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SERVO PILOTS FOR SELF ACTUATED PRESSURE REGULATORS IN NATURAL GAS APPLICATION

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ABSTRACT

The pressure regulators are used to regulate the pressure according to the system requirement for controlling upstream or downstream pressure. In natural gas application we generally use pressure regulators for controlling the downstream pressure, especially to supply gas to consumers. In some cases, these pressure regulators are also used to control pressure of one pipeline section as per PNGRB regulations. The pressure regulators based on self-actuated type are widely used for the above mentioned purposes. The pneumatic type PCV also has many advantages, however, due to many components and requirement of pneumatic compressor and its maintenance, drives the designers to move towards self-actuated type pressure regulator. One of the advantage of pneumatic pressure regulators is, it can be controlled from remote location. Hence, if this feature is combined to the self-actuated type pressure regualtors, It can help to control pressure from remote location.

The development in the field of IoT, may require tomorrow's pressure regulators to communicate with end user's equipment. The self-actuated type pressure regulators uses a pilot, in which we provide setpoint through spring compression. Scope of the study is possible use of servo pilots in the place of traditional pilots for remote activation of pressure regulators.

KEYWORDS

Pressure Regulators, Self Actuation, Servo Pilot, IoT application

1.0 INTRODUCTION

A typical pressure regulation skid for natural gas application is shown in Fig.1. In the direction of flow, a Slam shut valve, Monitor Regulator and Active Regulator is installed in each stream. If Active Regulator Fails monitor will come in line and monitor fails, SSV trips the stream and automatically the other stream will come in line. Hence, the SSV setting of the running stream is to be less than the stand by stream.

In Self actuated regulator, actuating medium is Gas which needs to be regulated. Hence, there is no external requirement for medium of actuation. It has a main valve and a pilot valve to function as regulator. Set Pressure is given in Pilot with spring setting.

Advantages are less component are required, No need of separate supply of air or other medium for valve actuation, economical, quick control on pressure variation, Simple in Operation, No need of any extensive knowledge on valve tuning, Low DP sizing for wide range of flow.

Disadvantages are the valve operation depends upon the upstream pressure, temperature and flow. Changes in any of these parameter changes the downstream pressure and there by it is not accurate in pressure regulation. It cannot be controlled from remote. It uses Spring for setting of pressure, again which has hysteresis error and lead to uncertain in pressure setting.

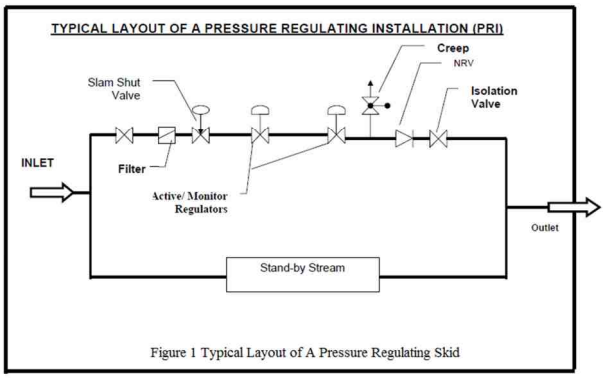

Figure 1 Typical Layout of A Pressure Regulating Skid

2.0 SELF ACTUATED PCV WORKING PRINCIPLE

Mostly the main valve control is being taken place with the help of a diaphragm. Please Refer Fig.2. Setting pressure for the regulator is given to a spring of the pilot. Spring develops pressure on one side of pilot diaphragm and other side was pressurised by regulator downstream. There is one impulse line which comes from the upstream side of the regulator to one side of the diaphragm of main valve against the downstream pressure.

When downstream pressure is less than the set pressure of the spring, the pilot diaphragm moves down and breath out excess gas from upstream to downstream, and hence, main valve diaphragm moves upward and allows maximum gas to pass through the valve. Pressure in the downstream will increase until it reaches the setpoint in the pilot spring.

When downstream pressure is more than the set pressure of the spring, the pilot diaphragm moves upward and cuts excess gas from upstream to downstream, and hence, main valve diaphragm moves downward and reduces amount of gas to pass through the valve. Pressure in the downstream will decrease until it reaches the setpoint set in the pilot spring. Thus, the predicted output flow of regulator depends upon the surrounding system pressure as given in equation .1

$$Q = \sqrt{\frac{520}{GT}} .C_h.C_g.P_1.\text{Sin}[\theta] \text{ Sft}^3/\text{Hr} \qquad (1)$$

Where,

$$\theta = \frac{59.64}{C_h}.\frac{C_v}{C_g}.\sqrt{\frac{P_1-P_2}{P_1}} \text{ radians} \qquad (2)$$

(within the limits 0 and $\frac{\pi}{2}$)

Where P_1 and P_2 are the upstream and downstream pressure respectively, and C_v and C_g are coefficients which are dependent upon the valves displacement position. Hence, for critical or chocked flow,

$$Qc = C_h C_g P_1 \sqrt{\frac{520}{GT}} \qquad (3)$$

Hence, Variation in theupstream pressure condition demands the change in setpoint value to maintain better pressure.

3.0 SERVO PILOT

In the existing Pilot Pressure Regulators the setting is given through Spring which causes, poor response to control when upstream pressure, temperature and flow changes to a greater extent. Based on my 12 years of field experience in pressure regulator, I certainly conclude it that, the Hysteresis property of the spring affects the reproducibility of the pressure regulator in totality. Most of the stations are remote and set pressure has to be changed if it consumer changes their flow pattern. Hence, accurate control of pressure has become vital in case of regulator operation.

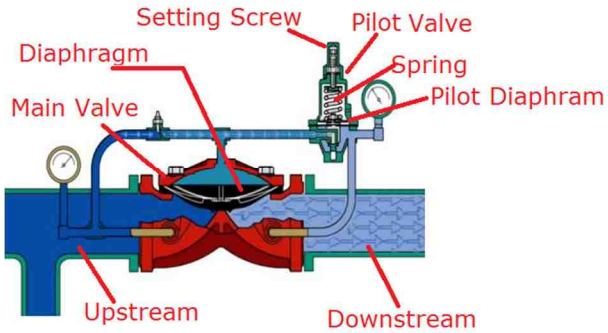

Fig-2. Working Principle of Self Actuated Pressure Regulator.

These self-actuated pressure regulators are cheaper than pneumatic air actuated regulators by capital cost and running cost. Hence, Self-actuated regulators

are widely preferred on the ground of cost and safety.

However, the limitation of the self-actuated regulator causes, sometime it gives pain in its application. These self- actuated pressure regulators tripped many plants due to their poor response in control at lower flow rates. Even when there is a cushion to open a valve at higher flowrate, they do not open due to their combined flow effect with spring setting. These causes frequent changes in pressure setting and requires continues monitoring.

These challenges have driven me to look for solution in these type of pressure regulator. The spring portion of the pilot has to be changed with same medium with the help of servo system as shown in the fig.3. I looked for a solution in the pressure regulator market for this issue. Though supplier guarantees that their regulator can function widely in the flow range but practically it does not. In the model of pressure regulator with servo pilot, the it can have a smooth control as we do not have spring tension to act against the pressure under control.

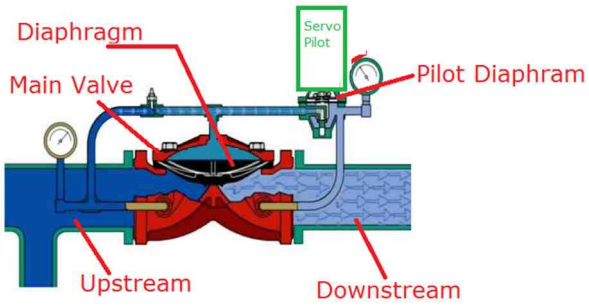

Fig-3. Servo Pilots for Pressure Regulators

3.1 Servo Pilot Working Principle:

Servo Pilot Regulators work by using a push valve, Control Valves and a vent valve to maintain the outlet pressure at the desired set-point. A small internal pressure sensor monitors the output pressure and a digital or analog controller adjusts the timing of the servo valves to maintain the set-point. It typically require a DC power supply and a set-point signal. Analog controllers typically accept either current (4-20 mA) or voltage (typically 0-10 or 0-5 VDC) input. With digital circuits it can accept serial communications (such as RS-232/485 or DeviceNet) in addition to the common analog standards.

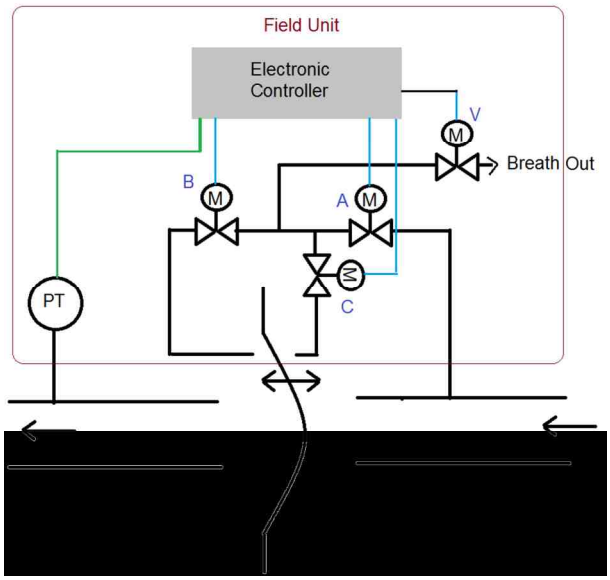

Fig-4 Schematic Diagram of Servo Pilot

The Electronic controller in the Servo pilot, takes information from pressure sensor PT, set point detail from remote location, and gives control signal to servo valves A,B,C and V.

When downstream pressure of regulator valve is less than set point, controller opens valve A and B which in turn Moves diaphragm back and creates more amount of gas to flow. The moment pressure crosses setpoint, controller closes Valve B and Opens C. By this way it controls the main regulator. If pressure saturation occurs across the main valve diaphragm, it will breath out excess gas through V, and brings the system in control.

The electronic controller can be connected with flow measuring devices like flow computers. This can enable the system to understand the practical demand of gas and intelligently it controls the pulsation of flow in low flow condition, by accurate control in position of servo valves. A control table for low flow condition and high flow condition can be fed into the controller for appropriate control action. Due to advancement in nano

technology, the complete device can be made small in size. Small filter housing may be provided before the Valve A for easy maintenance. The flowchart given in the fig. 5, explains about the controller logic.

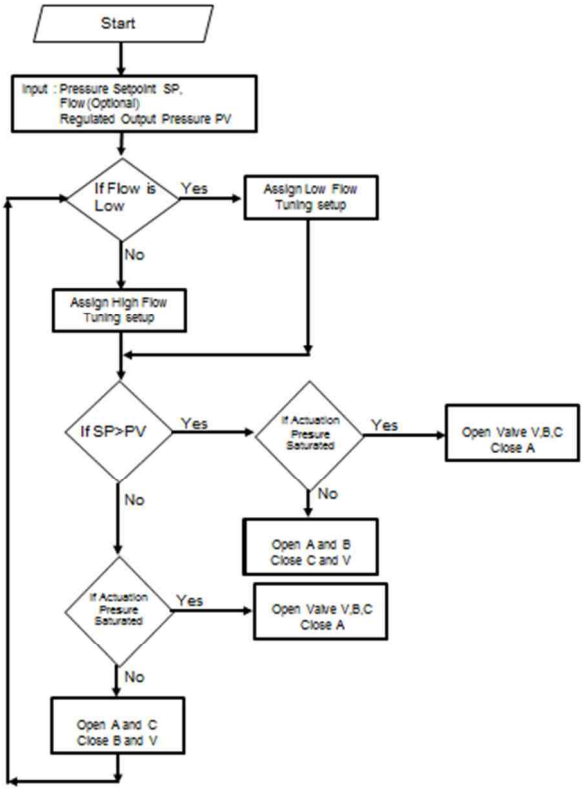

Fig-5 Flowchart of Controller Algorithm

The following Table-1 depicts the required control action.

Table-01Condition for Action By Controller

Condition	Required Action
If Flow is Low, and Set point is more than Outlet Pressure	Assign Small change in angle for Servo valves, Open Valve A and B, Close C and V
If Flow is Low, and Set point is less than Outlet Pressure	Assign Small Change in Angle, Open Valve A and C, Close B and V
If Flow is High, and Set point is more than Outlet Pressure	Assign Large change in angle for Servo valves, Open Valve A and B, Close C and V
If Flow is High, and Set point is less than Outlet Pressure	Assign Large Change in Angle, Open Valve A and C, Close B and V
If Pressure is Saturated across Diaphragm	Close Valve A,Open, B,C and V. Opening Angle of V depends upon the Sizing requirement

3.2 Internet of Things and Servo Pilot:

The Servo pilots can be connected through wi-fi to interact with, other equipments. For Example, the flow demand of the different consumer equipment gets changed, or under the way of changing, those equipments will communicate the requirement of pressure at their end to pressure network administrator(which inturn a pressure monitoring SCADA something like that).the pressure network administrator will convey the information to servo pilot controller about the future pressure settings. Accordingly, the servo pilots will activate the main valve regulator. Further this controller may communicate its subsequent upstream controllers about its minimum upstream pressure requirement. The day is not so far to get into there and to keep all happy.

3.3 Advantages

1. Accurate Pressure control.
2. Remote setting to Pressure control valve.
3. Quick control.
4. Capital Cost and Running Cost are Less than pneumatic air actuated valves.
5. Can be operated by Lithium battery and hence no need of any external power supply.
6. Chances of Failure rate is very less.
7. Reproducibility is improved.
8. Low DP sizing.
9. No need of any extensive knowledge on valve tuning.
10. No need of separate supply of air or other medium for valve actuation.

4.0 DISCUSSION:

The principle of operation of servo pilot above discussed will be definitely safe. In case, if the control action fails, it may lead to low gas pressure or high gas pressure. If Low gas pressure and the setting is less than the stand by stream, as discussed earlier, the stand by stream will come into service. If Hig

Gas pressure the monitor of the stream will come into action. Hence, the entire principle of operation in failure condition is safe. Apart from this condition, it is also easy to configure, failure to open or close condition for the actuator valve.

5.0 CONCLUSION:

It is clearly understood, this model of pilots for self-actuated PRVs can work for various different condition for Natural Gas Application along with various communication technology. It is possible to design low DP sizing valves, in case of very low header pressure, which is generally a killing crisis for successful function of pressure regulators.

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NOMENCLATURE

C_h	Correction factor for Sp. Heat Variation
C_v,C_g	Valve Coefficients
D	Pipeline Diameter
G	Specific Density
Q	Volumetric Flow rate
T	Temperature
P	Pressure
V	Vent Valve
A,B,C	Servo Control Valves

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