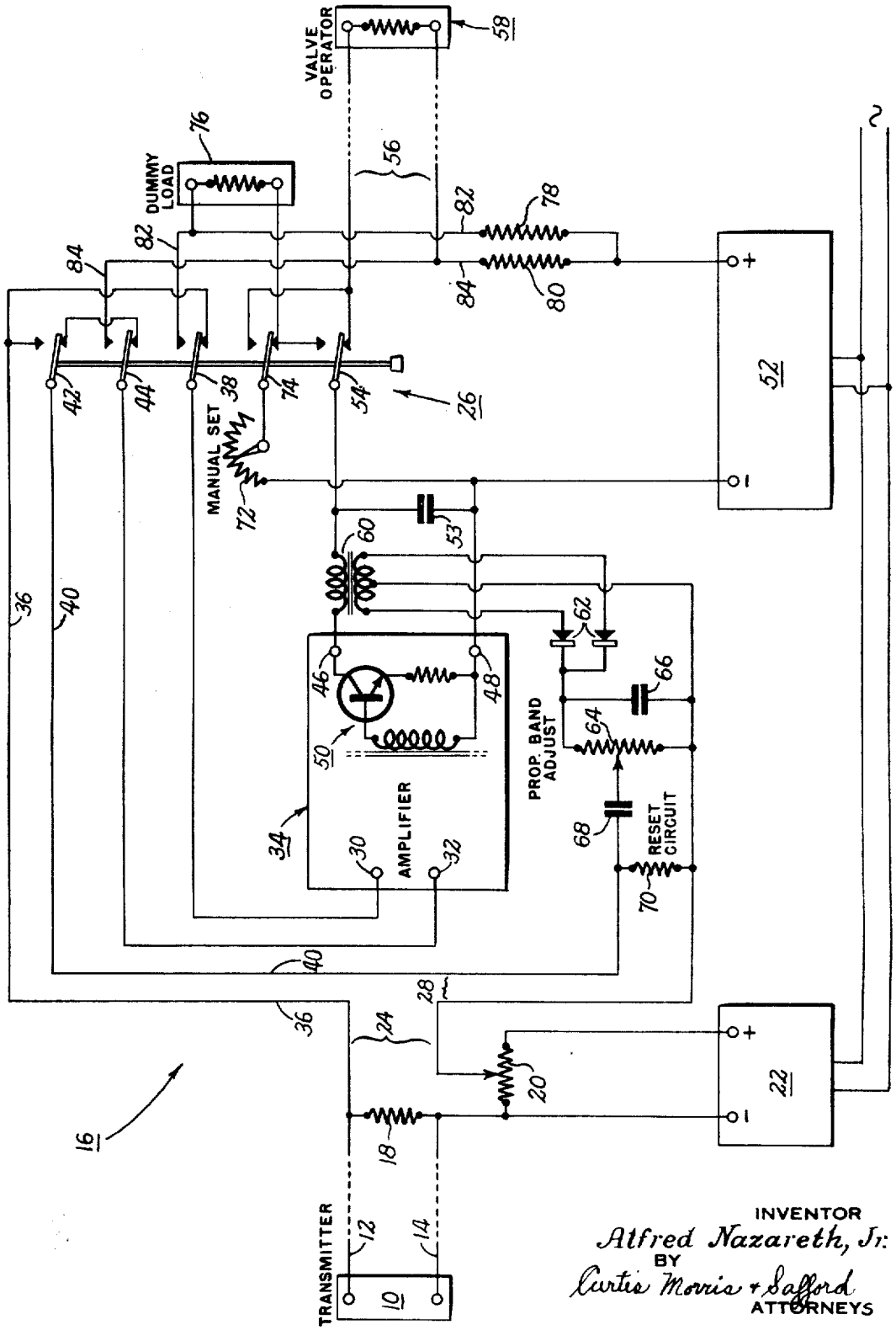
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INDUSTRIAL PROCESS CONTROL APPARATUS

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INDUSTRIAL PROCESS CONTROL APPARATUS

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Int. Cl. H03f *3/38*
U.S. Cl. 330—10 14 Claims

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

ABSTRACT OF THE DISCLOSURE

An electronic controller for use with an industrial process for maintaining constant a condition of the process, such as temperature, flow rate, etc., and comprising an amplifier to which is directed a deviation signal representing the difference between a condition measurement signal and a set point signal; the output of the controller normally being transmitted to a process valve operator or the like for automatically adjusting a process variable which influences the measured process condition, there being included with the controller an automatic-to-manual switch arrangement for directing to the process valve operator a manually adjustable signal in place of the automatic control signal and for storing during manual operation a signal level representing the difference between the deviation signal and the output of the controller, the controller output being caused to track the manually adjustable signal by feeding to the amplifier input a potential derived from the manually adjustable signal together with a feedback signal derived from the amplifier output so as to hold the amplifier input at null and thereby cause the amplifier output to follow the manually adjustable signal.

This is a continuation of application Ser. No. 138,034, filed Sept. 14, 1961. This invention relates to control apparatus for maintaining constant a condition of an industrial process, for example a process condition such as temperature or rate of liquid flow, etc. More in particular, this invention relates to improvements in electronic controllers of the type adapted to transmit an electrical signal to a remote operating device which positions a process valve or the like. For background information on certain aspects of such controllers, reference may be made to U.S. Patent 2,956,234, issued to Everett O. Olsen on Oct. 11, 1960.

During the operation of industrial processes, it sometimes is desirable to control the process manually rather than automatically by means of a process controller. Thus, controllers typically are provided with means for switching from "automatic" to "manual" operation, and in the latter condition a manually-adjustable constant-magnitude signal is developed to position the process valve. In such systems, a problem is encountered in switching the controller back to automatic condition in that, if the automatic control signal is different from the manual control

signal at the time of switchback, there will be a sudden change in the valve position which can produce an undesirable "upset" of the process, i.e., excessive fluctuations of the controlled process variable.

One method used heretofore to avoid this difficulty was to have the operator bring the measured process condition exactly to set point by adjusting the manual signal just prior to swtichback. Alternatively, the operator could adjust the set point to exactly equal the actual value of the measured condition. However, such "balancing" operations require time and effort, and any error by the operating personnel could have harmful effects particularly with controllers having "derivative" or "rate" action. Moreover, when the controller is provided with means for developing "reset" action (typically by means of a reset capacitor, such as described in the abovementioned Olsen patent), simply making the manual signal equal to the automatic signal will not necessarily prevent a process upset at the time of switching back to automatic operation. That is, while the process is on manual operation, the reset capacitor could be charged up to a level unsuited for the subsequent automatic control of the process. Under such circumstances, after switchback the process variable could fluctuate severely for some time while the reset circuit returns to normal.

In an embodiment of the present invention to be described hereinbelow, a reset controller is provided wherein, on manual operation, the automatic control signal is maintained equal to the manual control signal. This controller also includes means for continuously holding the reset capacitor charged to the proper level for assuring "bumpless" transfer back to automatic operation. To put the system back in automatic after having been on manual, the operator need do no more than throw the transfer switch from manual to automatic, and the process controller will take over to bring the controlled condition smoothly back to set point. Other objects, aspects and advantages of the invention will be in part pointed out in, and in part apparent from, the following description of the preferred embodiment considered together with the accompanying drawing.

Referring now to the drawing, in the upper-left hand corner is shown a condition-sensing device **10** which comprises a transmitter adapted to produce an output current corresponding to the value of a process condition being measured. This transmitter may, for example, be a device of the type disclosed in U.S. Patent 2,956,212, issued to E. Olsen et al. on Oct. 11, 1960, and may include a transistor oscillator and amplifier circuit for developing a D.-C. measurement current (e.g., in the range of 10–50 milliamps) as disclosed in U.S. Patent 3,051,933, issued on Aug. 28, 1962. The output terminals of this transmitter are connected through a two-wire transmission line, consisting of leads **12** and **14**, to the process controller generally indicated at **16**.

This controller includes an input resistor **18** (100 ohms) arranged to produce a measurement voltage (e.g., in the range of 1 to 4 volts) corresponding to the measurement current flowing in leads **12** and **14**. A set point potentiometer **20** is connected to the input resistor **18**, and is energized by a D.-C. power source **22** to produce an adjustable set-point signal in series-opposition to the measur-

ment voltage across resistor **18**. The difference between these two potentials is the "deviation" signal (**24**) having a magnitude corresponding to the extent to which the process condition has varied from its desired value, and a polarity determined by the direction of this variation.

Near the upper right-hand corner of the drawing is shown a two-position "automatic-to-manual" transfer switch **26** for conditioning the controller for either automatic or manual operation. When this switch is in "automatic" position (as shown), the deviation signal **24** is applied, together with a negative feedback signal **28**, to terminals **30** and **32** of an amplifier indicated in block outline at **34**. This input circuit can be traced along lead **36** through switch contact **38** to terminal **36**; and along lead **40** through switch contacts **42** and **44** to terminal **32**.

As described in the above-mentioned U.S. Patent 2,956,234, amplifier **34** may be a self-oscillating transistor circuit arranged to develop at output terminals **46** and **48** a pulsating current corresponding in average magnitude to the amplifier input voltage i.e. the difference in potential between terminals **30** and **32**. The gain of this amplifier is relatively high, e.g., a change in input voltage of minus 10 to plus 10 millivolts will drive the output current through its full range of 10 to 50 ma. with an output load resistance of 600 ohms.

To simplify the disclosure herein, only the final output stage **50** of the amplifier **34** has been shown. This stage is energized by a D.-C. power source **52** and its pulsating output current is filtered by capacitor **53** and fed, as the automatic control signal, through transfer switch contact **54** and a transmission line **56** to a remote valve-operating device generally indicated at **58**. This latter device may be of any conventional construction and may, for example, include a servo mechanism to position a valve in correspondence with the average current fed thereto.

The pulsating output current from amplifier **34** passes through the primary winding of a feedback transformer **60**, the secondary winding of which is connected to rectifiers **62** which develop across a potentiometer **64** and filter capacitor **66** a D.-C. voltage corresponding to the automatic control signal. The potential developed at the movable arm of potentiometer **64** is fed to a reset circuit comprising a series reset capacitor **68** and a shunt reset resistor **70**. The potential developed across resistor **70** is the feed back voltage **28** referred to previously. Any adjustment of the potentiometer **64** will correspondingly change the amount of feedback, and thus will determine the change in valve position for a given change in the measured process condition; for that reason, potentiometer **64** is referred to as the "proportioning-band" potentiometer.

Considering now the overall operation of the controller, if the controlled process condition is stabilized at the desired set point, the deviation signal **24** will be zero, the automatic control signal fed to the valve operator **58** will normally be stabilized at some midrange current level (e.g., 30 milliamps), the voltage developed across the proportioning-band potentiometer **64** will be at a corresponding midrange potential (e.g., 15 volts), and the feedback voltage **28** developed across the resistor **70** will be zero. Assuming now that there is an increase in the output of the transmitter **10**, a corresponding deviation signal **24** will be developed and fed to the input terminals **30** and **32** of the amplifier **34**. Instantaneously, as the output of the amplifier **34** changes in response, the D.-C. voltage developed across potentiometer **64** will change and, since the voltage across the reset capacitor **68** cannot change immediately, a corresponding feedback signal will be developed at **28** to oppose the deviation signal **24**.

The gain of the amplifier is sufficiently high that the feedback signal is substantially equal to the deviation signal. For example, with a deviation signal of 2 volts, the initial feedback signal might be 1.996 volts. Thus, the actual change in input voltage to the amplifier would be only 4 millivolts.

Subsequently, as the reset capacitor **68** charges up through the reset resistor **70** (which normally takes a long time, e.g., up to 30 minutes), the feedback signal **70** tends slowly to decrease and thereby gradually increase the output of the amplifier so as to augment the initial control action. Ultimately, of course, the process condition returns essentially to its set point, thereby reducing the magnitude of the deviation signal **24** and correspondingly reducing the input to the amplifier **34** until a new condition of balance in the process is achieved.

When the automatic-to-manual transfer switch **26** is operated to "normal" position, the D.-C. power source **52** furnishes a manual control signal to the valve-operating device **58**, the current passing through an adjustable "manual set" resistor **72** and transfer switch contact **74**. By changing the resistance of this resistor **72**, the current flowing through the device **58** can correspondingly be altered to shift the position of the process valve. Normally, prior to switchover to manual operation, the manual control signal will be made equal to the automatic control signal, through the aid of conventional meter means, not shown. The automatic control signal, which before switchover was fed to the valve-operating device **58**, now is directed by transfer switch contact **54** to a "dummy load" **76** having the same electrical characeristics as the device **58**.

Connected to the positive terminal of the power source **52**, and in series with the respective supply ciruits furnishing current to the valve-operating device **58** and the dummy load **76**, are two small resistors **78** and **80** (e.g., 75 ohms). The upper ends of these resistors are, when the transfer switch is in manual position, connected through respective leads **82** and **84** to the input terminals **30** and **32** of the amplifier **34**, the connections passing through switch contacts **38** and **44**. The amplifier serves in effect to sense any difference in potential between the leads **82** and **84**. If the manual control signal fed to the device **58** is equal to the automatic control signal being fed to the dummy load **76**, the voltage drop across the resistors **78** and **80** will be equal, and therefore the input voltage to the amplifier **34** will be zero. If there is any difference in current through resistors **78** and **80**, a corresponding voltage will be fed to the input of amplifier **34**. Accordingly, the amplifier output will change correspondingly to maintain the current through the dummy load **76** at a value such that the voltage drop across resistor **78** is again essentially equal to the drop across resistor **80**, i.e., the feedback action tends to produce a "null" at the amplifier input. Thus, it will be apparent that the automatic control signal fed to the dummy load **76** on manual operation will continuously "track" the manual control signal being fed to the valve-operating device **58**. For that reason, the signal fed by resistors **78** and **80** to the amplifier input may be referred to as a tracking signal.

Operation of the transfer switch **26** to its manual position also causes the deviation signal **24** to be fed directly to the reset capacitor **68**, the connection passing through switch contact **42**. Accordingly, the potential of the left-hand plate of the reset capacitor **68** will be maintained at a value equal to the deviation signal. Changes in the output of the amplifier **34** will alter the potential of the right-hand plate of the reset capacitor and thereby change the charge on this capacitor, but will have no effect on the potential of the left-hand plate which varies only with changes in the devitation signal.

When the manual-to-automatic switch **28** is returned to its "automatic" position, the deviation signal **24** and the feedback signal **28** again will be connected together, in series opposition, to the input terminals **30** and **32** of the amplifier **34**. However, since while on manual operation the deviation signal was fed directly to the reset capacitor **68**, at the instant of switchback to "automatic" the feedback signal will be equal to the deviation signal, and

therefore the input to the amplifier **34** will be zero. Consequently, because the amplifier input had previously been held at essentially zero voltage, after switchback to automatic there will be no significant change in the amplifier output current due to the stabilizing action of the negative feedback ciruuit.

Since there can be no immediate change in the amplifier output at switchback to automatic operation, there will be no sudden shift in the position of the valve controlled by device **58**. Thereafter, if the measured process condition differs from the desired set point, the reset capacitor **68** will gradually charge up (or discharge) to tend to reduce the feedback voltage **28** to zero. This in turn will slowly alter the current through the valve-operating device **58** to bring the process condition back to the desired set point smoothly, i.e., at the "reset rate" of the controller. Thus, in accordance with the present invention, inexpensive and reliable means are provided for a assuring "bumpless" transfer from manual to automatic condition.

Although a perferred embodiment of the invention has been set forth in detail, it is desired to emphasize that this is not intended to be exhaustive or necessarily limitative; on the contrary, the showing herein is for the purpose of illustrating the invention and thus to enable others skilled in the art to adapt the invention in such ways as meet the requirements of particular applications, it being understood that various modifications may be made without departing from the scope of the invention as limited by the prior art.

I claim:

[1. A process controller comprising amplifier means having an input circuit to receive a condition-responsive signal and adapted to produce an automatic control signal for transmission to a device for operating a process valve or the like, negative feedback means for said amplifier including energy storage means to develop reset action in said automatic control signal; an adjustable signal source for producing a manual control signal for said operating device; and switch means having "automatic" and "manual" positions, said switch means serving when in "automatic" position to connnect said automatic control signal to said operating device; said switch means serving when in "manual" position to connect said manual control signal to said operating device in place of said automatic control signal, and to connect said condition-responsive signal to said reset means to cause the output of said feedback means to be maintained energized at the level of said signal.]

[2. A process controller as in claim **1**, wherein said condition-responsive signal is a D.-C. voltage representing by its magnitude the deviation between the measured process condition and a set point value thereof.]

[3. A process controller as in claim **2**, wherein said reset means comprises a capacitor in said feedback circuit, said D.-C. voltage being applied directly to one side of said capacitor.]

4. A process controller comprising amplifier means having an input circuit to receive a condition-responsive signal and adapted to produce a corresponding automatic control signal for transmission to a device for operating a process valve or the like, an adjustable signal source for producing a manual control signal for manual operation of said operating device; circuit means for developing a tracking signal corresponding to the difference between said automatic control signal and said manual control signal; switch means having "automatic" and "manual" positions, said switch means being arranged when in "automatic" position to connect said automatic control signal to said operating device; said switch means being arranged when in "manual" position to connect said manual control signal to said device in place of said automatic control signal, and to connect said tracking signal to the input of said amplifier means to maintain said automatic control signal equal to said manual control signal.

5. A process controller as in claim **4**, including a dummy load arranged to receive said automatic control signal when the controller is on manual operation; and voltage-dropping means connected in series with said dummy load and said operating device to develop said tracking signal in accordance with the relative magnitude of current flow therethrough.

6. A process controller comprising an amplifier having an input circuit adapted to receive a condition-responsive signal and arranged to produce a corresponding automatic control signal for transmission to a device for operating a process valve or the like, a negative feedback circuit for said amplifier and including energy storage means to develop reset action in said automatic control signal; an adjustable signal source for producing a manual control signal for said device; circuit means for developing a tracking signal corresponding to the difference between said automatic control signal and said manual control signal; switch means having "automatic" and "manual" positions, said switch means being arranged when in said "automatic" position to connect the output of said amplifier to said operating device; said switch means being arranged when in said "manual" position to (1) connect said manual control signal to said operating device, (2) connect said tracking signal to the input of said amplifier means to cause said automatic control signal to follow said manual control signal, and (3) connect the output of said negative feedback circuit directly to said condition-responsive signal, whereby when the controller is switched back to automatic the amplifier input will be held at substantially zero voltage.

7. A controller as in claim **6**, including a dummy load to which the output of said amplifier is fed when on manual operation; said circuit means comprising voltage-dropping means connected in series with said dummy load and said operating device respectively to develop a tracking signal corresponding to the difference in current flow through said voltage-dropping means.

8. A controller as in claim **6**, wherein said input circuit includes a signal-comparison means to develop a D.-C. deviation signal having a potential corresponding to the difference between the measured condition and a set point value thereof, said deviation signal being fed to said amplifier input together with the negative feedback signal when on automatic operation, said deviation signal being fed directly to the output end of said feedback circuit on manual operation.

9. A controller as in claim **8**, wherein said feedback circuit includes a series reset capacitor and a shunt reset resistor, said deviation signal being connected directly across said reset resistor when on manual operation.

10. A controller as in claim **9**, including potentiometer means connected between said reset capacitor and the output of said amplifier to adjust the proportioning band of the controller.

11. A process controller comprising amplifier means having an input circuit to receive a condition-responsive signal and *an output circuit* adapted to produce an automatic control signal for transmission to a device for operating a process valve or the like, said amplifier being provided with negative feedback means *connected between the output and input circuits and* including energy storage means to develop reset action in said automatic control signal; means for producing a [manually adjustable] *continuous* signal, *said signal-producing means including manually-controllable means for adjusting the magnitude of said continuous signal to any level within a predetermined range;* switch means having "automatic" and "manual" positions, said switch means serving when in "automatic" position to connect said automatic control signal to said operating device; said switch means serving when in "manual" position to [disconnect] *deactivate* said automatic control signal [from said operating de-

vice] and to direct to said operating device *in place thereof* a [manual] *continuous steady* control signal corresponding to said manually-adjustable signal; *first circuit means operable with said switch means in "manual" position to maintain the amplifier output signal in correspondence to said continuous signal, so that said energy storage means receives a corresponding signal from said feedback circuit; and second* circuit means connected by said switch means when in "manual" position for directing to said energy storage means *a signal* [signals] corresponding to [both] said condition-responsive signal [and said manual control signal] to maintain said storage means energized at a level proportional to the combination of said *continuous and said condition-responsive* [last-named] signals.

12. Apparatus as claimed in claim **11**, wherein said switch means is operable in "manual" position to disconnect said condition-responsive signal from said input circuit, said switch means serving when in "manual" position to connect to said input circuit a signal derived from said manually-adjustable signal to produce at the output of said amplifier means a signal corresponding to said manually-adjustable signal, whereby said energy storage means receives a signal corresponding to said manual control signal through said negative feedback means.

13. Apparatus as claimed in claim **11**, wherein said circuit means maintains said storage means energized at a level proportional to the difference between said last-named signals.

14. Apparatus as claimed in claim **11**, wherein said condition-responsive signal is proportional to the difference between the value of the measured process condition and a desired value thereof.

15. In process control apparatus of the type having an amplifier the input of which is adapted to receive a deviation signal together with a feedback signal having a magnitude related to the positioning of a process valve or the like being controlled, said amplifier producing an output signal normally serving to set the valve position automatically such that changes in the deviation signal tend to produce corresponding changes in the valve position, the apparatus including automatic-to-manual switch means which when placed in "manual" position isolates the amplifier input from the influence of said deviation and feedback signals and directs these two signals to storage means to store therein a composite signal level reflecting a combination of both signals for subsequent use in preventing any sudden upset in the controller output upon switchback to "automatic" operation, the apparatus further including an adjustable manual signal source for establishing the value of a control signal for the valve when said switch is in "manual" position;

an improvement in such apparatus of the type wherein said feedback signal is developed directly from the output circuit of said amplifier;

the improvement including circuit means made effective by said switch means when in "manual" position to connect to the input of said amplifier a voltage derived from said manual signal source and responsive to changes in the adjustment thereof; and a negative feedback circuit activated by said switch means when in "manual" position to couple a signal from the amplifier output circuit to the amplifier input circuit in opposition to said voltage derived from the manual signal source and arranged to maintain said amplifier output continuously in correspondence with the set level of said manual signal source, whereby when the system is operating in "manual" mode the feedback signal directed to said storage means from the amplifier output corresponds at all times to the manually set control signal directed to the process valve.

16. In process control apparatus of the type comprising an amplifier having two input terminals and arranged to produce an output signal proportional to the difference in potential between said input terminals, with means normally operative to apply to said input terminals a deviation signal together with a feedback signal having a magnitude related to the positioning of a process valve or the like being controlled, the amplifier output normally serving to set the valve position automatically such that changes in the deviation signal tend to produce corresponding changes in the valve position, the apparatus including automatic-to-manual switch means which when placed in "manual" position isolates the amplifier input from the influence of said deviation and feedback signals and directs these two signals to storage means to store therein a composite signal level reflecting a combination of both signals for subsequent use in preventing any sudden upset in the controller output upon switchback to "automatic" operation, the apparatus further including an adjustable manual signal source for establishing the value of a control signal for the valve when said switch is in "manual" position;

an improvement in such apparatus of the type wherein said feedback signal is developed directly from the output circuit of the amplifier;

the improvement including circuit means made effective by said switch means when in "manual" position to connect to one input terminal of said amplifier a potential derived from said manual signal source and responsive to changes in the setting thereof; and a negative feedback circuit activated by said switch means when in "manual" position to couple to the other amplifier input terminal a potential derived from the amplifier output circuit and tending by negative feedback action to equal said potential derived from the manual signal source, said negative feedback circuit serving to maintain said amplifier output continuously in correspondence with the set level of said manual signal source, whereby when the system is operating in "manual" mode the feedback signal directed to said storage means from the amplifier output corresponds at all times to the manually set control signal directed to the process valve.

17. In process control apparatus of the type having an amplifier the input of which is adapted to receive a deviation signal together with a feedback signal having a magnitude related to the positioning of a process valve or the like being controlled, the feedback signal being transmitted through a circuit including a reset capacitor to produce reset action, said amplifier producing an output signal normally serving to set the valve position automatically such that changes in the deviation signal tend to produce corresponding changes in the valve position, the apparatus including automatic-to-manual switch means which when placed in "manual" position isolates the amplifier input from the influence of said deviation and feedback signals and directs these two signals to said reset capacitor to store therein a composite signal level reflecting a combination of both signals for subsequent use in preventing any sudden upset in the controller output upon switchback to "automatic" operation, the apparatus further including an adjustable manual signal source for establishing the value of a control signal for the valve when said signal is in "manual" position;

an improvement in such apparatus of the type wherein said feedback signal is developed directly from the output circuit of said amplifier;

the improvement comprising circuit means made effective by said switch means when in "manual" position to connect to the input of said amplifier a voltage derived from said manual signal source and responsive to changes in the adjustment thereof; and a tracking feedback circuit activated by said switch

means when in "manual" position to couple a signal from the amplifier output circuit to the amplifier input circuit in opposition to said voltage derived from the manual signal source, said tracking feedback circuit being arranged to maintain said amplifier output in correspondence with the set level of said manual signal source, whereby when the system is operating in "manual" mode the feedback signal directed to said reset capacitor from the amplifier output corresponds at all times to the manually set control signal directed to the process valve.

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