

May 3, 1960

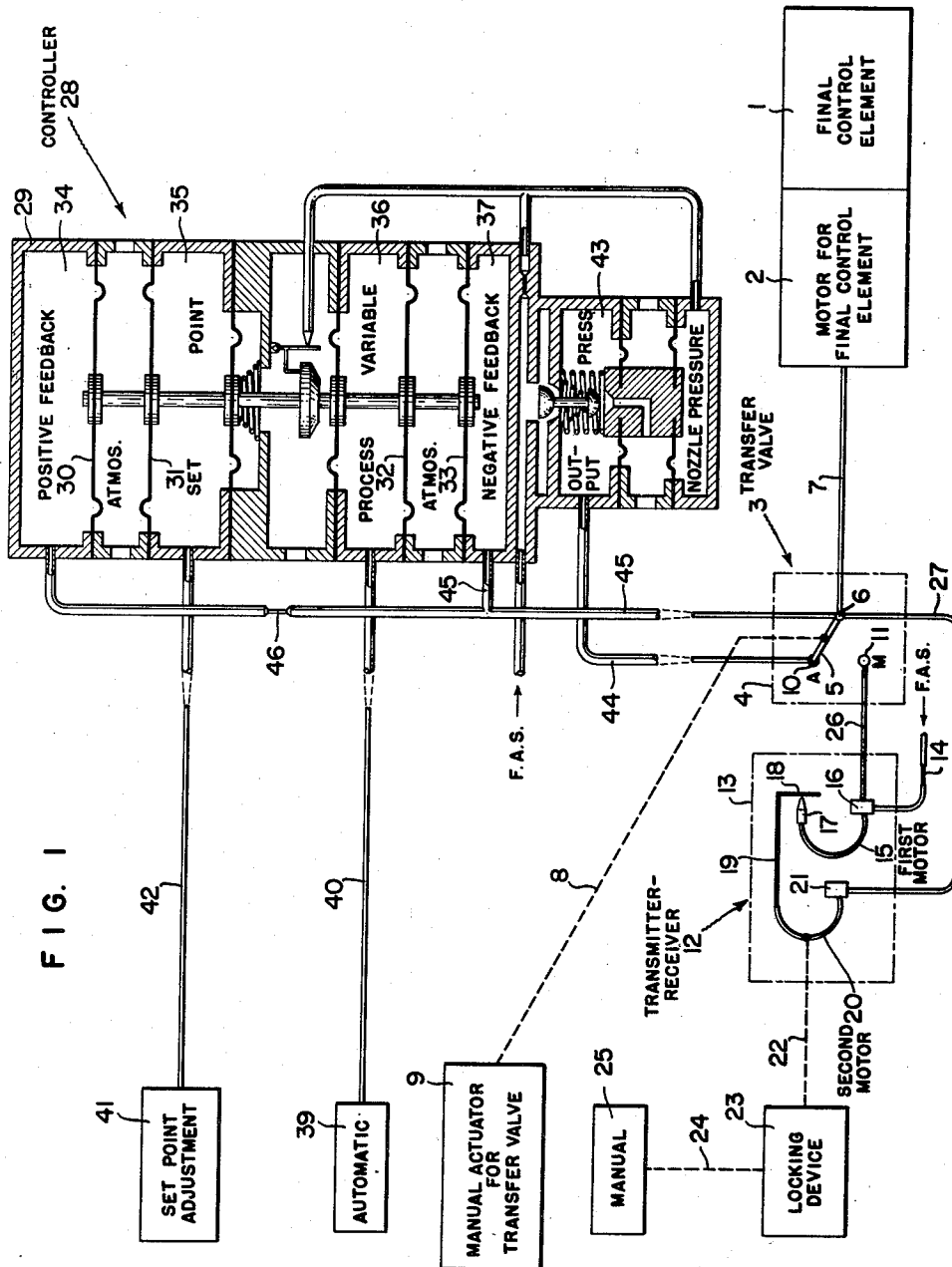
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2,935,077

BUMPLESS MANUAL AUTOMATIC SWITCH

Filed March 1, 1956

6 Sheets-Sheet 1



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BUMPLESS MANUAL AUTOMATIC SWITCH

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6 Sheets-Sheet 3

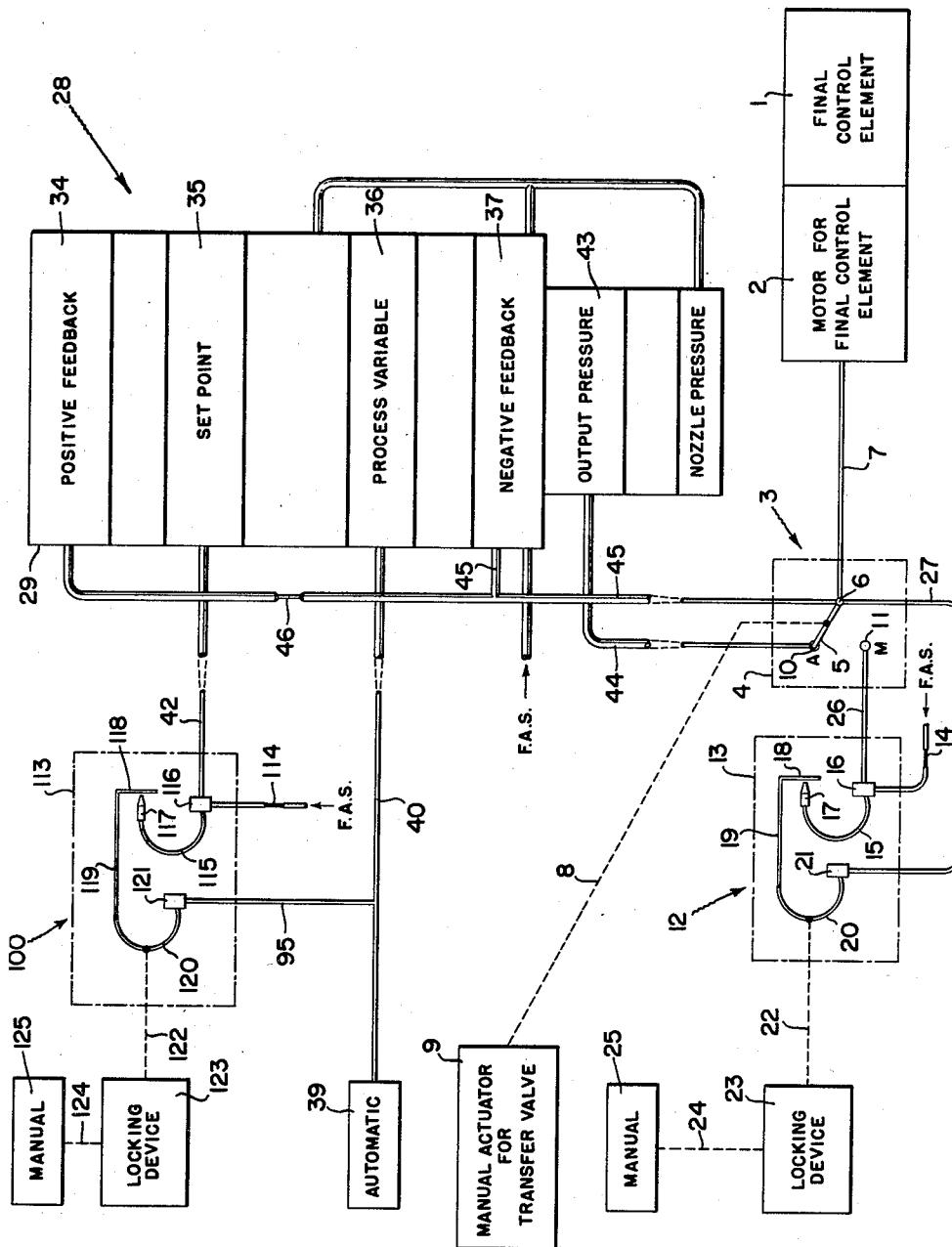


FIG. 3

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6 Sheets-Sheet 4

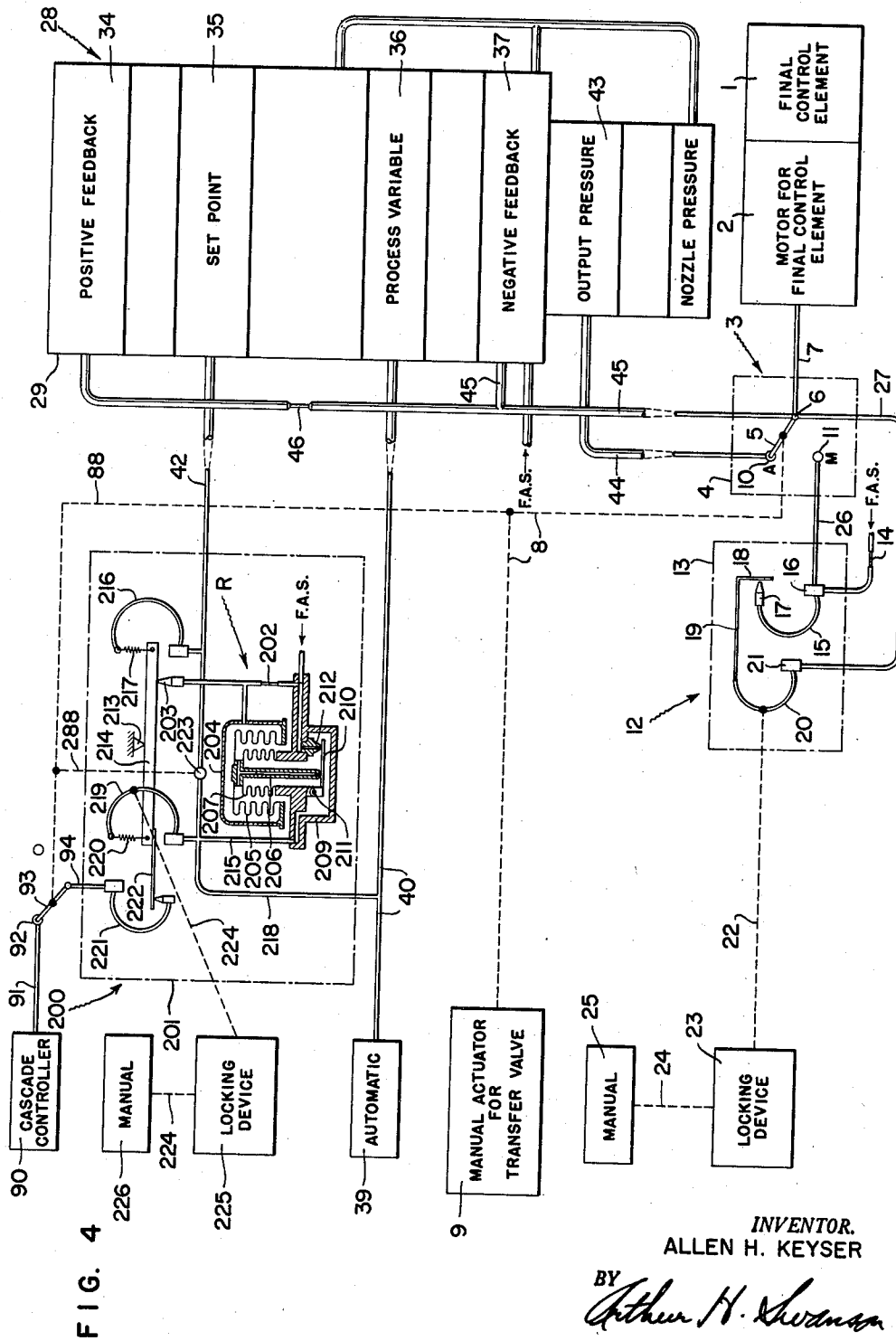


FIG. 4

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BUMPLESS MANUAL AUTOMATIC SWITCH

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6 Sheets-Sheet 5

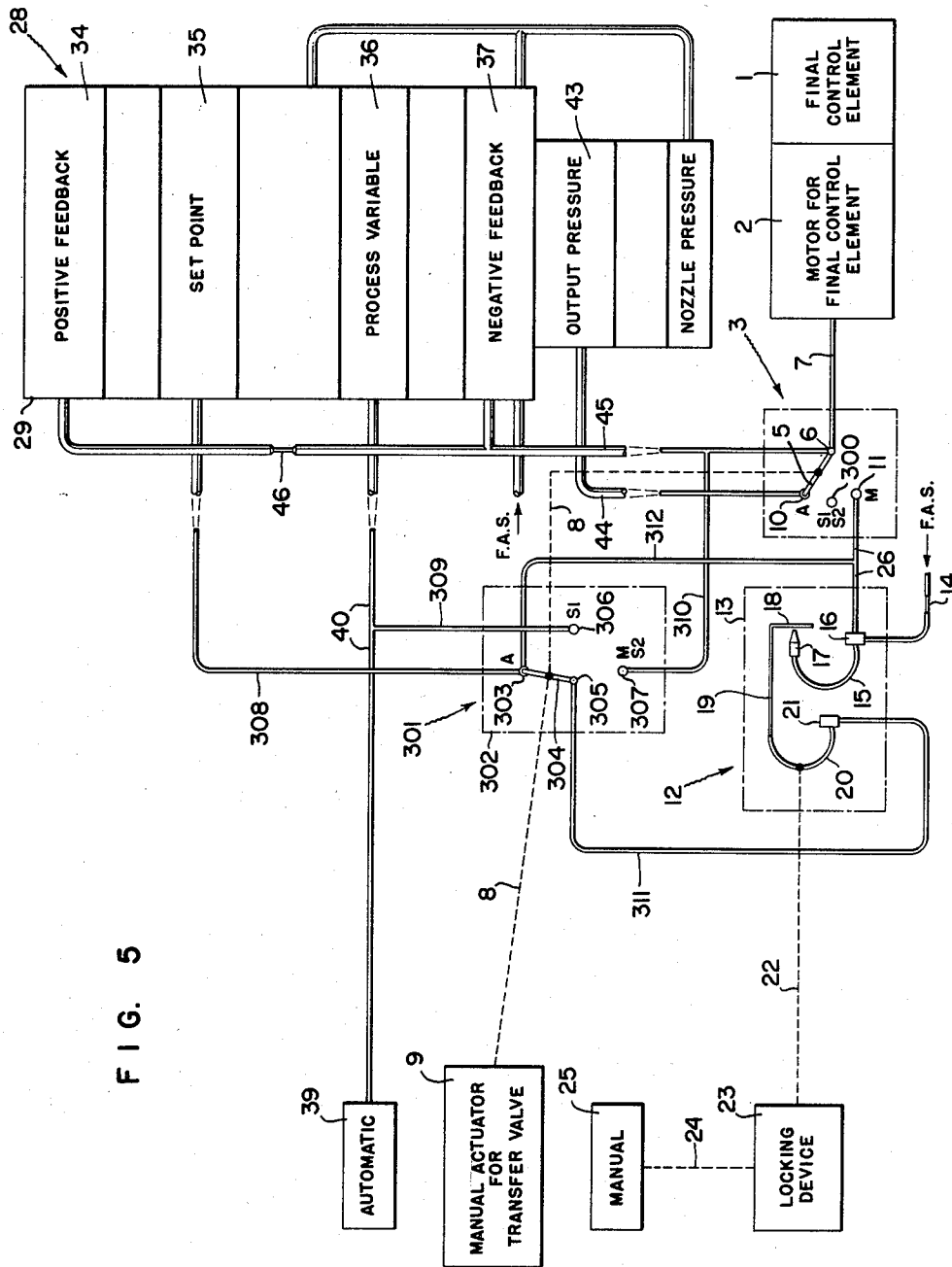


FIG. 5

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6 Sheets-Sheet 6

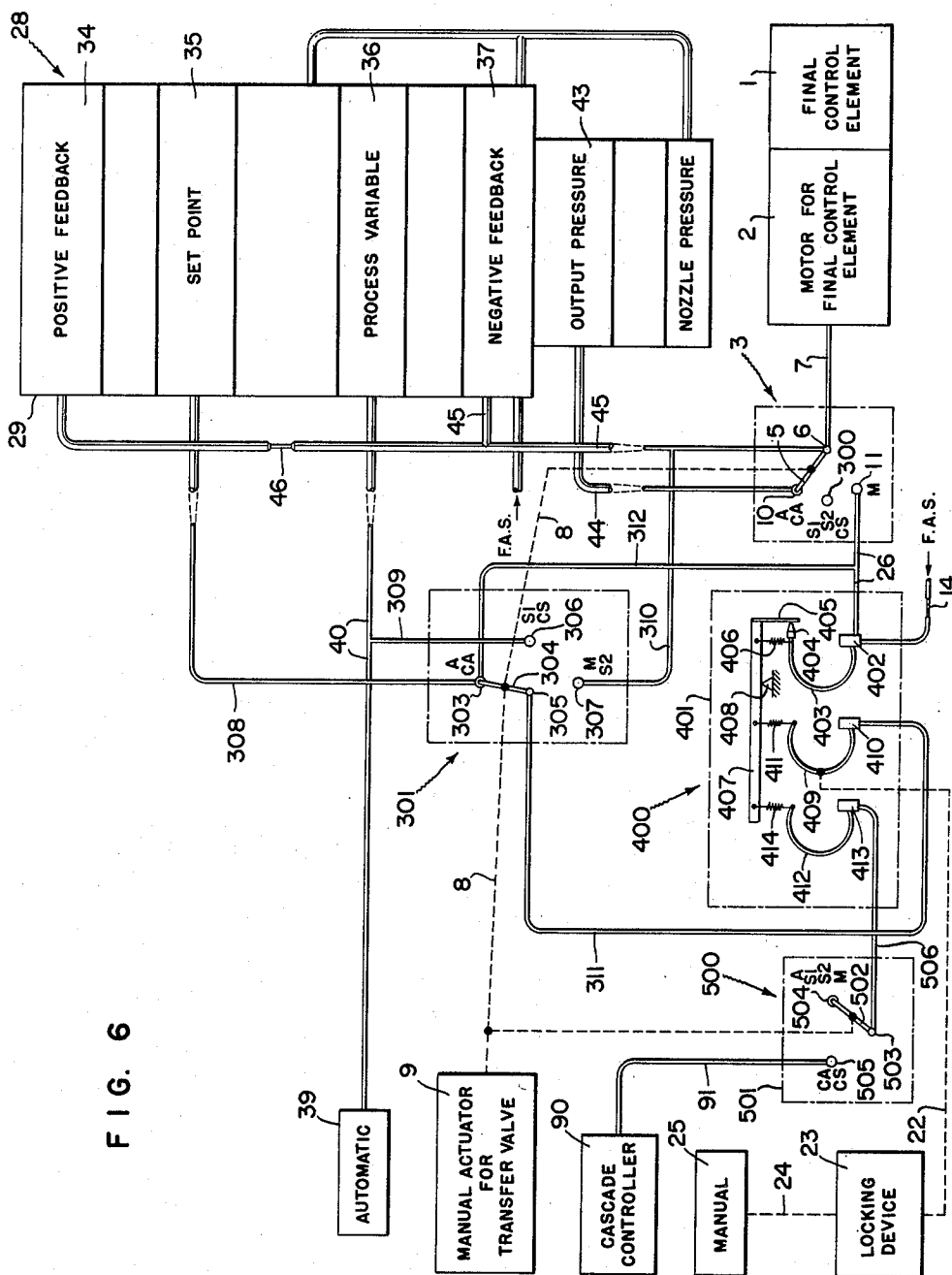


FIG. 6

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BUMPLESS MANUAL AUTOMATIC SWITCH

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Application March 1, 1956, Serial No. 568,782

8 Claims. (Cl. 137—82)

There are well known devices by means of which a valve, or the like, can be operated either manually, under the control of a human operator, or automatically, in response to the deviations of some variable from a set or selected value. These deviations are sensed by a measuring instrument which responds to changes in the chosen variable and converts such changes into variations in an air pressure. This variable air pressure is transmitted to a controller and thence to the air-operated motor for the valve. The manually operable means are similar and comprise, in their simplest form, a manually-operable valve for causing variations in an air pressure which is applied, either directly or after it has been amplified, to the air-operated motor for the valve. It is likewise known to include in the means for automatically operating the valve what is known as "cascade" control. In the "cascade" type of control, two controllers are employed, each responding to a different variable. One of these controllers is connected so as to adjust the set point of the other controller.

It is an object of this invention to provide means whereby the control of the valve may be transferred from the manual means to the automatic means or vice versa without disturbance of the position of the valve at the time transfer is made. This is particularly advantageous if the valve constitutes the final control element of apparatus controlling an industrial process because changes in the position of such a valve cause changes in the industrial process. These changes cannot be quickly eliminated and consequently there is a disturbance of the process under control and the resulting loss of efficiency.

More specifically, it is an object of this invention to provide a valve constituting the final control element of an industrial process and having an air-pressure-operated motor for operating it; manually-actuated air-pressure-operated means for operating said motor and said valve; automatically-actuated air-pressure-operated means for operating said motor and said valve; a transfer valve for taking the control of the valve away from the manually-actuated means and giving the control to the automatically-actuated means, or vice versa, in which the manually-actuated means includes: a transmitter-receiver having a first air-pressure-operated motor; a second air-pressure-operated motor; valve arrangements for maintaining the air pressures in said motors equal; and a handle, or the like, constituting means for operating one of said motors by hand.

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:

Figs. 1-6 each is a block diagram or schematic show-

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ing of one modified circuit arrangement for actuating a final control element.

In these drawings, the solid lines represent pipes or other connections for air under pressure. The dotted lines represent mechanical connections. The dot-and-dash lines represent the casing or other container in which various individual units are mounted. In each of these figures the circuit is shown in the automatic position.

Fig. 1 shows a final control element, such as a valve, and a motor 2 for actuating this final control element. Motor 2 may well be a diaphragm attached to the stem or actuating member of the valve and adapted to be exposed on one face to an air pressure and to be engaged, on the opposite face, by a spring.

The supply of air for actuating motor 2 is controlled by means of a transfer valve 3. This transfer valve comprises the parts enclosed within the dot-and-dash lines 4. A movable, air-conducting conduit 5 is pivoted at 6 and is connected to a conduit 7 which communicates with motor 2. By means of a connection 8, conduit 5 is connected to handle 9 which constitutes a manual actuator for the transfer valve. In automatic position, movable conduit 5 communicates with a stationary, air-conducting port 10 marked A to indicate that it communicates with conduit 5 when the device is in automatic position and is otherwise closed. Transfer valve 4 also includes another, stationary, air-conducting port 11 which is marked M to indicate that it communicates with conduit 5 when the device is in the manual position and is otherwise closed.

The manually-actuated means for operating valve 1 also include a transmitter-receiver, generally indicated at 12, and comprising the parts enclosed within the dot-and-dash line 13. Transmitter-receiver 12 forms the subject matter of a United States patent filed April 20, 1955 by Harold E. Eller and Robert D. Schmitt, No. 2,763,278. Transmitter-receiver 12 comprises a filtered air supply F.A.S. communicating through a restriction 14 with a first motor comprising a hollow Bourdon tube 15 having a stationary end 16 and a perforated, movable end 17 forming a nozzle cooperating with a flapper 18, or like valve, mounted on the movable end 19 of a second motor comprised by a Bourdon tube 20 having a stationary end 21. A mechanical connection 22 is connected to Bourdon tube 20 and connects to a locking device 23. A second mechanical connection 24 connects to a handle 25, which forms the manual actuator for valve 1. The stationary end 16 of the first motor 15 is connected by a conduit 26 to port 11. The stationary end 21 of second motor 20 is connected by conduit 27 to pivot 6 and pipe 7.

The automatically-actuated means for operating valve 1 include a controller, generally indicated at 28. Controller 28 is of the stack type. Such stack type controllers are well known in the art. Examples are U.S. Patent 1,991,309 to D. H. Annin and U.S. Patent 2,518,244 to C. B. Moore. In general, such stack type controllers comprise a rigid casing 29 divided by flexible diaphragms 30, 31, 32, and 33 into separate compartments or chambers each having a diaphragm as a movable wall thereof. The air pressure in chamber 34 opposes the air pressure in chamber 37. Chamber 34 is known as the positive feedback pressure chamber while chamber 37 is known as the negative feedback pressure chamber. An air pressure, which varies in response to the changes in the measured or process variable, is fed to chamber 36. This air pressure is supplied by means of a measuring instrument, which responds to changes in the process variable to which the valve 1 is to respond. These changes are measured by a measuring instrument, which converts the changes in the variable to changes in an air pressure and transmits them to chamber 36. Such measuring instruments and such means for converting

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them into changes in air pressure are well known. Examples are to be found in U.S. Patents 2,216,448 and 2,311,853, both to C. B. Moore. Therefore, such a measuring instrument is not illustrated in detail herein save by the block 39, which is marked "Automatic." Conduit 40 conducts the air pressure from the automatically-actuated measuring instrument 39 to the process variable pressure chamber 36.

The pressure of air in chamber 35 opposes the pressure of air in chamber 36. Air pressure is supplied to chamber 35 at a selected value by means of a set point adjustment 41 and a conduit 42. Such a set point adjustment may constitute a manually-actuated, air-pressure regulator, which is well known in the art and which is not illustrated herein in detail.

If the pressure in chamber 36 varies from the pressure in chamber 35, the output pressure of the controller in chamber 43, is varied and is transmitted by conduit 44 to the transfer valve 3. When the transfer valve 3 is in automatic position, pipe 44, conduit 5, and pivot 6 are connected to pipe 45 which conducts the air pressure applied to motor 2 to chamber 37 and, through restriction 46, to chamber 34. When the pressures in chambers 35 and 36 and in chambers 34 and 37 are equal, the controller 28 is in its balanced or normal position and the output pressure in chamber 43 and pipe 44 is at a selected ratio to the instantaneous value of the measure variable, as represented by the air pressure in set point pressure chamber 35. This is the condition of the controller 28 in the automatic position in which the device is shown in Fig. 1.

The operation of the device is as follows. In the automatic position shown in Fig. 1 any change in the process variable to which the measuring instrument 39 responds actuates the controller 28 and causes a variation in its output pressure. This output pressure passes through chamber 43 to pipe 44, conduit 5, pivot 6, and pipe 7 to the air-operated motor 2 for the valve or final control element 1. This moves valve 1 to an adjusted position. Simultaneously, the output pressure from controller 28 is fed through pipe 45 to chamber 37 and through restriction 46 to chamber 34. When the pressures in chambers 34 and 37 equalize, the controller again resumes its balanced or normal position. Simultaneously, the output pressure of controller 28 is fed from chamber 43 through pipe 44, conduit 5, pivot 6, and pipe 27 to second motor 20. Any variation in the pressure applied to second motor 20 causes its free end 19 to move. Consequently, flapper 18 moves relative to nozzle 17 on the free end of the first motor 15. Any movement of flapper 18 relative to nozzle 17 varies the pressure in first motor 15 and, consequently, the pressure applied from the source F.A.S. through restriction 14 and pipe 26 to stationary port 11. The motor 15 causes the nozzle 17 to follow the flapper 18 and to maintain a constant distance between the flapper 18 and the nozzle 17. Therefore, the pressures in motors 20 and 15 are equal.

Since the pressures in motor 20 and 15 are equal, the pressure in port 11 is equal to the pressure in motor 2. Consequently, handle 9 can be actuated to cause mechanical connection 8 to shift conduit 5 out of engagement with port 10, which is closed as a result, and into engagement with port 11, which is opened as a result. Since the pressure presently applied to motor 2, when the device is still in automatic position, is equal to the pressure applied to motor 2, when the device is shifted into manual position, this transfer of the control or governance of motor 2 and valve 1 can be made without changing the position of valve 1 and without disturbance to the process under the control of valve 1.

When the device is in manual position, the locking device 23 is unlocked. Handle 25 may then be operated by hand and causes second motor 20 to move regardless of the air pressure within it. Movement of the free end of second motor 20 causes flapper 18 to

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move relative to nozzle 17 and thereby varies the air pressure within the first motor 15. In manual position, air pressure within the first motor 15 is connected to its stationary end 16, pipe 26, port 11, conduit 5, pivot 6, pipe 27, and stationary end 21 to second motor 20. The pressure within motor 20 is therefore equalized with the pressure within motor 15 and any mechanical strain on the second motor 20 is relieved.

While still in manual position, in order to switch to automatic position, it is first necessary to adjust the set point adjustment 41 by hand so that the pressure in chamber 35 is equal to the pressure in chamber 36. Then, the handle 9 can be operated by hand to cause the transfer valve 3 to close the port 11 and to connect the port 10 to the motor 2. This can be done immediately without any intermediate stops or manual adjustments.

Fig. 2 shows an air-operated circuit very similar to that disclosed in Fig. 1 with the addition of cascade operation. Those elements of the device of Fig. 2 which are the same as the elements of Fig. 1, have been given the same reference characters. Only the following differences are to be noted. Adjacent port 10 is marked the letter A, adjacent port 11 is marked the letter M and adjacent port 47 are marked the letters CS and S. This will be explained hereinafter. Mechanical connection 8, which connects to the handle 9, which forms the manual actuator for the transfer valve 3, has a branch connection 88 which connects with a movable, air-conducting conduit 93 which, in the automatic position shown in Fig. 2, engages stationary valve stop 89. A second controller, which may be in every respect like controller 28, is indicated at 90 and connects, by conduit 91, to the stationary, air-conditioning port 92 adjacent which the letters CA and CS are marked. Controller 90, when the device is connected in the cascade position, operates the set point adjustment 41 and consequently varies the pressure in the set point pressure chamber 35 of controller 28.

The mode of operation of the device of Fig. 2 is as described in connection with Fig. 1 with the following differences. If it is desired to switch from automatic position to cascade position, the handle 9 is operated so that the transfer valve 3 is actuated and conduit 5 is moved out of engagement with port 10, which is closed, and into engagement with stop 47. This is the cascade seal position denoted by the letters CS. In the cascade seal position, the pressure in motor 2 is locked in motor 2, in second motor 20, and in chambers 37 and 34. When handle 9 is operated to move conduit 5 it moves movable conduit 93 by means of connection 88 at the same time. Conduit 93 is moved out of engagement with stop 89, with which it was engaged in the automatic position, as indicated by the letter A, and into engagement with the stationary port 92, with which it engages in the cascade seal position, as indicated by the letters CS. The controller 90 is then manually adjusted so that its output pressure is transmitted through pipe 91, port 92, conduit 93, pipe 94, set point adjustment 41, and pipe 42 to the set point pressure chamber 35. By means of the set point adjustment of second controller 90 (not shown), the pressure in set point chamber 35 can be adjusted to equal the pressure in the process variable pressure chamber 36. Handle 9 can then be operated so as to leave conduit 93 in engagement with port 92 in the cascade automatic position, indicated by the letters CA. Simultaneously, conduit 5 is moved by handle 9 and mechanical connection 8 from engagement with stop 47 and into engagement with port 10, so that the output of controller 28 is fed to motor 2. If it is desired to switch from automatic position from cascade automatic position, handle 9 is operated so that conduit 5 disengages from port 10 and engages with stop 47. Simultaneously, conduit 93 is disengaged from port 92 and engaged with stop 89. This is the seal position, indicated by the letter S. Set point adjustment 41 is then operated so as to adjust the

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pressure in set point chamber 35 to equal the pressure in the process variable pressure chamber 36. Handle 9 can then be operated again to disengage conduit 5 from stop 47 and to engage conduit 5 with port 10 so that the output of controller 28 is fed to motor 2.

Fig. 3 shows means similar to that shown in Fig. 1 for actuating a final control element and in which the same elements have been given the same reference characters. The difference is that a second transmitter-receiver 100 is employed to adjust the set point of controller 28. This transmitter-receiver, generally indicated at 100, comprises the parts enclosed within the dot-and-dash line 113. Transmitter-receiver 100 forms the subject matter of a United States patent filed April 20, 1955 by Harold E. Eller and Robert D. Schmitt, No. 2,763,278. Transmitter-receiver 100 comprises a filtered air supply F.A.S. communicating through a restriction 114 with a first motor comprising a hollow Bourdon tube 115 having a stationary end 116 and a perforated, movable end 117 forming a nozzle cooperating with a flapper 118, or like valve, mounted on the movable end 119 of a second motor comprised by a Bourdon tube 120 having a stationary end 121. A mechanical connection 122 is connected to Bourdon tube 120 and connects to a locking device 123. A second mechanical connection 124 connects to a handle 125, which forms the manual actuator for transmitter-receiver 100. The stationary end 116 of the first motor 115 is connected by a conduit 42 to set point pressure chamber 35. The stationary end 121 of second motor 120 is connected by conduit 95 to conduit 40 which conducts the air pressure from the automatically-actuated measuring instrument 39 to the process variable pressure chamber 36.

The advantage of using this second transmitter-receiver 100 to adjust the set point of controller 28 is that, since the second motor 120 of second transmitter-receiver 100 is connected by means of pipe 95 to pipe 40, which forms the output from the measuring instrument 39, the pressure in second motor 120 is maintained equal to the pressure in process variable chamber 36. Therefore, the control or governance of the final control valve 1 can be transferred from manual to automatic or vice versa, without a disturbance to the process under the control of valve 1.

Fig. 4 shows an apparatus by means of which valve 1 can be actuated manually, automatically, or automatically by two controllers in cascade. This apparatus is the same as that of Fig. 2 except that a novel form of transmitter-receiver is used between the second controller 90, which gives the cascade mode of operation, and the first controller 28, which is used to control the final control element 1 automatically. This second transmitter-receiver is generally indicated at 200. It comprises the subject matter of a United States patent by Harold E. Eller, No. 2,884,939, issued May 5, 1959. In general, this controller comprises the parts enclosed within the dot-and-dash lines 201. A filtered air supply F.A.S. is connected to a relay, generally indicated at R, and comprising a restriction 202 leading to a nozzle 203. Nozzle 203 is connected through a stationary wall 204 to a motor comprised by a bellows 205 whose free end carries a perforated, T-shaped, exhaust port 206. A smaller, sealing bellows 207 surrounds the stem or vertical leg of the exhaust port 206 and connects to a stationary casing 209. The lower end of the vertical leg of exhaust 206 engages a flapper 210 pivoted at 211. The free end of flapper 210 bears against an inlet port 212 directly connected to source F.A.S.

A stationary pivot 213 supports a beam 214. The output of relay R is connected by means of pipe 215 with the stationary end of first motor 216 formed by a Bourdon tube. The free end of first motor 216 is connected by a spring 217 to beam 214. A pipe 218 connects the output pipe 40 to the stationary end of a second motor 219 whose free end is connected by means

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of a spring 220 to a beam 214. A third motor 221 is connected at its free end by means of a leaf spring 222 to beam 214. Pipe 94 leads to the stationary end of third motor 221 from movable conduit 93. Conduits 215 and 218 communicate with one side of a valve 223 which is located between the stationary ends of first motor 216 and of second motor 219. Valve 223 is connected by a mechanical connection 288 to connection 88, which, in turn, connects the mechanical connection 8 so that it can be actuated by handle 9, which forms the manual actuator for the transfer valve. The second motor 219 is connected by a mechanical connection 224 to a locking device 225 and to a handle 226 which provides means for moving second motor 219 when the locking device is disengaged.

Fig. 4 shows the device in the automatic position. This device can be switched directly from manual to automatic to cascade position or vice versa. It is not necessary to vary any of the air pressures manually nor to match any air pressures by observing gauges to insure that the air pressures are equal. This is due to the fact that the second motor 20 of transmitter-receiver 12 is always connected to motor 2 so that the pressure in second motor 20 is always equal to the pressure in motor 2 and, consequently, conduit 5 can be switched out of engagement with port 10 and into engagement with port 11 without changing the pressure applied to motor 2. Likewise, since second motor 219 of transmitter-receiver 200 is connected to measuring instrument 39, the pressure in second motor 219 is always equal to the output pressure of relay R which is fed to set point pressure chamber 35 by means of pipe 42. Therefore, the output of controller 28 is always equal to the instantaneous value measured by measuring instrument 39.

Fig. 5 shows a device for actuating a final control valve 1 either manually or automatically. In this device, the transmitter-receiver 12 is used, not only to actuate valve 1 manually, but also to adjust the set point of controller 28 when the device is in automatic position. This permits the control or governance of valve 1 to be transferred directly from manual to automatic or vice versa. Two intermediate stops are required in order to do this. However, it is not necessary to manually adjust any air pressures while in these stop or seal positions. When the device is in stop or seal position the motor 2 is disconnected from the controller 6 and from transmitter-receiver 12. Therefore, the motor 2 is not actuated either manually or automatically.

To secure these results, the transfer valve 3 is provided with a stop 300 located intermediate port 10, which is open in the automatic position, as indicated by the letter A, and port 11, which is open in the manual position, as indicated by the letter M. The letters S1 and S2 applied to the stop 300 indicate that conduit 5 engages with stop 300 in the first and second seal positions.

In addition to transfer valve section 3, a second transfer valve section, generally indicated at 301, is employed. Transfer valve section 301 comprises the parts enclosed within the dot-and-dash lines 302. This transfer valve section comprises a stationary port 303, which is open in automatic position, as is indicated by the letter A. A movable valve conduit 304 is pivoted at 305 so that it can engage with port 303 or with a port 306 which is open in the first seal position, as indicated by the letters S1 applied to it. A third port 307 is open in the second seal position and in the manual position, as is indicated by the letters S2 and M applied to port 307. Port 303 is connected to set point pressure chamber 35 by conduit 308 and by conduit 312 with pipe 26. Port 306 is connected to pipe 40 by conduit 309. Port 307 is connected to pipe 45 by conduit 310. Movable valve conduit 304 is connected at its pivot 305 with the stationary end 21 of second motor 20 by means of conduit 311.

The sequence of operations in transferring the control or governance of valve 1 from manual to automatic control is as follows. In the manual position, transmitter-receiver 12 is actuated by handle 25 since locking device 23 is disengaged. Handle 25, by means of mechanical connections 24 and 22, moves second motor 20 regardless of the pressure existing within the second motor 20 and causes flapper 18 to move relative to nozzle 17 and consequently to vary the output pressure from source F.A.S. through restriction 14, pipe 26, port 11, conduit 5, and pipe 7, to motor 2. The air pressure in motor 2 is also applied through pipe 7, pivot 6, pipe 45, pipe 310, port 307, conduit 304, pivot 305, pipe 311, and stationary end 21 to second motor 20. The air pressure in second motor 20 is therefore equal to the air pressure in first motor 15. Handle 9, which forms the manual actuator for transfer valve sections 3 and 301, is then actuated so that mechanical connection 8 moves conduit 5 out of engagement with port 11, which is closed, and into engagement with stop 300. However, conduit 304 is not moved out of engagement with port 307 but remains in engagement therewith, as is indicated by the letters S2 applied to port 307. The device is therefore in the second seal position in which the manually adjusted air pressure from port 11 is cut off from motor 2 but in which the air pressure in motor 2 is applied to second motor 20 of transmitter-receiver 12.

Handle 9 is then actuated again but conduit 5 is not moved out of engagement with stop 300. However, conduit 304 is moved out of engagement with port 307 and into engagement with port 306. This is the first seal position, as is indicated by the letters S1 applied to stop 300 and to port 306. In this first seal position the air pressure in motor 2 is still cut off from the transmitter-receiver 12 but the second motor 20 of transmitter-receiver 12 is now connected to the measuring instrument 39 by means of pipe 40, pipe 309, port 306, conduit 304, pivot 305, and pipe 311. The air pressure in pipe 40 therefore actuates second motor 20 and causes flapper 18 to move relative to nozzle 17 so as to adjust the pressure in first motor 15 to equal the pressure in second motor 20. First motor 15 is connected from its stationary end 16 through pipe 26, pipe 312, port 303, and pipe 308, to set point chamber 35. Therefore, the pressure in set point chamber 35 is made to equal the pressure in process variable chamber 36. This causes the output pressure of controller 28 in pipe 44 and port 10 to equal the pressure locked in motor 2.

Handle 9 is moved once again. This causes conduit 5 to move out of engagement with stop 300 and into engagement with port 10, which is opened, so that the output pressure of controller 28 is fed from pipe 44 to motor 2. Simultaneously, conduit 304 is moved out of engagement with port 306, which is closed, and into engagement with port 303, which is opened. This is the automatic position, as is indicated by the letter A applied to the ports 10 and 303. In this automatic position, the handle 25 forms the set point adjustment. This is accomplished by disengaging the locking device 23 so that handle 25 can be moved manually so as to cause mechanical connections 24 and 22 to move second motor 20 and thereby vary the pressure in first motor 15. The pressure in first motor 15 is transmitted from source F.A.S. through restriction 14, stationary end 16, pipe 26, pipe 312, port 303, and pipe 308 to the set point pressure chamber 35 so that the pressure in chamber 35 can be varied to indicate a desired value of the process variable which it is desired to be maintained. Simultaneously, the pressure in first motor 15 is fed from port 303, conduit 304, pivot 305, pipe 311, and stationary end 21 to second motor 20. This relieves the mechanical stress in second motor 20 due to the movement of handle 25 causing second motor 20 to assume a position other than that which second motor 20 would assume due to the air pressure within it and equalizes the air pressures in motors 20 and 15.

Fig. 6 shows means by which valve 1 may be actuated manually, automatically, or by two controllers in cascade. In this modification, a single transmitter-receiver is used both to actuate the valve 1 manually, when the device is in manual position, or to actuate the set point of controller 28, when the device is in automatic position. These results are achieved by an arrangement very similar to that of Fig. 5 but in which the transmitter-receiver has a third motor in it.

In this device, the transmitter-receiver, generally indicated at 400, comprises the parts enclosed within the dot-and-dash lines 401. A filtered air supply F.A.S. is connected through restriction 14 to the stationary end 402 of the first motor 403 formed of a Bourdon tube having a nozzle 404 at its free end cooperating with a flapper 405 and connected by a spring 406 to a beam 407 mounted on a stationary pivot 408. A second motor 409 is formed of a Bourdon tube having a stationary end 410 and a movable end connected by a spring 411 to beam 407. A third motor 412 is formed of a Bourdon tube having a stationary end 413 and a movable end connected by a spring 414 to beam 407.

In addition to the transfer valve sections 3 and 301, this device is provided with a transfer valve section 500 comprising the parts enclosed within the dot-and-dash lines 501. These parts consist of a movable valve conduit 502 pivoted on a stationary pivot 503; the stationary valve port 504 connected to atmosphere or vent; and a stationary valve port 505 connected by pipe 91 to a second controller 90 which cooperates with controller 28 to actuate final control valve 1 in cascade.

By means of this device the control or governance of final control valve 1 can be switched directly from manual to automatic to cascade automatic or vice versa. Between these positions stops must be made but it is not necessary to manually vary any of the air pressures while in these stop or seal positions. Transmitter-receiver 400, when the device is in manual position, may be manually actuated to control the final control valve 1 and, when the device is in automatic or in cascade automatic position, may be manually actuated to supply the set point pressure to chamber 35.

The sequence of operations in transferring the governance or control of final control valve 1 from manual to automatic to cascade automatic is as follows. In manual position, the handle 25 may be actuated by hand, since the locking device 23 is disengaged, so as to move second motor 409 by means of mechanical connections 24 and 22. Mechanical movement of second motor 409 causes beam 407 to rock about its pivot 408 and to move flapper 405 relative to nozzle 404 and thereby vary the pressure in pipe 26. The pressure in pipe 26 is transmitted through port 11, conduit 5 and pipe 7 to motor 2. This pressure is also transmitted from motor 2 through pipe 7, pivot 6, pipe 45, pipe 310, port 307, conduit 304, pivot 305, and pipe 311 to second motor 409. This can be accomplished because the parts are in the manual position indicated by the letter M applied to ports 11, 307, and 504.

Handle 9, which forms the manual actuator for the transfer valve sections 3, 301, and 500, can then be moved by hand. Conduit 5 is moved out of engagement with port 11, which is closed, and into engagement with stop 300. Conduit 304 is not moved out of engagement with port 307. Conduit 502 remains in engagement with port 504. This is the second seal position indicated by the legend S2 applied to stop 300 and to ports 307 and 504. In this second seal position, the pressure in motor 2 is disconnected from port 11 and is locked in motor 2 and in chambers 34 and 37 and in second motor 409.

Handle 9 may then be moved. Conduit 5 remains in engagement with stop 300. Conduit 304 is moved out of engagement with port 307, which is closed, and into engagement with port 306, which is opened. Conduit 502 remains in engagement with port 504. This is the first seal position indicated by the legend S1 applied to stop

300 and to ports 306 and 504. In the first seal position, the air pressure is still locked in motor 2, the second motor 409 is disconnected from the pressure locked in motor 2 and is connected by means of stationary end 410, pipe 311, pivot 305, conduit 304, port 306, pipe 309, and pipe 40 with process variable pressure chamber 36 of controller 28. The pressure in second motor 409 is therefore governed by the measuring instrument 39. Second motor 409 actuates beam 407 and moves flapper 405 relative to nozzle 404 and thus causes the pressure in first motor 403 to become equal to the pressure set up by the measuring instrument 39 because the pressure in first motor 403 is equal to the pressure in second motor 409. The first motor 403 is connected by means of its stationary end 402, pipe 26, pipe 312, stationary port 303, and pipe 308 with the set point pressure chamber 34 of controller 28. The pressure in chamber 35 is therefore made to equal the pressure in chamber 36. This places the controller 28 in its normal or balanced position so that the motor 2 may be connected to the output pressure from controller 28 by means of pipe 44 and port 10 without movement of final control valve 1 and the consequent disturbance to the process under the control of valve 1.

Handle 9 is next caused to move conduit 5 away from stop 300 and into engagement with port 10, which is opened. Conduit 304 is moved out of engagement with port 306, which is closed, and into engagement with port 303, which is opened. Conduit 502 remains in engagement with port 504. In this automatic position, indicated by the letter A applied to ports 10, 303, and 504, the handle 25 may be actuated so as to cause the transmitter-receiver 400 to vary the pressure in set point pressure chamber 35. The pressure in chamber 35 is also fed back to second motor 409 so that the pressure in first motor 403 is equal to the pressure in second motor 409.

In order to switch from automatic position to cascade automatic position, it is first necessary to actuate handle 9 so that the parts assume the first seal position indicated by the legend S1 applied to stop 300, to port 306, and to port 504.

Handle 9 can then be actuated so that the device assumes the cascade seal position designated by the legend CS applied to the stop 300 and to the ports 306 and 505. In this cascade seal position, the output pressure from the second controller 90 is applied through pipe 91, port 505, conduit 502, pivot 503, and pipe 506 to the stationary end 413 of the third motor 412. In this cascade seal position, third motor 412 actuates beam 407 in response to the output pressure of the second controller 90 and thereby causes the pressure in first motor 403 to be governed by the second controller 90. The pressure in motor 403 is transmitted from source F.A.S. through its stationary end 404, pipe 26, pipe 312, port 303, and pipe 308 to the set point pressure chamber 35 of controller 28. Therefore, the pressure in set point pressure chamber 35 is governed by the second controller 90. Therefore, the output pressure of the first controller 28 is equalized with the pressure locked in the motor 2.

Handle 9 may then be actuated so as to move conduit 5 out of engagement with stop 300 and into engagement with stationary port 10. Conduit 300 is simultaneously moved out of engagement with port 306 and into engagement with port 303. Conduit 502 remains in engagement with port 505.

In transferring the governance or control of the final control valve 1 from cascade automatic to automatic to manual, the handle 9 is actuated so as to operate the transfer valve sections 3, 301, and 500 in the opposite sequence.

While, in accordance with the provisions of the statutes, I have illustrated and described the best form 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. In an air-pressure-operated mechanism for operating a final control element, means for shifting automatically between automatic actuation and manual actuation and cascade-automatic actuation without disturbing the pressure of the air being impressed on the final control element at the time of the shift, said means including, a first air-pressure-operated controller having a set point chamber therein responsive to a set point pressure representing that value of the process variable which it is desired that said controller maintain, an automatically or manually actuated transmitter-receiver, a first air-pressure-operated motor in said transmitter-receiver and adapted for connection to a supply of air under pressure, a second air-pressure-operated motor in said transmitter-receiver and connected to the final control element, valve means connected between and actuated upon relative movement of said first and second motors so as to vary the pressure of the air being impressed on said first motor in such a sense as to cause said first motor to follow the movements of said second motor, a manually or automatically actuated set point adjustment means connected to said set point pressure chamber, and transfer valve means having a first part connected to the air pressure being impressed on the final control element and operable to connect said pressure to the output pressure from said controller or to said first motor and having a second part connected to the air pressure being impressed on said set point adjustment means and operable to connect said pressure to a cascade controller whose output pressure represents a second process variable and is to be connected so as to actuate the set point chamber of said first controller and thereby actuate the final control element with the cascade mode of operation or to disconnect said set point adjustment means from said cascade controller.

2. In an air-pressure-operated automatically or manually actuated mechanism for operating a final control element, means for shifting automatically between automatic actuation and manual actuation without disturbing the pressure of the air being impressed on the final control element at the time of the shift, said means including, a first air-pressure-operated controller having a set point chamber therein responsive to a set point pressure representing that value of the process variable which it is desired that said controller maintain, a first automatically or manually actuated transmitter-receiver, a first air-pressure-operated motor in said transmitter-receiver adapted for connection to a supply of air under pressure, a second air-pressure-operated motor in said transmitter-receiver and connected to the final control element, valve means connected between and actuated upon relative movement of said first and second motors so as to vary the pressure of the air being impressed on said first motor in such a sense as to cause said first motor to follow the movements of said second motor, transfer valve means having a first part connected to the air pressure being impressed on the final control element and operable to connect said pressure to the output pressure from said controller or to said first motor, and a second transmitter-receiver providing set point adjustment means, a first air-pressure-operated motor in said second transmitter-receiver adapted for connection to a supply of air under pressure and to the set point chamber of said controller, a second air-pressure-operated motor in said second transmitter-receiver and connected to means for automatically actuating said controller, and valve means connected between and actuated upon relative movement of said first and second motors so as to vary the pressure of the air being impressed on said first motor of said second transmitter-receiver and on said set point chamber of

said controller in such a sense as to cause said first motor to follow the movements of said second motor.

3. In an air-pressure-operated mechanism for operating a final control element, means for shifting automatically between manual actuation and automatic actuation and cascade automatic actuation without disturbing the pressure of the air being impressed on the final control element at the time of the shift, said means including, a first air-pressure-operated controller having a set point chamber therein responsive to a set point pressure representing that value of the process variable which it is desired that said controller maintain, a first automatically or manually actuated transmitter-receiver, a first air-pressure-operated motor in said transmitter-receiver and adapted from connection to a supply of air under pressure, a second air-pressure-operated motor in said transmitter-receiver and connected to the final control element, valve means connected between and actuated upon relative movement of said first and second motors so as to vary the pressure of the air being impressed on said first motor in such a sense as to cause said first motor to follow the movements of said second motor, a second transmitter-receiver providing set point adjustment means, a first air-pressure-operated motor in said second transmitter-receiver and adapted for connection to a supply of air under pressure and to the set point chamber of said first controller, a second air-pressure-operated motor in said second transmitter-receiver and connected to means for automatically actuating said first controller, a third air-pressure-operated motor in said second transmitter-receiver, a cascade controller whose output pressure represents a second process variable and is to be connected so as to vary the air pressure in said set point chamber of said first controller and thereby actuate said final control element with the cascade mode of operation, and transfer valve means having a first part connected to the air pressure being impressed on the final control element and operable to connect said pressure to the output pressure from said first controller or to said first motor in said first transmitter-receiver and a second part connected to said third motor in said second transmitter-receiver and operable to connect said third motor to the output pressure from said cascade controller or to vent said third motor to atmosphere.

4. In an air-pressure-operated mechanism for operating a final control element, means for shifting automatically between automatic actuation and manual actuation without disturbing the pressure of the air being impressed on the final control element at the time of the shift, said means including, an air-pressure-operated controller having a set point chamber therein responsive to a set point pressure representing that value of the process variable which it is desired that said controller maintain and having a process variable chamber therein responsive to a process variable pressure representing the instantaneous value of the process variable as sensed by a measuring instrument, an automatically or manually actuated transmitter-receiver, a first air-pressure-operated motor in said transmitter-receiver and adapted for connection to a supply of air under pressure, a second air-pressure-operated motor in said transmitter-receiver, valve means connected between and actuated upon relative movement of said first and second motors so as to vary the pressure of the air being impressed on said second motor in such a sense as to cause said first motor to follow the movements of said second motor, an automatically actuated measuring instrument connected to said process variable chamber, and a transfer valve means having a first part connected to the air pressure being impressed on the final control element and operable to connect said pressure to the output pressure from said controller or to said first motor or to an intermediate seal position between said connected positions and having a second part connected to said second motor and operable to connect said second motor to said final control element or to said process variable cham-

ber of said controller or to said set point chamber of said controller, whereby said transmitter-receiver may be manually operated to adjust the final control element in manual position or to adjust the set point pressure in said set point chamber in automatic position or may be automatically operated to adjust the pressure in said first motor in an intermediate seal position.

5. In an air-pressure-operated mechanism for operating a final control element, means for shifting automatically between manual actuation and automatic actuation and cascade automatic actuation without disturbing the pressure of the air being impressed upon the final control element at the time of the shift, said means including, a first air-pressure-operated controller having a set point chamber therein responsive to a set point pressure representing that value of the process variable which it is desired that said controller maintain and having a process variable chamber therein responsive to a process variable pressure representing the instantaneous value of the process variable as sensed by a measuring instrument, an automatically or manually actuated transmitter-receiver, a first air-pressure-operated motor in said transmitter-receiver and adapted for connection to a supply of air under pressure, a second air-pressure-operated motor in said transmitter-receiver, a third air-pressure-operated motor in said transmitter-receiver, valve means connected with and actuated upon relative movement of said first and second and third motors so as to vary the pressure of the air being impressed on said first motor in such a sense as to cause said first motor to follow the resultant of the movements of said second and third motors, a cascade controller whose output pressure represents a second process variable and is to be connected so as to vary the air pressure in said set point chamber of said controller and thereby actuate said final control element with the cascade mode of operation, transfer valve means having a first part connected to the air pressure being impressed on the final control element and operable to connect said pressure to the output pressure from said first controller or to said first motor in said transmitter-receiver or to lock the air pressure being impressed on the final control element therein when said first part is in a position intermediate said connected positions and having a second part connected to said second motor in said transmitter-receiver and operable to connect said second motor to said final control element or to said process variable chamber of said first controller or to said set point chamber of said first controller and having a third part connected to said third motor in said transmitter-receiver and operable to connect said third motor to the output pressure from said cascade controller or to vent said third motor to atmosphere.

6. In an air-pressure-operated automatically or manually actuated mechanism for operating a final control element, means for shifting between automatic and manual actuation and vice versa without disturbing the pressure of the air being impressed on the final control element at the time of shift, said means including, automatically actuated mechanism comprising a measuring instrument having an output air pressure representing the instantaneous value of the process variable and an air-pressure-operated controller having a process variable chamber and at least one feedback chamber in it, said process variable chamber being responsive to the output air pressure from said measuring element and said feedback chamber being responsive to the output air pressure being impressed on the final control element, manually actuated mechanism comprising a first air-pressure-operated motor adapted for connection to a supply of air under pressure and a second air-pressure-operated motor connected to the final control element when the mechanism is in manual position and a handle connected to said second motor and manually operable to move said second motor and to override the pressure of the air within said second motor, valve means connected between and actuated upon

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relative movement of said first and second motors so as to vary the pressure of the air being impressed on said first motor in such a sense as to cause said first motor to follow the movements of said second motor, and a transfer valve means connecting the final control element to said first motor of said manually actuated mechanism or to said automatically actuated mechanism.

7. In an air-pressure-operated automatically or manually actuated circuit for operating a final control element, means for shifting automatically between automatic or manual operation without disturbing the value of the air pressure being impressed on the final control element at the time of the shift, said means including, a controller having separate interacting pressure-responsive chambers therein, one of said chambers being a process variable chamber responsive to air at a pressure representing the instantaneous value of the process variable, another of said chambers being a set point chamber responsive to air at a pressure representing the value of the process variable which it is desired that said controller maintain, another of said chambers being a feed-back chamber, and another of said chambers providing the output pressure of a controller, a manually-operable transmitter-receiver, a first air-pressure-operated motor in said transmitter-receiver adapted for connection to a supply of air under pressure, a second air-pressure-operated motor in said transmitter-receiver, a handle engaging said second motor and manually operable to move said second motor, a valve having a first part connected to said first motor and a second part connected to said second motor and operable so that relative movement between said first and second motors varies the value of the air pressure being impressed on said first motor from said source and causes said first motor to follow the movements of said second motor, and a manually operable transfer valve having one part connected between the output pressure from said controller and a motor which actuates said final control element and adapted to open or close said connection and another part connected between said first motor and said second motor of said transmitter-receiver and adapted to open or close said connection.

8. In an air-pressure-operated automatically or manually actuated circuit for operating a final control element, means for shifting automatically between automatic or manual operation without disturbing the value of the air pressure being impressed on the final control element at the time of the shift, said means including, a con-

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troller having separate interacting pressure-responsive chambers therein, one of said chambers being a process variable chamber responsive to air at a pressure representing the instantaneous value of the process variable, another of said chambers being a set point chamber responsive to air at a pressure representing the value of the process variable which it is desired that said controller maintain, another of said chambers being a feed-back chamber, and another of said chambers providing the output pressure of said controller, a manually-operable transmitter receiver, a first air-pressure-operated Bourdon tube in said transmitter-receiver adapted for connection to a supply of air under pressure, a second air-pressure-operated Bourdon tube in said transmitter-receiver, a handle engaging said second Bourdon tube and manually operable to move said second Bourdon tube, a valve having a first part connected to said first Bourdon tube and a second part connected to said second Bourdon tube and operable so that relative movement between said first and second Bourdon tubes varies the value of the air pressure being impressed on said first Bourdon tube from said source and causes said first Bourdon tube to follow the movements of said second Bourdon tube, and a manually operable transfer valve having one part connected between the output pressure from said controller and motor which actuates said final control element and adapted to open or close said connection and another part connected between said first Bourdon tube and said second Bourdon tube of said transmitter-receiver and adapted to open or close said connection.

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