the intermediate section 15. This section is adjusted in response to the moisture variations in the web so that the paper as it leaves the machine will have a substantially constant moisture content. The general arrangement of the drying machine which is described above is similar to that disclosed in Krogh Patent 2,401,832, granted on June 11, 1946, and the control provisions of the temperature and flow responsive instruments may be the same as the instruments described in that patent. The invention in this application is particularly directed to the manner in

which the various moisture responsive devices are connected in circuit so that the instrument is responsive not only to the general trend of the moisture content of the paper but also to sudden fluctuations in this moisture content. The moisture measuring and control apparatus per se is, of course, adapted to be used in connection with other control systems than that disclosed herein.

The moisture measuring circuit disclosed herein depends upon the resistance of the web. It is known that the electrical resistance of a web of paper varies with the percentage of the moisture therein. As is diagrammatically shown in Figure 2 the moisture measuring circuit is in the form of a Wheatstone bridge. As is shown therein one leg of the bridge consists of a fixed resistance 36 and a variable resistance including the web 23, as it passes between rollers 24 and 25. These latter rollers are shunted by a condenser 37. A second leg of the bridge consists of a variable resistance formed by the web as it passes between rollers 26 and 27, a second variable resistance consisting of the web as it passes through rollers 28 and 29 and a fixed resistance 40. A third leg of the bridge consists of a fixed resistance 38 while the fourth leg of the bridge consists of an adjustable resistance 39 which may be adjusted to some fixed value to correct the constants of the circuit. The last two mentioned legs of the bridge are connected by an adjustable resistance 41 that is automatically adjusted as the bridge is unbalanced to rebalance the bridge circuit. D. C. current is supplied to energize the bridge from a suitable source 42 and is connected into the circuit between points 43 and 44. Unbalance of the bridge is detected and amplified by a detecting and amplifying mechanism 45 which is connected to the opposite points of the bridge at 46 and 47. Any unbalance that may occur is applied to a relay mechanism 48 which serves to adjust the value of resistance 41 to rebalance the bridge system and simultaneously to a relay 49 which serves to adjust a supply of air under pressure. The adjusted pressure is applied through pipe 35 to the control point adjusting mechanism of flow controller 17. It is noted that the bridge mechanism above described is substantially the same as that disclosed in Figure 5 of Wills Patent 2,215,805, that was granted on September 24, 1940. The detecting and amplifying mechanism 45 may be of the type disclosed and contemplated in that patent. The relay mechanism 48 and the air relay 49 are similar to that used to balance the potentiometer and to adjust the air relay in a manner described in the above mentioned Krogh patent. It is intended that the showing herein is diagrammatic rather than being the detailed description of the type made in the Krogh and Wills patents.

In the operation of the present system, the bridge circuit is unbalanced by changes in the resistance of the various arms produced by the moisture carried by the web. Assuming that the web's moisture content has remained constant for a period of time long enough for the bridge to be balanced and that the pairs of rollers 24, 25 and 26, 27 are placed close enough along the line of web travel so that changes in web moisture will affect the resistance between the pairs of rollers substantially simultaneously. With the bridge balanced there is the same potential drop across the pairs of rollers due to web resistance, and condenser 37 is charged to that

potential. Upon the occurrence of a moisture change in the web the resistance between the pairs of rollers will change. The potential drop between rollers 26 and 27 will change immediately to cause unbalance of the bridge. Such a change is detected and amplified and produces an operation or relay 48 to adjust resistance 41 in a direction to rebalance the bridge. The above mentioned resistance change of the web will also produce a change in the potential drop across rollers 24 and 25. This change will not take effect immediately, however, due to the charging or discharging of condenser 37. After a period of time depending upon the circuit characteristics condenser 37 will assume a charge equal to the new potential drop across rollers 24 and 25 which will be equal to that across rollers 26 and 27. While the charge of condenser 37 is changing the bridge circuit is being unbalanced in the opposite direction to that mentioned above so that resistance 41 will be shifted back to its original value. Thus any change in web moisture will produce a temporary bridge unbalance in one direction or the opposite direction that is removed at a rate depending upon the condenser circuit characteristics. As relay 48 is being operated to adjust resistance 41 it is also adjusting the air relay 49 so that the latter will produce air at a pressure that is proportional to the unbalance of the bridge and the moisture content of the web. This air pressure is applied to the control point adjusting mechanism of flow meter 17 to change the supply of steam to the drying drums in the intermediate section of the dryer. Thus, the drying effect of the drums is made to anticipate changes in moisture of the web being fed to it. Preferably the characteristics of the condenser circuit are such that the change in its potential will take place during the time that the web which produced the change is passing through the machine. Therefore the change produced by the above described bridge unbalance will only be of a time sufficient to correct for the fluctuations in moisture content of the web as it approaches the dryer.

The potential drop across rollers 26 and 29 is determined by the resistance and therefore the moisture content of the web as it leaves the dryer. Changes in the resistance of the web at this point will not be sudden, but will be the result of the over-all operation of the system. Therefore any unbalance of the bridge circuit will produce a sustained correction in the adjustment of the flow controller so that the web leaving the dryer will have a substantially constant moisture content.

From the above it will be seen that the location of the moisture responsive devices with respect to web travel and their position in the control circuit produces a control system that can correct for changes in the moisture content of the web as it is both entering and leaving the drying machine. Such a control system will produce a web of more nearly constant moisture content than it has previously been possible to obtain. The system, while making rapid changes, will not be subject to hunting. The average adjustment over a period of time will be the result of the moisture content of the web as it leaves the machine.

When a recording mechanism is also operated by relay 48, as is usually the case, the circuit above described will produce a record that takes into account the moisture content of the web both as it enters and as it leaves the machine. At times it is desirable to have a record of the

moisture content of the web as it leaves the machine. This may be accomplished by removing from the circuit the effects of the moisture responsive devices placed at the entrance to the machine. To this end there is provided a shunt circuit around the pairs of rollers 24, 25 and 26, 27. This circuit is provided with a pair of switches 51 and 52 that are normally open to render the circuit ineffective. When switches 51 and 52 are closed the bridge will be unbalanced only in response to moisture variations at the moisture responsive device at the exit of the drying machine, or rollers 28 and 29. The record produced at this time will be responsive to the moisture content of the web only at the exit of the machine. The control will also be responsive to the moisture content of the web at this point, but for reasonably short periods of time this should not be objectionable.

From the above description it will be seen that by connecting the moisture responsive elements into a circuit in the manner described there is provided a control system which will correct the drying capacity of the machine so that it is able to handle the web as the latter reaches the machine. There is also provided a means to correct the drying capacity of the machine for sustained changes in the web's moisture content as it is moving from the paper making and drying machine to a storage roll.

While in accordance with the provisions of the statutes, I have illustrated and described the best forms of the invention now known to me, it will be apparent to those skilled in the art that changes may be made in the form of the apparatus disclosed without departing from the spirit of the invention as set forth in the appended claims, and that in some cases certain features of the invention may sometimes be used to advantage without a corresponding use of other features.

Having now described my invention what I claim as new and desire to secure by Letters Patent is as follows:

1. For use in a drying machine having a plurality of drying drums and means to supply a heating medium to the drums, the combination of means to regulate the supply of drying medium, means responsive to the moisture content of the material being dried as it enters the machine, means responsive to the moisture content of the material as it leaves the machine, and means jointly responsive to said last two mentioned means to adjust said means to regulate the supply of drying medium.

2. For use in a drying machine having a plurality of drying drums over which a material to be dried passes and means to supply a drying medium to the drums, the combination of a first means responsive to the moisture content of the material being dried as it enters the drying machine, a second means responsive to the moisture content of the material being dried as it enters the drying machine, said first and second means being connected so that the response of one is opposed by the response of the other, means to delay the response of said second means with respect to the response of said first means, means to regulate the supply of drying medium to said drums, and means controlled jointly by said first and second means to adjust said regulating means.

3. For use in a drying machine having a plurality of drying drums over which the material to be dried passes and a supply of drying medium

for the drums, the combination of means to regulate the supply of drying medium, means responsive to changes in the moisture content of the material being dried before it enters the machine, and mechanism to adjust said regulating means operable in accordance with the response of said responsive means whereby the drying capacity of the machine will be adjusted for said material as it enters said machine, said responsive means including means to dissipate the action of said responsive means and the adjustment of said regulating means effected by said mechanism whereby the response of said responsive means to a change in the moisture content of the material being dried and the adjustment of said regulating means made by said mechanism in accordance with the response of said responsive means exists only for a predetermined time.

4. For use in a drying machine having a plurality of drying drums over which the material to be dried passes and a supply of drying medium for said drums, the combination of means to regulate the supply of drying medium to said drums, and mechanism responsive to changes in the moisture content of the material being dried as it enters the machine to adjust said regulating means, said mechanism including means to dissipate after a predetermined time the adjustment of said regulating means effected by said mechanism in response to changes in the moisture content of the material being dried as it enters the machine.

5. For use in a drying machine having a plurality of drying drums over which material to be dried is passed and a supply of heating medium for said drums, means to regulate the supply of heating medium to said drums, an electrical bridge circuit, a pair of means responsive to the moisture content of the material forming part of said bridge circuit and being in opposing legs thereof, means to delay the response of one of said means whereby upon a change in the moisture content of the material one of said means will respond immediately and the other will respond at a later time to cancel out the response of the first, said bridge circuit being unbalanced upon the occurrence of a different response of said means, means responsive to unbalance of said bridge circuit, and mechanism operated by said last mentioned means to adjust said regulating means.

6. For use in a drying machine having a plurality of drums over which a web of material to be dried passes and a supply of heating medium for the drums, means to regulate the supply of heating medium, first means responsive to the moisture content of the web as it enters the machine, second means responsive to the moisture content of the web as it leaves the machine, mechanism of which said first and second means form a part, and operative to respond to the joint action of said means, and means operated by said mechanism to adjust said regulating means.

7. For use in drying machine having a plurality of drums over which a material to be dried passes, and a supply of heating medium for said drums, means to regulate the supply of heating medium to the drums, a first means and a second means

each responsive to the moisture content of the material prior to the time it reaches the drying machine, a third means responsive to the moisture content of the material as it leaves the drying machine, mechanism including said first and second means connected so that the response of these means is in opposition to each other and said second and third means so that the response of these means are additive, means to relay the response of said first means upon a change in moisture content of the material, operating mechanism operated in accordance with the joint response of said three means, and means to adjust said regulating means by said operating mechanism.

8. For use in a drying machine having a plurality of drums over which material to be dried passes and a supply of heating medium for said drying drums, first means responsive to the moisture content of the material prior to the time it enters the machine, second means responsive to the moisture content of the material as it leaves the machine, an electrical circuit of which said means form a part, said circuit having a response varying in accordance with the responses of said first and second means, a recording mechanism, means to shift said recording mechanism to positions varying with the response of said circuit, and means to adjust said circuit to remove the response of said first means whereby said recording mechanism will be moved only in accordance with the response of said second means.

9. For use in a drying machine having a plurality of drums over which a web of material to be dried passes and a supply of heating medium for the drums, a first and a second means each responsive to the moisture content of the web prior to entering the machine, a third means responsive to the moisture content of the web as it leaves the machine, a bridge circuit including said first and second means connected in opposition to each other, and including said second and third means connected in additive relation to each other, means to retard the response of said first means, switch means operative to remove the effect of the response of said first and second means on said circuit, the change in response of said three means due to changes in moisture content of the web operating to unbalance said bridge circuit, means responsive to unbalance of said bridge circuit to rebalance the same, and mechanism operated by said last mentioned means to adjust the supply of heating medium to the drums.

CHARLES B. SPANGENBERG.

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