ICE 3015: CONTROL SYSTEM COMPONENTS

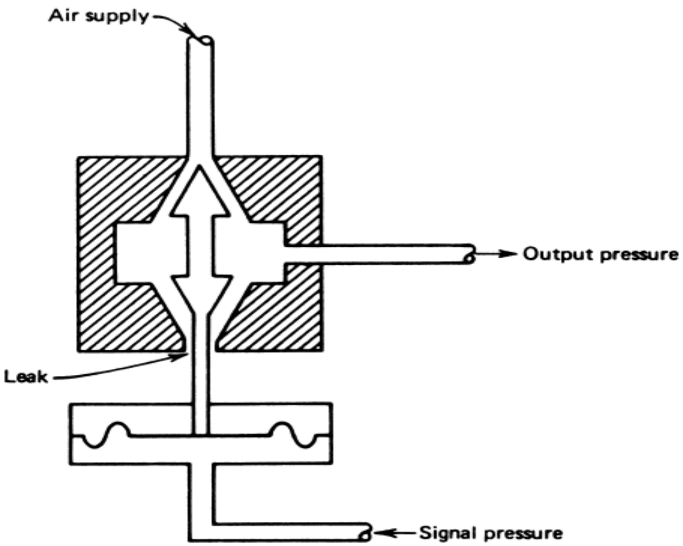
Flapper Nozzle & I/P Converter

Amplification By Booster

Raises the pressure and/or air flow volume by some linearly proportional amount from the input signal.

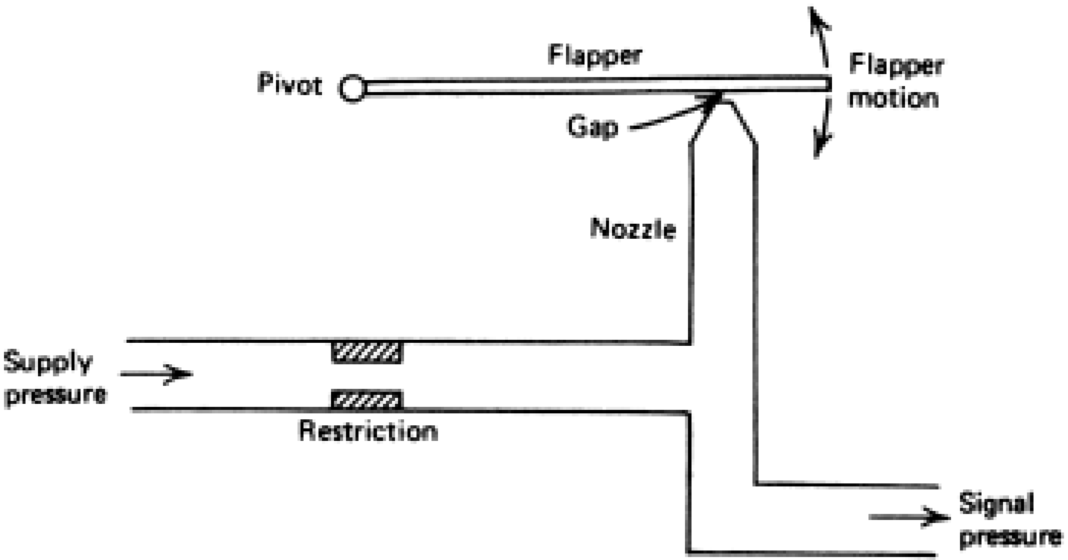
Thus, if the booster has a pressure gain of 10, the output would be 30 to 150 psi for an input of 3 to 15 psi.

.This device shown is reverse acting, because a high-signal pressure will cause output pressure to decrease.



Nozzle / Flapper System:

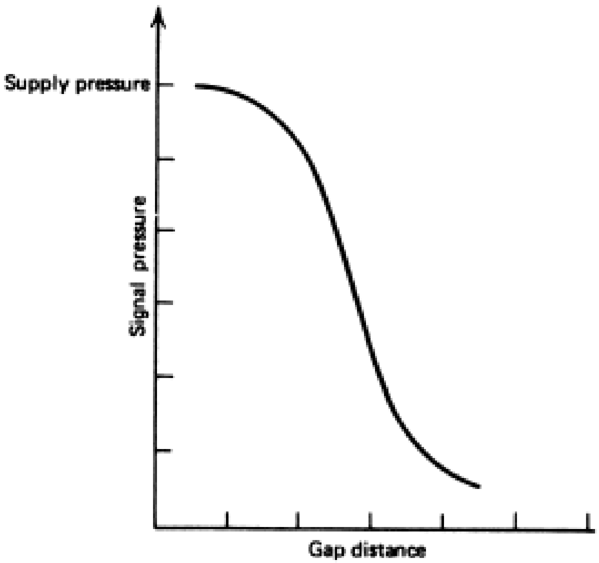
- Signal conversion from pressure to mechanical motion and vice versa can be provided by a nozzle/flapper system (sometimes called a nozzle/baffle system).
- A diagram of this device is shown in Figure.



Nozzle / Flapper System:

- A regulated supply of pressure, usually over 20 psig, provides a source of air through the restriction.
- The nozzle is open at the end where the gap exists between the nozzle and flapper, and air escapes in this region.
- If the flapper moves down and closes off the nozzle opening so that no air leaks, the signal pressure will rise to the supply pressure.
- As the flapper moves away, the signal pressure will drop because of the leaking gas.
- Finally, when the flapper is far away, the pressure will stabilize at some value determined by the maximum leak through the nozzle.
- Figure shows the relationship between signal pressure and gap distance.

Nozzle / Flapper System:

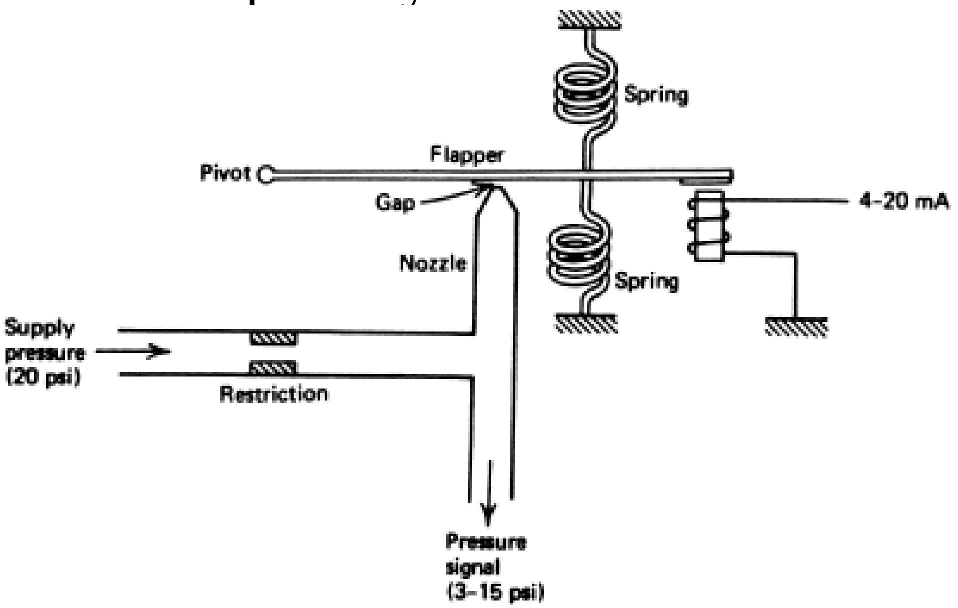


b) Signal pressure versus gap distance

- Note the great sensitivity in the central region.
- A nozzle/flapper is designed to operate in the central region, where the slope of the line is greatest.
- In this region, the response will be such that a very small motion of the flapper can change the pressure by an order of magnitude.
- This system is used in pneumatic controller design.

Current-to-Pressure Converters:

- The I/P converter gives us a linear way of translating the 4- to 20-mA current into a 3- to 15-psig signal.
- There are many designs for these converters, but the basic principle almost always involves the use of a nozzle/flapper system.
- Figure illustrates a simple way to construct such a converter.

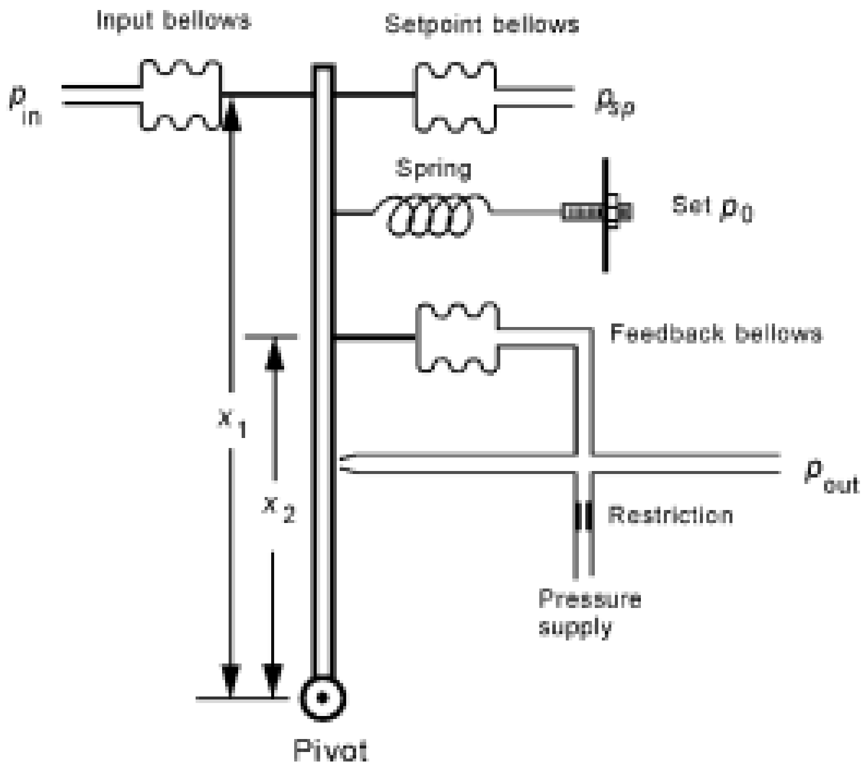


Pneumatic Controllers:

- The outward appearance of a pneumatic controller is typically the same as that for the electronic controller.
- The same readout of setpoint, error, and controller output appears, and adjustments of gain, rate, and reset are available.
- The working signal is most typically the 3- to 15-psi standard pneumatic process-control signal, usually derived from a regulated air supply of 20 to 30 psi.
- As usual, we use the English system unit of pressure because its use is so widespread in the process-control industry.
- Eventual conversion to the SI unit of N/m^2 or Pa will require some alteration in scale (of measurement) to a range of 20 to 100 kPa.

Pneumatic Proportional Controllers:

- A proportional mode of operation can be achieved with the system shown in Figure.



p_{sp} = setpoint pressure
x_2 = feedback lever arm (m)
A_2 = feedback bellows effective area (m^2)
p_{out} = output pressure (Pa)
x_1 = level arm of input (m)
A_1 = input and setpoint bellows effective area (m^2)
p_{in} = input pressure (Pa)
p_0 = pressure with no error

Pneumatic Proportional Controllers:

- Operation is understood by noting that if the input pressure increases, then the input bellows forces the flapper to rotate to close off the nozzle.
- When this happens, the output pressure increases so that the feedback bellows exerts a force to balance that of the input bellows.
- A balance condition then occurs when torques exerted by each about the pivot are equal, or

$$\left(P_{out} - P_0\right) A_2 x_2 = \left(P_{in} - P_{sp}\right) A_1 x_1$$

- This equation is solved to find the output pressure

$$P_{out} = \frac{x_1}{x_2} \frac{A_1}{A_2} \left(P_{in} - P_{sp}\right) A_1 x_1 + P_0$$

Pneumatic Proportional Controllers:

Where,

$$K_p = \left(\frac{x_1}{x_2}\right)\left(\frac{A_1}{A_2}\right)$$

- Because the bellows are usually of fixed geometry, the gain is varied by changing the lever arm length.
- In this simple representation, the gain is established by the distance between the bellows.
- If this separation is changed, the forces are no longer balanced, and for the same pressure a new controller output will be formed, corresponding to the new gain.

Pneumatic Proportional Controllers:

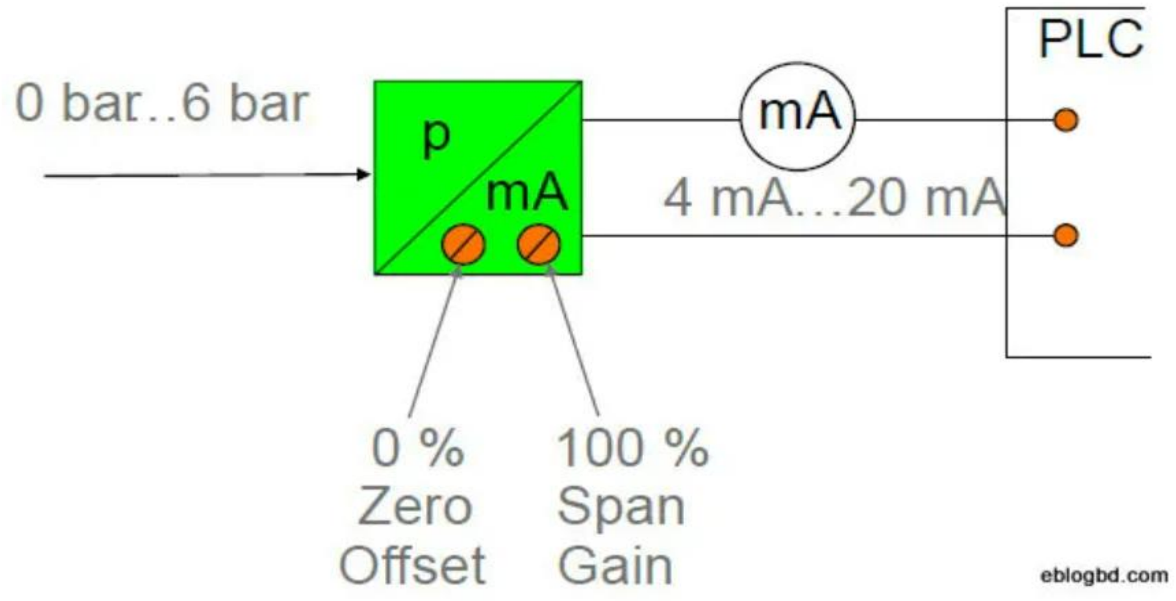
Try:

- Suppose a proportional pneumatic controller has $A_1 = A_2 = 5$ cm^2, $x_1 = 8$ cm and $x_2 = 5$ cm. The input and output pressure ranges are 3 to 15 psi. Find the input pressures that will drive the output from 3 to 15 psi. The setpoint pressure is 8 psi, and $P_0 = 10$ psi. Find the proportional band.

Solution:

$$K_p = \left(\frac{x_1}{x_2}\right)\left(\frac{A_1}{A_2}\right) = \frac{8}{5} \times \frac{5}{5} = 1.6$$

Calibration of P/I converter transmitter



I to P Converters

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References:

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- https://control.com/textbook/control-valves/control-valve-problems/