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Monitor Regulator Basic Principles

May 11, 2026

General Station Considerations

Station Design

- Delivery pressure, max & min flowrate, temperature
- Allowable noise

Station Piping

- Station Bypass piping
- Redundant regulator runs
- Sufficient block and bleed valves

Building

- Electrical Area Classification
- Ventilation methods, hazardous gas detection

RTU & Telemetry

- Measurement calculations
- Automated local equipment control system

Filtration

- Particulate
- Moisture
- NGLs

Heating

- Mainline heater
- Pilot heater

Power

- Local AC power or on-site solar power

Cathodic Protection

- Method of underground corrosion protection

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

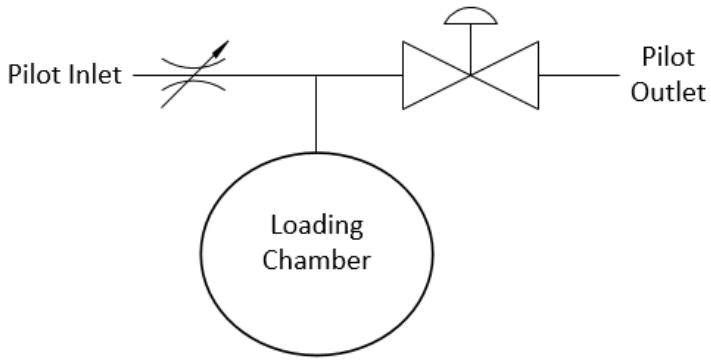
Shuts off gas flow when worker fails

Regulator Intro

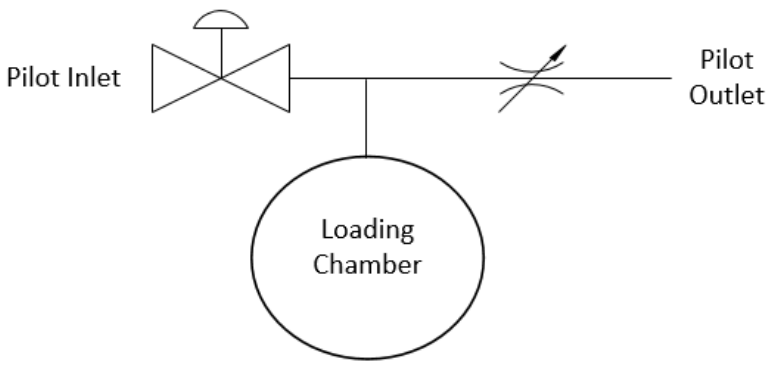
- Direct Operated
  - Small Flow – Large Droop (10 to 20%) – Simple Installation
- Pilot Operated – Unloading Style
  - Restrictor Fills and Pilot Dumps (Unloads) Chamber
  - High Flow – Low Droop (2 to 5%) - Simple Regulator
  - Restrictor first then pilot
- Pilot Operated – Loading Style
  - Pilot 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

Droop

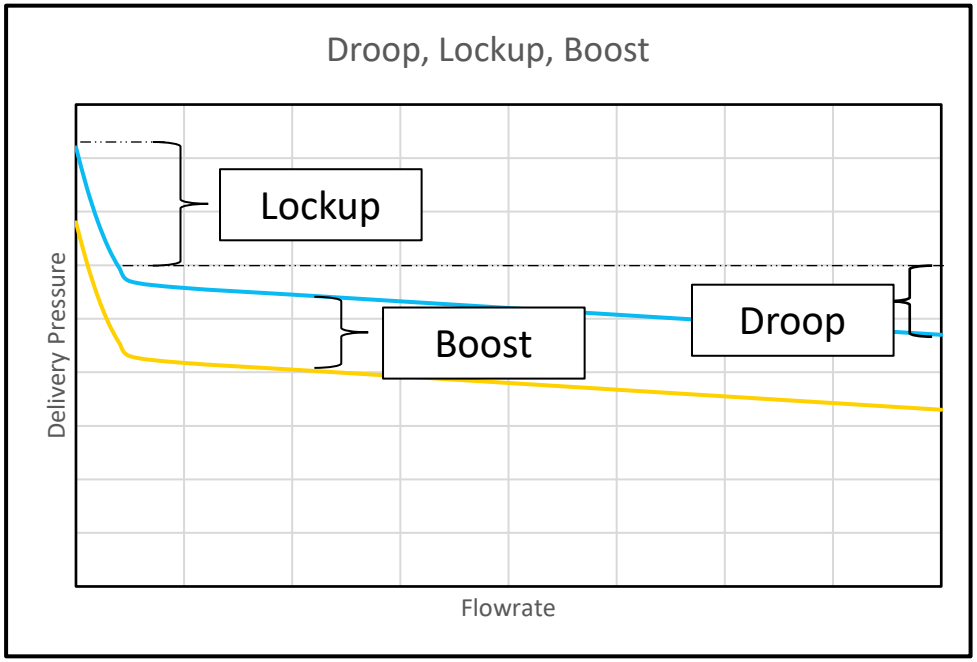
- Pressure drop from 5% flow to 80% flow

Lockup

- Pressure increase from 5% flow to 0% flow

Boost

- Shift in Set Pressure from large inlet pressure changes



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

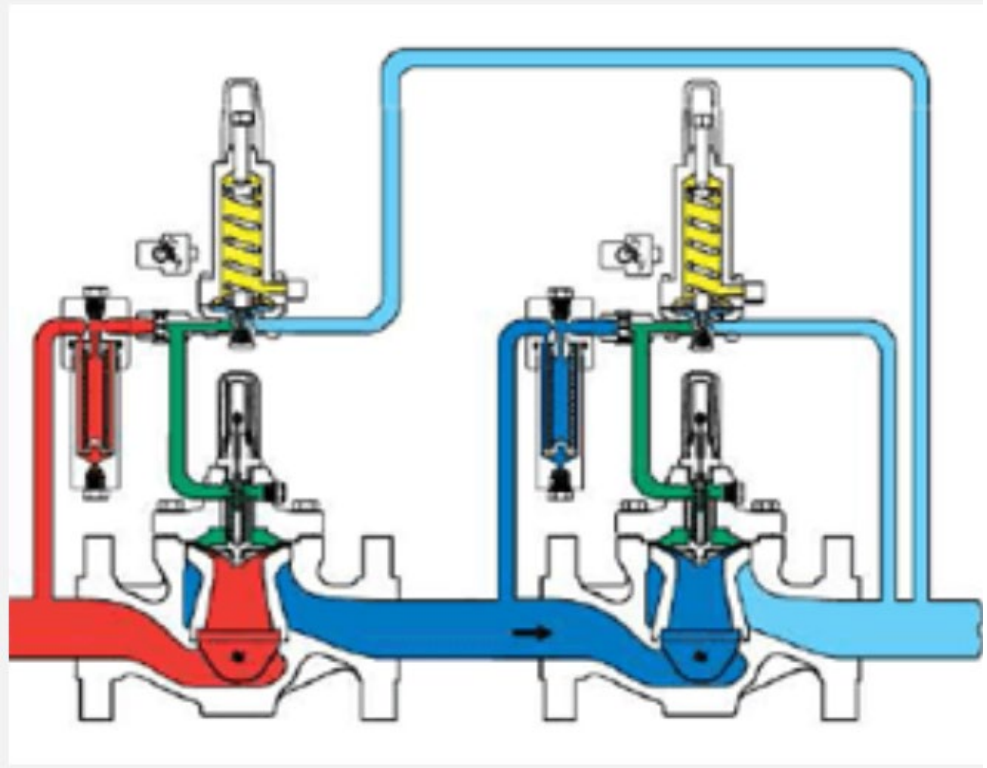
Pilot Performance

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

Expected Regulator Performance

Mooney FlowGrid Regulators

Standby Monitor Configuration

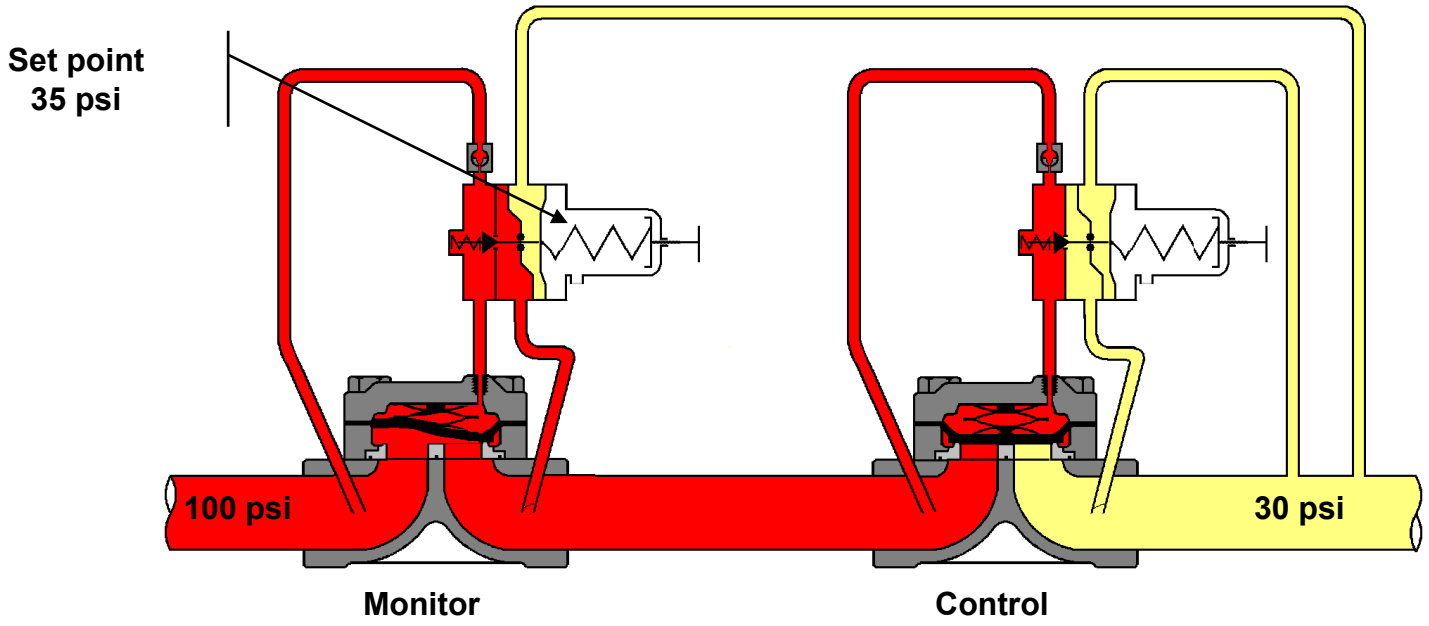


- Monitor Regulator provides Overpressure Protection if the Worker Fails
  - During normal operation, the standby monitor is 100% open with almost no pressure drop
  - Monitor can either be upstream or downstream by changing pilot set points
  - Recommendation: Monitor Upstream

Standby Monitor

Closed Position

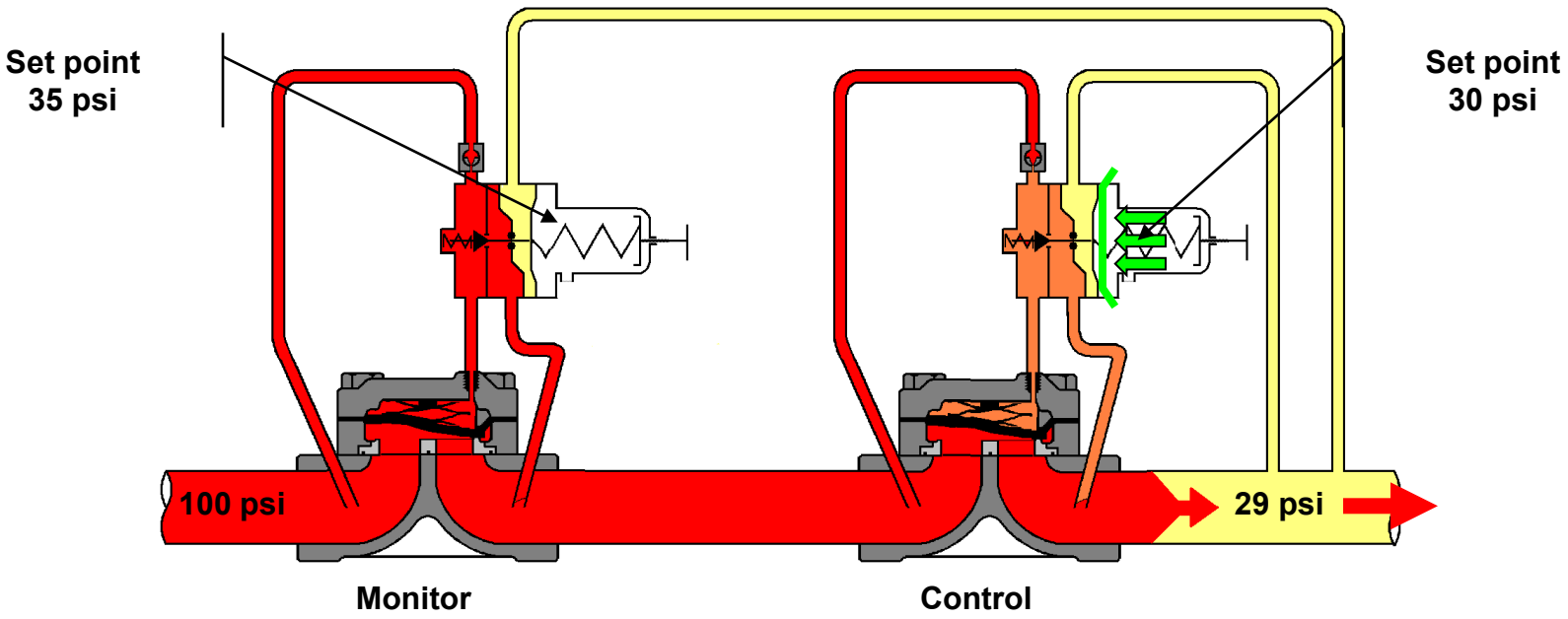
- When outlet pressure is less than the set point of monitor regulator, monitor remains wide open.
- Control regulator is closed because outlet pressure is greater than or equal to set point



Standby Monitor

Downstream Demand

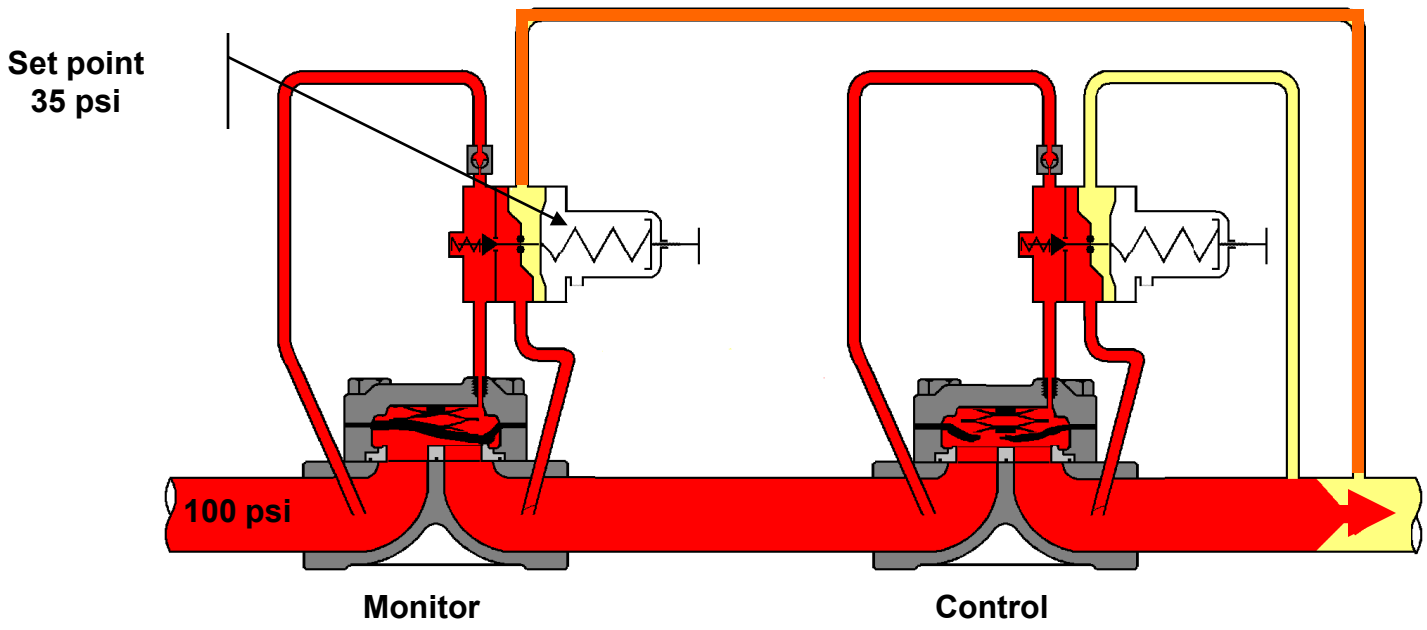
- When demand occurs outlet pressure begins to drop, opening control pilot, allowing control regulator to open and satisfy demand
- Monitor regulator remains open because downstream pressure is below set point.



Standby Monitor

Control Regulator Failure

- Regulators goes full open sending high pressure gas downstream
- Monitor regulator's sense line senses the increase in downstream pressure

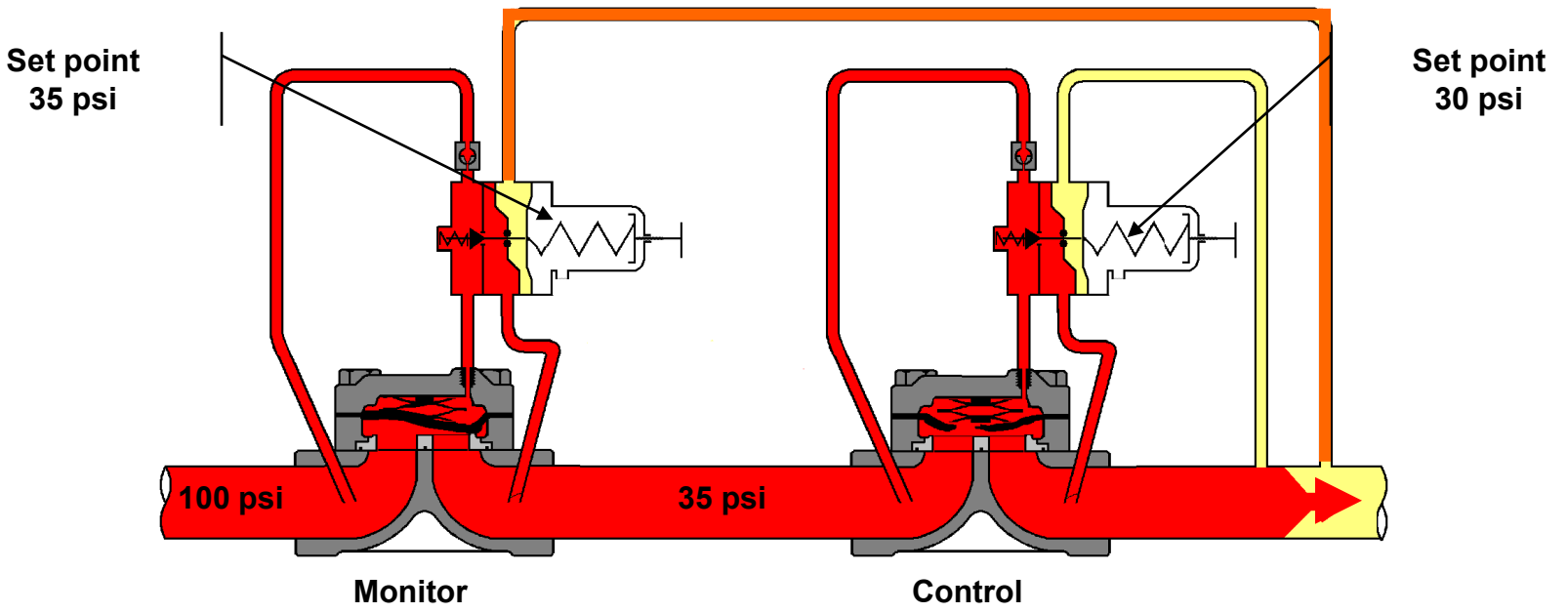


Standby Monitor

Control Regulator Failure

- The increased pressure on the underside of the pilot diaphragm begins to close pilot
- Allowing monitor regulator to take immediate control

Monitor Regulator Takes Over

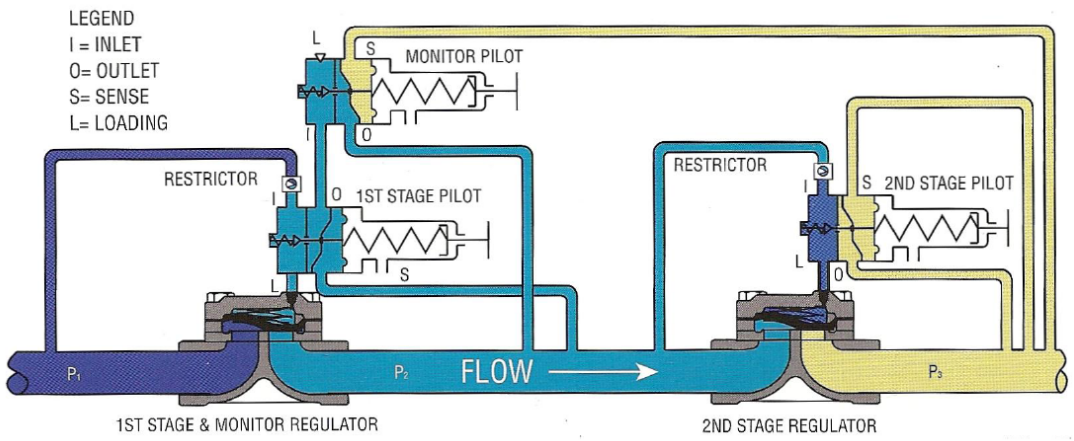


Standby Monitor

Downstream Monitor Advantages

- Monitor opens & closes with flow rate.
- Normally a lower delta P across monitor.
- Lower flow of gas through monitor pilot system.
- Monitor always in position to take over control.
- Token Relief recommended or form of alarming

Working Monitor Configuration



- 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

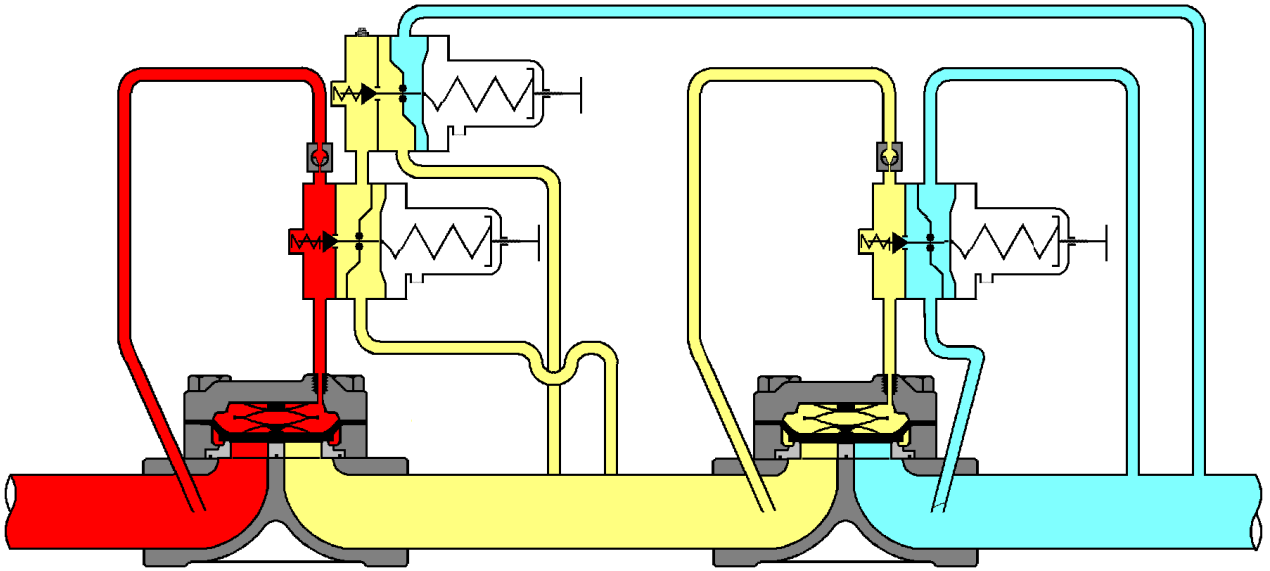
Working Monitor

Two stage pressure cut reduces stress on regulators

- Quieter operation

Each regulators performance is evaluated

- Cost effective

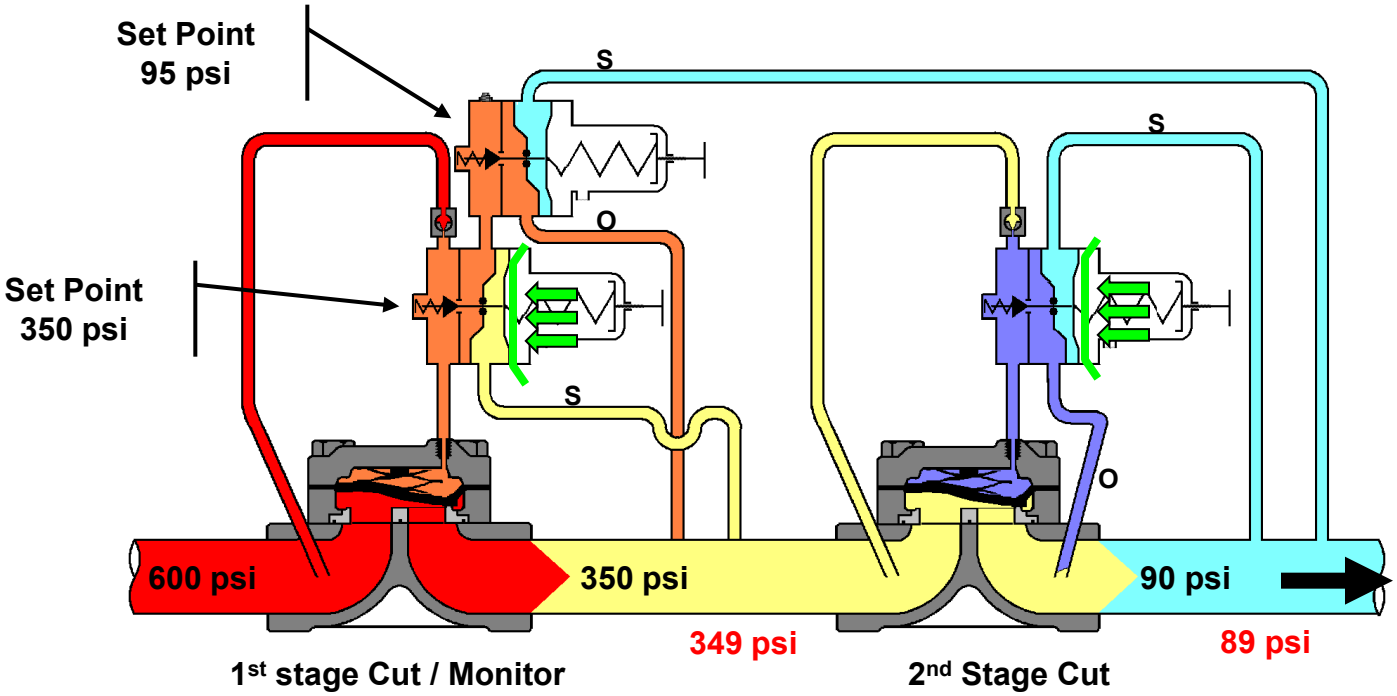


1st stage Cut / Monitor

2nd Stage Cut

Standby Monitor

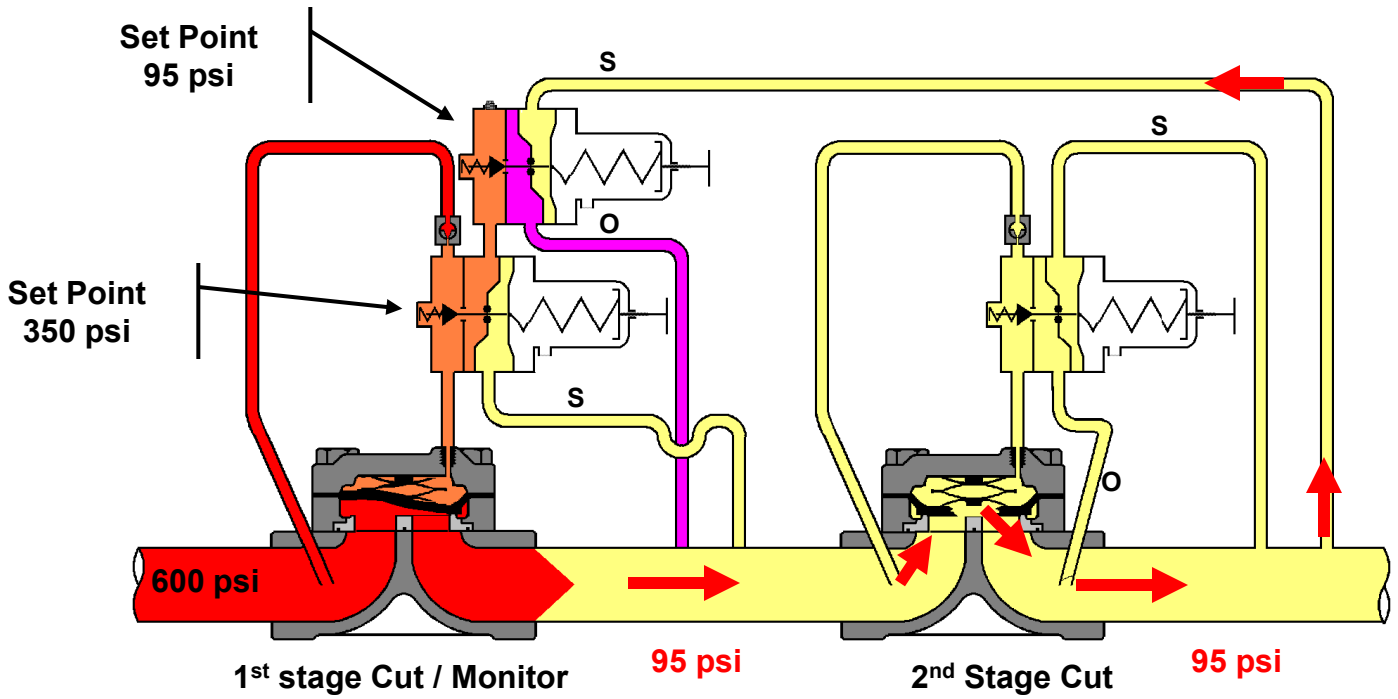
Principle of Operation



Standby Monitor

Should 2nd Stage regulator fail the 1st stage regulator can handle the complete load requirements

2nd Stage Failure!



Causes of Regulator Malfunctions

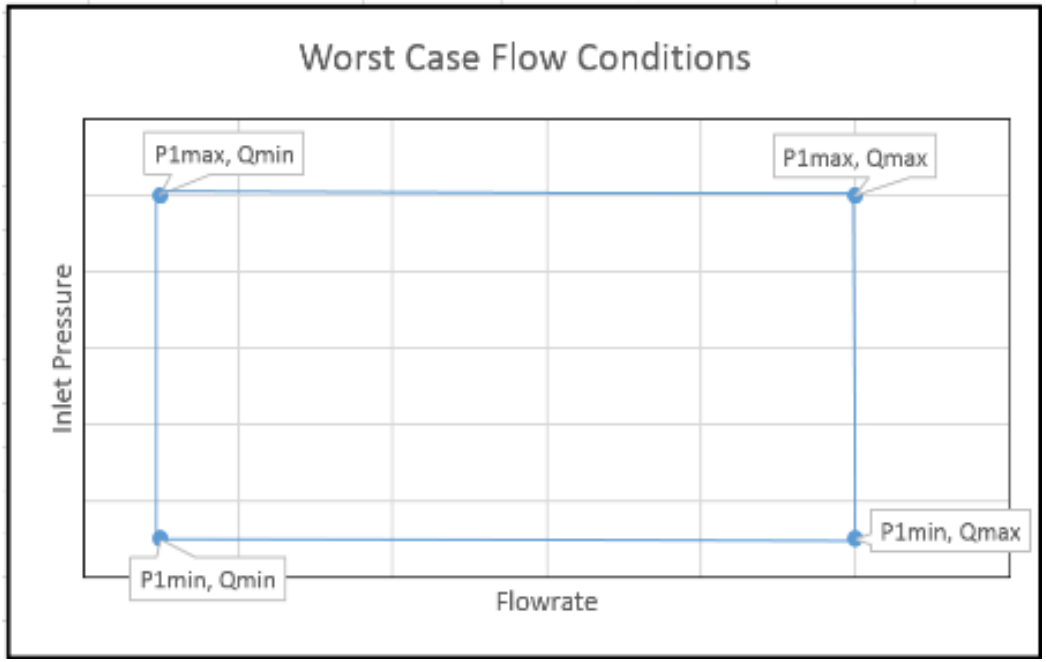
- Turndown exceeded
- Valve chattering or cycling
- Icing
- Particulate
- Elemental Sulfur

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

1. Ensure regulator can meet station capacity (P1min, Qmax)
2. Ensure regulator does not exceed rated turndown (P1max, Qmin)
3. Calculate max regulator noise (P1max, Qmax)
4. 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

		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
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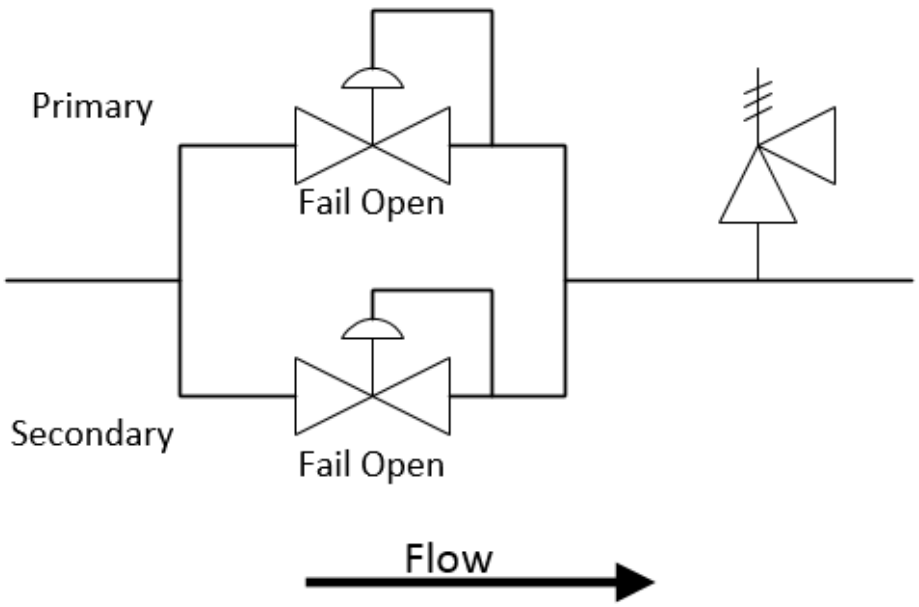
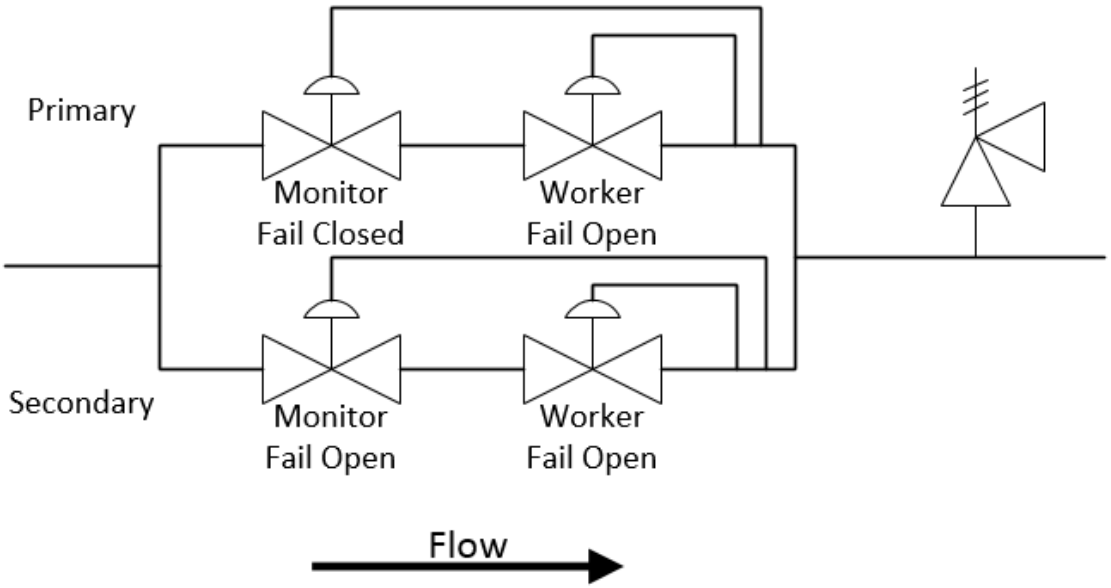
Station Failure Modes



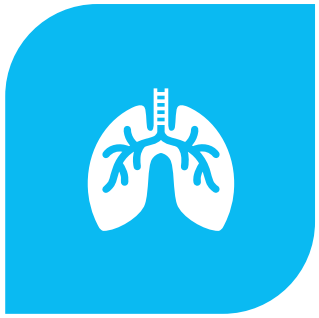
System Layers of Protection	
1	Layers to Relief Valve
2	Layers to prevent overpressure
2	Layers to prevent shutoff

Station Failure Modes



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

Remotely ‘see’ a regulator failure

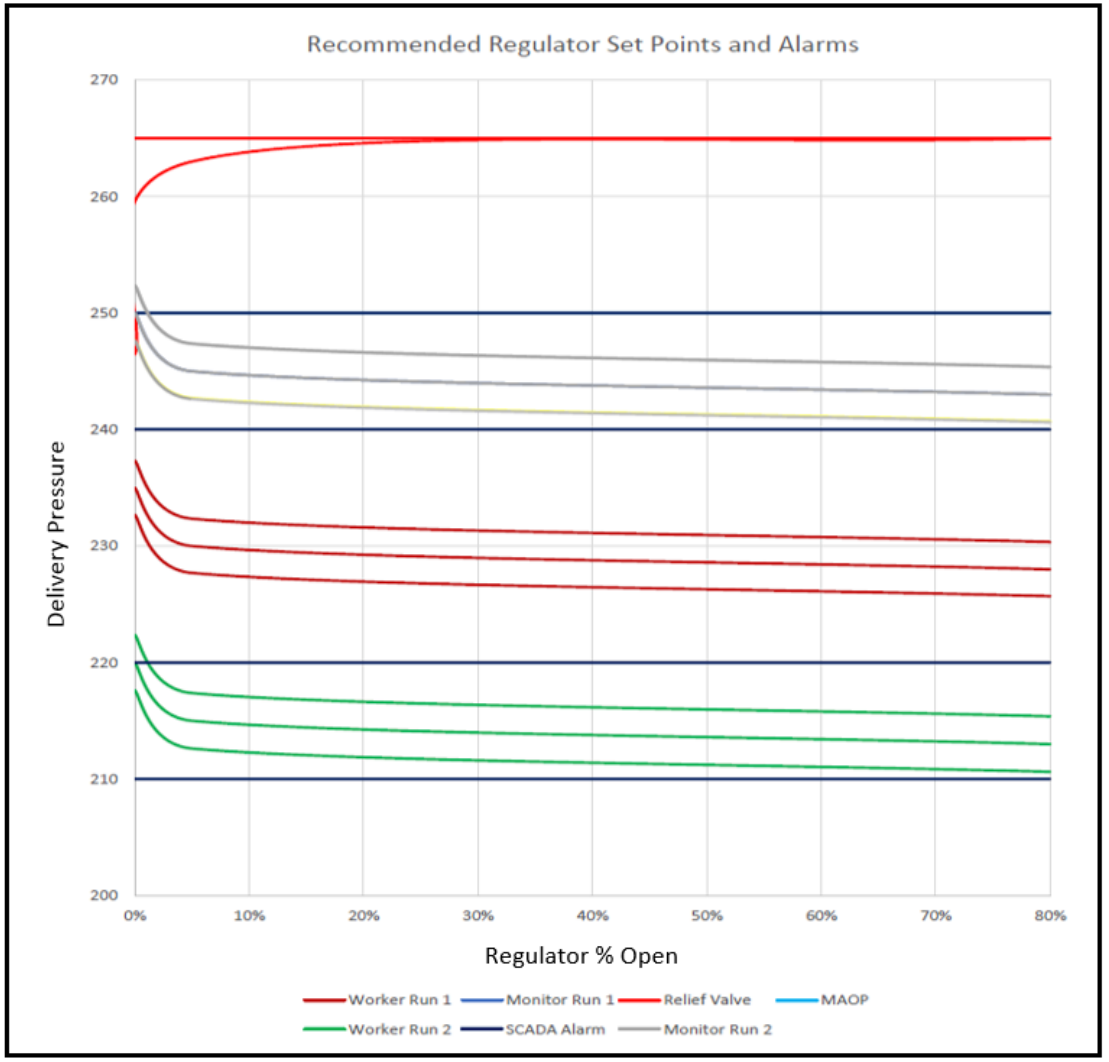


WHY IS IT IMPORTANT TO BE QUICKLY NOTIFIED OF A REGULATOR FAILURE?

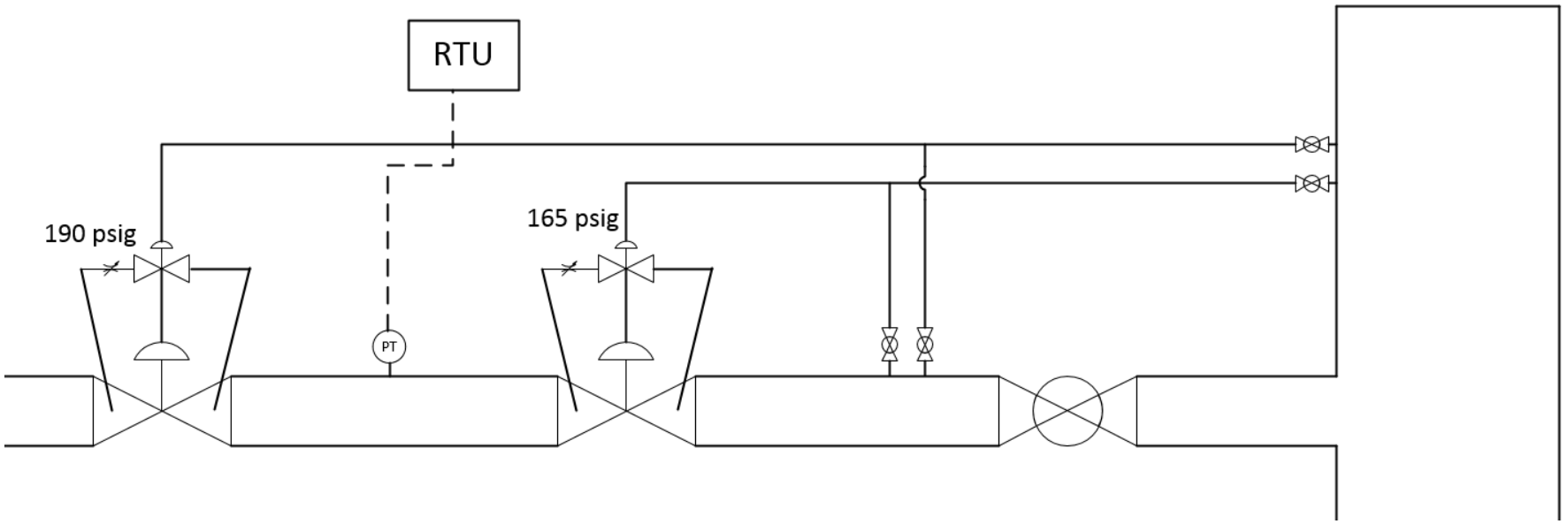
HOW IMPORTANT IS IT TO CATCH A STATION ISSUE BEFORE GETTING TO THE RELIEF?

DOES STATION FEEDBACK IMPROVE STATION SAFETY?

Remote Failure Detection from Delivery Pressure



Remote Failure Detection – Interstage Pressure Monitoring



Resolving Station Noise Issues

- Add more pressure cuts (Working Monitor)
- Reduce Valve Size
- Reduce Piping Turbulence
- Use regulators with special noise reduction trim
- Noise blankets
- Buildings
- Bury Valve and/or outlet header

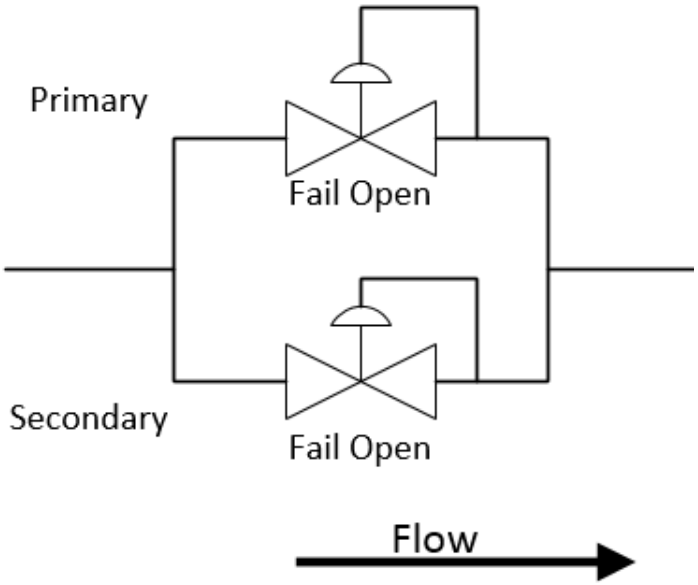
The Power of Multiple Runs

Regulation

- Increase reg turndown
- Protects customer from shutoff

Measurement

- Increase measurement turndown
- Must use run switching



THANK YOU