# Proportioning Plus Integral Controller

## A. Automatic Reset (Integral)

1. Basic components of an automatic reset (integral) controller are:

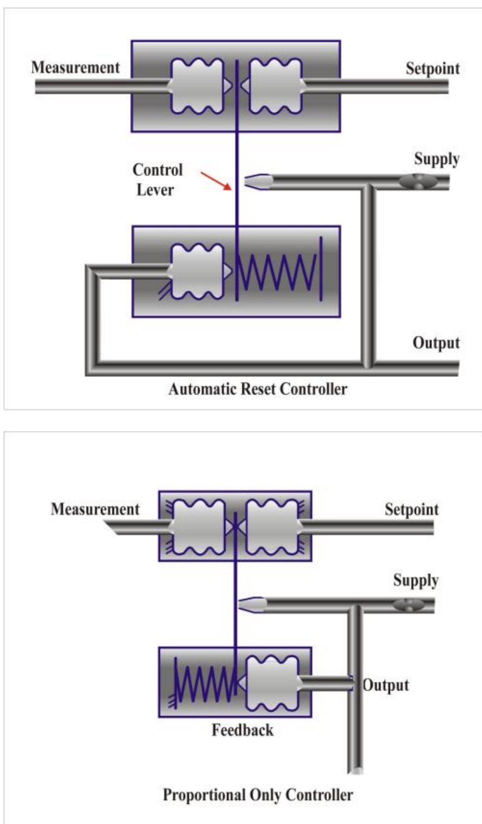
   a. Comparison mechanism

   b. Detector mechanism

   c. Feedback mechanism

   d. Adjustable restriction

2. In the illustration below, compare the automatic reset (integral) controller with the proportional-only controller. Note the position of the bottom (feedback) bellows-spring arrangement.




**Picture 1, Automatic Reset (Integral) Controller VS Proportional-only Controller**

3. Automatic Reset (Integral) Operation

   a. Assume that the controller is at equilibrium with the following conditions:

      1) 9 psi at measurement bellows

      2) 9 psi at setpoint bellows

      3) 9 psi at the nozzle

## B. Process due to an increase in measurement:

1) The measurement bellows expand, the lever moves toward the nozzle, increasing the backpressure at the nozzle. In turn, the pressure at the feedback bellows increases.

2) The feedback bellows expands, causing the lever to move even closer to the nozzle.

3) The backpressure at the nozzle increases even more.

4) This cycle will continue until the nozzle backpressure equals the supply pressure.

b. Process due to a decrease in measurement:

   1) The measurement bellows contracts, the lever moves away from the nozzle, decreasing the backpressure at the nozzle. In turn, the pressure at the feedback bellows decreases.

   2) The feedback bellows contracts, causing the lever to move even farther from the nozzle.

   3) The backpressure at the nozzle decreases even more.

   4) This cycle will continue until the nozzle backpressure is zero.

   5) This process is called positive feedback because it adds to the error signal.

c. Putting the controller into equilibrium

1) Apply 9 psi to the setpoint bellows and the measurement bellows.

2) The lever will assume a fixed position.

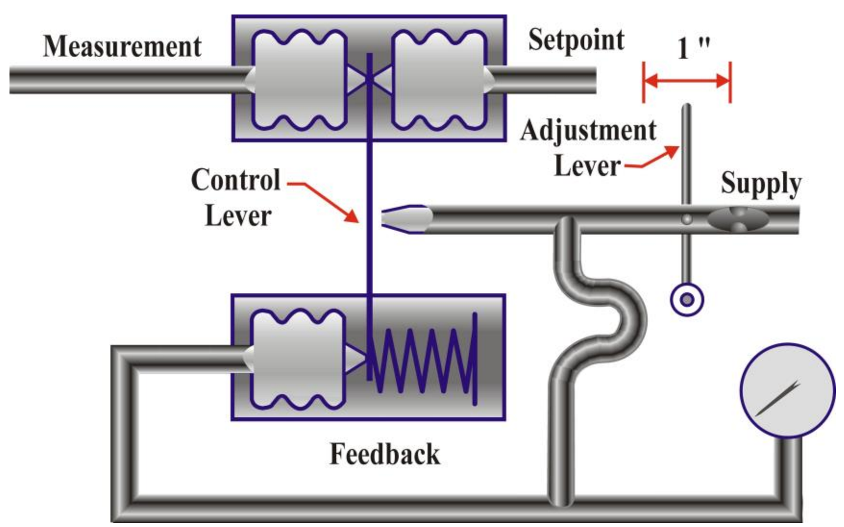
3) Position the nozzle far enough from the lever so that there is no back pressure.

4) This in turn allows the feedback bellows to fully contract. The spring will be fully extended.

5) With these as the starting conditions, follow the process as the nozzle is moved toward the lever.

d. Moving the nozzle toward the lever

1) The illustration below shows a controller with a moveable nozzle. It will be used in the following explanation.




**Picture 2, Reset (Integral) Controller With Moveable Nozzle**

2) The explanation will begin with the nozzle at a distance from the lever so there is no backpressure at the nozzle.

3) With no pressure at the nozzle, there is no pressure at the feedback bellows.

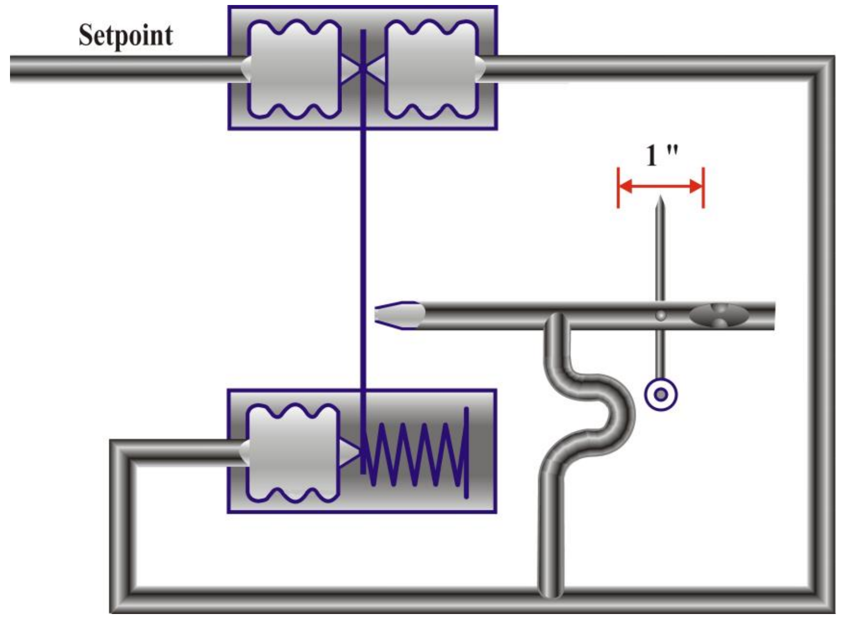
4) As the nozzle is moved towards the lever, the lever begins to restrict air flow, thus causing backpressure at the nozzle.

5) If the nozzle is not moved away from the lever, because of positive feedback (as discussed previously), the backpressure at the nozzle will be driven to the supply pressure.

6) To allow output correction without the nozzle pressure driving to supply pressure, the nozzle must approach the lever until backpressure begins to build. At that point, the nozzle must be moved away from the lever at a slightly slower rate than the feedback bellows moves the lever towards the nozzle. When the feedback bellows and nozzle movements coincide, the controller will be in equilibrium. At this point the nozzle motion should be stopped.

2. Closed Loop Control

a. The illustration below shows a reset (integral) controller with the output being fed to the bellows that opposes the setpoint bellows (in the previous examples, the measurement bellows). This is known as a closed loop controller.




**Picture 3, Closed Loop Reset (Integral) Controller**

b. In previous examples, the setpoint was on the opposite side of the lever and the measurement bellows was on the same side of the lever as the feedback bellows, thus a direct acting controller.

c. In this example, the configuration is such that the setpoint bellows is on the same side of the lever as the feedback bellows, thus a reverse acting controller. For a closed loop controller to equalize, it must be reverse acting.

d. Assume the setpoint is at 0 psi. Likely there will be enough distance between the nozzle and the lever such that the backpressure at the nozzle is 0 psi. The pressure at the feedback and measurement bellows will also be 0 psi. For the purposes of this explanation, this condition will be assumed.

e. As the setpoint pressure increases, the nozzle backpressure will increase, increasing the pressure at the feedback bellows and the measurement bellows.

f. The measurement bellows begins to counter act the motion of the setpoint bellows. This causes the lever to move away from the nozzle, reducing the backpressure at the nozzle. The measurement bellows simulates moving the nozzle away from the lever as in the previous example. The controller will reach equilibrium when the movement lever by the measurement bellows equals the movement of the lever by the feedback bellows.

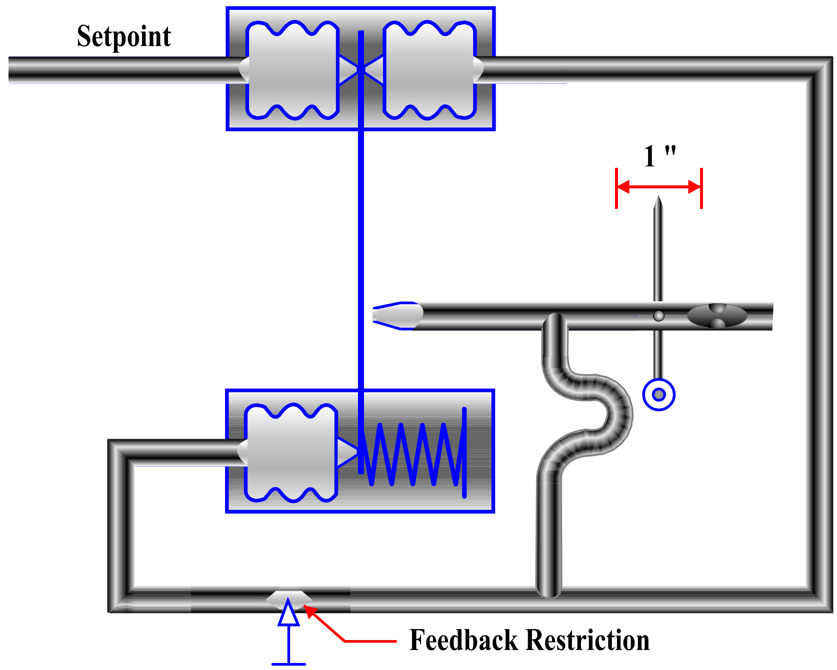
3. Reset (Integral) Offset

   a. .In the example above, it is very possible for the controller to reach equilibrium even though the setpoint and measurement pressures are not equal. This condition is called reset (integral) offset.

   b. By moving the nozzle with respect to the lever, we can change the point at which the controller reaches equilibrium.

4. Adjusting the rate of change

   a. By placing an adjustable restriction between the nozzle and the feedback bellows, the rate at which the controller reaches equilibrium can be adjusted.




**Picture 4, Adjustable Feedback Restriction**

## C. Proportional Plus Reset (Integral) Controllers

1. The proportional-only controller output is always proportional to the error signal.The ratio of the output to the input depends on the linkage configuration. In most cases the linkage is adjustable, provide a gain range of 0 to about 250. In the proportional-only controller, the feedback mechanism is arranged so that the feedback motion is subtracted from the error motion (negative feedback). In the automatic reset (integral) controller, the feedback mechanism is arranged so that the feedback motion is added to the error motion (positive feedback). The proportional plus reset (integral) controller incorporates both arrangements.

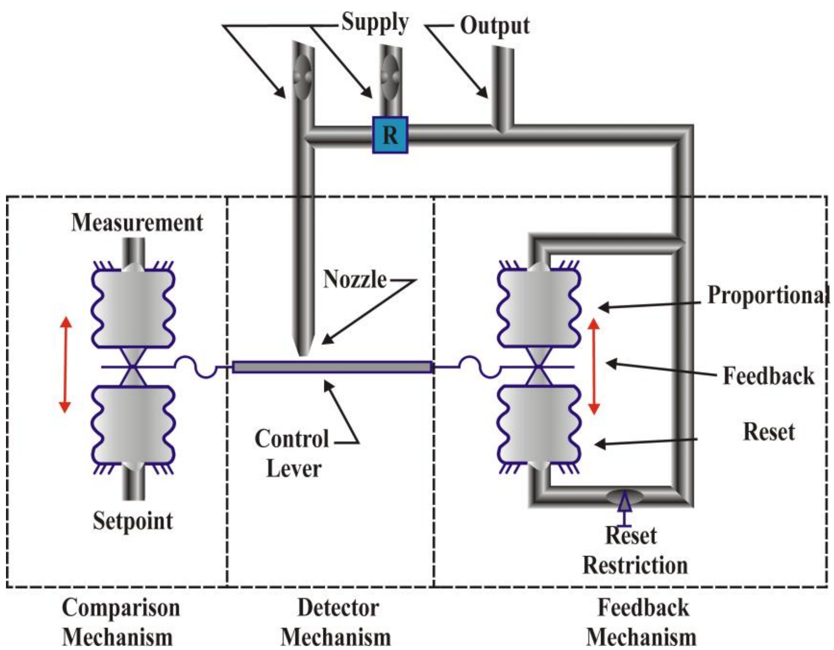
2. Components of a Proportional Plus Reset (integral) Controller are:

   a. Comparison mechanism

   b. Detector mechanism

c. Feedback mechanism with both positive and negative bellows/spring feedback elements

3. The illustration below shows a proportional plus reset (integral) controller.




**Picture 5, Proportional Plus Reset (Integral) Controller**

a. The comparison mechanism (setpoint and measurement bellows) is at one end of the lever.

b. The two feedback bellows are at the opposite end of the lever.

c. The detector mechanism is located between the comparison and feedback mechanisms.

d. There is a restriction in the air pressure line to each of the feedback bellows. Some controllers use the characteristics of the bellows to perform the function of a spring. Otherwise a spring would be required for each feedback bellows.

e. With equal pressure at the setpoint and measurement bellows, there is zero error signal (difference between the setpoint and measurement, therefore no demand for change.

f. Assume that the backpressure at the nozzle is 11 psi. Therefore there will be 11psi at both feedback bellows. The restrictions are partially closed.

g. When the error signal moves the lever toward the nozzle, the nozzle backpressure begins to increase. Proportioning actions occurs. Because of the restriction, the reset (integral) feedback bellows will not equalize to the nozzle pressure right away. The time required to do so is dependent on the pressure difference and the amount of restriction.

h. With the insertion of the reset (integral) restriction, for a short period, the controllers responds as a proportional-only controller. For a longer period of time, the controller acts like a reset (integral) only controller.

i. Now, assume the reset (integral) restriction is wide open (no restriction), otherwise the conditions of the previous example exists

j. As the difference between the setpoint and measurement pressures (error signal) cause the lever to move towards the nozzle, the nozzle backpressure increases. The pressure at both feedback bellows increase by the same amount. With no restriction in the reset (integral) air line, both bellows expand at the same rate. Since the pressures change at the same rate, no movement of the feedback end of the lever takes place, thus no feedback signal

k. Without feedback, the controller responds just as a high gain controller would, producing, basically, an on-off controller.

l. Assume the reset (integral) restriction is fully closed (no flow to reset (integral) bellows) and the other conditions the same as the previous example.

m. As the error signal causes the lever to move toward the nozzle, the nozzle pressure increases, as does the pressure to the proportional bellows. Since the airline to the reset (integral) bellows is closed, it will not respond.

n. With the reset (integral) restriction completely closed, the controller is rendered a proportional-only controller.

o. By introducing a variable restriction in the reset (integral) air line, it can be a proportional-only, a reset (integral) only, or a combination thereof, controller. By varying the restriction, different reset (integral) rates can be achieved. As the restriction is increased, the reset (integral) time increases. A difference between the setpoint and the measurement pressures (error signal) must be present for any action to occur.

p. Reset (Integral) time is stated as "the number of repeats in a unit of time." It can be stated as "10 minutes per repeat" or "0.1 repeats per minute."

## D. Fisher "Multitrol" Proportional Plus Reset (Integral) Controller

1. Components

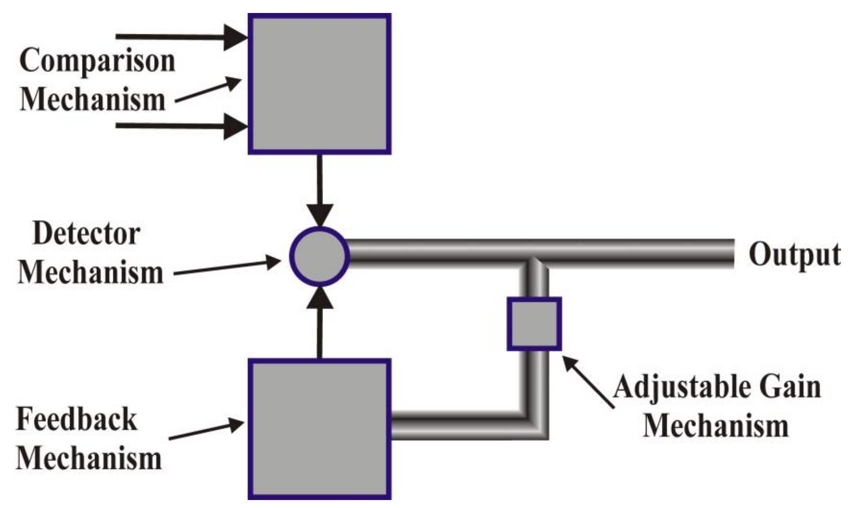
a. Comparison mechanism

b. Detector mechanism

c. Feedback mechanism

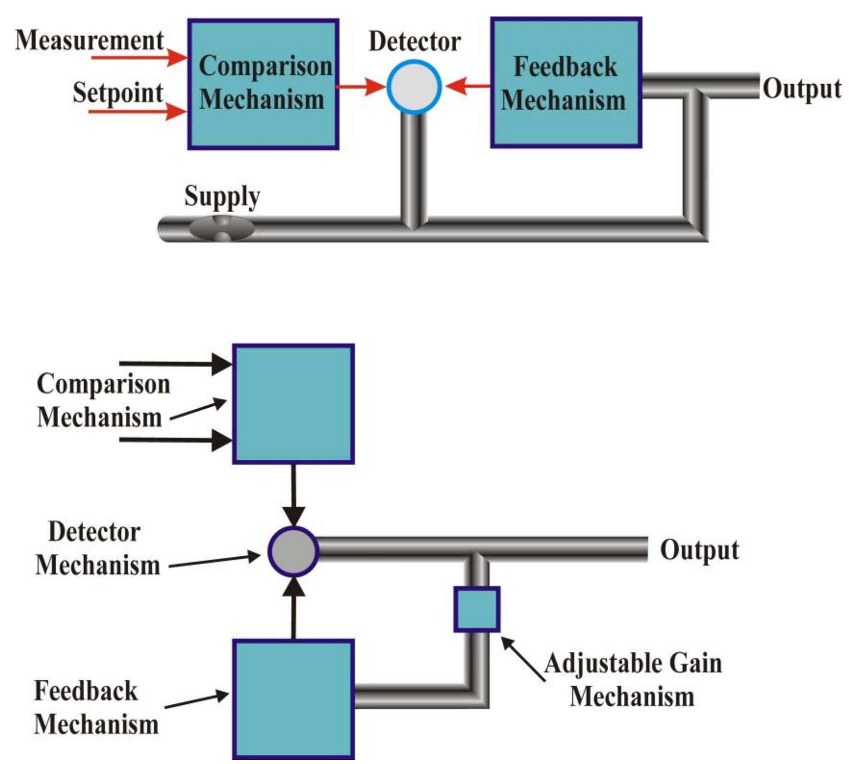
d. Adjustable gain mechanism

2. The illustration below shows a Multitrol controller in its basic form.



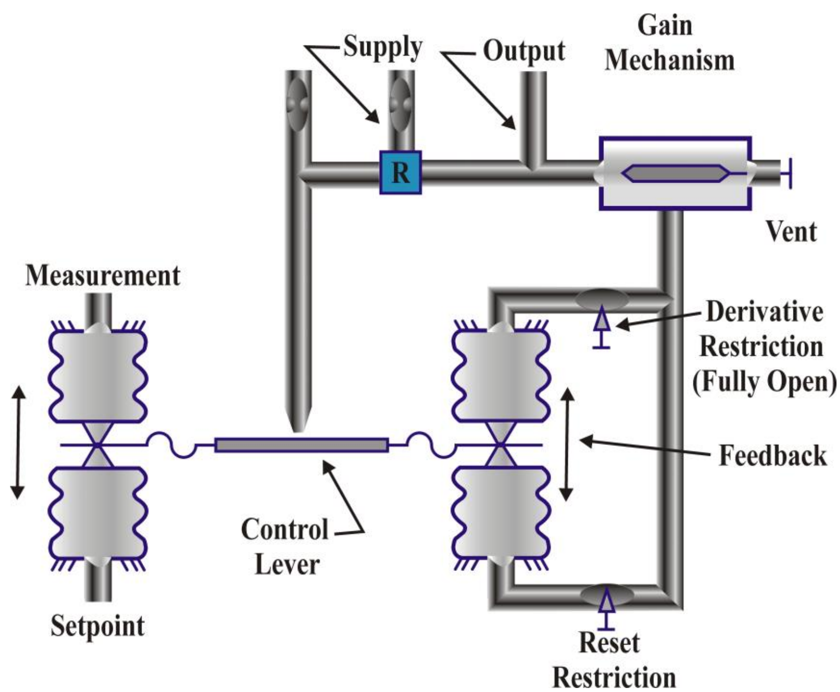

**Picture 6, Multitrol Controller Block Diagram**

3. This is similar to the controller block diagram discussed earlier; the difference being the adjustable gain controller between the detector and the feedback mechanism.



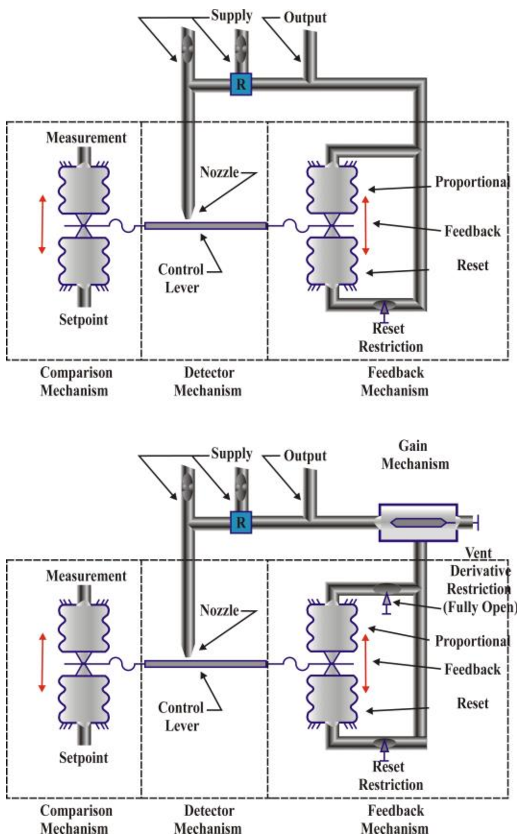

**Picture 7, Controller Block Diagram Comparison**

4. The illustration below is a more detailed illustration of the Fisher Multitrol controller.




**Picture 8, Fisher Multitrol Controller Diagram**

5. Compare the above diagram with that of the previously discussed proportional plus reset (integral) controller.




**Picture 9, Controller Diagram Comparison**

6. The difference is the gain mechanism between the output and the feedback mechanism.
7. The operation of the Fisher Controller is essentially the same as that of the fundamental controller discussed previously. This controller is closed loop connected, thus the output is connected the measurement bellows.
8. Assume the controller has zero air supply, and that there is a 9-psi setpoint signal applied to the setpoint bellows. With no air supply the pressure in the proportioning, measurement, and reset (integral) bellows is zero. The pressure in the setpoint bellows causes the lever to be pushed against the nozzle.
9. When air is supplied to the controller, backpressure quickly increases at the nozzle. The increased pressure drives the relay, causing the output pressure to increase. The output pressure connected to the measurement bellows produces a measurement force that opposes the setpoint force, thus reducing the error signal.
10. The increase in output also acts on the proportional bellows, which tends to move the lever away from the nozzle. Very quickly the input will jump to that value which, when applied to both the measurement and proportioning bellows, will automatically balance the setpoint signal.
11. The increase in pressure encountered upon applying pressure to the controller, will slowly pass through reset (integral) restriction and enter the reset (integral) bellows. The reset (integral) bellows will return the feedback end of the lever to the position that it took when there was no air supply. lThis happens because having the same pressure in both the proportioning and reset (integral) bellows is the sam as having zero pressure in both bellows. Therefore, we can expect that when the controller is in equilibrium, the feedback end of the lever will have assumed the same position that it had when the controller had no supply.

12. When and if the pressures in the measurement setpoint bellows become equal, the comparison end of the lever will also assume a predetermined position. In our case we applied a setpoint signal of 9 psi. The measurement must also be equal to 9 psi if the error signal is going to be zero. The controller output will dirve to whatever output (hence measurement pressure) is necessary to position the lever to a position that will bring the controller into equilibrium. It doesn't matter what the measurement and setpoint signals are, the controller will always seek equilibrium.

13. The intent of the controller is to keep the setpoint and measurement pressures equal. Therefore the lever and nozzle must be positioned such that the controller to be at equilibrium when the setpoint and measurement pressures are equal. Further, they must be positioned such that equilibrium will be reached when the setpoint and measurement are equal at any value (within range) for the setpoint.

14. Observe that the components are lined up to a center line.

15. Three points on the center line are of concern, the feedback point, the detector point and the comparison mechanism point.

16. After a time, the feedback point is fixed. The nozzle position is fixed to the instrument chassis.

17. The only point not fixed is the comparison mechanism point. Therefore the comparison mechanism must drive so that its point falls on the same line established by the detector and feedback positions.

18. To have the same pressure in both of the comparison mechanism bellows, the resulting position must be accepted. The nozzle then becomes the point that must be adjusted to the center line.

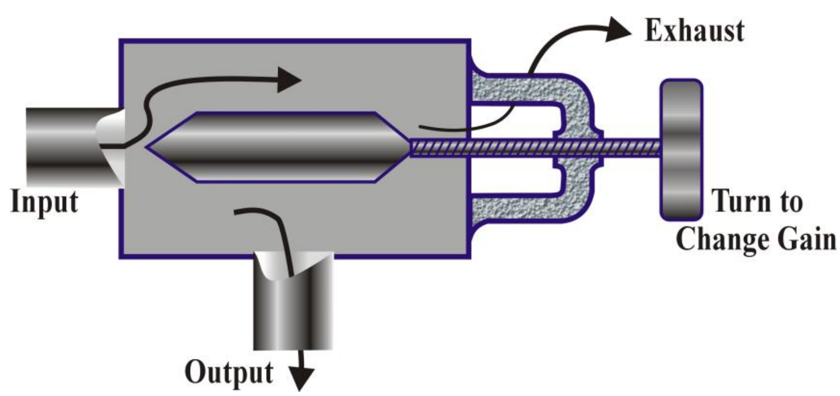
19. Understanding this motion is critical to understanding the alignment of automatic reset (integral) controllers.

20. The controller discussed here is relatively easy to understand because it is symmetrical about a center line. However, the principle of two points establishing a line is always applicable.

## E. Pneumatic Gain Mechanism

1. Previously discussed controllers used mechanical gain mechanisms. The Fisher controller discussed here uses a pneumatic gain mechanism.

2. The pneumatic gain mechanism is basically a three way valve arrangement. As it is adjusted, a vent port closes (or opens) as the inlet port opens (or opens). Between these two ports is an output connection. The illustration below shows the pneumatic gain mechanism.




**Picture 10, Pneumatic Gain Mechanism**

3. The previous illustration shows a pneumatic gain mechanism installed in the controller.

4. As previously discussed, the purpose of an adjustable gain mechanism is to allow changing of the input to output ratio. The output of the pneumatic gain mechanism is the pressure between the two podrts. The input to the gains mechanism is the relay output.

5. Assume that the plug is positioned so that it closes the exhaust port. For that plug position, all of the relay output will pass by the plug and out into the feedback bellows. For this plug position, the ouotput equals the input; thus, the

gain is one. As the exhaust port is slightly opened, the input port is slightly closed. Some of the input signal is vented. As a result, the output pressure will be less than the input pressure. In other words, the ratio of the output to input will be changed.

**PRACTICE:**

1 Name four basic components of a pneumatic automatic reset (integral) controller.

2. In a proportional plus reset (integral) pneumatic controller, how can the effect of the reset bellows be eliminated?