Regulator Station Overview

General Station Considerations

- Define Station Design Specifications
  - Flow Capacity, delivery pressure, min flowrate, temperature
  - Allowable noise level at the fence
- Station Piping
  - Station Bypass piping
  - Redundant regulator runs
  - Sufficient block and bleed valves
- Telemetry
  - Method of remote communications
- RTU
  - Measurement calculations
  - Automated local equipment control system

General Station Considerations

- Building Considerations
  - Electrical Area Classification
  - Ventilation methods, hazardous gas detection
- Station Filtration
  - Particulate, moisture, liquids
- Power
  - Local AC power or on-site solar power
- Cathodic Protection
  - Method of underground corrosion protection
- Gas Heating
  - Mainline heater or pilot heater

Overpressure Protection

- Monitor Regulator
  - Redundant regulator that takes control when the worker fails
- Relief Valve
  - Vents excess gas to atmosphere when worker fails
- Slam Shut Valve
  - Shuts off gas flow when worker fails

Meter Run Considerations

- Meter placement
  - Upstream or downstream of regulator
- Flow Conditioning
  - Upstream and downstream length of straight pipe
  - Flow Conditioner
  - Reduce distorted velocity profiles, gas swirl
- Meter protection
  - Downstream flow limiters for turbine meter protection
- Meter piping configuration
  - Piping configuration that insulates meter from regulator turbulence and noise

Regulator Intro

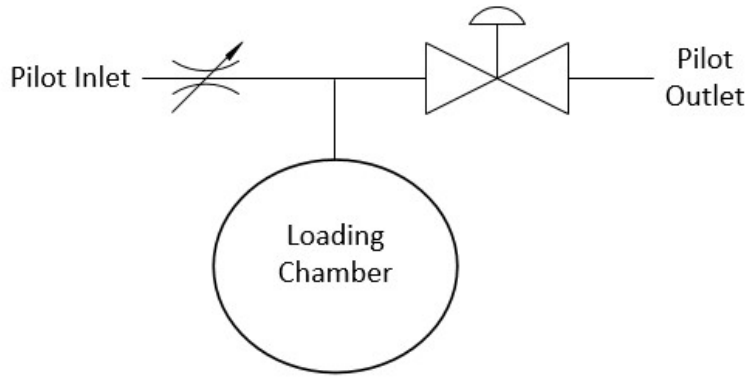
- Direct Operated
  - Small Flow – Large Droop (10 to 20%) – Simple Installation

- Pilot Operated – Unloading Style
  - Restrictor Fills and Pilot Dumps (Unloads) Chamber
  - High Flow – Low Droop (2 to 5%) - Simple Regulator
  - Restrictor first then pilot

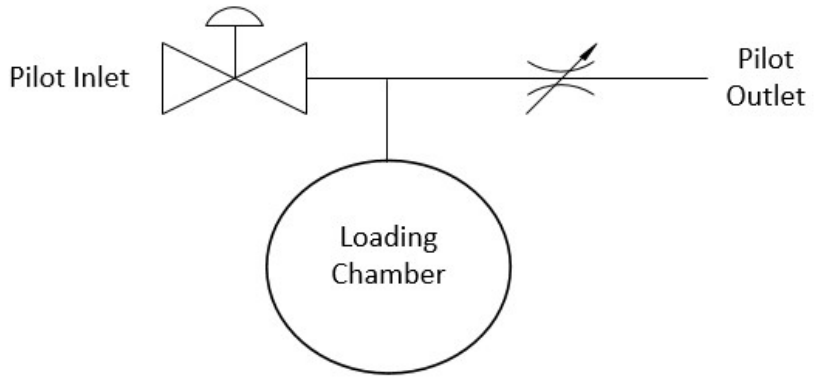
- Pilot Operated – Loading Style
  - Pilot Loads and Restrictor Dumps Chamber
  - High Flow – Low Droop (1 to 2%) - More Complex
  - Pilot first then restrictor

Unloading vs Loading Pilot Operated Regulators

Unloading Pilot Operated

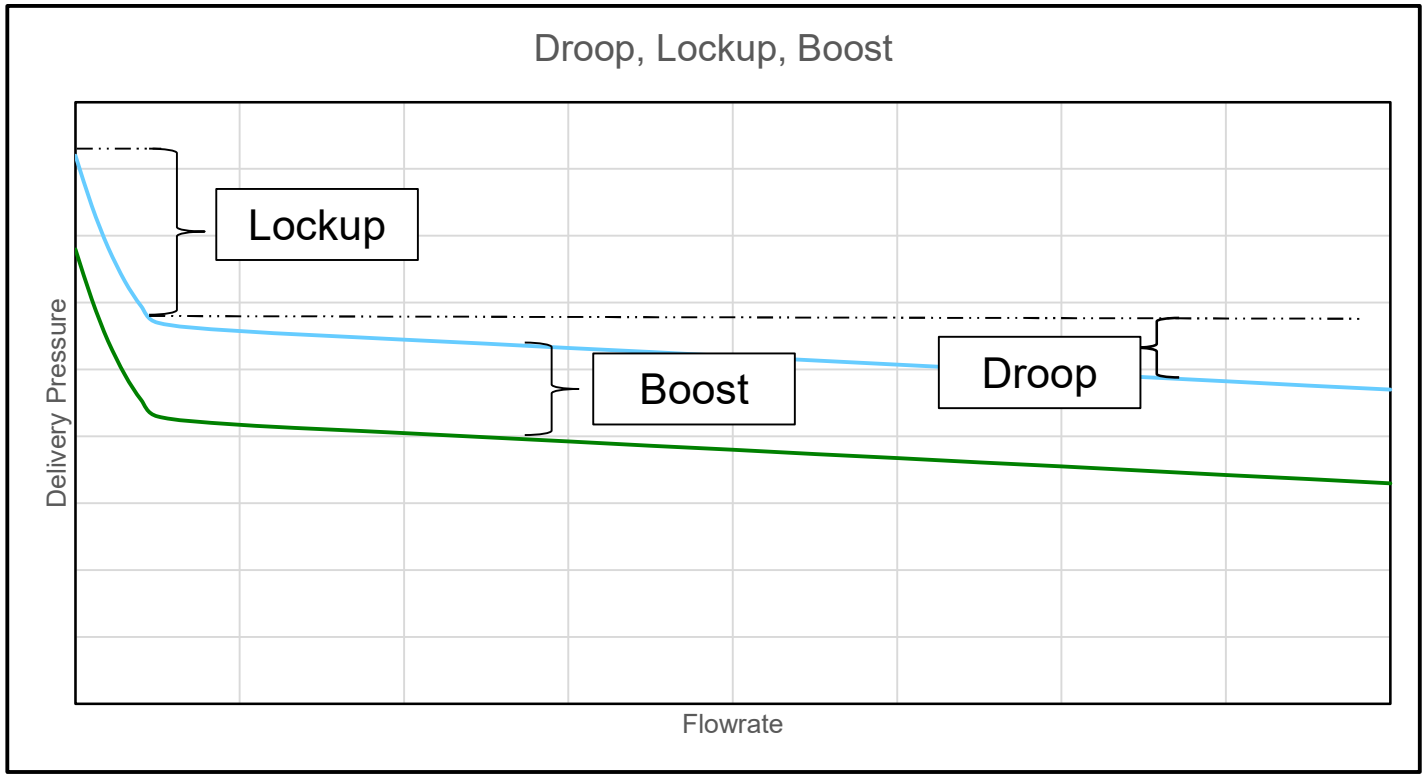


Loading Pilot Operated



Regulator Performance Curve

- Droop
  - Pressure drop from 5% flow to 80% flow
- Lockup
  - Pressure increase from 5% flow to 0% flow
- Boost
  - Shift in Set Pressure from large inlet pressure changes



Expected Pilot Performance

Series 20

Pilot Performance

Series 20 Pilot		Pressure Reducing Mode Restrictor Set at 4		
Spring Range	Color	Lock-up (psi)	Droop (psi) @ Max. Capacity [1]	Boost @ Constant Flow (psi)[3]
3-12 [2]	Red	1.0	0.3	0.7
10-40 [2]	Silver	1.0	0.3	0.7
25-90	Blue	2.0	0.6	0.7
60-200	Purple	2.0	1.30	0.7
100-260	Black	5.0	2.00	0.7
200-450	White/Green	10.0	4.00	0.7

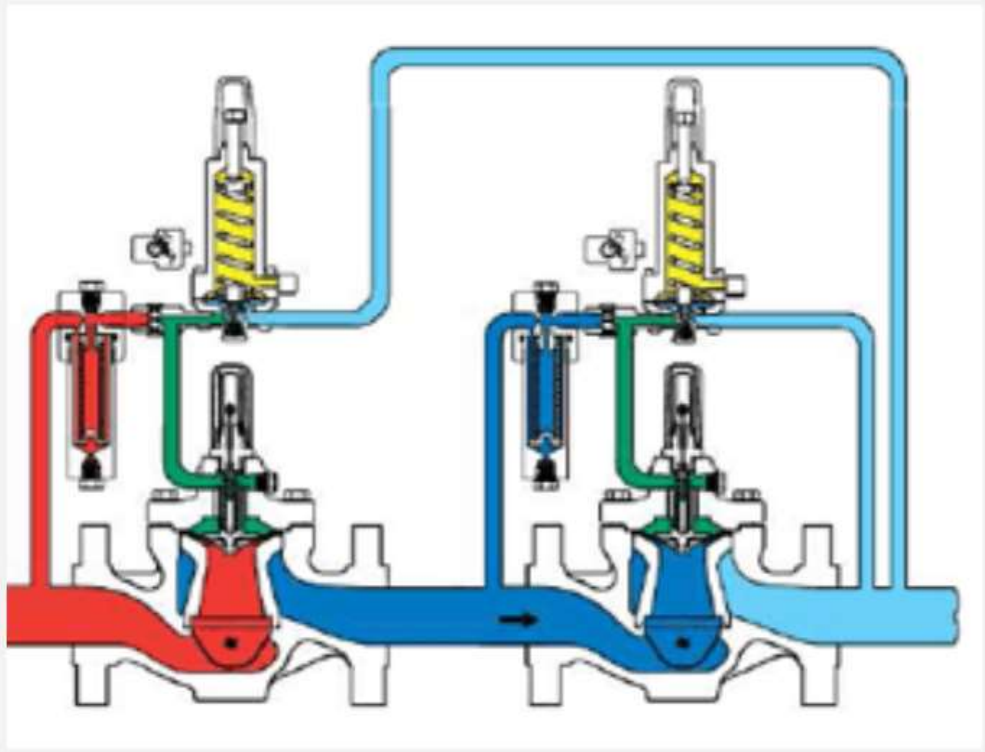
Series 20H

Pilot Performance

Series 20 Pilot		Pressure Reducing Mode Restrictor Set at 4		
Spring Range	Color	Lock-up (psi)	Droop (psi) @ Max. Capacity [1]	Boost @ Constant Flow (psi)[3]
200-520	Black	10.0	4.00	1.50
400-900	White/ Green	20.0	8.00	1.50

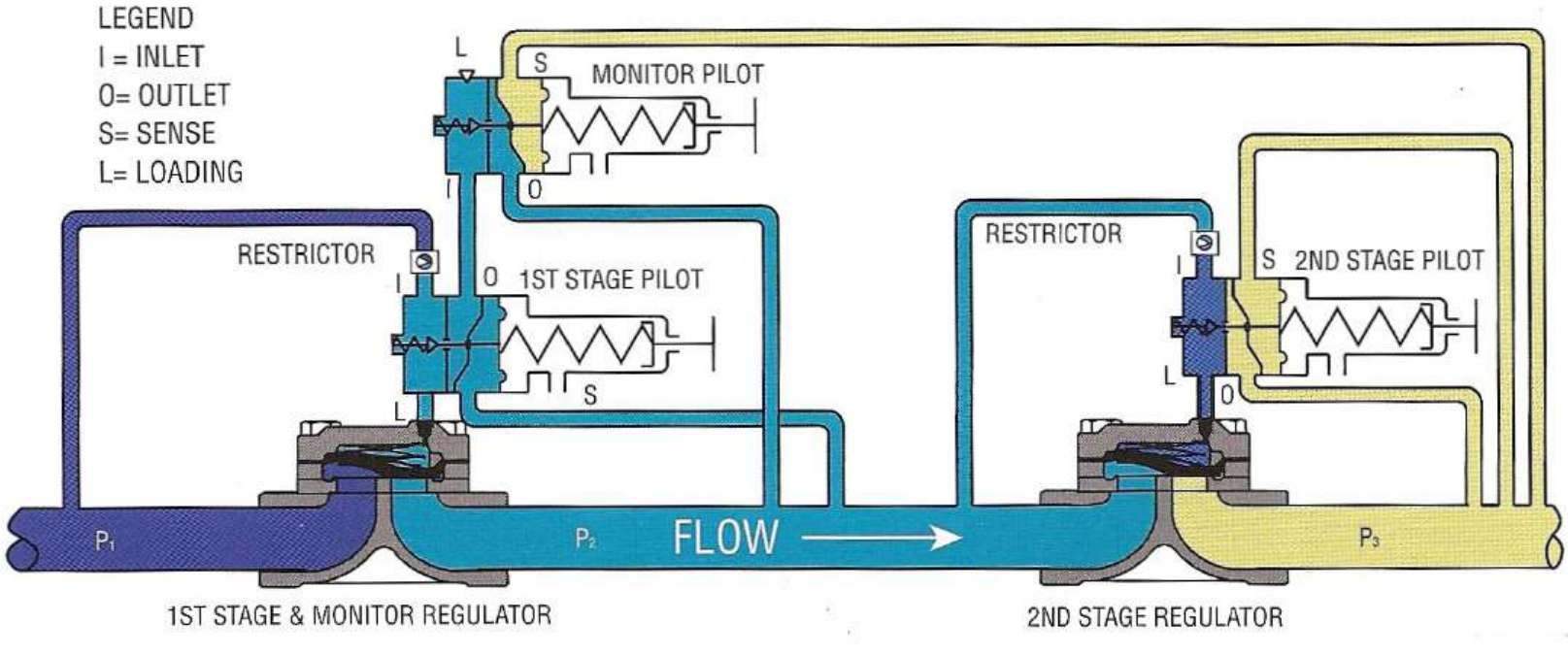
Worker Monitor Regulation

- Monitor Regulator provides Overpressure Protection if the Worker Fails
  - During normal operation, the standby monitor is 100% open with almost no pressure drop
  - Monitor can either be upstream or downstream by changing pilot set points
  - Recommendation: Monitor Upstream



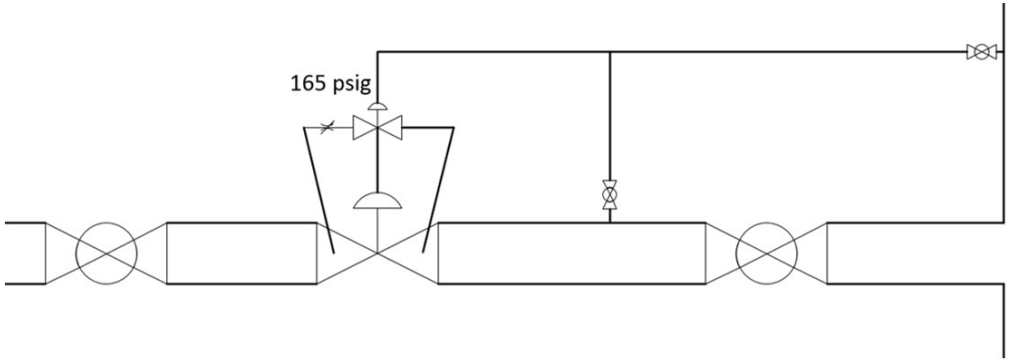
Working Monitor Regulation

- Working Monitor Regulator provides Overpressure Protection plus provides a second pressure cut
  - The Monitor must be upstream and has two pilots
  - During normal operation, both the monitor and the worker take a pressure cut
  - If the worker fails open, the monitor will take the full pressure cut
  - Benefits of taking a dual pressure cut: longer diaphragm life, less noise

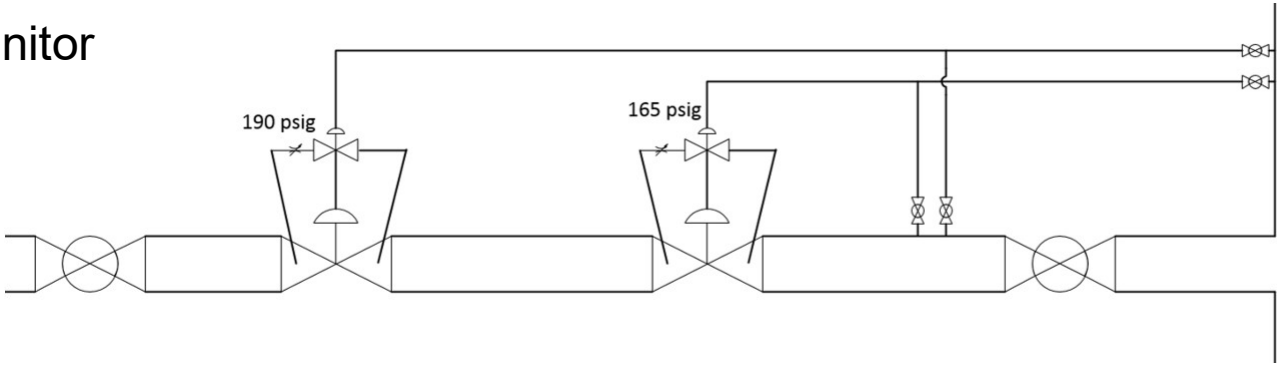


Schematics Overview

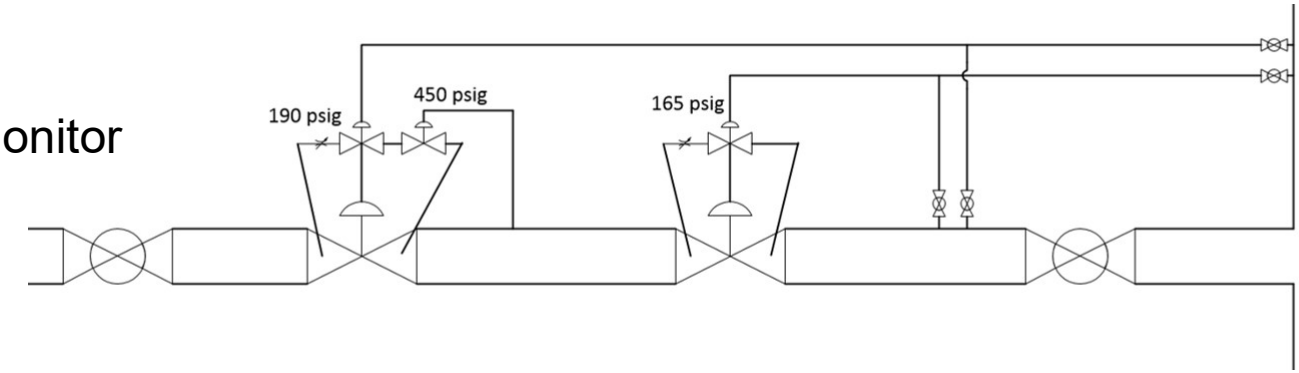
Single Cut



Worker Monitor



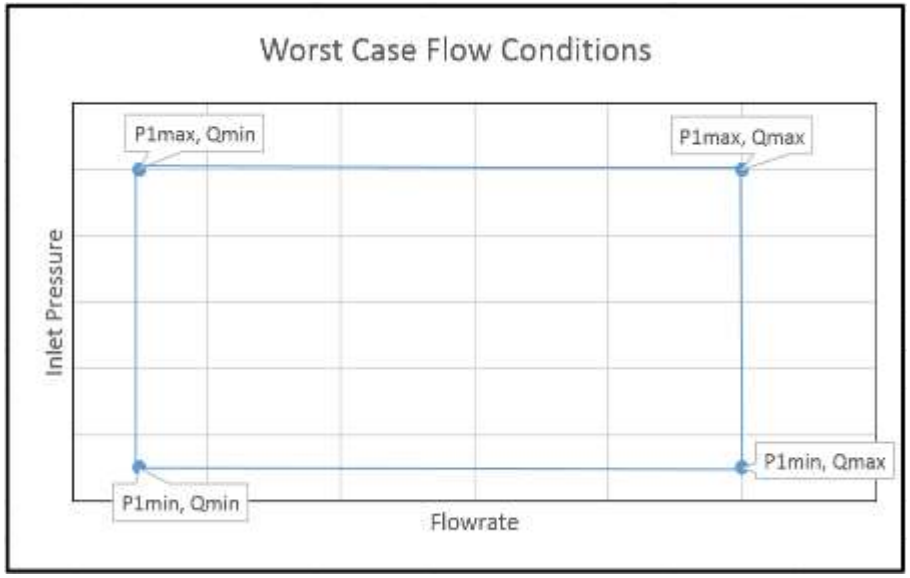
Working Monitor



Increase Regulator Life & Decrease Failures

- Proper Regulator Sizing and Selection
- Do not Exceed Regulator Turndown Capabilities
- Limit the pressure differential across each regulator

Regulator Sizing



- Ensure regulator can meet station capacity (P1min, Qmax)
- Ensure regulator does not exceed rated turndown (P1max, Qmin)
- Calculate max regulator noise (P1max, Qmax)
- Verify the following
  - That the outlet temp is not too low
  - That the regulator is not chocking in the regulator outlet
  - That downstream pipe velocities are not too high

Regulator Sizing - Example

Regulator Sizing

				Location							
SG	P1 (max)	800	psig	Equipment Selection							
0.6	P1 (min)	500	psig	Notes							
Patm	T1	60	F								
14.7	dpipe	2	in	Standby Monitor							
	Q (max)	5000	mscfd								
	Q (min)	50	mscfd								
					Cg required	% open	Critical flow	Velocity (ft/s)	Temp (F)	Turndown	
Mooney	Cg		610	Pmin/Qmax	314	51	No	175	39	2	
FlowGrid	C1		30	Pmax/Qmin	2	0.3	Yes	2	18	308	
2"	P2	200	psig	Pmin/Qmin	3	0.5	No	2	39	194	
35%	dpipe	2	in	Pmax/Qmax	198	32	Yes	167	18	3	

Increase Regulator Station Safety & Reliability

- Layers of protection can significantly improve station safety and reliability
- Monitor regulators increase layers of protection from overpressure condition
- Having primary and secondary operational runs increase protection from station shutdown

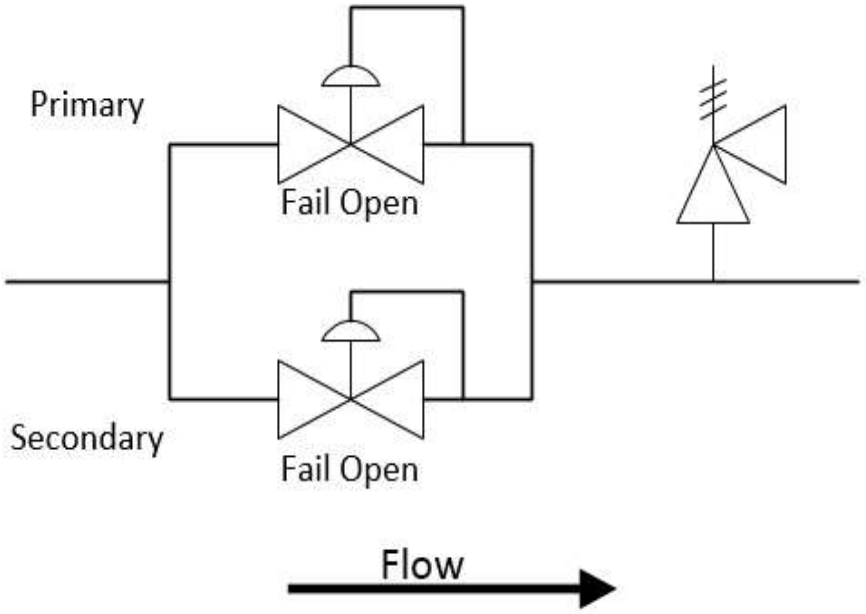
Regulator Failure Modes

> What is a failure mode?

> Most likely failure condition

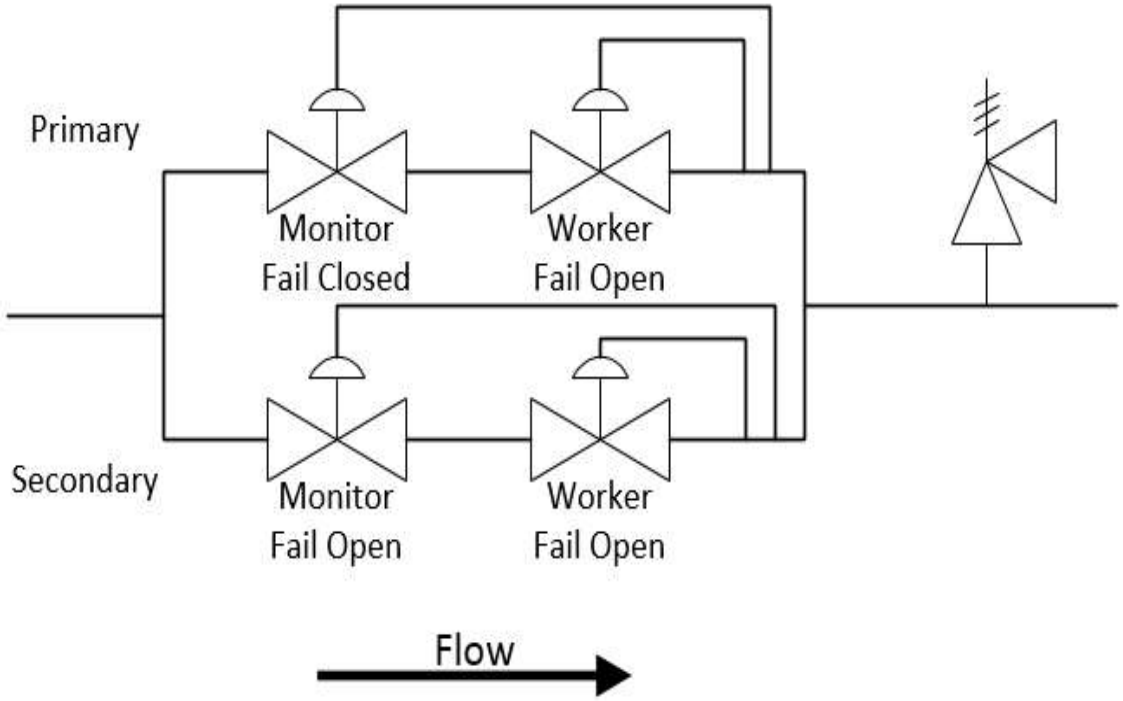
> What is the difference between a fail open and fail closed regulator?

Regulator Failure Modes



System Layers of Protection	
1	Layers to Relief Valve
2	Layers to prevent overpressure
2	Layers to prevent shutoff

Regulator Failure Modes



System Layers of Protection	
4	Layers to Relief Valve
5	Layers to prevent overpressure
2	Layers to prevent shutoff

Regulator Failure Modes

		Fail Open	Fail Closed	Likelihood	Comments	Mitigation
Unloading style regulators	Reg - Damaged Seat / Diaphragm	up to 10%		High		500 psid max per regulator, increase reg turndown
	Reg - Hole through throttling diaphragm	100%	100%	Medium	Normally fail open	
	Reg - Sulfur buildup	up to 10%	up to 100%	Medium	Gradual loss of pressure	
	Pilot - internal icing	up to 10%	up to 100%	Medium	Depends on gas H2O content, pressure cut	Pilot heater
	Pilot - internal sulfur clogging	up to 10%	up to 100%	Medium	Gradual drift up or down in delivery pressure	Sulfur filtration, pilot heater
	Pilot - external icing covering vent			Low	erratic control	Pilot heater
	Pilot - sense line loses pressure	up to 100%		Low		Overpressure protection
Loading style regulators - fail closed	Reg - Damaged Seat / Diaphragm	up to 10%		High		500 psid max per regulator, increase reg turndown
	Reg - Hole through actuation diaphragm		up to 100%	Low		
	Reg - Sulfur buildup	up to 10%	up to 100%	Medium	Gradual loss of pressure	
	Pilot - internal icing	up to 10%	up to 100%	Medium	Depends on gas H2O content, pressure cut	Pilot heater
	Pilot - internal sulfur clogging	up to 10%	up to 100%	Medium	Gradual drift up or down in delivery pressure	Sulfur filtration, pilot heater
	Pilot - external icing covering vent			Low	erratic control	Pilot heater
	Pilot - sense line loses pressure	up to 100%		Low		Overpressure protection
Loading style regulators - fail open	Reg - Damaged Seat / Diaphragm	up to 10%		High		500 psid max per regulator, increase reg turndown
	Reg - Hole through actuation diaphragm	up to 100%		Low		
	Reg - Sulfur buildup	up to 10%	up to 100%	Medium	Gradual loss of pressure	
	Pilot - internal icing	up to 100%		Medium	Depends on gas H2O content, pressure cut	Pilot heater
	Pilot - internal sulfur clogging	up to 100%		Medium	Gradual drift up or down in delivery pressure	Sulfur filtration, pilot heater
	Pilot - external icing covering vent			Low	erratic control	Pilot heater
	Pilot - sense line loses pressure	up to 100%		Low		Overpressure protection

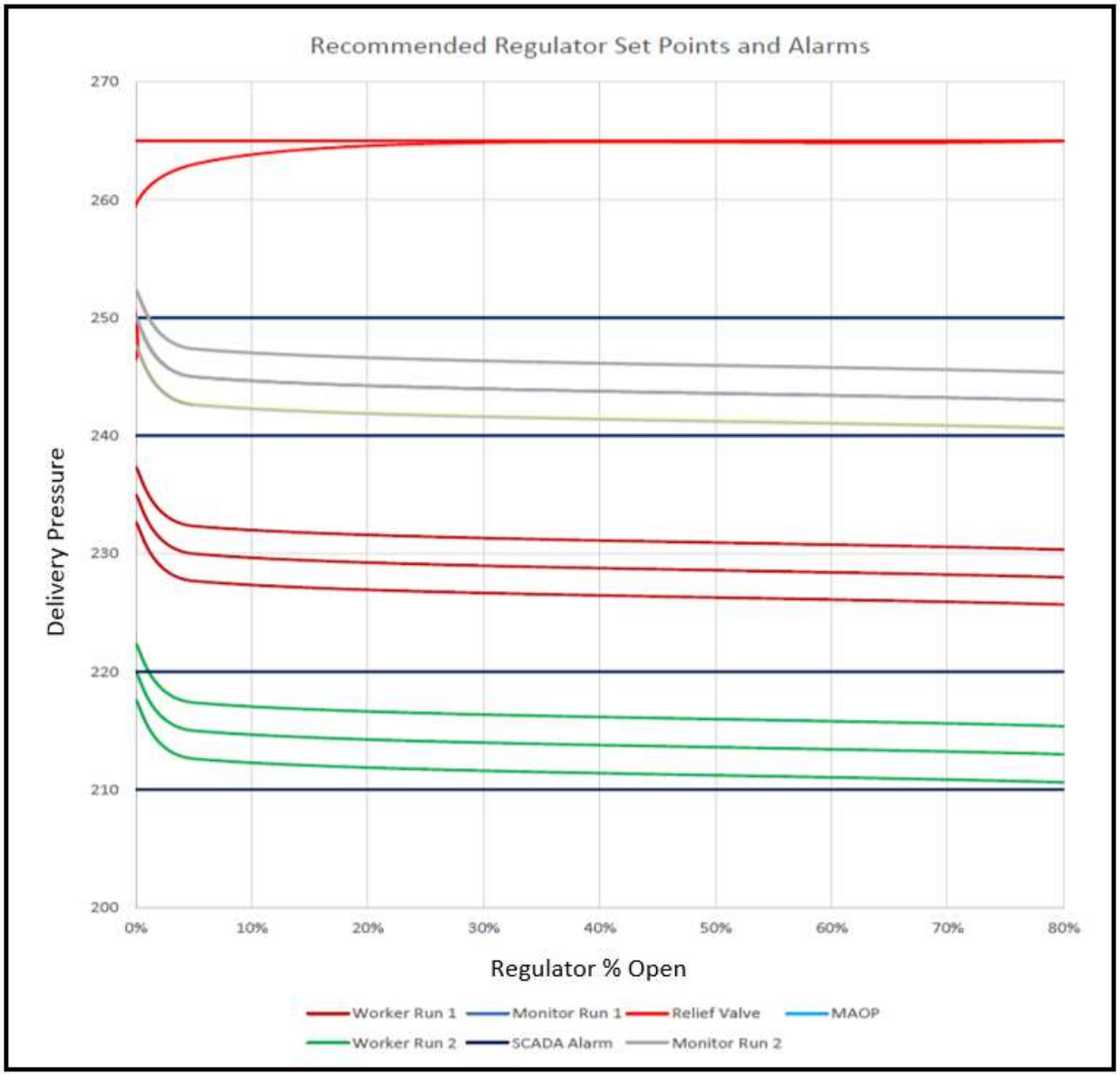
Remotely ‘see’ a regulator failure

> Why is it important to be quickly notified of a regulator failure?

> How important is it to catch a station issue before getting to the relief?

> Does station feedback improve station safety?

Remote Failure Detection from Delivery Pressure



Remote Failure Detection – Interstage Pressure Monitoring