Proportioning Controller

Pneumatic controllers provide a method to control process quality or quantity, or both.

At the conclusion of this training unit the trainee should be able to:

Describe the features, operation, and use of pneumatic controllers.

Following this objective, you should be able to:

Recall typical features, general operation, and typical uses for pneumatic controllers.

Relate how pneumatic controllers aid in controlling processes.

Identify the effect improperly calibrated pneumatic controllers have on plant equipment.

At the conclusion of this training unit the trainee should be able to describe common features, typical operation, and proper use of pneumatic controllers and relate these principles to their individual job. Trainees may be evaluated by completing a written exam comprised of questions from this training unit and others included in this course. A minimum of 80% accuracy is required to satisfactorily complete this training.

Proportioning Controller

MAIN IDEA:

A. General Purpose / Typical uses

1. Typically, a pneumatic controller is used to control plant processes. Many times pneumatic controllers are used instead of electronic controllers in explosive atmospheres. Sometimes they are used because large air tanks can store air pressure to supply operating power in case of an electrical power loss.

B. General Use

1. To use a pneumatic controller, it must be connected to the other devices. At a minimum, there must be a process input, a process setpoint, and a process output.
2. An improperly calibrated pneumatic controller will cause incorrect control, or no control of the controlled process.

C. Common Controls/Adjustments

1. Pneumatic controllers typically have the following controls/adjustments:
    a. Proportional-only Controller (P)
        1) A method to change the proportional value
        2) A method to adjust the setpoint value
        3) A method to set direct or reverse acting
        4) A method to change from automatic to manual control
        5) A method to calibrate the setpoint indicator
        6) A method to calibrate the process indicator
        7) A method to calibrate the output indicator

b. Proportional and Integral Controller (PI)

1) All the adjustments for a proportional-only controller

2) A method to adjust the Integral value

c. Proportional, Integral, and Derivative Controller (PID)

1) All the adjustments for an Proportional and Integral controller

2) A method to adjust the Derivative value

D. Common Inputs/Outputs

a. Typically, pneumatic controllers will have the following connections:

1) A connection to the process measurement converter (i.e. temperature input device

2) A connection to the process controlling device (i.e. valve actuator, speed governor, etc.).

3) Some controllers may have and external input for the setpoint.

E. How to connect to other equipment for calibration

Typically, the output/input connections of the pneumatic controller are connected to a calibration device using flexible tubing.

NOTE: Reset is the same as integral, gain is the same as proportional or proportional band, pre-act is the same as derivative.

F. Pneumatic proportioning controllers

1. Basic components are:

a. Measurement input

b. Setpoint input (reference input)

c. Feedback components

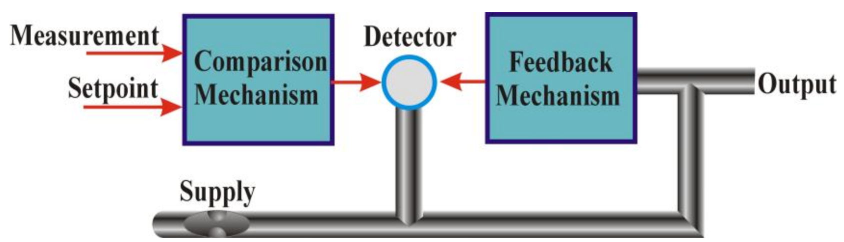
d. A detector mechanism

e. A lever system

2. Theory of operation:

a. The measurement and setpoint inputs are fed into a comparison mechanism. The output is dependent on the relationship of the two input signals.

b. The detector, feedback mechanism, and the comparison mechanism work together to produce an output based on the setpoint and measurement (process) inputs.

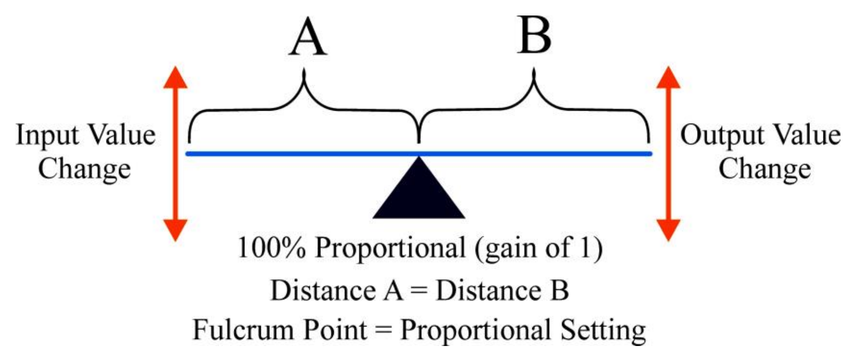


Picture 1, Pneumatic Proportional Controller Block Diagram

c. In a proportional-only controller, the output responds to a change in the setpoint or a change in the measurement. If the input (or setpoint) changes (while in automatic mode), the output will change based on the proportional setting.

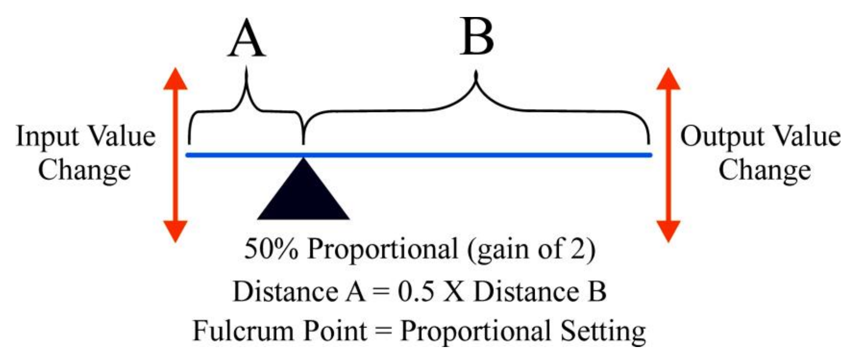
d. Proportional Band is inversely equivalent to gain or amplification or multiplier.

1) A Proportional Band setting of 100% equals a gain of 1.0. Therefore, a 10% input value change will cause a 10% output value change.



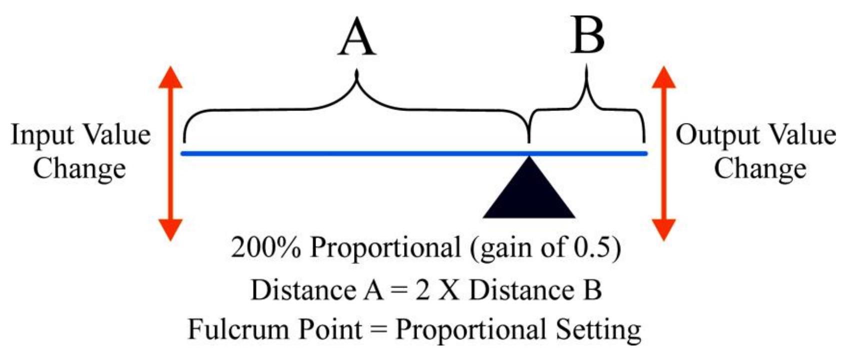
Picture 2, Proportional Band Setting of 100%

2) A Proportional Band setting of 50% equals a gain of 2. Therefore, a 10% change input value change will cause a 20% output value change.



Picture 3, Proportional Setting Of 50%

3) A Proportional Band setting of 200% equals a gain of 0.5. Therefore, a 10% change input value change will cause a 5% output value change.



Picture 4, Proportional Band Setting of 200%

e. Disadvantages of proportional-only controllers.

1) If the proportional setting is not correct, the output will change too much or too little as the input changes. Since there is no way to automatically correct for this, proportional-only controllers may not be able to adequately compensate for changes in the process. Changes in the process may require that the output of the controller be adjusted manually to compensate for the process change.

2) Normally, proportional-only controllers have to be manually adjusted for the correct process value; then placed in automatic control.

f. Component Functions

1) Comparison Mechanism

a) The comparison mechanism has two inputs and one output.

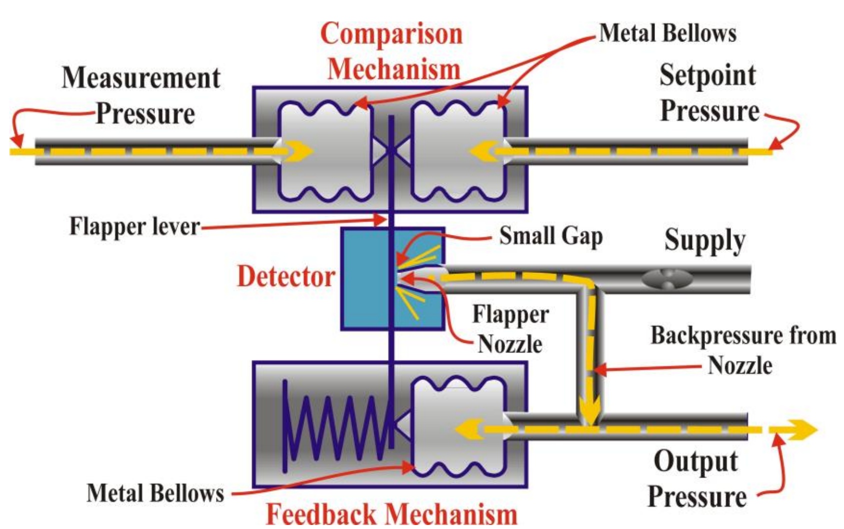
(1) The two inputs are compared, and the difference is the output to the detector.

(2) The output of the detector is the output of the controller which is normally applied to the process controlling device.

g. Inside the boxes - basics

1) Inside the comparison box there are two bellows opposing each other. One bellows is driven by the process measurement signal, the other is driven by the setpoint signal.

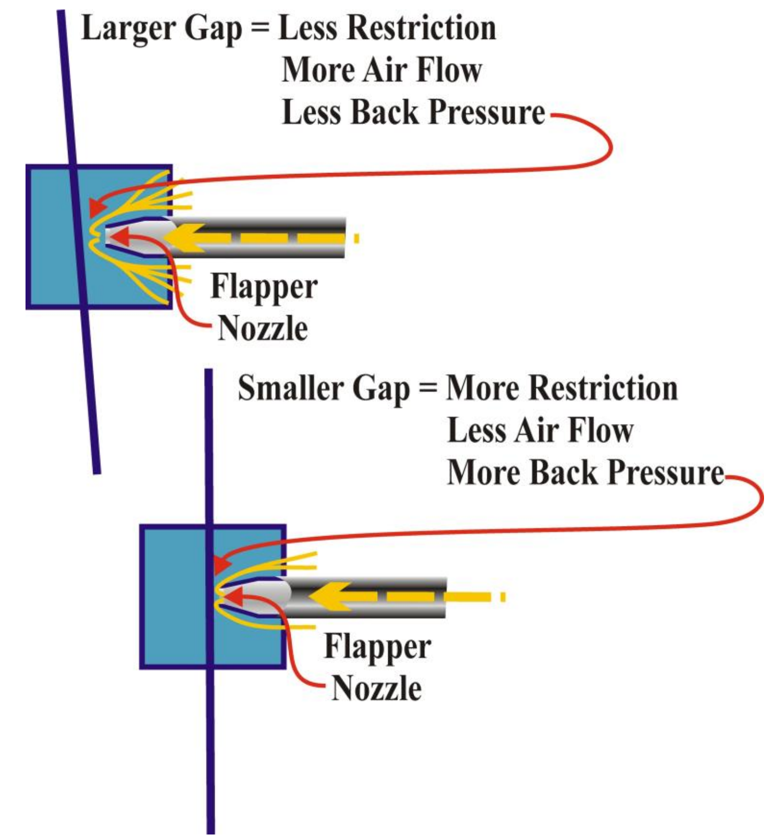
2) The two bellows are attached to opposing sides of a lever (flapper). As air pressure is applied or removed from the two bellows, the bellows expand or contract. A difference in pressure between the two bellows will cause the lever to move. In the illustration below, if the measurement bellows has a greater pressure than the setpoint bellows, the lever will move closer to the nozzle in the detector. As the lever approaches the nozzle, backpressure in the nozzle increases. Increased backpressure in the feedback bellows moves the lever away from the nozzle. This prevents the lever from moving all the way to the nozzle. Eventually, the forces on the lever equalize. The output pressure is also increased. If the pressure is greater in the setpoint bellows, the opposite occurs.



Picture 5, Proportional-only Controller Components

3) As the flapper lever gets closer to the nozzle, airflow becomes more restricted, producing more backpressure. As the flapper lever moves

away from the nozzle, there is less airflow restriction, therefore less backpressure.



Picture 6, Flapper-Nozzle Operation Principle

h. Functionality in the process

1) The illustration below shows the internal workings of the controller in an actual process application (Flow control).

2) As flow increases, the transmitter senses the higher differential pressure across the flow orifice. The output of the transmitter will increase. (The output range is usually 3-15 psi).

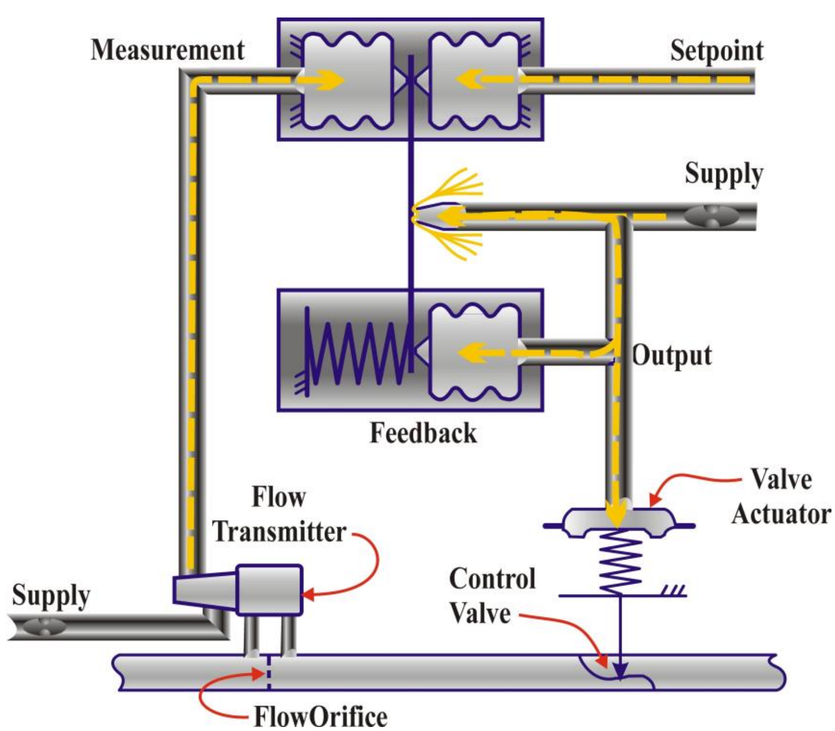
3) The measurement bellows expands, pushing the flapper lever towards the setpoint bellows.

4) The flapper lever gets closer to the nozzle, causing less air flow, therefore more backpressure.

5) The pressure at the valve actuator is the same as the pressure at the nozzle. The increased backpressure at the nozzle causes the actuator to expand, closing the valve.

6) As the valve closes, less flow is sensed at the flow orifice, causing the reverse action to occur throughout the controller. For a given process change, depending on the system parameters, at some point the controller reaches equilibrium (no more changes made).

7) A simple step change has been discussed; however, processes tend to change. The controller continually monitors the process and adjusts the output in response to any detected change.

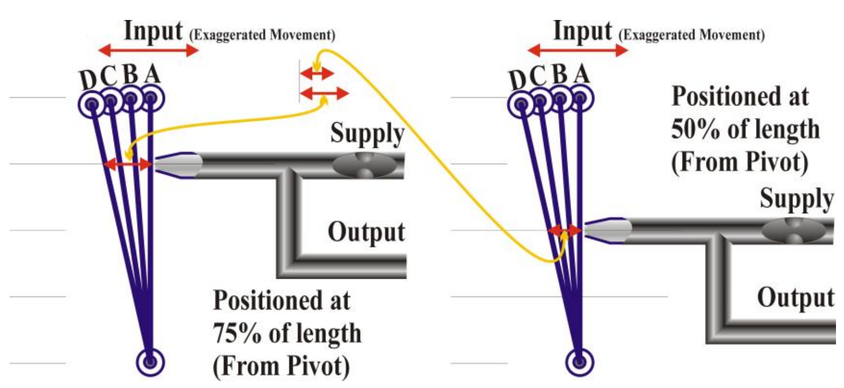


Picture 7, Flow Control Process

i. Controller Gain

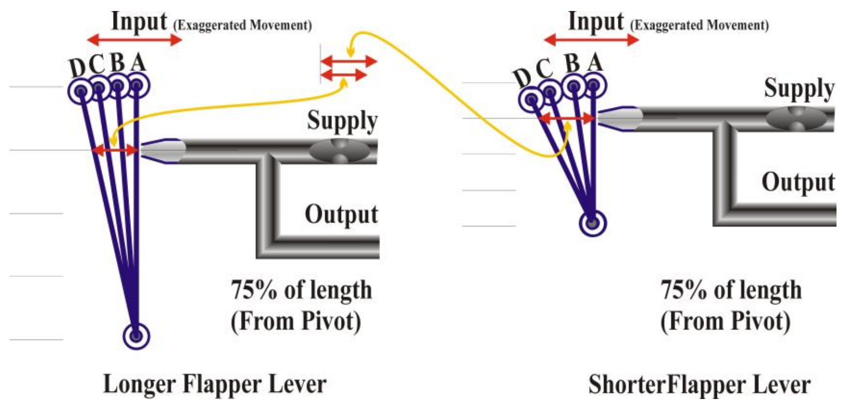
1) The controller proportionality or gain depends on the position of the nozzle with respect to the pivot of the flapper lever as well as the length of the flapper lever. In the previous examples, the nozzle has been shown in the center of the flapper lever, thus producing a gain of 1 (100% proportional band).

2) In the illustration below the nozzle is shown at two different positions with respect to the flapper lever pivot point. At Lever position "A", the lever distances from the nozzle are the same. At lever position "B", the lever distances from the nozzle is slightly different. At lever positions "C" and "D" the difference is ever greater. The backpressure at the nozzles is inversely proportional to the gap between the nozzle and the flapper lever. Therefore, at positions "B", "C", and "D", the back pressure of the nozzle at 75% is less than the respective positions at 50%.



Picture 8, Nozzle Positions

3) The illustration below depicts the effect of flapper levels of different lengths. The nozzles of each are at 75% from the pivot. At lever position "A" the gap is the same. At lever position "B" the gap is slightly more for the shorter lever. At lever positions "C" and "D" the gap difference is even greater. For the same lever positions, the backpressure of the nozzle with the shorter lever is less than the nozzle with the longer lever.



Picture 9, Flapper Lever Length

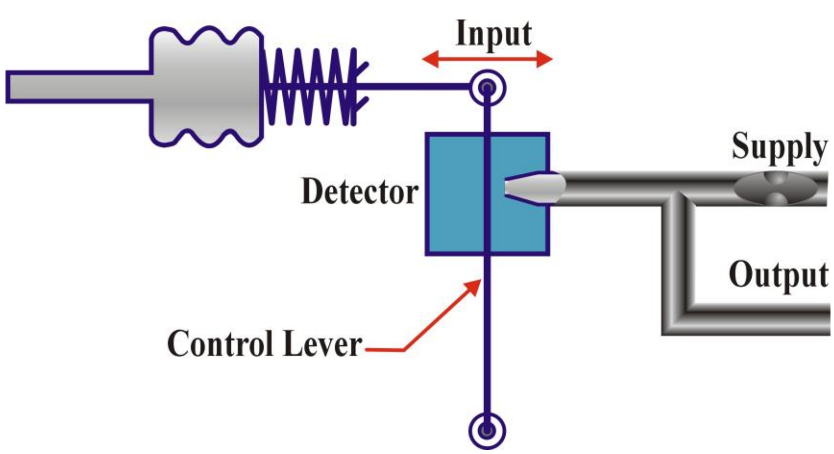
j. Simplest Controller

1) The following are the minimum components required for a controller:

a) Measurement input

b) Detector

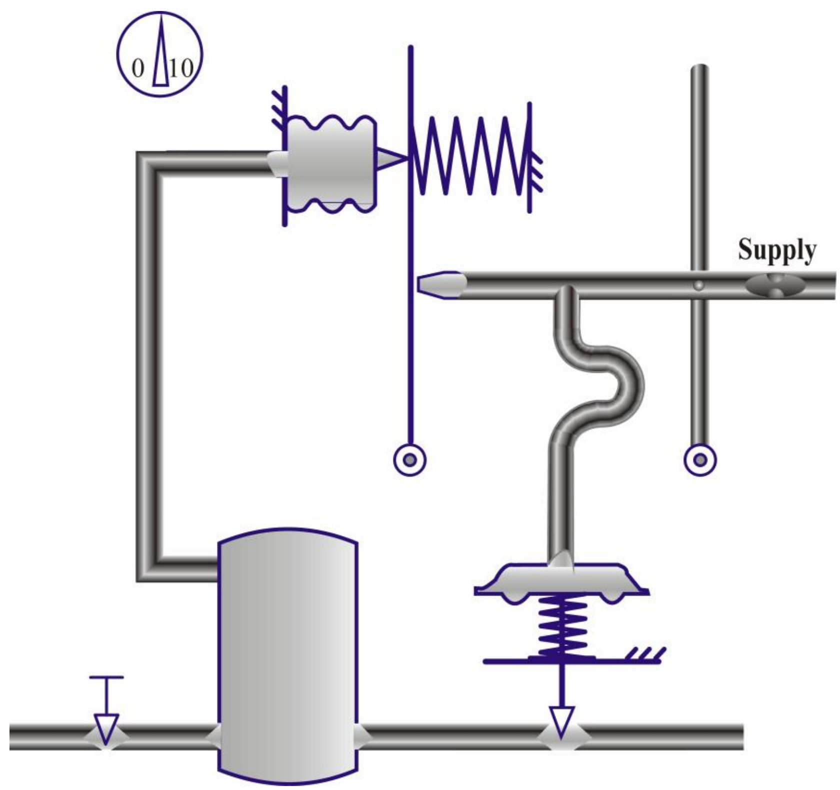
c) Control lever



Picture 10, Simplest Controller Components

k. Blind Pressure Controller

1) The following illustration depicts a pressure controller on a tank. It may be called a blind controller because there is no indication or recording of the process value.



Picture 11, Blind Pressure Controller

2) Blind Controller Operation

a) Assumptions:

(1) The measurement range of the controller input bellows to be 0-10 psi.

(2) 9 psi at the control valve diaphragm produces 5 psi inside the tank.

(3) The design parameters of the nozzle and flapper lever are such that given (1) and (2) above, the nozzle is 0.001 inches from the lever.

b) With an increase in up stream pressure:

(1) Flow through the valve would increase.

(2) The pressure in the tank would increase because the output valve position has not changed allowing less output flow than input flow.

(3) The pressure on the input bellows increases, causing the flapper lever to nozzle gap to decrease.

(4) The decreased gap allows less air flow through the nozzle.

(5) Less air flow through the nozzle causes the nozzle backpressure to increase.

(6) The increased pressure at the nozzle is applied to the diaphragm of the valve, causing the valve to close more.

(7) As the valve closes, it reduces the flow through the valve.

(8) The process now reverses, causing less pressure in the tank.

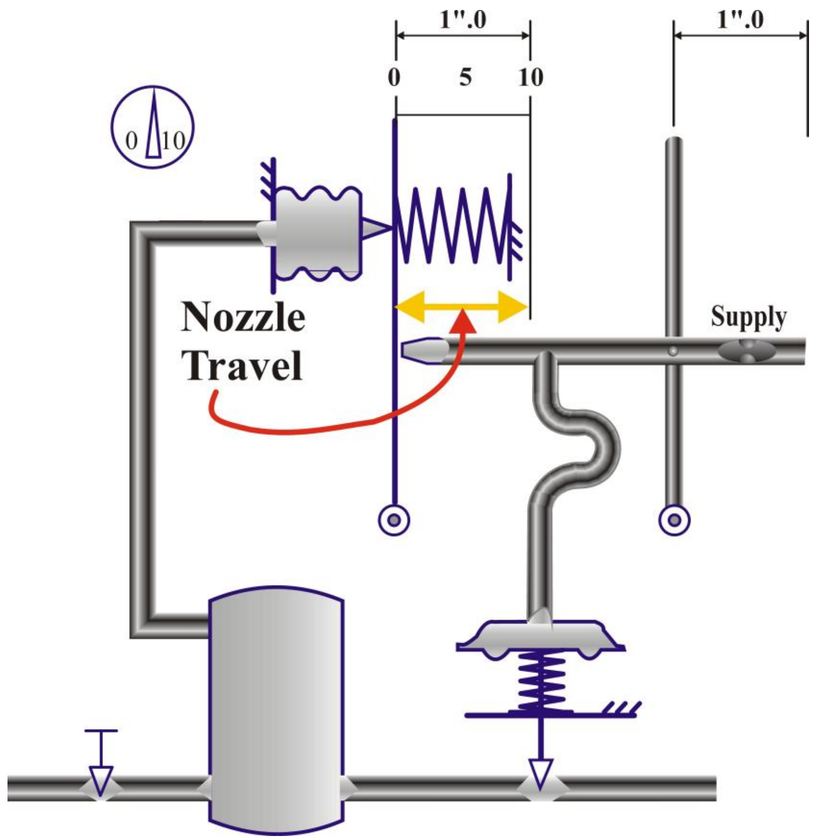
(9) At some point the controller reaches equilibrium at a valve diaphragm pressure slightly higher than before the increase in upstream pressure occurred. The higher diaphragm relates to the valve being more closed, there by a reduced flow rate.

c) Changing setpoint

(1) By moving the nozzle closer or farther from the flapper lever, point at which the controller controls can be changed.

(2) Moving the nozzle away from the lever will cause less pressure on the valve diaphragm, therefore allowing the valve to open more, raising the pressure in the tank.

(3) Moving the nozzle closer to the lever will cause an increased diaphragm pressure, closing the valve more, lowering the pressure in the tank.



Picture 12, Changing Setpoint By Varying Nozzle Position

(4) Other ways to change the setpoint would be to alter the design of the bellows or spring opposing the bellows.

d) More on gain

If the gain is set too high, the controller will continuously cycle the output valve open and closed

PRACTICE:

1 To what gain value does a proportional value of 50% equate?

2. Name the three basic components of a proportional only pneumatic controller.