Valve Positioners - A Primer
Pneumatic Positioners

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Introduction:

Positioners, as the name indicates, help to position the operating mechanism of a control valve, normally the stem, to a desired position. It is expected that, if the stem (or the operating mechanism, in general) is moved to the required position, the valve will control the fluid flowing through it to the required quantity.

While the above words will help to understand the meaning of positioners, definitions abound to make the study of positioners rigorous. For example one of ISA's definition is 'Pneumatic Valve positioners is a device which precisely positions, by the use of air, the moving part (or parts) of a pneumatically operated valve in according with a pneumatic signal.' This definition is adequate before we embark on understanding the basics of positioners.

Working model for understanding positioners in general:

Human operators are the first positioners (and may be the last one, too, when every thing else fails).

Human control valve operator could be a model for our understanding of positioners. To start with, let us assume that the valve in question is a valve with a pneumatic actuator. Let us also assume, for the present, that the human operator does not know anything about the final controlled output of the process even though this process is controlled by the valve operated by him. Let him know only about the relationship between a signal, which in our model will be a pressure, which he will receive from the process persons and the position to which he should move the stem depending on the signal which he receives. He can have a pressure gauge to understand the signal he receives and a caliper scale which he uses to measure the position of the stem from its fully closed position. For simplicity sake, the valve is assumed to be a linear motion control valve like a globe control valve.

In case of our imaginary situation, let 80 mm be the full movement of the stem and the maximum value of signal that he can get is limited to 15 psi. The following table can represent the signal (in psi), he may receive, and the position of the valve stem desired, (in mm) for each of the signals he may receive.

Signal being received	Travel of stem	Travel of stem as % of full travel
15 psi (maximum signal)	80 mm (full closed)	100
12 psi	60mm	75
9 psi	40mm	50
6 psi	20mm	25
<= 3 psi (no signal or minimum signal)	0 mm (full open)	0

When he receives a signal of 9 psi he has to move the stem to a open position of 40mm. being the operator of the valve he has the freedom of increasing or decreasing the actuator pressure to move the valve stem to the required position. Thus his basic work or operation is checking the signal he receives and increasing or decreasing or holding still the actuator pressure till the required stem travel is achieved as per table above.

Our model is temporarily complete, for understanding various terms and functions of positioners. The important thing to keep in mind is that our human operator becomes a device called positioner which can not have the intelligence of a human being to 'fill –in – the gaps 'of understanding.

In the balance portion of this article, references would shift between this model and the actual positioner to facilitate easy understanding.

Inherent characteristic of a valve and modification of characteristics by valve positioners

One application of positioners is to alter the flow characteristics of a valve (within reasonable limits). For this use to be understood, an idea of inherent and installed flow characteristics of valve is needed.

In the above paragraphs I had mentioned that the positioner does not bother or know about the output of the valve. The positioner is concerned only with the stem position (which is the controlled variable for the positioner) depending on the signal (called the controlled signal) that is received. One can easily see the interest of any responsible person, is broader than just moving the stem to the position desired. His interest will be to get the flow that is desired. We can easily realize this to be possible only if we know the flow for various stem positions.

Flow through the valve for various stem positions is called the flow characteristics. Both the parameters, flow and stem travel, are expressed as percentage of their full positions.

The table below is an example of the flow characteristics of a control valve which is

Signal being received	**Stem travel in mm (0 mm is fully closed) (called as stem lift)**	**Stem travel as % of full travel**	**Flow in lpm**	**Flow (as % of flow at full travel position)**
15 psi (maximum signal)	80 (fully closed)	100	0	0
12 psi	60	75	16	3
9 psi	40	50	50	10
6 psi	20	25	158	31
<= 3 psi (no signal or minimum signal)	0	0	500	100

called equal percentage flow characteristics. Only the third and fifth column is relevant.

Characteristics data for another valve which is called linear characteristic is provided

Signal being received	**Stem travel in mm (0 mm is fully closed) (called as stem lift)**	**Stem travel as % of full travel**	**Flow in lpm**	**Flow (as % of flow at full travel position)**
15 psi (maximum signal)	80 (fully closed)	100	0	100
12 psi	60	75	375	75
9 psi	40	50	250	50
6 psi	20	25	125	25
<= 3 psi (no signal or minimum signal)	0	0	500	0

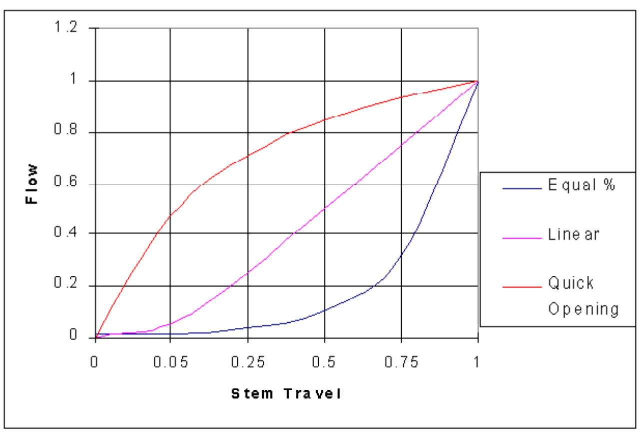
below:

Signal being received	**Stem travel in mm (0 mm is fully closed) (called as stem lift)**	**Stem travel as % of full travel**	**Flow in lpm**	**Flow (as % of flow at full travel position)**
15 psi (maximum signal)	80 (fully open)	100	500	100
12 psi	60	75	465	93
9 psi	40	50	420	84
6 psi	20	25	353	70
<= 3 psi (no signal or minimum signal)	0	0	0	0

Characteristics data for a third valve which is called quick opening characteristic is provided below:

In a field situation when the valve stem travels and flow is altered, the differential pressure between the upstream and downstream of the valve would vary. For example at 100%, stem travel, the pressure drop or the differential pressure will be low and the flow will be high. (For the uninitiated, the pressure drop produces velocity head which flowing through the opening in the valve produces the flow). Stem travel, flow and pressure drop comes into play together in the characteristics of a valve.

However in the above tables, we have concerned ourselves with the flow only and not the pressure drop. Inherent in our thinking is that pressure drop is constant. Such constant pressure drops is a rarity in real situations. To a manufacturer the actual pressures or the pressure drops at sites are unknown and would vary from one application to another. If he has to provide data about the flow in the valve for various stem position, he can only assume the pressure drop will be constant. The above table of stem travel versus the flow is the outcome of such an exercise. This relationship, which assumes a constant pressure drop, is called inherent characteristics of a valve.



The graph below provides three typical inherent flow characteristics of control valves described in

When a valve gets installed, the installed characteristics will be different than the inherent characteristics. This is mainly due to the pressure across the valve varying with each flow (or one can say that a constant pressure source which can meet all flows is not available in any situations). In an installed situation, the characteristics curves tend to move up depending on the amount of pressure drops ahead and beyond the valve along with the pressure drop across the valve. By upward movement of the curve it is meant that equal percentage tends towards linear, linear moves towards quick opening etc..

Let us now look at how a positioner can alter the installed valve characteristics. One has to keep in mind that inherent valve characteristics is something to do with the design of a valve. By positioner altering the valve characteristics, we mean that the positioner can alter the characteristics of input signal to flow.

In case of the linear characteristics, in the example above, a signal 9 psi, can produce a flow of 250 lpm by moving the stem to 50%, while in case of equal percentage valve the same signal produces flow of 50 lpm for the same 50% movement of stem. For getting only 50 lpm, in the linear

Signal being received	Stem travel in mm (0 mm is fully closed) (called as stem lift)	To be understood as movement of stem in %
15 psi (maximum signal)	80 (fully open)	100
12 psi	60	94
9 psi	40	85
6 psi	20	70
<= 3 psi (no signal or minimum signal)	0	0

valve the stem has to be moved only by 8%. Let us assume that our model human positioner is given another table as below :

When he finds that the stem has moved to 75mm (5mm from fully open position) or 94% of travel, he should look up the above table and understand that it has moved to the 75% of travel position. In a similar way he should translate each movement of the stem to a movement as given in the table above. If he adjusts the position of stem by adjusting the actuator pressure accordingly, he would have made the relationship of control signal to flow, of a linear valve into an equal percentage valve. While for a human positioner model the above translation table can be provided, for the actual positioner, a cam is interfaced between the stem and the positioner which modify the stem movement input into the positioner in a manner similar to the above table. The exact way a cam is made will be discussed later.

It is not possible to get an exactly matching equal percentage curve for stem travel between 0 to 20mm of actual movement of stem. For this movement, note the above table gives a very large percentage movement. The implication is that for lower flows the modification will not produce good results. For example, gate valve is a linear motion valve. It is difficult to control and get a low flow in these valves (unless the valve itself is changed into a smaller valve).

Overcoming stem friction in the valve and positioners:

Another important use of positioner is to overcome varying stem friction.

Varying stem friction due to gland leakages, new packing, metallic contacts etc would need varying actuator pressures to get the correct position of stem and in turn the required flow. Use of positioners brings in this advantage automatically. Depending on the manufacturing and design accuracies, positioners can control stem movement within 0.02mm, with a high amount of varying stem friction. Accuracy of positioning expressed as ercentage of travel is an important aspect of any positioner .Linearity and hysterisis are other important part aspects of valve positioners. Design and manufacturing accuracies can only produce a reliable positioner.

Control valve's speed of response and positioner:

Alternative to a positioner is the process controller directly controlling the valve position. This is similar to removing the human valve operator in our model and the process controller who is watching the process controlling the valve directly. In majority of the situations except for highly fast processes, this will decrease the speed of response if the control system is a pneumatic control system.

This is due to

a. When the actuation needs large forces, large amount of air may have to be moved from the controller to actuator over long lengths. Positioner signals, on the other hand, need very small volume of air to be moved. Amount of air to be moved along with the length and diameter of connection would determine the time.

b. The construction of controller, how fast it pushes the air requirements to the valve actuator would also determine the control valve speed. In case of the positioner, a pilot senses and opens a larger port for movement of air; this opening will be normally very large compared to the opening in the pilot relay.

Sluggishness is a disadvantage introduced by a positioner:

When a process changes fast, the elements described above will result in sluggishness.

Avoidable delays like faster communication by means of digital signals or by means of lesser mass in the communication circuits can improve the response time

Split range operation and positioners:

There are occasions when operation of two valves has to be done on the basis of a signal being sent by a controller. Frequent example is Valve for Gas Compression and Valve for flaring. For example, signal may trigger operation of one valve stroking when the signal is from 3 to 9 psi and another valve stroking when the signal is between 9 to 15 psi. Positioner with only change of spring can achieve this.

Flow medium and positioners:

Some media forms deposits, erodes stem surfaces and generally increase the force needed to close valves over operating cycles. An application of positioner is such situations is necessary. By their construction they take care of such situations.

Similarly when higher pressure is required to operate the valve due to fluid pressure variations, positioners can easily take care of such situations.

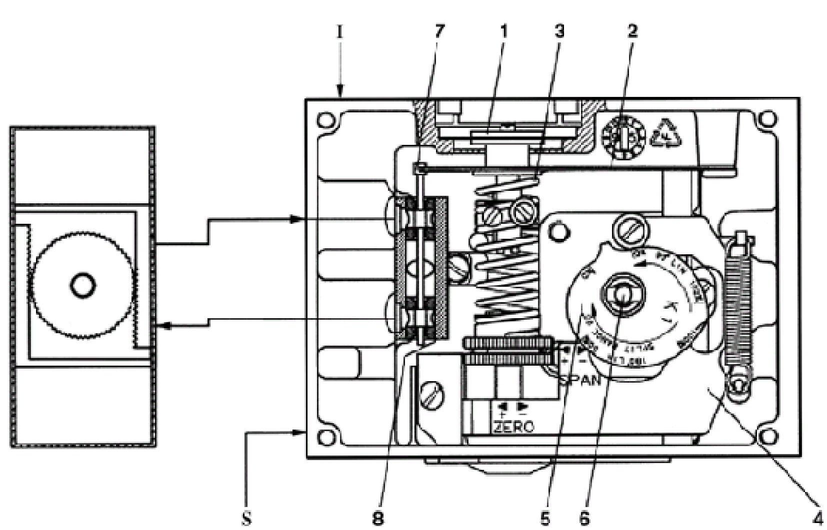
Requirement of wide band of operaton:

When small changes in the control signal needs to operate the valve over a wide range due to process needs, positioners are the only solutions. The reasons are obvious: range of signal pressure changes and the resulting changes in the movement of the stem are the basic principle of operation of the positioner. A small change in signal without the positioner may not get translated into the larges changes in operator pressure that may be needed to operate the valve.

Reversing action of a valve actuator and positioner :

When the control signal increases, the air pressure to an actuator may need to increase. In some cases when the control signal decrease, the air pressure to the actuator may need to decrease. Without a positioner this reversal of action will involve complication in control. A positioner

Assume an equilibrium position. An increased control signal will deflect the diaphragm (1) down, compressing the feedback spring (3). The balance arm (2) moves the spool (7) in the pilot valve (8) supplying air to the actuator. At the same time, air is exhausted from the actuator and is vented to atmosphere through the pilot valve. When the pressure imbalance exists, the actuator rotates moving the positioner shaft (6). The shaft and cam (5) rotate, forcing the lower arm (4) upwards compressing the feedback spring (3). The motion will continue until the two forces are equal and the unit is in an equilibrium position.



(direct acting in the first case and reverse acting in the second case) is most of the time amenable to a change even in the field.

Construction and design of valve positioners:

Pneumatic valve positioners are precision engineering products and have to be carefully designed and manufactured.

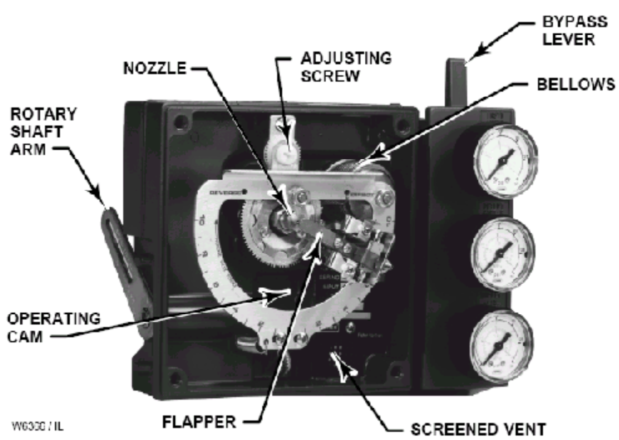
In the construction of the product , it would be obvious , that an

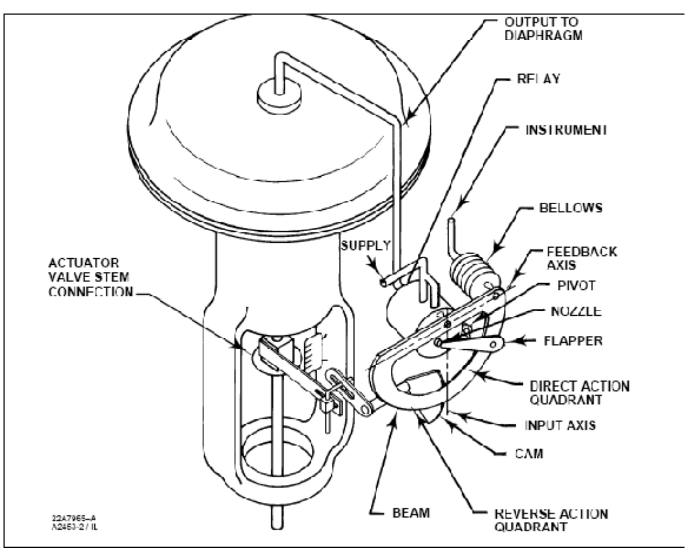
a) arrangement would be needed to pick up the pressure signal being conveyed to the positioner from the controller,

b) arrangement to pick up the position of the stem,

c) arrangement to alter the supply of air to , and exhaust from, the actuator based on the above two variables

All these arrangements have to made possible within a short space and the design along with material used should be able to withstand frequent and large no of cyclic loading and still maintain accuracy. Fortunately for the designer, except for boundary containing actuator pressure, higher pressures need not be handled. Also higher temperatures or corrosion or erosion are rarity.





Large no of design variations are available for each of the above functions. Incorporations of other 'add-ons' like variation in gain (amount of air into the actuator that will be moved compared to signal pressure), split operation, zero adjustments (to take care of slackness), travel adjustment(for various valves) etc. also introduce design variations.

Before 'how to design or evaluate a positioner' is covered let us look at a popular design approach adopted to cover the essential elements of design listed above.

Incoming signal is normally led into one side of sealed diaphragm (or a sealed bellow) which can convert the pressure into force and convey the force to a link. The link can be arm of a lever or a simple column.

The movement of the stem (or position) can be also converted into a force. One easy method available in mechanical engineering to convert linear movement into a force is compression or elongation of a spring. This spring can be part of arm of a lever mechanism described .Movement of stem, which will be linear, can be converted before it is conveyed to the lever,into desired characteristics by means of a cam.

Both the above forces can be made to balance one against the other. If the unbalanced force operates an air valve, needed additional air will get let into the actuator and /or exhausted from the actuator which will make the stem move and the balance to be resorted. A spool valve or a nozzle is the usual arrangement to achieve this.

The following two diagrams are taken our of operation manuals of two well known manufacturers. In the first example the operation is also described. Readers would notice how the broad design approach described above is adopted in each of these two cases. It would be interesting to note how the levers, are different from tradition 'levers', in appearance but are essentially same in function. Arrangements of fulcrum point of the lever look different but serve the same purpose. Each of the points in the designs adopted have their advantages and disadvantage.

First iteration for a designer of pneumatic valve positioner normally starts with the signal pressure and leads to deciding on the bellow / diaphragm design. Required areas are decided to the minimum extent that will produce necessary forces assuming again minimum leverage ratios. Spring design is then completed. Pressure range and thus the load range, space, compression of spring based on the lever and stem movements, life are some of the important factors that will go into spring design. Flow of primary air for the variations will decide the nozzle area (need for spools when large airs have to be moved, can possibly be appreciated, by the reader now) and air inlet and movement of nozzle openings. Levers and other parts are designed next and the iteration is repeated.

In evaluating a design of a positioner it has to be kept in mind that a good designer can make any design to be an acceptable design, when he takes note of all issues and incorporates them. However what makes a good design differ from an average design is the ease and repeatability with which accuracies are achieved.

Specification for a valve positioner:

A comprehensive specification for a valve positioner should cover the following:

a. Standard stroke without any cam

b. Cams available and their stroke limits along with charateristics

c. Gain

d. Supply pressure

e. Supply pressure effect

f. Air flow capacity into actuator

g. Airflow capacity exhaust to actuator

h. Pneumatic connection sizes

i. Overall and mounting dimensions

j. Material of construction for enclosure, air enclosure and pilot valve and other main parts

k. Enclosure standard

c Control signal input range : (e.g.: 3 to 15 psig)

d.. Testing standard for accuracy : (e.g. ISA S75.3)

e Resolution : (e.g.: 0.1% of maximum span)

f. Accuracy : (e.g.: 1% of maximum span)

g. Hysterisis : (e.g. : 0.5% of maximum span)

h. Repeatabiity : (e.g. : 0.2% of maximum span)

i. Deadband : (e.g.: 0.2% of maximum span)

j. Linearity; (e.g. :0.8% of maximum span)

k. Weight:

l. Operating temperature limits:

m. Storage temperature limits:

n. Humidity for operation / storage :

o. Drive shaft options for the cam drive

p. Accessories specification for pressure gauges, special speed control orifices, mounting kits, indicators, indicator lights, air filter with mounting, air regulator with mounting, external by pass valve if needed, manifold blocks if provided

q. Spare parts needed for 3 year operation

r. Approvals obtained

In the next part of article, we will cover how each of these characteristic are obtained or varied during design and manufacturing.

Concluding remarks:

This article does provide a work book for design, nor a manual for evaluation of pneumatic positioners. It attempts to cover various aspects of pneumatic positioners used with valves.

In the second part of this article, we will cover the electro pneumatic positioner, and the digital (frequently referred smart po[1] sitioners) along with bus issues.

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