TROUBLESHOOTING CONTROL VALVES

A SYSTEMATIC PROBLEM SOLVING APPROACH

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Troubleshooting Control Valves is a very broad subject to cover given the vast array of Valves, Actuators, and Control Instrumentation available in the market today. We have Ball Valves, Globe Valves, Plug Valves, Butterfly Valves, and Segmented Ball Valves just to name a few. All of these Control Valves can be outfitted with various types of Valve Trim, Actuators, and Control Instrumentation to characterize and fine-tune the performance of the valve to achieve a desired control effect. The possible problems that can arise can be as simple as an external leak to a total loss of Process Control. Technicians are tasked to fix mechanical, electronic, and pneumatic issues as well as be qualified to perform complex tuning of the Control Valve System to achieve solid Process Control under many varying conditions. With all these variations, the job of the Control Valve Technician is a challenging one that requires a person to be adept in Mechanics, Pneumatics, Instrumentation, and Electronics. Even if a Technician is qualified in all of these areas, their success in troubleshooting control valves requires them to be knowledgeable in two critical areas:

1. **The Technician must be trained in *Basic Control Valve Theory* and the *Function of the Particular Control Valve System* he or she is tasked to maintain.**
    - A fundamental understanding of Control Valve Theory and "How it Works" is critical to the success and speed in solving Control Valve problems. Also, Technicians who are not trained on a particular Control Valve System can't be expected to troubleshoot and diagnose problems on that system. Each company should have a comprehensive in-house training program or bring in the Manufacturers to train their Technicians on the Equipment they are using.
2. **The Technician must employ a *Systematic Problem Solving Approach* to Control Valve problems.**
    - Even if the Technician is comprehensively trained on the specific Control Valve System, and is qualified in Mechanics, Pneumatics, Instrumentation, and Electronics, troubleshooting a problem is not always a simple task. A Systematic Approach will simplify the process and put you on the right track to finding out what is wrong. This means that you will need to wear many hats, from Detective to Analyst to Technician.

With all of the different types of Control Valve Systems in service today, it would be difficult to cover all the specifics of Troubleshooting Control Valves without producing a large comprehensive document. With this in mind, I will make the following assumptions and statements:

- I will assume that the Technician is educated on Basic Control Valve Theory and is qualified on the equipment he or she is assigned to maintain.
- I will focus this paper on providing a Systematic Problem Solving Approach to Troubleshooting Control Valves that are typically found in our Natural Gas Transmission and Distribution Systems.
- In specific examples or references, I will refer to the three most common control valves used in the Natural Gas Industry; the Ball Valve, the Globe Valve, and the Plug Valve.
- All Actuators referenced in this paper will be the pneumatic operating type.
- Many times I will refer to the term "Process". By this I am referring to the Process of "Pressure Control" or the Process of "Flow Control"; the two typical modes of operation at our City Gate Stations and our Natural Gas Main Transmission Facilities.
- Each Control Valve System can have many different possible causes for a given problem or symptom. It would be very difficult to provide a list of **Symptoms, Possible Causes**, and **Corrective Actions** since there are

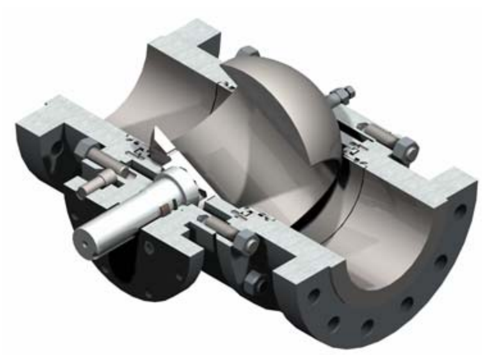
many different combinations of Control Valve Assemblies in the field. It will be up to the Technician to bridge the gap between the basics of troubleshooting as listed in this paper to the unique control valve he or she is working on.

INTRODUCTION TO CONTROL VALVE PACKAGES

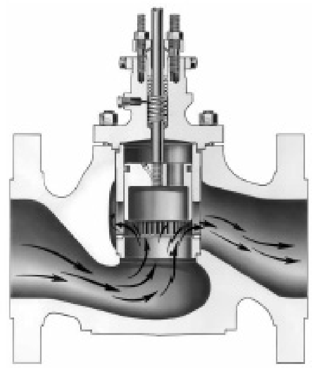
Before we look at a Systematic Approach to Troubleshooting Control Valves, let's look at some of the equipment we are going to talk about in this paper.

Control Valves in the Natural Gas Industry

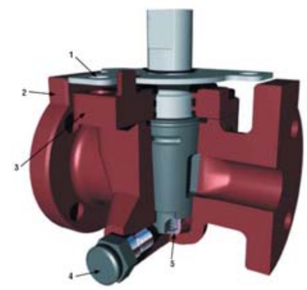
The most common types of Valves used for Control Service are the Ball Valve, Globe Valve, and Plug Valve.



Ball Valve Cutaway View



Globe Valve Cutaway View



Plug Valve Cutaway View

Control Actuators in the Natural Gas Industry

Actuators come in two basic forms: Quarter Turn and Linear. The most common types of Quarter Turn Actuators are the Crank Arm style Rotary Piston Double Acting (RPDA), the Crank Arm Rotary Piston Spring Return (RPSR), the Scotch Yoke Double Acting (SYDA), and the Scotch Yoke Spring Return (SYSR). The most common type of Linear Actuator is the Spring & Diaphragm Actuator.

RPSR Cutaway on a Ball Valve

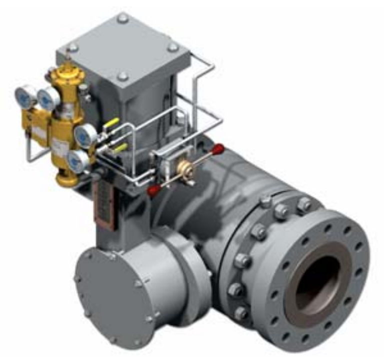
RPDA Cutaway on a Ball Valve

SYDA Cutaway on a Ball Valve

Spring & Diaphragm Actuator on a Globe Valve

Complete Control Valve Packages

There are many different variations of control valves used in the Natural Gas Transmission and Distribution systems. Below are some typical Control Valve Systems.



Ball Valve Regulator with Double-Acting Actuator and Pilot Controls

Ball Valve Regulator with Spring Return Actuator and Electro-Pneumatic Positioner

Globe Valve with Spring & Diaphragm Actuator &Electro-Pneumatic Positioner

Ball Valve Regulator with Spring Return Actuator and PID Pilot Controls

Compressor Surge Control Ball Valve Regulator with Spring Return Actuator and Pneumatic Positioner

Globe Valve Regulator with Spring Return Actuator and Pilot Controls

CONTROL VALVE TROUBLESHOOTING USING A SYSTEMATIC PROBLEM SOLVING APPROACH

Good problem solvers are the cornerstones of successful operations in our highly mechanized and electronic workplace. Most companies consider these individuals to be among their most valuable assets. Their expertise is recognized and they are always in demand to solve the most important problems on a daily basis. If you follow each successful problem solver, you will notice that they handle most technical problems in a Step-by-Step approach.   Solving Control Valve problems is no different.

The 5 basic steps are:

1. ***Gather your Tools***
2. ***Check & Reset all the Basic Settings***
3. ***Inspection & Analysis***
4. ***Isolate & Repair the Problem***
5. ***Document the Problem & Solution***

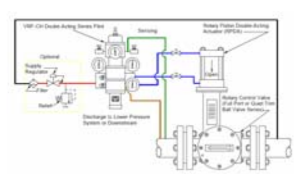
As simple as this looks, these steps are not always followed. Most Technicians jump past the first 3 steps and go right to step 4; they try to Isolate & Repair the problem without fully understanding what is really wrong!   When they do this, they usually are chasing a Symptom of the Problem, not the problem itself. We think we know what the problem is without doing any analysis; we go straight to what we ***think*** is wrong and chase down that thread until we realize that there was ***nothing*** wrong with that part of the system after all. Some Technicians will start manipulating adjustments on the control valve package looking for improvement without performing the first three steps of the process, and sometimes that makes the problem worse. Most Technicians will only step back and proceed in a methodical manner **after** they have spent a great deal time and energy "searching" for the quick solution.

> *Now, here is the disclaimer, there are some technicians who can ignore these first three steps and seem to get the problem solved in relatively short order. These folks usually have years of experience with the equipment, the process itself, and the location; they literally can run through the first three steps in their head.   However, most of us are wearing too many different hats and are responsible for too many different types of equipment. We are spread too thin and we cannot devote all our time to One type of Control Valve Package, One type of Control Valve process, and One Control Valve Location. We all hope we get good enough to do that someday, but until then; we should use a Systematic Approach to solving these problems.*

Taking a Systematic Problem Solving Approach has proven itself over time to be the most cost effective solution to Control Valve Problems. The problem is resolved quicker, there is less down time for the process, less replacing of unnecessary parts, and reduced Operations and Maintenance costs. With this in mind, let's look at the 5 steps in the process.

Step 1 - Gather Your Tools

- Tools & Test Equipment
- Literature and Manuals



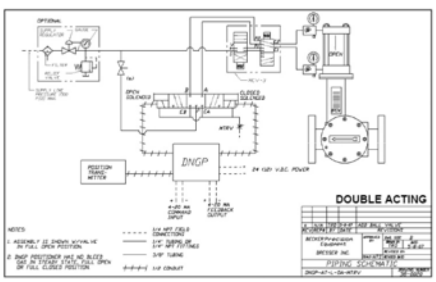
In this step you will put together your equipment and the documentation that you normally go to the jobsite with. Technicians should have all of their tools and documentation with them on their truck given the large distances between major stations. Too much time is lost because we do not have the proper test equipment or documentation to be effective when we arrive on station.

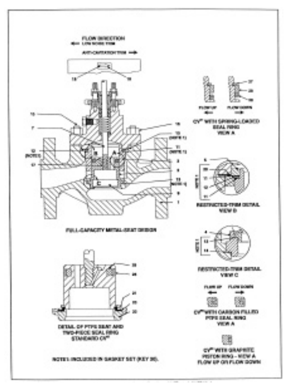
Tools & Test Equipment

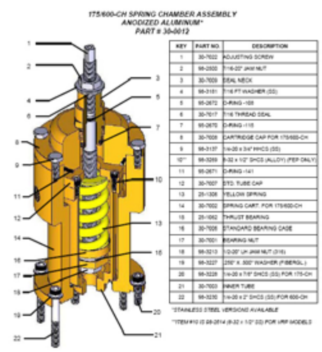
Control Valve Troubleshooting starts with gathering your tools to solve the problem. Besides having the basic hand tools for the job, a good technician also has a set of calibrated pressure gauges, a pressure calibrator, and a Multi-Meter for electrical tests. If the Control Valve is RTU Controlled, it helps to have a laptop and software that can be plugged into the RTU so you can view Controller Outputs, Manipulate the PID Loop, Simulate Outputs, and view the Process Variable in real time to help in diagnosing the problem. The RTU may also have historical data that can be accessed.

Literature and Manuals

The tools to be gathered are not just wrenches, gauges, multi-meters, and diagnostic equipment, but they also include the "Documents and Literature" on the particular Control Valve System you are working on. Many of these documents are readily available to us through the Shop Library, the Internet, or direct from the Manufacturer. For each control valve in use there is a **Maintenance and Operations Manual** that will explain the *"Theory of Operation"* of how the valve package is supposed to work and how to perform maintenance on it. You may have to get a separate document for each part of the Control Valve, but it is imperative to have these at your fingertips. These manuals are loaded with great information on the Valve, Actuator, Pilots, and Controllers. In these manuals you will find *Material Specifications, Programming and Adjustments, Calibrations, Diagrams & Schematics, Pictures, Specific Repairs, Parts Lists*, and much more to help you in solving the problem. Too many times I have arrived on station to assist technicians and when I ask for the manuals I get the "1000 yard stare", which usually means that they do not have any documentation with them. *Next to your brain, this is the best tool in your tool box.* You don't show up to a gun fight without a gun, so don't show up to troubleshoot a control valve without the Manuals!







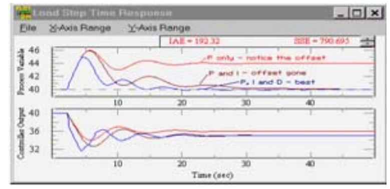
Step 2 - Check & Reset all the Basic Settings

- Check all Gas Pressures & Electrical inputs
- Check for leaky tubing and fittings
- Make obvious Repairs and see if the problem still exists

In this step you will check all the fundamental needs of the system that allow it to function correctly. Often times the simplest things are the root of complex problems. Something as simple as low actuator operating pressure can cause the Control Valve to react sluggish and it looks like it is "hunting" or not maintaining steady state control. Very often we arrive at the Jobsite and start troubleshooting the valve, the actuator, the Pilot or Controller, only to find out later that the gas pressure was low or a particulate filter is clogged preventing proper operation of the system.

Before doing anything, check all the simple things first. Check the System Supply Pressures to the Actuator, Pilots, or Controllers. Make sure that they are set correctly. Check any power to electronic controls and see if the proper voltage is available. Fix any leaking tubing and fittings. Check any filters to see that they are clean. After all the basics are checked, make any minor repairs or adjustments and test the system to see if it corrects the problem. If the problem still exists, move on to Step 3.

Step 3 – Inspection & Analysis



- Gather your Data and Inspect the Control Valve System
- Analyze your Data to look for potential problems

In this step, you will start to understand and get your hands around the problem. You will begin to identify what you believe is causing the problem based upon the data you have put together. Then you can put a plan together to test the various parts of the Control Valve System to isolate the problem exactly. It all starts with Gathering your Data.

Gather your Data and Inspect the Control Valve System

Control Valve problems can manifest themselves in many ways that are deceiving; what first looks like a controller or pilot problem can ultimately be traced to something as simple as an Actuator leak. We do not tackle Control Valve problems with the analogy of "Ready…..Shoot….Aim", we need to take our time and line up the target correctly before we troubleshoot. In this step you must do a little detective work to gather information and evidence surrounding the problem.

By Data Gathering, you will want to talk to whoever can tell you about the problem. It's amazing how much you don't know about what you don't know. Therefore, it's critical to get input from other people who notice the problem and who are affected by it. You will need a description of how the valve is acting. You will need to ask: How is it happening? Where is it happening? When is it happening? You will also need to collect the process information for when the problem is occurring. You will need to know the Upstream and Downstream Gas Pressure, the Gas Flow Rate, the Gas Temperature, the Controls Settings, and the Valve Positions when the problem is occurs. You will need to know if the problem is intermittent or happens under all conditions. You will need to have a look at some historical information. If you have access to Charts or Graphs of the process, see if you can get a download or printout for you to look at. These will put a visual reference to the problem, and as we all know, sometimes a picture is worth a thousand words. You will need to also perform an initial visual inspection to look for any visible signs of loose or bent linkages, leaks, and unusual sounds. Don't rely on your memory to record all this information, write it down. Good Technicians keep a notebook on their work so the can reference it later in the job or for similar problems in the future.

<u>All this data when written down will give you a starting point to work from, it will be a reference of all your initial settings, and it can be used when you document the problem and the repair.</u>

In short – gather the following data if applicable:

- A brief description of the problem
- The process conditions
  - Inlet Pressure
  - Inlet Temperature
  - Outlet Pressure
  - Flow Rate
- Valve position where it exhibits the trouble
- PID Settings
- Pilot or Controller Settings
- Historical Graphs or Charts of good control and of the incorrect control
- Any visual or audio information from the inspection

<u>All of the above usually takes only 10-15 minutes to document, collect, or inspect</u>.

If there is nothing that stands out in your visual inspection and everything seems in order, at this time I usually will check the sizing of the control valve for the given conditions to see if it is still sized correctly. It may be that the only problem is that the process has changed and the control valve is no longer sized correctly for the application. This is usually very simple if you have the sizing software. If you do not have the sizing software available, a quick call to your Engineer or the Manufacturer can get this done for you in short order.

Analyze your Data to look for Potential Problems

At this point, if you don't already have an idea of what is wrong, you can start to look for potential problems. From the inspection information and the data gathered, study the schematics and diagrams to see if you can spot where the trouble is or what is potentially causing the problem. It is easy to mentally review the system with diagrams and schematics to see how best to check them out. There is no set formula for this and the only direction you can take is from the data you gathered and what you see and observe.

Step 4 – Isolate and Repair the problem

- Divide the system up and function test the three major components
  - Valve
  - Actuator
  - Controls
    - Pneumatic Pilots/Controllers/Positioners
    - Transmitters
    - Electronic Controllers/Positioners
    - Controls Tuning (PID)

Each Control Valve System is comprised of three basic sub-assemblies; A Throttling Valve, A Throttling Actuator, and the Controls (Instrumentation). All three parts together make up the Control Valve System. Each sub-assembly can be isolated and tested to see if it is performing correctly. A good Technician will test each sub-assembly to identify if it is causing the problem. If it function checks good, they can eliminate it from their list of potential problems. By splitting up the system and checking out sub-assemblies, you will quickly focus in on where the problem lies.

It may be clear which sub-assembly is having trouble based upon the Initial Inspection and Data Gathering. Where to start will depend on what you found in your Initial Inspection and Analysis step. For example:

- If you found a noisy valve, you will want to start here and check the valve.
- If the actuator is sticking, you will want to check the actuator.
- If the Pilot or Positioner is venting gas, you will start here to investigate this first.
- If the Controller has loose linkages, you will want to have a look here.
- If there is nothing readily apparent, you will want to function-check out all three of these sub-assemblies to possibly eliminate them from the equation.

It also should be noted that there may be nothing wrong with the Valve, Actuator, or Controls. All of these systems my individually function test okay and the problem lies in the Tuning of the System. The Pilot, Positioner, or the Controller PID loop settings may need to be tuned to achieve the correct performance of the process. It is easier to Function Test the individual sub-assemblies first before any tuning takes place unless you are sure that all three of the sub-assemblies are in good working order. With the above in mind, let's look at the function tests of the sub-assemblies.

FUNCTION TESTING THE VALVE & ACTUATOR

With Control Valves, both the Valve and the Actuator are usually Function Tested at the same time since there is a mechanical connection between them. When function testing Ball Valves or Globe Valves, we are testing five basic areas of interest to verify the condition of the valve and actuator.

1. **Proper Valve and Actuator Stroking**
2. **Actuator Seal, Housing, and Vent Inspection**
3. **Valve Stem Seal Leakage**
4. **Lost Motion**
5. **Valve Seat Leakage**

Proper Valve and Actuator Stroking

When the Control Valve is stroked from one end of the travel to the other, the Control Valve should exhibit the following:

- Relatively smooth, continuous stroking from one end of travel to the other (spring return actuators may cause a slight hint of jumpiness across the stroke due to the restriction of the instrument exhaust).
- No Stalling or Stopping of the valve or actuator in mid-stroke
- Consistent stroking speed
- No abnormal noises (scraping, chattering, or metallic sounds)

Causes of improper Valve and Actuator Stroking:

- Sticky or High Torque Valves
- Damaged Valves
- Lost Motion in the Valve or Actuator linkages
- Damaged Actuator Cylinder
- Damaged or Leaking Actuator Cylinder Seals
- Obstructions in the Body or Internals of the Valve

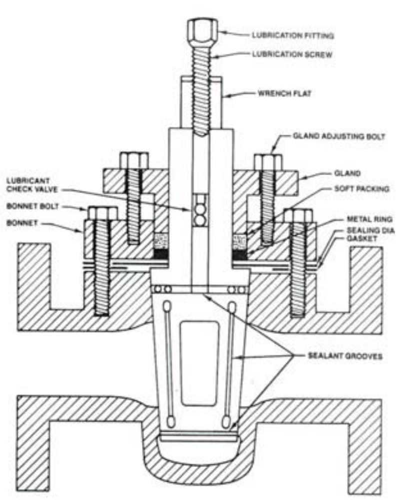
How to check for Proper Valve and Actuator Stroking

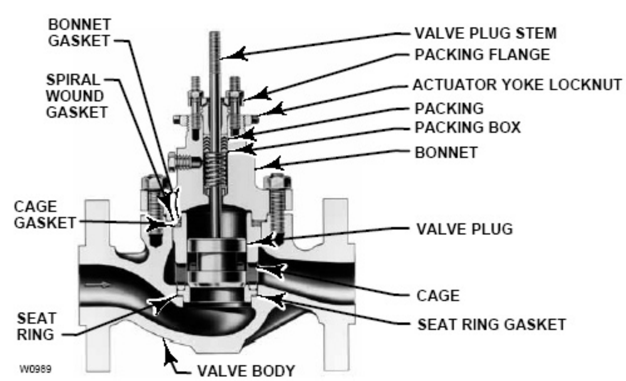
(Each Valve & Actuator manufacturer has a maintenance manual that should be referenced for this inspection due to the minor differences between manufacturers)

- Check and Maintain full Actuator Power Gas
- If the Control Valve is equipped with a Manual Control Valve, stroke the Control Valve from one end of travel to the other.
- If the Control Valve is not equipped with a Manual Control Valve, the actuator may be stroked by…
    - Adjusting the measured variable to the Pilot or Controller to produce a “false signal” to the control valve to move it.
    - Adjusting the Instrument Signal to the Control Valve Positioner to move it.
    - Triggering any other overriding devices on the Control Valve to move it.
- As the actuator strokes from one end of travel to the other, the position indicator scale should be checked for the Proper Valve and Actuator Stroking action.
- If the Control Valve exhibits stroking difficulty or any of the above mentioned unusual characteristics, corrective action is probably necessary.

Possible Corrective Actions:

- First, Check the Lubrication of the Ball Valve or a Plug Valve (Globe Valves are not Lubricated)
- If lubrication does not correct the improper Valve and Actuator stroking, the Valve and Actuator must be further checked for linkage problems, leaks, or internal damage. If the Actuator Function Checks good, the valve must be inspected for internal damage or obstructions.





Actuator Seals, Housing, and Vent Leak Inspection

When inspecting the Actuator, we are testing the seals, diaphragms, and o-rings to see that they are holding pressure and are not leaking internally or externally.

Causes of Actuator Seal Leakage or wear:

- Excessive side-loading of the Actuator Rod by the Valve or Actuator mounting
- Excessive cycling of the Control Valve System
- Normal wear after long service
- Incorrect lubricant used that damages the seal or o-ring
- Over-pressurizing the Actuator
- Foreign debris in the Actuator Gas supply system

How to check for Actuator Leakage

Piston Type Actuators – RPSR (Rotary Piston Spring Return), RPDA (Rotary Piston Double Acting), SYSR (Scotch Yoke Spring Return), and SYDA (Scotch Yoke Double Acting) actuators are **Piston Type** actuators. Refer to Fig. 1 for a typical location of the seals to be checked. (Each Actuator manufacturer has a maintenance manual that should be referenced for this inspection due to minor differences between manufacturers).

The basic steps for **Piston Type** Double Acting and Spring Return actuators are:

- **Vent** - Check any Actuator Housing Vents for obvious gas leaks. If the Actuator Housing Vent is venting gas, it is possible that there is a leak in the valve stem or in the Actuator Cylinder Piston Seal or Rod Seal.
- **Cylinder Rod Seal Leak Check** –
    - o Install pressure gauges on both sides of the Cylinder Piston including block valves (see Fig. 2).
    - o Pressurize the "Rod" side of the piston to full actuation pressure and close the block valve locking in the pressure. Vent the opposite side to zero on the pressure gauge then close the block valve.
    - o Observe gauge needle opposite from "Rod" side of cylinder. If the gauge moves, or increases in pressure, piston seals may need replacement.
    - o Re-pressurize "Rod" side of the piston to full Actuation pressure.
    - o Observe gauge needle on the "Rod" side of Cylinder. If needle shows a decrease in pressure, Piston Rod Seals may need replacement.

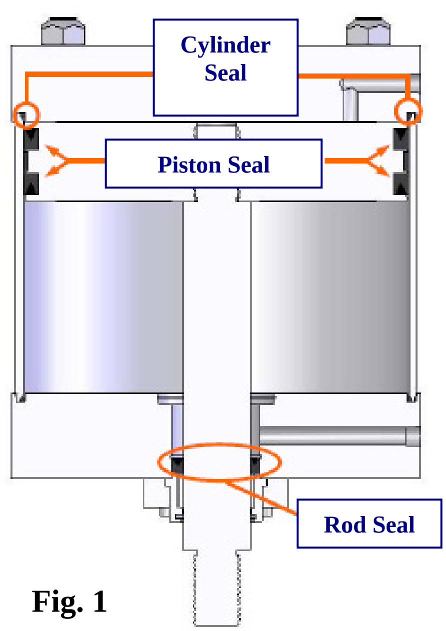


Fig. 1

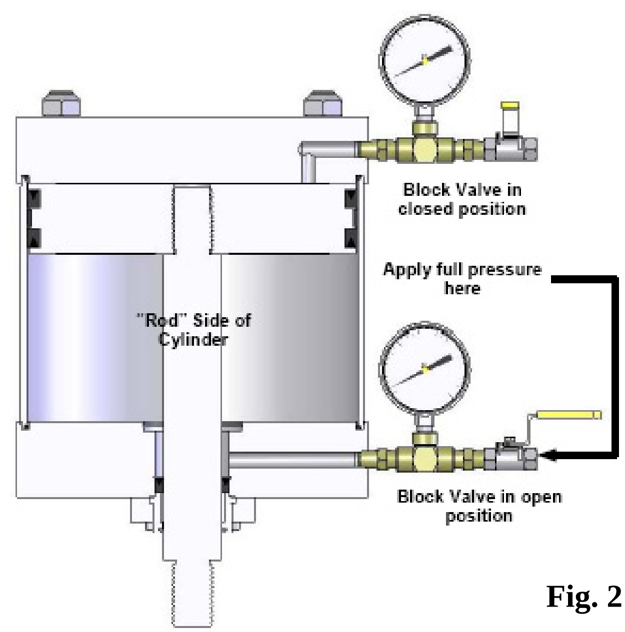


Fig. 2

- **Piston Seal Test** - Pressurize one sides of the piston with Full Actuator Pressure (See Fig. 3) and leave the opposite side at Zero Pressure. Check for Piston Seal leakage at the "Zero" pressure port, it should be "bubble tight". Pressurize the other sides of the piston with Full Actuator Pressure (See Fig. 4) and leave the opposite side at Zero Pressure. Check for Piston Seal leakage at the "Zero" pressure port, it should be "bubble tight". If there is leakage, piston seals need to be replaced.
- **Cylinder Seal Test –**
  - **Double Acting Actuator-** Pressurize both sides of the actuator piston and soap test the outside of the cylinder to identify if the Cylinder Seals are leaking.
  - **Single Acting Actuator-** Pressurize the "normally pressurized" side of the actuator piston and soap test the outside of the cylinder to identify if the Cylinder Seals are leaking.

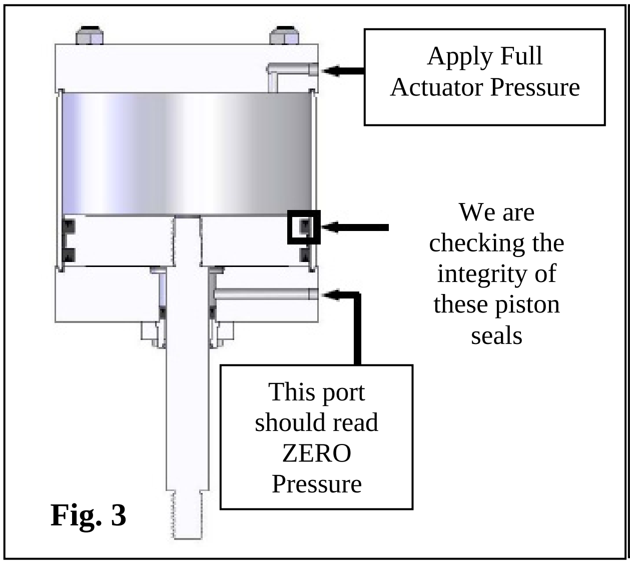


Fig. 3

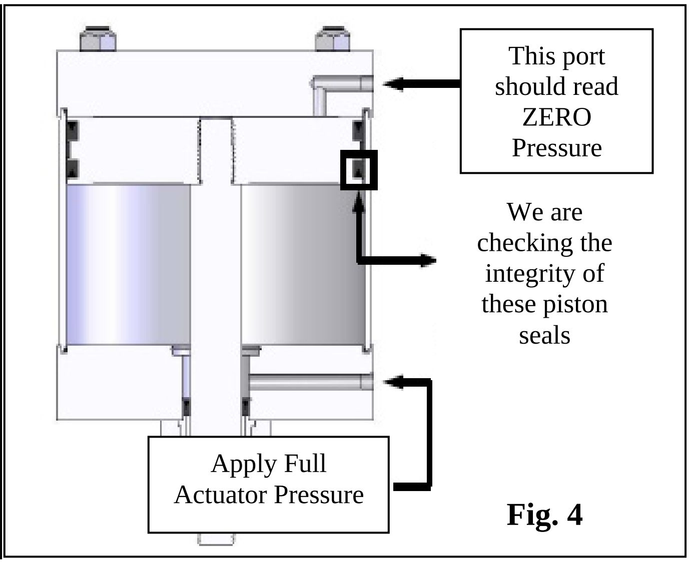
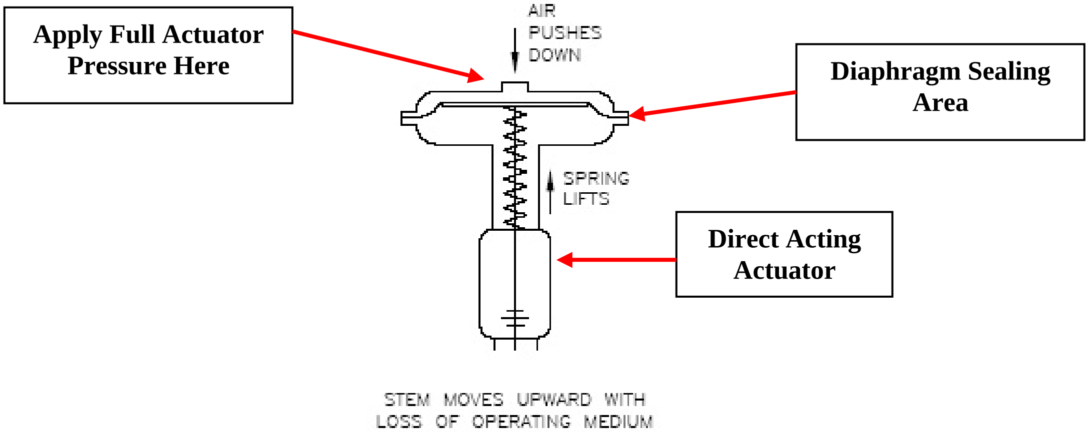


Fig. 4

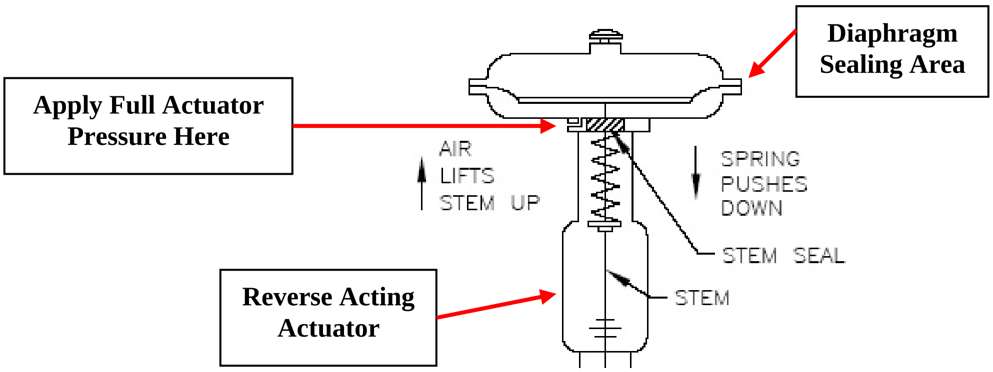
Spring & Diaphragm Type of Actuators –Checking the Actuator for leaks is a simple process. (Each Actuator manufacturer has a maintenance manual that should be referenced for this inspection due to minor differences between manufacturers).

The basic steps for checking the **Spring & Diaphragm Type** of actuators for leaks are:

- **Direct Acting Diaphragm Actuator-** – Install pressure gauge on Actuator inlet fitting including block valve. Pressurize this side of the Diaphragm to full actuation pressure and close the block valve locking in the pressure. Observe gauge needle. If needle drops off, the diaphragm is leaking internally or externally. Soap test the sealing area around the diaphragm to detect external leaks. If this reveals a leak, correct and re-test. If the soap test does not reveal a leak, then the leak is internal and replacement of the diaphragm might be necessary.



- **Reverse Acting Diaphragm Actuator-** – Install pressure gauge on Actuator inlet fitting including block valve. Pressurize this side of the Diaphragm to full actuation pressure and close the block valve locking in the pressure. Observe gauge needle. If needle drops off, the diaphragm or stem seal is leaking. Check the diaphragm for external leakage first. Soap test the sealing area around the diaphragm to detect external leaks. If this reveals a leak, correct and re-test. If the soap test does not reveal a leak, then the leak is internal and replacement of the diaphragm or stem seal might be necessary.



Valve Stem Seal Leakage

Ball Valves and Globe Valves utilize seals around the stem to provide a seal between the valve stem (which protrudes from the valve) and the valve body (which is pressurized). While valve stem seals do not normally cause control valve process issues, it is important to minimize these leaks. Through abnormal stem side loading or excessive operation, Valve Stem Seals can deteriorate causing gas to leak through the Stem Seals into the Actuator Housing on Ball or Plug style control valves, or to atmosphere on Globe style control valves.

Causes of Valve Stem Leakage:
- Excessive side-loading of the valve stem by the actuator
- Excessive cycling of the Control Valve
- Normal wear after long service
- Incorrect lubricant to the stem seal port that damages the seal or o-ring
- Over-pressurizing the Stem Seal Lube Port while applying lubricant or sealant

How to check for Valve Stem Seal Leakage

Ball Valve and Plug Valves have a different procedure than Globe Valve for Stem Seal Leak tests (Each Valve manufacturer has a maintenance manual that should be referenced for this inspection due to the minor differences between manufacturers).

Ball Valve & Plug Valve Stem Seal Leak Test- Since both Ball and Plug valves are almost always mounted with Piston type Actuators, the actuators will cover the valve stem area from direct visual inspection. Also, most Piston Type actuators have a vent that is common to both the Valve Stem and the Actuator Piston Rod Seal. In order to separate the two potential leak paths, it is important to de-pressurize the Actuator from the instrumentation gas for this test. If the Vent is leaking and it stops when you de-pressurize the actuator, the leak is coming from the actuator and you must test the Rod Seals in the Actuator cylinder. If the gas continues to leak after de-pressurization, most likely the valve stem is leaking. You must remove any cover plates to access this area and soap test the area around the Valve Stem. Most Ball Valves have a small grease port that can have emergency sealant injected into the Valve Stem to temporarily stop the leak until repair can be made. Refer to the Valve Manufacturers Maintenance Manual for repairs. Plug valves normally will only need the standard sealant to correct this problem.

Globe Valve Stem Seal Leak Test – Most Globe Valve Stems are exposed directly to atmosphere since they are actuated by Spring & Diaphragm Actuators. Checking for a leak on or around the stem is a simple soap test to expose leaking gas. In the event of leaking gas, the packing can be tightened or replaced. Refer to the Valve Manufacturers Maintenance Manual for repairs.

Lost Motion

Lost Motion is a lag between the making of a change and the response or effect of that change. In Control Valve jargon it is also called “slop” or “Loose Linkage” when referring to the valve or actuator. Control Valves are manufactured to exacting tolerances in order to achieve precise, accurate control. Lost Motion occurs when the actuator linkage does not have continuous communication with the controlling element of the Valve (the Ball in a Ball Valve, the Plug in the Plug Valve, or the Plug in the Globe Valve). Continuous Cycling of the Control Valve while in control is a common symptom of Lost Motion.

Lost Motion can be defined as wear in the following areas:

- Actuator linkage connections
- The connection between the actuator and the Valve Stem
- The connection between the Valve Stem and the Valve controlling element

Causes of Lost Motion:

- Excessive cycling of the Control Valve
- Normal wear after long service
- Improper disassembly or reassembly

Inspecting for Lost Motion

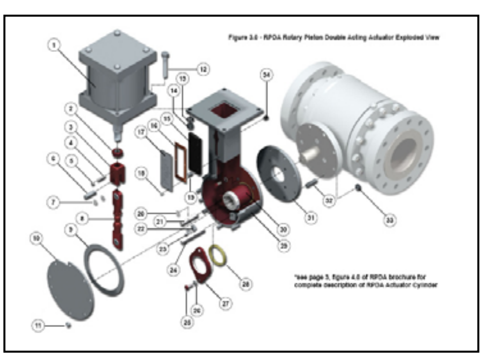
The method of inspecting for lost motion is applicable to all control valves that are using pneumatic actuators. A test is conducted to produce slight movement of the actuator linkage while observing the valve controlling element for a corresponding movement. (Each Actuator manufacturer has a maintenance manual that should be referenced for this inspection due to the minor differences between manufacturers)

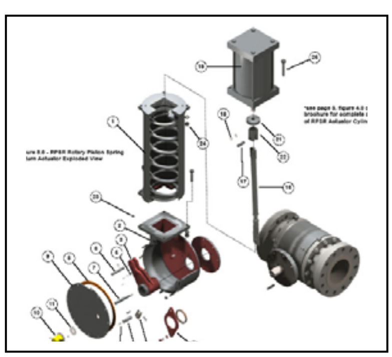
Spring Return Actuators:

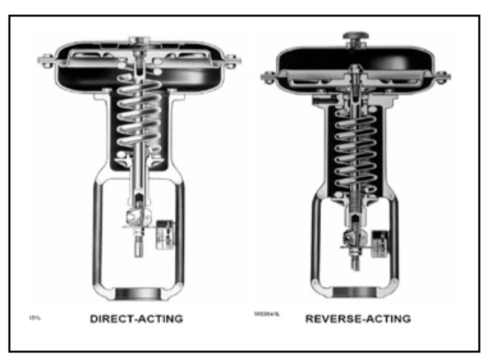
- Supply full pressure to the loading side of the actuator compressing the spring.
- Reduced the power gas supply pressure in small increments of 1-2 psig.
- It is advisable to maintain a pressure differential across the valve to prevent the valve from moving.
- Observe the valve position indicator or the valve stem to note movement. If actuator movement occurs with a very small drop in loading pressure but there is no movement of the valve position indicator or valve stem, then lost motion is present. Measure the total lost motion. If it exceeds ¼”, then corrective action is recommended.

Double Acting Actuators:

- Close the Control Valve.
- Reduce the power gas supply to 10 psig or less.
- It is advisable to maintain a pressure differential across the valve to prevent the valve from moving.
- Adjust the measured variable (Pilot operated) or the instrument signal (Positioner operated) such that the instrumentation and actuator will attempt to OPEN the valve.
- With the power gas limited to 10 psig, the actuator should have only enough torque to exhibit Lost Motion in the actuator **without** rotating the valve.
- Measure the amount of linear movement of the actuator. If it exceeds ¼”, then excessive Lost Motion is present and corrective action is recommended.







Valve Seat Leakage

Valve Seat Leakage is defined as the amount of gas that flow through a valve while it is in the FULL CLOSED position. The American Petroleum Institute (API) has developed specific definitions for valve seat leakage. All Control Valves when new have a Leakage Classification upon installation.

Causes of Valve Seat Leakage:
Control Valves may experience leakage after some time in service due to Modulation and Valve Seat exposure to high velocity flows that cause erosion. The leak rate of the Control Valve depends upon several variables:

- Flow Rates
- Pressure drop across the Control Valve
- Length of Service
- Frequency of Service
- Quality of Gas (debris, pipe scale, etc)

Inspection for Valve Seat Leakage

Individual Companies should have their own guidelines for properly checking allowable valve leakage rates. After many years of service, the leakage rate of active control valves may become excessive and the valve will require rebuilding or replacement. Determination of excessive leakage rate is based on the discretion of the owner or Company. The following types of valve applications should not exhibit leakage since the Valve Seats are rarely exposed to erosive flow and should usually maintain API Class VI "Bubble Tight" shutoff: **Refer to ANSI B16.104 for a Control Valve Seat Leakage Classification Chart**

- On-Off Valve Applications
- Ball Valve Monitor Regulators
- Relief Valves (overpressure protection)
- Standby Control Valves

NOTE: It should be noted that when using Globe Style Valves for Monitor service, their ability to maintain API Class VI "Bubble Tight" shutoff is difficult due to the fact that the seat assemblies are constantly exposed to erosive flow.

FUNCTION TESTING THE CONTROLS

The Controls is the third sub-assembly of the Control Valve Package after the Valve and the Actuator. The Controls function is to:

1. **Directly sense, or accept from another device, the Measured Variable (Pressure, Flow, etc).**
2. **Compare it to a Process Setpoint.**
3. **Determine the Error between the Measured Variable and the Process Setpoint**
4. **Output a Signal to the Actuator to correct the Error.**

The above four steps are constitute a "Closed-Loop Control System". The Control System utilizes "feedback" and thus "closes the loop". ***Feedback is the information that is used by Pilots, Controllers, PLC, RTU's, or Flow computers to make decisions about the changes to the output control signal to the Actuator***. Typical feedback information is Sensing Pressure for a Pressure Control application or Flow Rate for a Flow Control application. These Controls also may have some adjustments to help the control process. We will cover these in the discussion on PID Loop tuning later in this document. The Modes are: Proportional, Integral, and Derivative (PID). These are also called respectively Gain, Reset, and Rate Control.

Control Valves are controlled either locally or remotely. Local control is usually in the form of a Pilot or Pressure Controller while remotely controlled units are usually done electronically by an On Site RTU, PLC, or Flow Computer.

- Pneumatic Pilots and Pressure controllers directly sense the Measured Variable pressure, compare it to a Setpoint, and output a pneumatic signal to the actuator directly or to a "Positioner" to position the valve.

- Electronic controllers will take in a Pressure input or a Flow input signal from external transmitters, compare it to a Setpoint, and output an electronic command signal to a Positioner that will “Position” the Actuator to the correct point.

There are many types of Control Systems available and there are many Manufacturers of these devices. It would be impossible to cover in detail all the aspects of Function Testing the different Controls System packages in the Market Place. You will need to refer to the Manufacturers Operations and Maintenance Manual for specific check-out procedures of the devices on your Control Valve Package. A general Rule of Thumb for this equipment used in the Natural Gas Industry is:

- Pneumatic Pilots and Controllers are used for Pressure Control
- Electronic Controllers are used for Pressure Control or Flow Control
- Pneumatic and Electro-Pneumatic Positioners work in conjunction with a Pilot or Controller to “Position” the valve based upon the output.

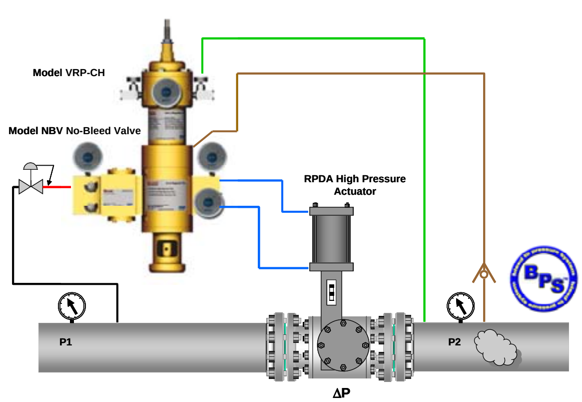
The essence of Function Testing these devices are to determine if they are functioning properly and are not a contributing factor to the problems you are investigating in your Control Valve System. Each Pilot, Controller, Positioner, or Electronic Controller will need to be checked out in accordance with the Manufacturers Instructions to determine that it is working correctly. With these basics in mind, let’s look at some of these devices.

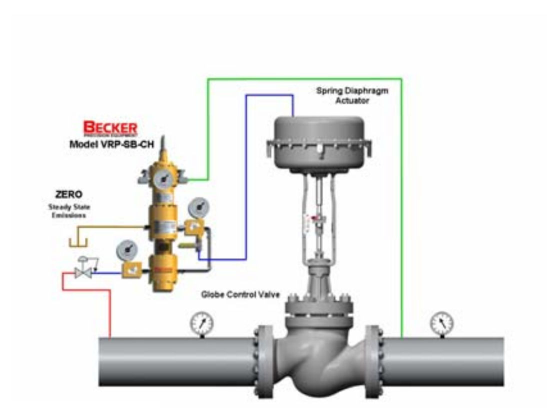
Pneumatic Pilots

The Pilot provides pressure control when used in conjunction with an Actuator and Control Valve. For Pressure Control applications, the pilot measures the downstream pressure, compares it to a Setpoint, and outputs a pneumatic signal to the Actuator to reposition the Control Valve maintaining the desired downstream pressure. Most pilots do not have Gain, Reset, or Rate Adjustments, however, there are some pilots used for pressure control at Natural Gas Fired Power Plants that have these adjustments. For most of the Transmission and Distribution applications, Pilots used on Control Valves only have a dead-band adjustment. These adjustments are not needed due to the nature of large pipeline systems. Pilots are they are the workhorses of the Transmission and Distribution Systems and have a long track record of success. They are extremely robust and this is the most widely used device in the Natural Gas Industry for Pressure Control applications.

When you are Function Checking a Pilot, refer to your Operations and Maintenance manual for proper testing procedures and settings. The basic inspection items we are checking are:

1. **Instrument Gas Supply** – Check Gas Supply for proper pressure and check any filters.
2. **Pilot Seats and Internal Balance Valves** – Apply a “False Signal” or Simulate the Sense pressure to generate an output to check Seats or Balance Valves for proper operation.
3. **Gauges** – While checking the Pilot Seats and Balance Valves, Observe Gauges for proper operation and accuracy.
4. **Leak Checks**– Pilots have Diaphragms and O-Rings that can leak pressure for the pilot. A soap test of the sealing surfaces and the vents will reveal any leaking Diaphragms and O-Rings.
5. **Pilot Adjustment** – Checking the adjustment of the Pilot for proper dead-band and Setpoint.
6. **Friction Test** - Check for any internal friction of moving parts.
7. **Vary the Measured Variable and Observe** – Change the Sensing Pressure to simulate the varying pressure in the pipeline and observe the output from the pilot to the actuator.





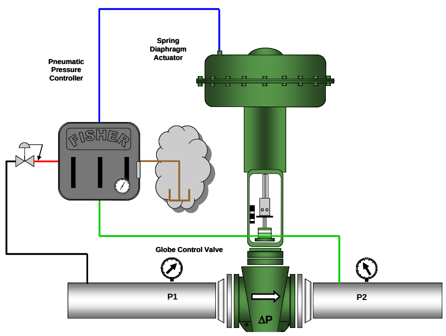
Pneumatic Pilot Control

Pneumatic Controllers

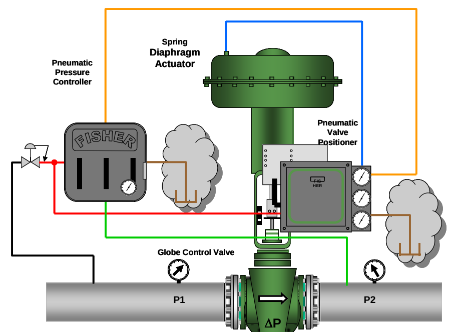
Controllers are another device for use in the Natural Gas Pipeline System that usually has two or three modes of adjustment (Proportional, Integral, and Derivative). The Controller usually provides pressure control when used in conjunction with an Actuator and Control Valve. For Pressure Control applications, the Controller measures the downstream pressure, compares it to a Setpoint, and outputs a pneumatic signal to the Actuator to reposition the Control Valve maintaining the desired downstream pressure. Sometimes this is sent to a “Positioner” that will position the valve to the desired value. The use of a Positioner is usually a function of the size of actuator and actuator pressure requirements.

When you are Function Checking a Controller, refer to your Operations and maintenance manual for proper testing procedures and settings. The basic inspection items we are checking are:

1. **General –** Mechanical linkages, Valves, Nozzles, Flappers and Restrictions must be kept clean for proper operation.
2. **Instrument Gas Supply** – Check Gas Supply for proper pressure and check any filters.
3. **Linkage Calibration** – Measured Variable linkages must be checked for wear and must be calibrated
4. **Controller Section Calibration** –Calibrate the various Gain, Reset, and Rate function blocks of the controller.
5. **Gauges** – Observe Gauges for proper operation and accuracy.
6. **Vary the Measured Variable and Observe** – Change the Sensing Pressure to simulate the varying pressure in the pipeline and observe the output from the pilot to the actuator.



Pneumatic Controller



Pneumatic Controller
And Positioner

Electronic Controllers

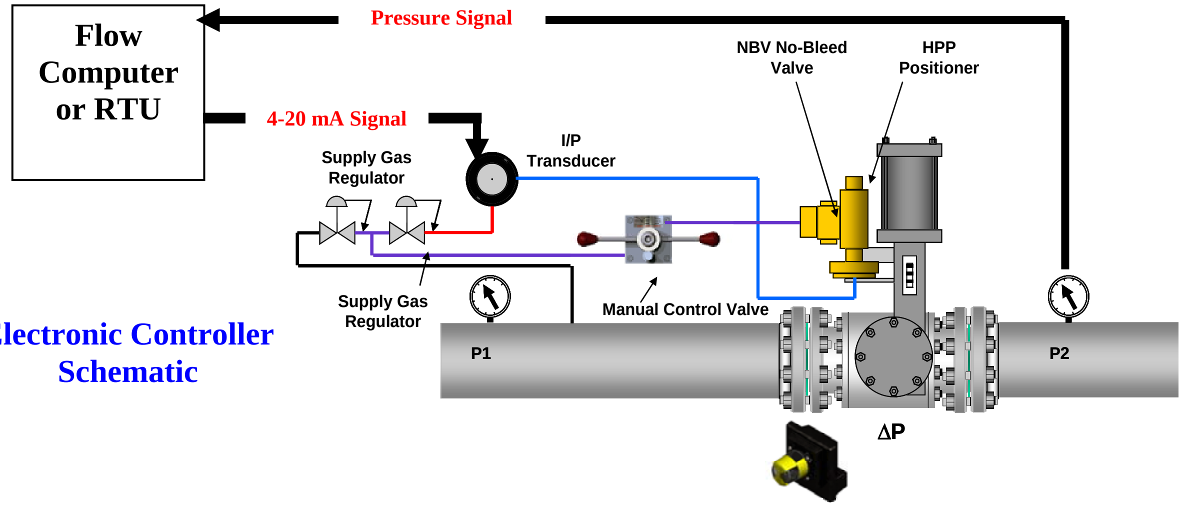
Most Major Transmission Stations have some sort of Electronic PLC, Flow Computer, or RTU that serves as the Nerve Center for all the operations at the station. These devices are the “controllers” that accept all the transmitter I/O information from the various points in the station and also control the various functions at the station including the Control Valves. The Station Flow Computer can perform Communications, Calculations, and Data Storage as some of the many functions in its daily routine. Electronic Controllers have the ability to perform PID Process loop controls on any variable that is present at the station. It is this device that performs the function of controlling the Control Valve. It handles this process the same as a Pneumatic Controller.

1. Sense from another device, the Measured Variable (Pressure, Flow, etc).
2. Compare it to a Process Setpoint.
3. Determine the Error between the Measured Variable and the Process Setpoint
4. Output a Signal to an I/P transducer / Valve Positioner or directly to the Valve Positioner to correct the Error.

When you are Function Checking an Electronic Controller, refer to your Operations and Maintenance manual for proper testing procedures and settings. The basic inspection items we are checking are:

1. **Transmitters –** Electronic Controllers get their information from the various Transmitters at the station; Pressure, Temperature, Flow Rate, etc. It is important to check that the proper Process Variable Transmitter is functional and in good working. Check the calibration of this instrument because if it is reading erratically or in error, the Control Valve will also be erratic or in error.
2. **Output Checks –** Each RTU or Flow Computer has the ability to simulate a Signal Output. Use this function to operate the Positioner and see that the signal reaches the Positioner.

3. **PID Loop Settings –** The PID Loop settings may have been changed or be incorrect for the Process. Check the Tuning of the system.



Electronic Controller Schematic

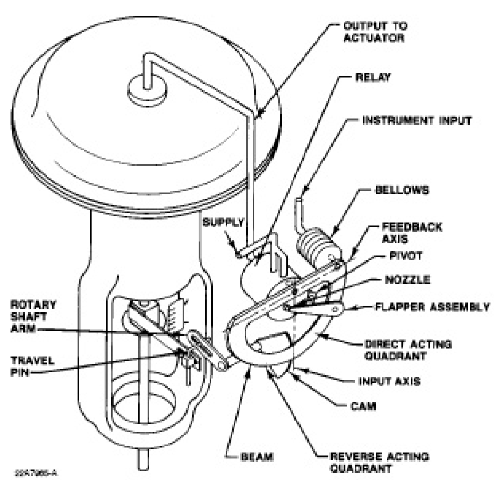
Pneumatic Positioners

Pneumatic Positioners receive a pneumatic signal from a Process Controller or Pilot. This signal is usually a 3-15 psig or 6-30 psig signal that is converted to valve position. The Positioner then supplies the valve actuator the proper gas pressure to move the valve to the required position. Positioners require a control signal from an outside source and only move where they are told too, they do not make any decisions themselves. Positioners require Valve Position Feedback usually in the form of a balance beam and spring to know it has moved to the proper position thus satisfying the controller output. There are many types of Positioners in use that work on the above principals; however, they can be vastly different in construction.

When you are Function Checking a Pneumatic Positioner, refer to your Operations and Maintenance manual for proper testing procedures and settings. The basic inspection items we are checking are:

1. **Instrument Gas Supply** – Check Gas Supply for proper pressure and check any filters.
2. **General –** Mechanical linkages, Springs, Valves, Nozzles, Flappers and Restrictions must be kept clean for proper operation.
3. **Calibrations** – Check the calibration of the unit. Refer to the specific Maintenance Manual.
4. **Gauges** – Observe Gauges for proper operation and accuracy.
5. **Leak Checks**– Positioners have Diaphragms and O-Rings that can leak.
6. **Friction Test** - Check for any internal friction of moving parts.
8. **Positioner Adjustment** – Check the Positioner for proper Dead-Band, Bias, and Range adjustments.
9. **Vary the Controller Signal and Observe** – Change the Controller signal and observe the output to the actuator.

Pneumatic Positioners

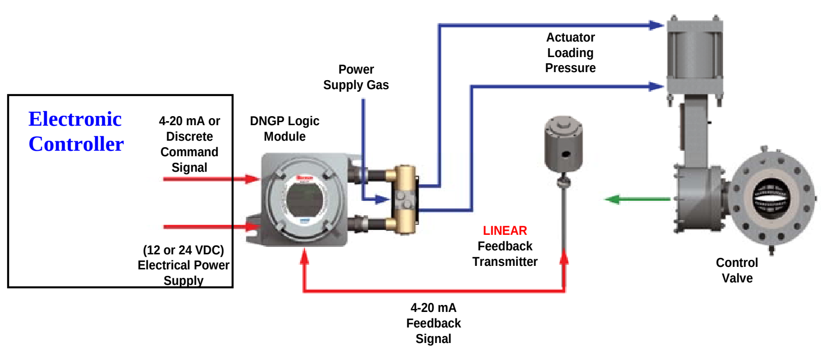


Electro-Pneumatic Positioners

Electro-Pneumatic Positioners work essentially the same as Pneumatic Positioners except the controller signal is electronic instead of pneumatic. The signal comes in the form of a 4-20 mA control signal, a 1-5 VDC control signal, a pulse control signal, or it comes in on an electronic protocol data string. The electronic position signal from the controller is converted directly to a pneumatic output signal to the Valve Actuator to move the valve to the correct position. The Valve Position Feedback Transmitter feeds position to the Electronic Positioner to tell it that the valve moved to the proper position thus satisfying the controller output. There are many types of Electronic Positioners available today and although they function on the same principals, they can be vastly different in construction.

When you are Function Checking an Electro-Pneumatic Positioner, refer to your Operations and Maintenance manual for proper testing procedures and settings. The basic inspection items we are checking are:

1. **Instrument Gas Supply** – Check Gas Supply for proper pressure and check any filters.
2. **Electronics** – Check for the correct input power and the full range of the electronic command signal.
3. **Calibrations** – Check the calibration of the unit and any Valve Position feedback transmitter. Refer to the specific Maintenance Manual.
4. **Gauges** – Observe Gauges for proper operation and accuracy.
5. **Leak Checks**– Electronic Positioners have pneumatic solenoids and o-rings that can leak.
6. **Positioner Action** – Check the Positioner for proper Valve Action relative to the controller action (Direct Acting or Reverse Acting).
7. **Vary the Controller Signal and Observe** – Change the Controller signal and observe the output to the actuator.



Electro-Pneumatic Positioner

CONTROLS TUNING (PID)

It may turn out that the only thing wrong with the controls system is the PID tuning. This is the part of Control Valve troubleshooting where patience and a "Feel" for proper Process control is important. Tuning Control loops is a bit of science, a little Black Magic, and a fundamental understanding of how your Process works. A Basic understanding of what PID Control is and how each term affects the process is important to tuning success. The study of PID loop tuning is a very large subject and cannot be covered in depth in this paper. I will give a brief description of the PID Terms and describe their general effects on the process. PID loop tuning takes study and field experience to be proficient and it is a lot of trial and error. There is just no substitute for experience.

Description of PID Units

A Porportional-Integral-Derivitive Controller (PID) is a generic control loop feedback mechanism used in the Natural Gas Industry to control a process. A PID Controller attempts to correct the error between a measured process variable and a desired Setpoint by calculating and then outputting a corrective action that can adjust the process accordingly and rapidly, to keep the error minimal. The PID Controller calculation (algorithm) involves three separate parameters:

Proportional Band	Also known as	Gain
Integral	Also known as	Reset
Derivative	Also known as	Rate Control

Proportional Term –Proportional Term is the amount added to the output based on the current error. Typically the main drive in a control loop, it reduces a large part of the overall error.

- ***Proportional Gain (P-Gain)*** is a Multiplier as a percentage. If the error is 10 psi and the Proportional Gain is 0.5, then the output will move 5%.
    - The higher P-Gain the faster (and less stable) control
    - The lower P-Gain the slower (and more stable) control
- ***Proportional Band (P-Band)*** is a Divider as a percentage. If the error is 10 psi and the Proportional Band is 200%, then the output is (10*(100/200))= 5%
    - The higher P-Band the slower (and more stable) control
    - The lower P-Band the faster (and less stable) control
- ***Conversion between P-Gain and P-Band:*** P-Band=100/P-Gain **or** P-Gain=100/P-Band

Integral Term – Integral Term is the amount added to the output based on the sum of the error. It reduces the final error in a system. Summing even a small error over time produces a drive signal large enough to move the system toward a smaller error.

- ***Time Constant*** is the term for on full repeat of the Proportional Term. If the Proportional Term is 5% and the Time Constant is 10 seconds, then the output will ramp up 5% every 10 seconds.
- ***Reset Rate*** is the amount the output will move in one second. If the Proportional Term is 5% and the Reset Rate is 0.1 Repeat per Second, then the output will move (0.1)*5 every second and take 10 seconds for the full repeat of the P-Term of 5%
- ***Integral Gain (I-Gain)*** is the same as the Reset Rate multiplied by the P-Gain
- ***Conversion between Time and Reset Rate***
    - Reset Rate = 1/Time Constant
    - I-Gain = (1/Time Constant)*P-Gain

Derivative Term- Derivative Term is the amount subtracted from the output based on the rat of change of the error. Derivative counteracts the Proportional and Integral terms when the output changes quickly. This helps reduce overshoot. It has no effect on final error.

- ***Time Constant*** is the amount of time the controller will look forward
- ***Derivative Gain*** is the amount of time the controller looks forward multiplied by the P-Gain

Tuning the Loop

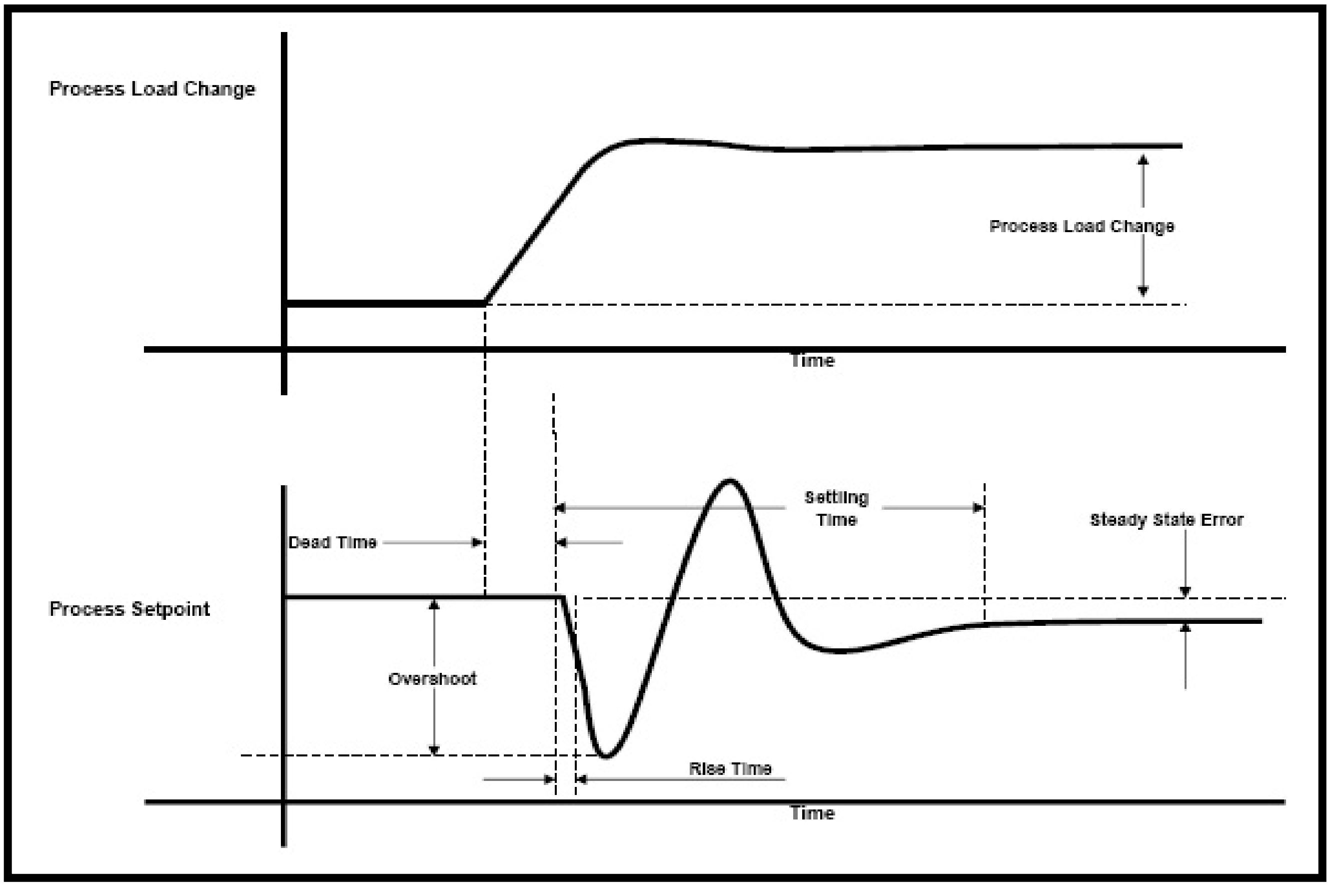
Before you can tune a PID Loop Process you must know three basic things:

1. **Know the Process** - Knowing the process should be fairly easy since you are the one working on the Control Valve. If you come to the problem with no background on the process, you must get educated on what is going on with the process and what is expected out of the process. You need to know the speed of the loop. For the Natural Gas Industry, we usually are dealing with Fast Loops where the Loop must have a response time from about one second to about 10 seconds. For most systems, a Proportional – Integral (PI) Controller is sufficient. Faster Loops are sometimes required such as in front of a Natural Gas Fired Power Plant which requires a Proportional-Integral-Derivative (PID) controller.
2. **Know the Terms** – There are many terms used in PID Loop Controls. See the above list of these terms.

3. **Know your Controller –** Identify the units of you PID controller. Many Controllers will use a mix of different terms and units. Before you start tuning, make sure you know the terms and the units to avoid incorrect settings.
    a. The **Proportional Term** most used is either P-Gain or P-Band
    b. The **Integral Term** can be a Time Constant (in Minutes or Seconds), Reset Rate (1/Minutes or 1/Seconds), or Integral Gain (Reset Rate * Proportional Gain)
    c. The **Derivative Term** can be Time Constant (in Minutes or Seconds) or Derivative Gain (Derivative Time Constant * Proportional Gain)

When Tuning a PID Loop we are interested in five major characteristics of the Closed Loop Step response. They are:

1. **Dead Time:** The difference in time it takes for the Process Variable to start to change after an upset to the system.
2. **Rise Time:** The time it takes for the Process Variable to achieve 90% of the new desired level for the first time.
3. **Overshoot:** How much the peak level is higher that the new steady state level
4. **Settling Time:** The time it takes for the system to converge to its steady state
5. **Steady-State Error or Offset:** The difference between the steady state output and the desired output. This is also called "Offset".



Effects of **INCREASING** each of the Controller Parameters can be summarized as:

Mode	Rise Time	Overshoot	Settling Time	S-S Error
P-Gain	Decrease	Increase	Small Change	Decrease
I-Gain	Decrease	Increase	Increase	Eliminate
Derivative Gain	Small Change	Decrease	Decrease	Small Change

Please note that these correlations may not be exactly accurate, because all three Modes are dependent on each other. Changing one of these variables can change the effect of the other two. For this reason, the table should only be used as reference.

Basic Rules of Thumb

As a general rule, the following rules will help you in getting an unstable or “Hunting” system slowed down so you can start the tuning process if all else fails.

1. SET **P** - Starting with P=0, I=0 and D=0, increase P until the output starts overshooting
2. SET **D** - Increase D until the overshoot is reduced to an acceptable level
3. SET **I** - Increase I until the final error is equal to zero

You can effectively Take the Gain to a minimum Value, take the Integral and Derivative to Zero, and you will have a Proportional Controller only. From this point with a very low gain value, the process will be very slow or sluggish, but should not oscillate or “Hunt”. You will have some Steady State Error or Offset, but from here you can start to crank up the Gain, Integral, and Derivative to begin the tuning process.

Step 5 – Document the Problem & Solution

This final step in the Troubleshooting Process is important for future repairs and for a historical analysis of the system. Many times if you have access to the previous repairs it will give the technician a good perspective of what has been happening over time and give them a good place to start. It also can serve as a guide to the PID tuning process if the Loop Tuning Parameters are documented along with the process conditions. The old saying is still true….."The Job is not complete until the Paperwork is done”.

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