April 4, 1967 T. D. FENLEY 3,311,947

CONTROL DEVICE FOR PREPARING A CONTINUOUS PRODUCT

Filed May 20, 1964 3 Sheets-Sheet 1

Fig. 1.

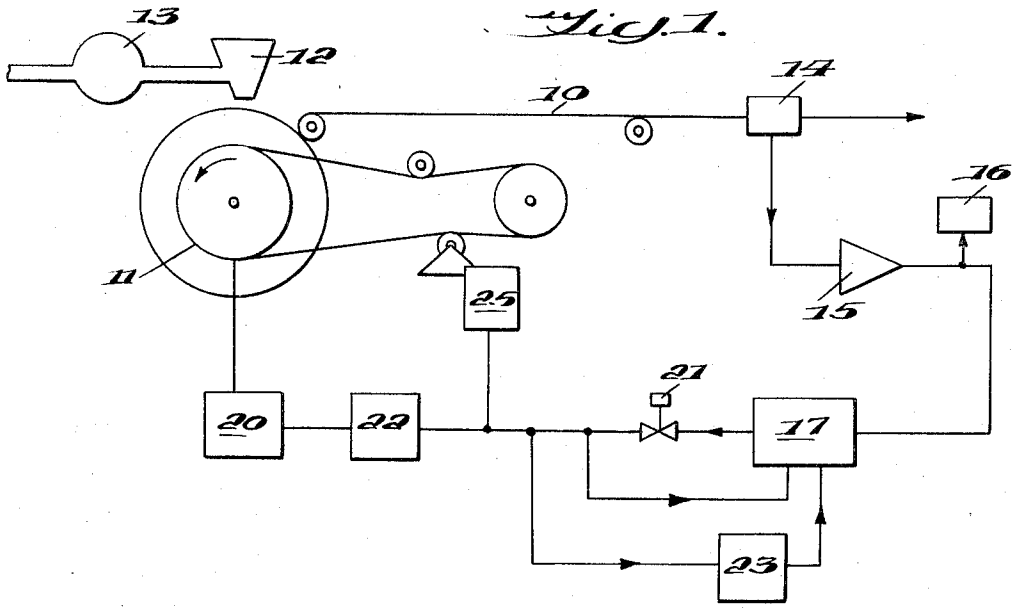
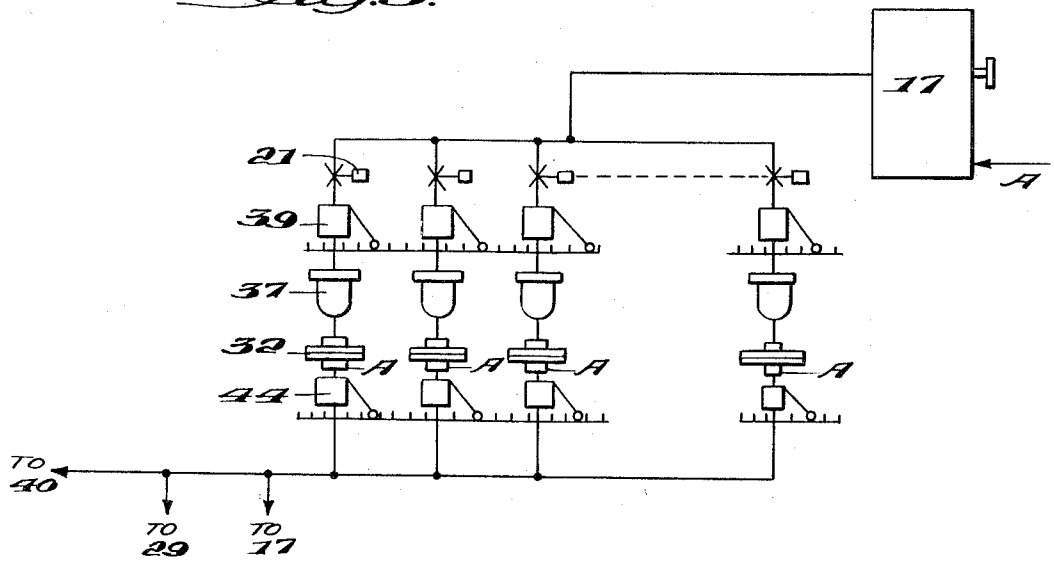


Fig. 3.



A → AIR SOURCE

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CONTROL DEVICE FOR PREPARING A CONTINUOUS PRODUCT

Filed May 20, 1964 3 Sheets-Sheet 2

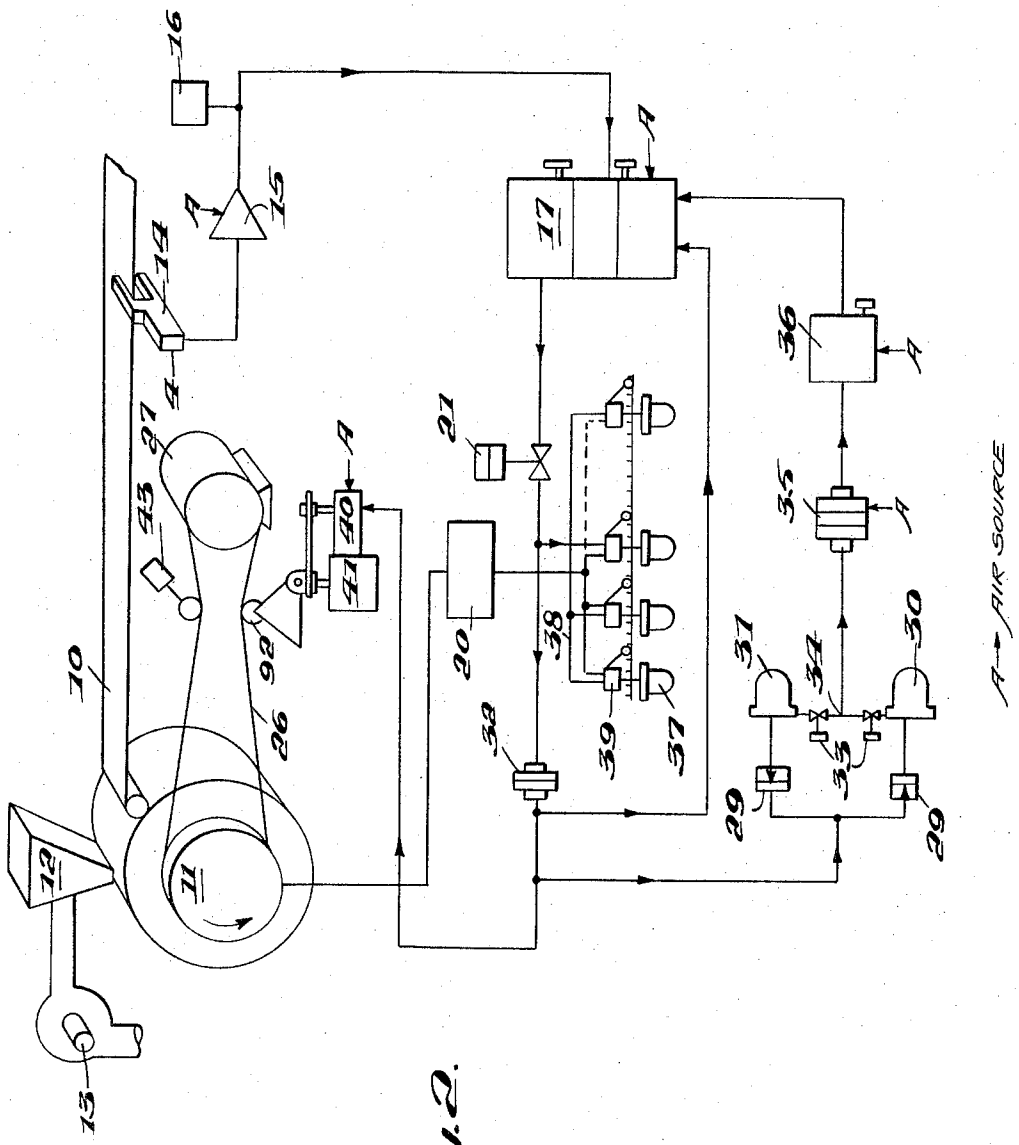


Fig. 2.

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CONTROL DEVICE FOR PREPARING A CONTINUOUS PRODUCT

Filed May 20, 1964 3 Sheets-Sheet 3

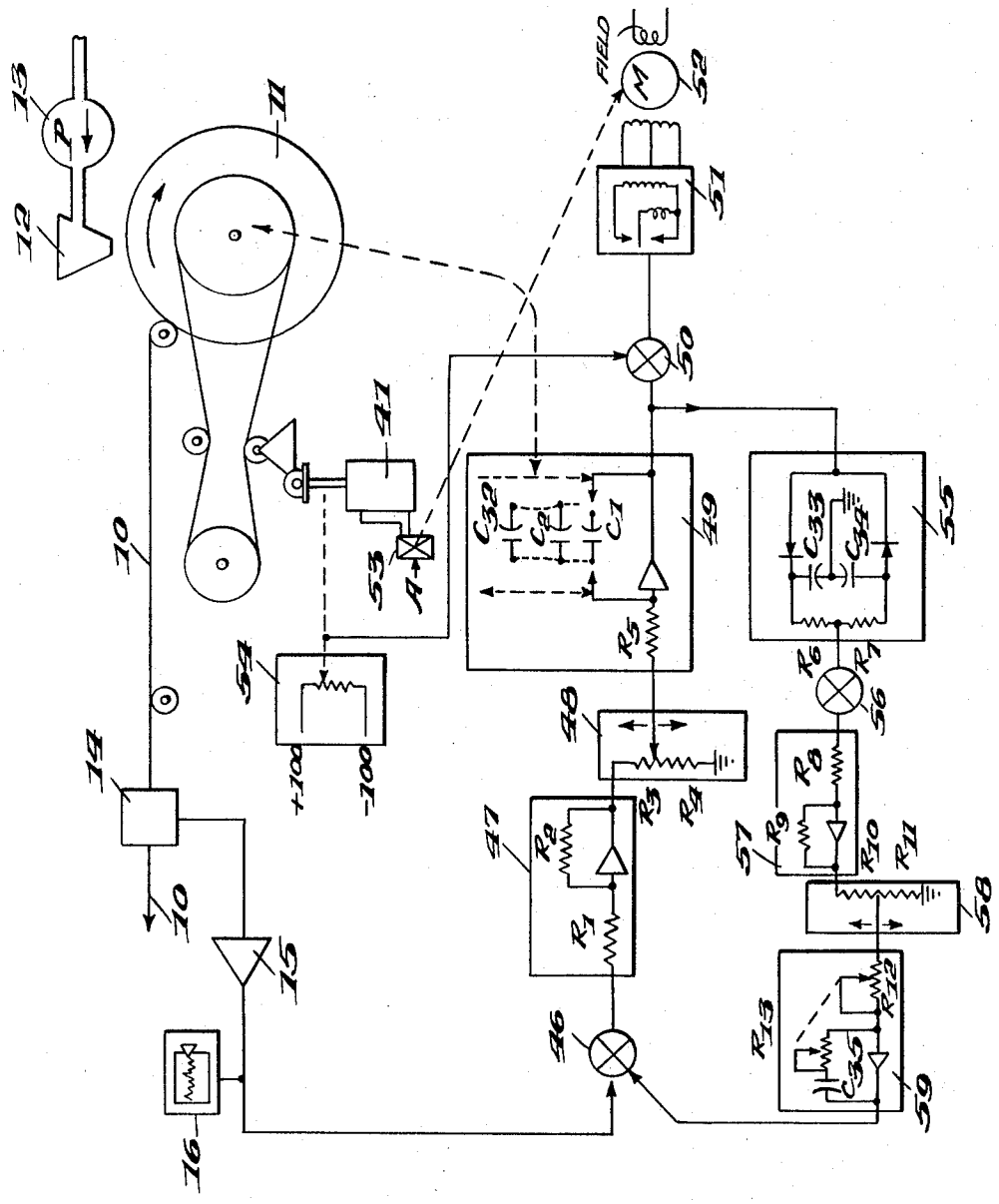


Fig. 4.

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United States Patent Office

3,311,947

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3,311,947

CONTROL DEVICE FOR PREPARING A CONTINUOUS PRODUCT

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Filed May 20, 1964, Ser. No. 368,814
9 Claims. (Cl. 18—2)

This invention is related to an apparatus for controlling the production of web material. More particularly, this invention relates to an apparatus for controlling a multiple of similar variables in a web producing apparatus.

The process of forming webs of various material, such as polyesters, by casting is of widespread use in the film industry. A description of such a process and suitable means for carrying it out may be found in U.S. patents, Alles et al. 2,728,941 and Bicher 2,821,746. Where the thickness of the cast web must be maintained within narrow limits, various problems have occurred which have resulted in yield losses. One of the problems encountered is a repetitive thickness variation in the longitudinal direction. The surfaces of casting wheels have "run out," i.e., the distance or radius between the surface of the roll to the center or axis of rotation has small variations around the circumference. These variations result in corresponding repetitive variations in the thickness of the web. It is not presently possible to machine a casting wheel to such accuracy and finish to avoid these minute variations, and to approach the required tolerances by lapping or other processes is very expensive as the accuracy must be on the order of ± 0.0001 inch. Additionally, the materials presently available for casting wheels do not have a perfectly elastic memory at these dimensions and as a result do not resume the original dimension after prolonged pressure or thermal loadings.

It is therefore an object of this invention to provide apparatus for automatically controlling a multiplicity of related process variables with stable control of the over-all process. A further object is to provide an apparatus that eliminates repetitive errors in a cyclical operation by utilizing an automatic feedback control. Another object is to provide a control apparatus that has rapid speed of response and will sustain the correcting action when the repetitive errors have been eliminated.

A still further object is to provide a control apparatus that keeps its correcting action centered about the limits of travel of the variable which are corrected. Other objects will be apparent from the drawings and descriptions appearing hereinafter.

These and other objects are accomplished by the invention as defined in the appended claims and described below in its preferred embodiments.

This invention is useful in all processes and apparatus where the formed product is effected individually by many of the same type of process variable to give a uniform product as in a casting apparatus where the cast thickness of a moving web must be maintained within narrow limits, and is particularly useful in the casting of base for photographic film.

The invention is better understood by reference to the following drawings and discussion wherein:

FIGURE 1 is a block diagram illustrating the functional relationship of the basic elements of this invention.

FIGURE 2 is a schematic diagram of this invention using pneumatic control means.

FIGURE 3 is an alternate memory or storage circuit for the pneumatic control means.

FIGURE 4 is a schematic diagram of this invention using electronic control means.

Referring to FIGURE 1, in the process of continuously

forming a web 10 by the extrusion of molten polymer onto a cooled casting wheel, the thickness of the web is dependent upon several factors, one of which is the speed of the casting wheel 11 as it passes the lips of the hopper 12. Some of the other factors are the viscosity of the polymer, the speed of the polymer pump 13, and the distance between the lips of the hopper and the casting wheel. In this exemplary operation, the speed of the casting wheel is the variable that will be manipulated to eliminate repetitive variations in thickness of the web in the longitudinal direction. When the other factors that determine the thickness of web remain essentially constant, an increase in the speed of the casting wheel will decrease the cast web thickness and a decrease in speed will increase the thickness. In controlling the speed the casting wheel is divided into a selected number of circumferential segments and the speed of each segment past the lips of the hopper is acted upon independently by the automatic control system. The thickness of the web, or the process variable, is sensed by a thickness measuring means 14. The sensing means transmits a signal that represents the thickness of the moving web, i.e., the primary feedback. This signal is amplified or transduced 15, recorded 16 and transmitted to a comparison controller 17. The measured portion of the web was cast on a specific segment of the casting wheel 11. Thus measurements of web thickness are directly related to a specific segment of the wheel.

The comparison controller, in analog fashion, computes an actuating signal for each segment of the casting wheel based upon the time integral of the difference between the primary feedback for the web cast on that particular segment and a reference signal. To perform this function the controller compares the primary feedback signal with a reference input signal, amplifies the difference, adds a secondary feedback signal and transmits the resulting signal through a restriction 21 which serves to integrate with respect to time the algebraic sum of the secondary feedback signal and the amplified difference.

The secondary feedback represents a stored signal from the memory circuit 22 for that particular segment and represents the signal transmitted to the final control element during the final portion of the prior scan of that segment. The secondary feedback signal permits the comparison controller to produce an output signal when there is no error or variations in thickness represented in the primary feedback.

The reference input signal is determined by a circuit 23 that can be called the set point circuit. This circuit has two functions, one to keep the reference input representative of the average thickness of the entire web and second to keep the final control element's stroke or correction action centered about the limits of its travel. The latter function is of particular importance where the final control element involves apparatus using a piston, and a complete piston stroke would discontinue the correcting action of the final control element. This circuit receives and stores two signals, one representing the largest signal during the control operation and the other the smallest signal. The two signals are averaged and the resulting signal is compared to a fixed reference representing the center of the action of the final control element, or the piston travel in this illustration. The difference is integrated with respect to time and represents the reference input signal or set point signal.

The memory circuit 22 stores the signals that represent the speed required for each segment. Each segment of the casting wheel has a storage chamber to store its particular signal. This memory circuit in conjunction with the restriction 21 minimizes the effect of short term variations in the process and prevents the control apparatus

from over-correcting or giving false correction or spurious signals. When the controller is comparing the primary feedback with the reference input for a particular segment, the storage chamber for that segment is opened to the control circuits. When this occurs, the circuit between the memory 22 and the restriction 21 assumes the value of the stored signal. This signal is fed to the final actuating element, to the controller and to the set point circuit 23 where it is used to determine the reference input signal which is used by the controller.

The signal from the controller after being integrated by passing through the restriction 21 is combined with the signal from the memory circuit 22. This is then the final actuating or control signal which is transmitted to the final control or actuating element 25. In the absence of an error on any or all segments, the stored signal from the memory circuit for each segment will be the controller output signal and will continue to repeat for every revolution of the wheel. The final actuating element receives the signal and through a servo-mechanism regulates the speed of the casting wheel over each segment to eliminate the thickness variation.

FIGURE 2 shows the preferred embodiment of this invention, with the use of pneumatic control devices and circuits. Pneumatic means are desirable because of low initial cost and the long useful life of pneumatic instruments thereby reducing maintenance expenses. Most of the means involved are available pneumatic control elements, but some of them require specific modification as will be explained.

The casting wheel 11 is driven by a belt 26 connected to a driving means 27. In some applications where other means of rotating the casting wheel are involved the final control element will have to be changed accordingly. As the polymer forming the web 10 is stripped off, its thickness in the longitudinal direction is measured by an air gauge 14. The air gauge is located at a distance from the lips of the hopper 12 equal to some multiple of the circumference of the casting wheel preferably as small a multiple as possible. Thus the passage of a segment of the casting wheel past the lips of the hopper is in phase with the measurement downstream of the web cast on that segment. In the air gauge, the web passes between two nozzles and the thickness of the web determines the back pressure produced within the gauge. This back pressure is sent as a pneumatic signal to an amplifier or transducer 15. This device transduces the air gauge back pressure to a signal pressure with a midpoint of 9 p.s.i. and a 3 to 15 p.s.i. range. Thus for a thickness variation of $\pm.0003$ inch there will be a pneumatic signal variation of ± 6 p.s.i.

The signal is then recorded on recorder 16 and sent to a modified proportional plus reset pneumatic controller 17. If desired, the pneumatic recorder (Moore Products, Model 5311T4R) can be equipped with a second recording pen that can record one of several selective signals in the system, i.e., the set point signal, the memory circuit signal or the final control signal. This would be of benefit in discovering trouble in the system.

The controller is modified so that a rapid equalization of pressures will take place within the controller during the time a particular wheel segment is being examined. This controller, first produces an actuating signal by comparing the primary feedback signal with the reference signal from the set point circuit, this latter signal represents the average web thickness correlated with the mechanical midpoint of the final control element.

The set point circuit consists basically, of two equal one way flow valves 29 connected to two volume chambers 30 and 31. Within this circuit, chamber 30 in conjunction with flow valve 29 will assume the highest pressure in the entire system while chamber 31 will assume the lowest. The construction of this circuit allows the chambers to retain the proper pressures and restricts the flow of pressure from one chamber to the other. The

pressure of the higher of the two chambers is slowly bled through two equal needle valves 33 to the lower; and, at the junction 34, the pressure signal is equal to the average of the two pressures, i.e.,

$$\frac{P_{\text{high}}+P_{\text{low}}}{2}$$

This signal will change as the average of the highest and lowest memory signals change, thus maintaining a signal corresponding to the average of these two extremes. The signal pressure at 34 is then sent to an inverse derivative unit 35 (Moore Products Inverse Derivative, Model 59R) if it is necessary or desirable to reduce the effect of spurious signals and smooth out the signal curve. A description of the construction and operation of the inverse derivative unit may be found in U.S. Patents 2,431,297 or U.S. 2,501,957.

A multi-function relay 36 (Moore Products *M/F* Relay 68VT17) such as described in U.S. Patent Nos. 2,312,201 and 2,359,236 is then used to compare the average thickness signal 34 with a fixed reference signal that represents the center of travel of final control elements. The difference is then integrated with respect to time by the action of relay 36 and transmitted as the reference input signal to controller 17 to represent a signal for the average web thickness correlated to keep the final control element centered within the limits of its travel.

The difference between the primary feedback and the reference input, if any, is then amplified within the controller. Thus, for a given deviation from the reference input signal, the controller output contains the deviation times a factor dependent upon the amplification factor of the controller.

The secondary feedback pressure for the particular segment being scanned is transmitted to the controller. It is algebraically added to the amplified difference between the primary feedback and the reference signal to determine the controller output. Thus if no error exists for any particular segment, i.e., the difference between the primary feedback and reference signal is zero, the controller output will equal the secondary feedback and the memory will be sustained. Also the secondary feedback is the constant of integration for the controller output as it is integrated with respect to time by the action of the needle valve 21. The needle valve is a precision restriction with a micrometer dial and it reduces the effect of spurious signals and integrates sustained signals. This integrated signal is then combined with the signal from the memory chamber for the wheel segment being scanned and is transmitted by the 1:1 relay 32 (Moore Products Precision Booster 1:1 Relay) to the final control element, the set point circuit and the controller as the secondary feedback.

The memory system is an arrangement of a number of volume chambers 37, one for each wheel segment, connected to a common manifold 38 through a series of micro-valves 39, one for each chamber. Each valve is actuated in sequency by a timing means such as a rotating cam assembly 20 synchronized to the casting wheel. As each part of the memory system is opened, the stored signal is instantaneously sent to the final control element, the set point circuit and the comparison controller and immediately afterwards the newly computed signal for its particular segment is transmitted to it. The memory chambers must be bubble tight for proper operation, and the ratio of manifold volume to memory volume must be kept as small as possible to avoid line losses and interaction between memory chambers. Also, the cam and micro valves assembly must be adjusted so that there is no overlap between the opening and closing of memory chambers, otherwise the pressure for a particular segment will not achieve its proper value and will affect overall control performance.

The purpose of the 1:1 relay 32 is to isolate the mani-

fold from the secondary feedback circuit, the reference or set point circuit and the final control circuit which governs the wheel rotation. This relay is essential in keeping air volume of the manifold 38 as small as possible. This relay physically seals the manifold from said other portions of the system while allowing a signal of the same magnitude to continue in the system.

The final control element is composed of a power positioner 40 used in conjunction with an air cylinder 41 to position a pulley 42 on the belt drive. The pulley rides the belt drive, when it is raised it increases the speed of the casting wheel and when it is lowered it decreases the speed. The increase in speed results in a decrease of web thickness, and vice versa, a decrease in speed increases web thickness.

The positioner 40 compares the final control signal with the spring force that represents the position of the piston within the air cylinder. The difference between the two signals is used to operate a four way valve that in turn operates the piston within the air cylinder. The movement of the piston is transmitted to the pulley and thus modulates the casting wheel speed. Another pulley 43 is used to maintain the same tension in the belt regardless of the position of speed changing pulley 42.

The means used to sense the thickness of the web in the preferred embodiment is an air gauge. There are several other methods of measuring the thickness of a moving web such as ultraviolet radiation, nuclear radiation, air shoes, and roller contacts employing the use of linear differential transformers. The air gauge was chosen as it is compatible with the pneumatic circuit and would provide a measurement without coming into contact with the moving web. Such gauges are well known in the art as exemplified by an air gauge manufactured by Pratt and Whitney, Hartford, Conn., with a nozzle to web spacing of .002 inch which may be used.

The transducer 15 or amplified is a pressure to pressure transducer designed to deliver to 3–15 p.s.i. pneumatic output for a 28–31 p.s.i. pneumatic input from the air gauge. A description of the operation of a typical unit of this type (Moore Products Pressure Transducer, Model 174) may be found in Bulletin 17301, published by Moore Products Company, Philadelphia 24, Pa., and copyrighted in 1961.

A controller 17 that can be used is the Moore Products Nullmatic 56MF after having been modified to reduce the over-all volume of the reset reference chamber to an infinitesimal amount to permit a rapid equalization of pressures within the controller during the time a web portion corresponding to a specific wheel segment is being examined. To modify this controller the reset needle valve is removed and the connection is plugged, the volume of the reset-reference chamber is greatly reduced by a plug filler and the feedback is fed into the reduced chamber by tapping in a connection. A description of this controller and its operation may be found in Instruction Book, SD50–3 entitled "Nullmatic Controller" published by Moore Products Co., Philadelphia 24, Pa. and copyrighted in 1958, or in the following U.S. Patents 2,312,201; 2,359,236; 2,518,244; and 2,520,468.

A restriction 21 (Hoke Inc. Calibrated Restriction) is added to the controller output circuit which integrates the controller output signal with respect to time. The eliminaion of reset or integrating-action within the controller by the mentioned modifications provides for a fast speed of response for scanning a multiple of process variables, and a simple circuit is achieved with only one controller.

In the preferred embodiment the casting wheel was divided into 32 segments. The wheel must be divided into a sufficient number of segments to permit effective reduction of the repetitive process variable, but because of the resistance and capacitance of the circuit and the design speed of the casting wheel, the wheel should not be divided into too many segments. If this is done, the reaction of the system would be too slow to properly control the speed and thickness of the web. Thus the number of segments is a function of the frequency of the repetitive process variable and the speed of response of the control system.

The memory circuit consists of 32 bubble tight volume chambers, one for each segment. For proper operation it is necessary to have a sealed system with no interaction between the volume chambers. The chambers are opened into a common manifold by a cam rotating in synchronization with the casting wheel, the cam acting upon 32 micro valves. The opening and closing of the chambers can also be accomplished by the use of miniature electric solenoid valves with a stepping relay to control their opening and closing.

A further improvement in control performance in the memory circuit may be obtained at the cost of additional equipment such as shown in FIGURE 3. In this embodiment each volume chamber has a needle valve 21, a 1:1 relay 32 and an additional micro valve 44. During operation, the micro valve 44 opens several milliseconds before micro valve 39 allowing the secondary feedback signal to appear in the controller output signal prior to the opening of micro valve 39. The controller output signal for each particular segment is integrated by the restriction for that segment's volume chamber. When the next segment is being scanned, micro valves 39 and 44 for the prior segment close simultaneously and the valves for the next chamber open in sequence. This embodiment produces the same control signal but the ratio of the volumes of the manifold and chambers has no effect on memory retention.

The final control element consists of a positioner 40 and an air cylinder 41. Here it is necessary to have accurate positioning, good speed of response, and stable control. The positioner must have an excellent frequency response for the high frequency-small amplitude variations received. Positioners such as described in Bulletin SC–12 published by the Foxboro Company, Foxboro, Mass., and copyrighted 1957 were found to give satisfactory performance.

The speed changes necessary to correct the thickness variations can be made by a two inch movement of the pulley on the belt drive. The air cylinder used to move the pulley must provide accurate positioning and stable control. An air cylinder with a large bore and short stroke aids in positioning stability and accuracy. A suitable cylinder having an eight inch bore and a six inch stroke can be obtained from the Flick-Reedy Corp., Melrose Park, Illinois.

FIGURE 4 shows an alternate means of producing the signal for the control circuit, i.e., an electronic circuit which could be employed if the pneumatic circut were too slow for the design speed of the wheel and the number of segments required for good control.

FIGURE 4 is a drawing of an equivalent control circuit employing electronic circuitry to accomplish the same objects. Basically in the electronic circuit, a detector senses the thickness of the product and produces an electrical signal representing the magnitude of the thickness. This signal is compared with a reference voltage in a null-indicating circuit where the reference voltage is applied in opposition to the polarity of the signal from the measuring means. Thus, if there is any difference, an error correcting voltage is created. This error voltage is amplified, algebraically added to prior correcting voltages, integrated with respect to time, and sent to a servo-mechanism to correct and maintain the process.

More particularly, the casting wheel is again divided into 32 segments and the thickness of the web 10 is sensed by a sensing means 14 located at distance from the hopper 12 equal to some multiple of the circumference of the casting wheel. If a pneumatic web sensing gauge is used the output can be transduced 15 into a D.C. electrical signal that varies in proportion to the magni-

tude of the thickness and is in the range of 0 ± 100 volts. If an electrical sensing means, i.e., an X-ray gauge, is used the output signal may need to be amplified so that the signal voltage will be in the 0 ± 100 volt range. A recording potentiometer **16** can be used to graphically portray the thickness of the web.

The thickness voltage or primary feedback is then received by a summer **46** where it is compared with a reference signal voltage to develop an error or difference signal. The manner in which the reference voltage is developed will be explained later. The summer can be any of many electronic devices that produce an output voltage representing the difference between two voltage inputs. Within the summer if the thickness voltage equals the reference voltage, indicating no error in the thickness of the web, the output or error voltage will be zero.

Any error voltage is then received by a stabilized operational amplifier **47**, wherein the D.C. error voltage is amplified. To give the amplifier adjustable proportional response a potentiometer **48** may be used, the potentiometer having manually adjustable amplification. Thus if $R_1=1$, $R_2=50$; $R_3=99$, and $R_4=1$, the amplified output voltage from the potentiometer could range from a gain of 50 to a gain of 0.5 depending upon the manual setting.

The amplified voltage is then integrated with respect to time in an integration circuit **49**. This circuit also contains the memory means, which consists of 32 capacitors, one for each segment. A stepping relay (indicated by dotted line from capacitor C_1 to capacitor C_{32}) synchronized with the casting wheel revolutions connects the capacitor for a wheel segment into the integration circuit while that particular segment is under the hopper and its thickness is being measured downstream by the sensing means **14**. Each capacitor stores the prior computed voltage signal for its segment as the volume chambers do in the pneumatic embodiment.

The output from the integration circuit is in the same operational form as the pneumatic signal sent to the pneumatic positioner **40** when using the pneumatic system of FIGURE 2. This controller output signal is then compared in a summer **50** with a signal voltage representing the position of the piston in the final control element **41**. The development of the piston position voltage will be explained hereinafter. The difference between the two voltages fed into the summer **50** is sent to a chopper-amplifier **51** and subsequently is the power input that operates an A.C. reversible motor **52**. The movement of the reversible motor is mechanically linked to a four way valve **53**. The opening and closing of this valve operates a piston within an air cylinder **41** and modulates the casting wheel speed as previously explained in the pneumatic embodiment.

The movement of the piston within the air cylinder **41** is mechanically linked to a position transmitter **54**. This position transmitter produces the piston position voltage that is a function of the piston position and is sent to the summer **50** where it is compared with the controller output voltage as previously explained. Thus if the piston positioning voltage equals the controller output voltage, no difference voltage will be produced. This indicates that the speed of the casting wheel is correct for that particular segment and the final control element will not be activated.

The reference input voltage going to summer **46** serves two purposes. The first is to represent an average of the web thickness for a basis of comparison when measuring the thickness in any particular segment. The second purpose is to keep the extremes of travel of the piston in the air cylinder **41** equally spaced about its center.

The reference input voltage is developed in a set point circuit **55**. Within this circuit a capacitor C_{34} in conjunction with a diode assumes the highest voltage in the system, while capacitor C_{33} in conjunction with another diode assumes the lowest voltage. These voltages pass through equal resistances R_6 and R_7 and at the juncture, the voltage is equal to the average of the two. This voltage will change as the average of the highest and lowest capacitors changes, thus maintaining a signal corresponding to midpoint of the highest and lowest capacitor charges.

This high-low average signal can be sent to a summer **56** where it is compared with a manually set voltage that represents the midpoint of the piston **41** travel. In applications where this manually set voltage would equal zero, this summer may be omitted.

The difference in the voltages is then acted on by a conventional electronic proportional integral controller composed of an operational amplifier **57**, adjustable proportional response **58** and an integrating circuit **59**. The output of this controller which is the amplified and integrated error voltage is then the reference input and is compared with the primary feedback as previously explained.

A microswitch (not shown) actuated by a cam on the casting wheel **11** can be used to produce a signal that advances the stepping relay within the memory circuit. The cam would rotate **32** times for each casting wheel revolution, or once per segment.

The invention has many advantages over the prior art and one is a reduction in the time required to correct a process upset. This system has little or no dead time and will operate effectively when the process upsets occur in the nature of gradual drifts. The storage capacity and related circuitry of the apparatus of the invention minimize the effect of short-term deviations, which have an upsetting effect on the control of the process. Additionally, the use of the moving web's average thickness as the reference input enables the attainment of a more uniform web than with controllers which utilize a preselected, set-point reference.

Many other modifications and uses within the scope of the present invention will be obvious to those skilled in the art. For example, instead of changing the casting wheel speed, the thickness could be controlled by the automatic readjustment of the spacing between the hopper lips along the length of the hopper or modulating the distance between the lips of the hopper and the casting wheel. The control apparatus of the invention can be used in any process wherein a repetitive pattern is detected and memorized, and the pattern is continuously adapted or upgraded, e.g., it could be used in a calendering operation to correct thickness variations.

The automatic control apparatus of this invention has many advantages over the prior art. The apparatus permits the rapid scanning of a multiple of similar process variables, the computing and storing of a correcting signal for each process variable with a single controller. By only requiring one controller the system will be economical in cost and greatly reduce the control circuitry needed. Also, this apparatus produces stable control of the over-all process even when the process variables are interrelated such that control on one affects the other.

What is claimed is:

1. In an apparatus for preparing web material composed of a hopper adapted to contain said material, an extrusion orifice joined to said hopper for passage of said material, a rotatable casting roll to receive said extruded material and a windup roll to receive said cast web material the improvement which comprises a control system for governing the rotational speed of circumferential segments of said casting roll past said orifice said system having sensing means for measuring and signalling web thickness; correction signalling means for creating a corrective signal by measuring said web thickness signal against a reference signal and adding a third signal representing said corrective signal issued during the last rotation of said roll for the same circumferential segment now being measured and actuating means for adjusting the rotational speed of said casting roll segment corresponding to that upon which said measured portion of said web was formed.

2. An apparatus for preparing web material comprising a hopper for containing said material said hopper having an orifice through which said material can be extruded; a rotatable casting roll to receive said extruded material on said roll surface and forming a web of said material; sensing means for issuing a signal for the thickness of a portion of said web that was cast on a designated circumferential segment of said roll; correction signalling means for issuing a signal governing the movement of said roll segment past said orifice by determining the difference between said thickness signal and a reference signal and algebratically adding said difference to the last correction signal issued for said segment of the roll; actuating means for moving said roll in response to said correction signal and windup means for removing said web.

3. An apparatus as in claim 2 where said sensing means is an X-ray thickness guage.

4. An apparatus as in claim 2 where said correction signalling means has individual signal storage cells corresponding to the number of said circumferential segments whereby said corrective signals for each segment are stored and then used individually as a base signal for formulating the next corrective signal for the same roll segment.

5. An apparatus for preparing a web of material which comprises a hopper with an extrusion lip for containing said material; a rotating casting roll for forming a web of said material as it is passed from said extrusion lip; web thickness sensing means for measuring and signalling the thickness of said web; multiple storage means, one for each designated angular segment of said roll surface, for storage of correction signals affecting said roll rotation for said corresponding designated roll surface segment as it passes said extrusion lip; correction signalling means for measuring the diqerence of said thickness signal for web cast on said designated segment and a reference signal and adding said difference to said stored correction signal for said designated segment; adjusting means for responding to said newly formed correction signal whereby said speed of rotation for said designated roll segment is affected as it passes said extrusion lip; timing means for opening the storage means corresponding to the surface segment being measured and windup means for removing said web.

6. An apparatus as in claim 5 where said reference signal represents an average of the largest and smallest thickness signals detected in said web where said average is correlated with the operative control range of said adjusting means.

7. A control device for eliminating repetitive variations in a continuous product by forming correction signals to actuate individual product formation elements of a plurality of similar product formation elements where each element is capable of effecting a segment of said product, said control device comprising:

(A) sensing means for signalling the measurement of said variation in succeeding segments of said product,

(B) controller means for comparing said variation measurement wtih a reference signal and creating a correction signal for said difference;

(C) set point means for forming said reference signal by correlating (1) the average of the highest and lowest controller signal previously created by said controller with (2) a signal for the actuating limits of said formation elements;

(D) memory means having a memory element for each formation element for separately storing said controller correction signals for each formation element whereby said memory element contains the total of the prior control signals for said individual formation element and algebraically adds the latest correction signal to said total to form a revised total which is transmitted to said formation element to correct said element; and

(E) timing means for opening a specific memory element in synchronization with the variation measurement of a particular segment whereby said stored signal for said particular segment is transmitted to said set point means and is open to receive the new correction signal from said controller.

8. A control device as defined in claim 7 where said memory is a plurality of pneumatic volume chambers.

9. A control device as defined in claim 9 where the volumn of said memory storage members are large enough to be only slightly affected by changes in its contents when opened by said timing means thereby preventing over-correcting by said formation elements.

References Cited by the Examiner

UNITED STATES PATENTS

2,156,895	5/1939	Godat	18—21
2,726,922	12/1955	Merrill et al.	18—21
2,988,641	6/1961	Gough	18—21 XR
3,000,438	9/1961	Alexander.	
3,122,784	3/1964	Jolliffe	18—21
3,150,213	9/1964	Doering	18—21 XR
3,178,770	4/1965	Willis	18—21 XR

WILLIAM J. STEPHENSON, *Primary Examiner.*