Gas Regulators And Controls

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The oil and gas industry has such an abundance of fluids to handle that it has long been aware that automatic control is economical. Only in some batch processes, such as custody transfer, could the industry afford to have a man turn the valves off and on. A few years ago, just very large fields could justify lease automation, but today almost every field is studied for its automation economics. The subject of gas regulators and controls is most appropriate for consideration by all levels of oil and gas company personnel. These devices are an important part of automation of any fluid flow endeavor.

There are 4 topics that pin point the problems. Solutions are suggested. If you can pick up some useful ideas on the hardware, various control functions, valve sizing, and applications, you will be able to show a larger net profit, or work a little less for the same profit in your operation of oil and gas facilities.

HARDWARE

The regulators and controllers can be categoried into means of operation:

1. Hand Operated
   a. Chokes
   b. Plug valves
   c. Butterfly valves
2. Self Operated
   a. Spring loaded
   b. Weight loaded
   c. Constant pressure loaded
3. Pilot Operated
   a. Time cycle
   b. Pressure pilot
   c. Flow controllers
   d. Temperature controllers
   e. Thermal value controllers

Mention is made of the hand operated units because there have been many placed in service; many more will be placed in service. Everyone familiar at all with field operations has seen these. The term "regulator" implies that something dynamic needs taming -- that some variable in a process is apt to get out of bounds unless there is a way to control it. "Hand operated" announces that a human hand is necessary to make these changes. How many times a day is a setting change necessary? The frequency of the change required and the availability of a hand govern the acceptability of hand-operated controls.

Of increasing interest to the cost-conscious operator is the automatic regulator.

Low pressure operation can be accomplished with "self-operated" regulators. "Self-operated" announces that automatic compensation for changes is made as the changes occur. Pressure is a usual variable to be regulated. Typically the fluid pressure pushes against a flexible diaphragm. The center of the diaphragm is attached to a stem and plug. The edge of the diaphragm is enclosed in a case. The force on the diaphragm caused by operating fluid pressure is resisted by a spring, or by a static weight, or by a pressure. A typical regulator is a spring-loaded back-pressure regulator shown in Figure 1. Control of a back or upstream pressure is obtained because a higher-than-wanted pressure will open the flow area between plug and seat and relieve the pressure; a lower-than-wanted pressure causes a reduction in flow area and the flow builds back the pressure. Self-operated regulators seldom are used for pressure above 125 psig.

Pilot-operated regulators are used for more accurate control and for high pressure control. Figure 2 illustrates a diaphragm control valve.

Typical operating pressure range of the diaphragm operator is 3 to 15 psig. Valve bodies are rated from 125 lb ASA cast iron to 10,000 lb API in alloy steel, with higher working pressure available as specials.

The "pilots" that send the 3 to 15 psig signal to a valve diaphragm may be used for the following variables:

1. Time
2. Pressure
3. Flow

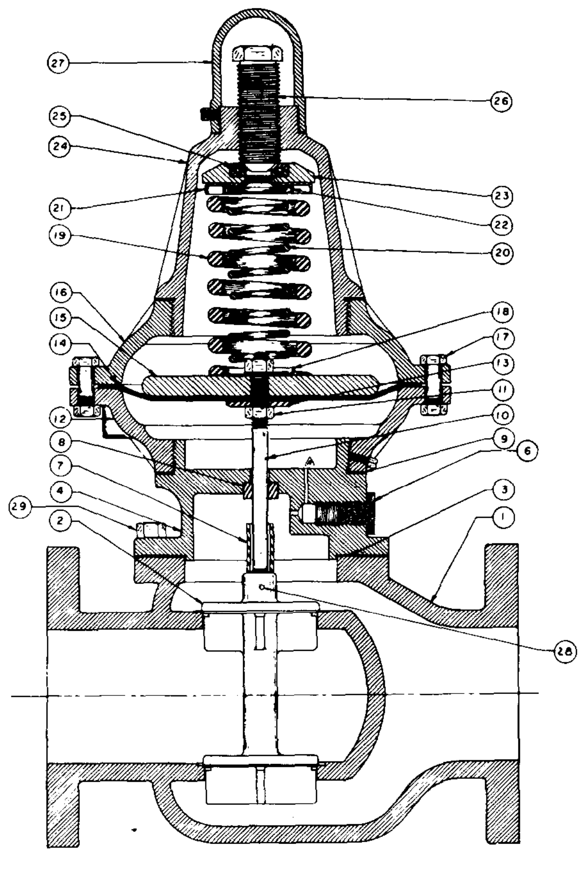

Fig. 1 – Type 73-05 Regulator

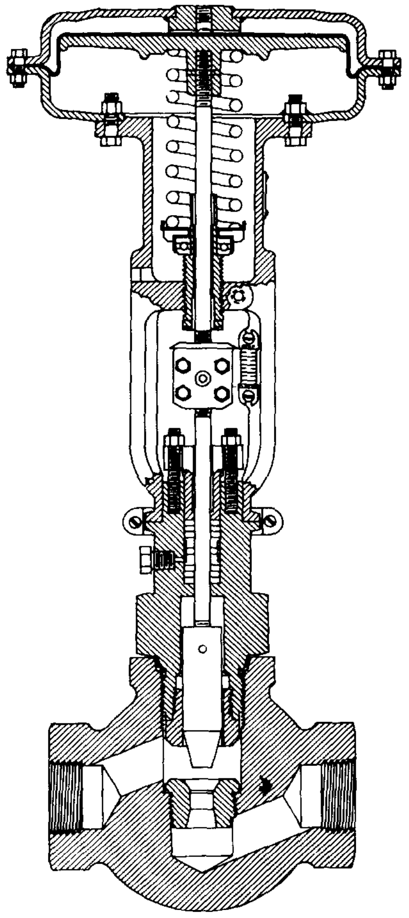

Fig. 2 - Type 70-18-1

4. Temperature
5. Gravity
6. Luquid Level
7. BTU Content

There are other controllable variables, but these are most common.

CONTROL FUNCTIONS

Someone must decide that a regulator is needed and what it is wanted to do. Assuming a typical variable of pressure, shall the controller be designed to give on-off, proportional, proportional plus reset, proportional plus rate, or proportional plus rate and reset control?

Self-operated controllers are available with proportional action only. Most oil field applications of controls are for on-off or proportional control.

On-off control defines itself.

In proportional control there is a fixed relationship between the value of the variable and the travel of our inner valve from open to closed positions. Usually this control type adequately handles field applications of throttling control.

If proportional control cannot keep a controlled variable within limits, addition of automatic reset, or rate, or both may be desirable. Systems with wide ranges of flow conditions and with slow response of the variable to a change in valve position should be considered for reset and rate.

As situations require more sophisticated instrumentation, reset and rate functions with pilot operated controls are typically used. The appended glossary defines the combined functions.

SIZING

The discussion so far has laid the ground work for the most interesting part of regulating valve planning -- sizing.

Old timers tell me that valve sizing used to be easy -- if you had a 4 in. line, you put in a 4 in. valve.

After World War II, rising costs and more demanding control requirements made people take a second look -- then the rule of thumb became: "Valve size one size less than line size."

Rules of thumb are better than none, but as with many other disciplines, sizing has become less an art and more a science.

Users must know or estimate limits of conditions of flow and from these the valves can be sized. For those of you not familiar at all with valve sizing, you may wish to ask for some reprints of technical papers presented by valve manufacturer's personnel.

The concept of the flow coefficient Cv was first introduced in the 1940's, and rapidly gained acceptance.

There are 3 basic equations used:

Liquid; $$Cv = GPM \sqrt{\frac{SpGr}{\text{Pressure drop}}}$$

Gas; $$Cv = \frac{SCFH}{963} \sqrt{\frac{G_g \times T^\circ R}{P_1^2 - P_2^2}}$$

Steam; $$Cv = \frac{\#/hr.}{63.4} \sqrt{\frac{V_2}{P_1 - P_2}}$$

The liquid formula is the definition of Cv. Other equations are derived from it because of the usefulness of the Cv concept. The derivation of the gas and steam Cv equations are given in previous publications 1, 2. Each of these 2 is derived from an energy balance from inlet to outlet of the valve. One energy from not found to change with non-compressible liquids is kinetic; lowered pressure at the outlet of a valve causes the specific volume of a gas to increase, which requires a velocity increase; hence, kinetic energy must be considered in energy balance. With most fluids flowing through a valve, increased flow can be realized by lowering the downstream pressure, but it is found that there is a limit to downstream pressure reduction for increasing gas flow. The limiting pressure is called the critical pressure.

The reason we size a gas valve using only the drop to critical pressure across the valve is that all the upstream energy is used in accelerating a gas to the speed of sound. This limiting velocity is obtained when the pressure drops to about 55% of the upstream (absolute) pressure.

Most valve manufacturers caution the valve users that while downstream pressures less than 55% of upstream pressure can be obtained and controlled, valve size is determined by this limiting thermodynamic consideration.

The sizing equations can be worked out with calculator or standard slide rule. Nomographs are available for solving these equations.

But the latest method for quick solution is the special slide rule.

There are several of these available for your examination. Let us work an example or two:

EXAMPLE 1

Liquid GPM = 420 gal per min
Sp Gr = .8
P_1 = 150 psia
Delta P = 80 psi

$$Cv = 420\sqrt{\frac{.8}{80}} = 42$$

EXAMPLE 2

Gas SCFH = 2MM natural gas
G_g = .6
T = 60° F = 520 R
P_1 = 1000 psig = 1015 psia
P_2 = 500 psig = 515 psia

Critical drop check P_1 x .55 = 1015 x .55 = 558

$$Cv = \frac{2{,}000{,}000}{963}\sqrt{\frac{.6 \times 520}{1015^2 - 558^2}}$$

$$= \frac{2{,}000{,}000}{963}\sqrt{\frac{.6 \times 520}{(1015 \text{ plus } 558) \times (1015 \text{ minus } 558)}}$$

$$= 43.3$$

Or, with the sizing rule

C_a = 56 ; FCV = .771 ; Cv = 43.2

Both examples show only a single set of flowing conditions. Not often do conditions stay the same. But how much do they vary? A valve or regulator should be sized on minimum and maximum conditions. Choice of inner valve characteristic is based on variations of Cv requirements.

APPLICATION

After sizing the inner valve and plug, the minimum valve size is established. There are several styles to choose from.

The following considerations decide what style of valve:

1. Price, initial and upkeep
2. Shut off requirements
3. Temperature limitations
4. Future increase or decrease in Cv
5. Ease of maintenance
6. Service life
7. Noise possibility

From the examples sized above, let us choose valves based on some of the considerations. A partial specification sheet attached can be used.

CONCLUSIONS

The information presented should provide a basis for understanding the problems connected with proper choice of gas regulators and controls. The examples given plus other samples of calculation in the sizing guide will guide you to solutions of sizing problems.

REFERENCES

1) D. J. L. Lin and A. J. Hanssen. "The Application Limits and Accuracies of Control Valve Flow Coefficient Cv," ASME Paper No. 56-IRD-22 (September 17, 1956)
2) D. J. L. Lin and A. J. Hanssen. "Control Valve Sizing for Gas Flows," presented at 31st and 32nd Southwest Gas Measurement Short Course; Norman, Oklahoma
3) "Recommended Voluntary Standard Formulas for Sizing Control Valves," Fluid Controls Institute, Inc., Pompano Beach, Florida, adopted May 16, 1962.

GLOSSARY

I. Liquid

$$Cv = GPM\sqrt{\frac{SpGr}{\text{Pressure drop}}}$$

Cv Valve flow coefficient
GPM U. S. gallons per minute flowing through valve
SpGr Specific gravity at operating temperature referenced to water at 60° F.
Pressure drop Pressure at valve inlet less pressure at valve outlet
Note: Outlet pressure for calculation should be no lower than saturation pressure

Special case of flow through angle valve

$$Cv = \frac{GPM\sqrt{SpGr}}{(\text{Pressure drop})^{.385}}$$

This equation is for flow in the side, out the bottom.

II. Gas

$$Cv = \frac{SCFH}{963}\sqrt{\frac{G_g \times T(\ R)}{P_1^2 - P_2^2}}$$

$$= \frac{SCFH}{963}\sqrt{\frac{G_g \times T(\ R)}{P_1 \text{ plus } P_2\text{) Delta P}}}$$

SCFH Standard cubic feet per hour at 60° F, 14.7 psia, to flow through valve
963 Conversion constant to allow use of familiar terms of pressure in psi, etc.
G_g Gravity of gas, refered to air as 1.000 it is also equal to Molecular Weight of gas divided by Molecular Weight of air
T (°R) Absolute temperature which is degrees Fahrenheit plus 460

P_1 — Pressure, pounds per square inch, absolute, at entrance of valve

P_2 — Pressure, PSIA, at exit of valve, but P_2 is P critical if P_2 is less than about (.5) P_1

$$P_{critical} = \left[P_1 \left(\frac{2}{N \text{ plus } 1}\right)\right]^{\frac{N}{N-1}}$$

N = ratio of specific heat

Note: Compressibility factor, Z, can Correctly be inserted as

$$Cv = \frac{SCFH}{963}\sqrt{\frac{G_g - Z - T(°R)}{P_1^{\,2} - P_2^{\,2}}}$$

III. Steam

$$Cv = \frac{\#/Hr.}{63.4}\sqrt{\frac{V_2}{P_1 - P_2}}$$

#/Hr. — Steam rate of flow in pounds per hour, to flow through valve

63.4 — Conversion constant

V_2 — Specific volume, cubic feet per pound, of steam at outlet conditions, i.e., is enthalpic expansion from inlet conditions to outlet pressure

P_1 — Inlet pressure, psia

P_2 — Outlet pressure, psia. Again P_2 for sizing can be no lower than critical drop. P critical is about equal to .57 P_1 for saturated steam or equal to .55 P_1 of superheated steam

Valve Trim — All parts on inside of body touching the flowing fluid with the exception of the body itself, the bottom plate, if any, and the bonnet, and not including the packing. Normal trim: inner valve, seat ring, or rings, lower stem, inner valve pin, guide bushings, packing follower and packing spring.

Characteristics — The variation of flow capacity with inner valve travel is called the characteristic. Typical types are quick open, linear, and percentage. Normal Cv values are given by manufacturers in 5 or 10 equal increments of total valve travel.

Rangeability — The ratio of maximum controllable flow coefficient to minimum controllable. Usually taken as ratio at 90% Cv to 10% Cv. A 40 to 1 rangeability is about as much as any manufacturer normally offers.

Top Works — The hardware outside the valve body that is mechanically attached to the inner valve and which the operating medium works on.
The top works consist of a yoke or adapter and a diaphragm operator. The diaphragm operator is sometimes called air motor, air operator, diaphragm actuator.
Usually the diaphragm is spring opposed. Cylinders and pistons are sometimes used with air or hydraulic liquids if long strokes of the inner valve are necessary.

Control Functions — Proportional plus reset. Reset added to a proportional controller gives a gradual shift of controller output pressure to compensate for load changes.
Proportional plus rate. Rate added to proportional control provides a more rapid correction to the controller output pressure when the deviation from control point is rapid. Rate acts as a temporary narrowing of the proportional band.
Proportional plus rate, plus reset. Adding both rate and reset to a proportional controller provides control with small deviations from set point in systems, where load changes are large, where variable being controlled varies rapidly, and where response of variable to a valve change is slow.

QUOTATION

INQUIRY No. ____________
Date ____________

TO: ____________

Page ____ Of ____

VALVES & REGULATORS

		SPECIFICATION	SPECIFICATION
Item or Tag No.			
Service			
	Type No. & Quantity		
BODY:	Size, Rating & Type Conn's.		
	Form & Mat'l		
	Bonnet		
	Gaskets		
TRIM:	Trim: Size & Mat'l		
	Type: D.P. – S.P. – 3-Way		
	Guiding		
	Seat Cons't.		
	Packing (Teflon Standard)		
ACTUATOR	Size & Dia. Range		
	Stroke		
	Air Press. Pushs Dn ☐ Up ☐ to		
	I.V. Action on Air Failure		
ACCESSORIES			
Actuating Device (Instr. Self, Etc.)			
CON-	Type No. & Control Point		
TROL-	Tube Mat'l & Range		
LER	Mounting – Yoke, Panel		

		OPERATING CONDITIONS			OPERATING CONDITIONS		
Flowing Medium		LIQUID			GAS		
		Minimum	Normal	Maximum	Minimum	Normal	Maximum
PRES-	Inlet, PSIA		150			1015	
SURE:	Outlet, PSIA		70			515	
	Operating Diff., PSI		80			457*	
Temperature °F			60			60	
SPECIFIC	Flow Temp.		.8			.6	
GRAVITY	+60°F						
DESIGN	SCFH					2MM	
FLOW	GPM		420				
RATE	#/Hr.						
Cv. Required @ __ % Travel			42			43.3	
Max. Cv. of Valve							
Max. Valve Capacity							
Shut off Differential, PSI							
Velocity, Ft/Sec. Inlet __ Exit __							