SPARTAN CONTROLS

Experience Industrial Innovation

Basics of Pilot Loading Regulators

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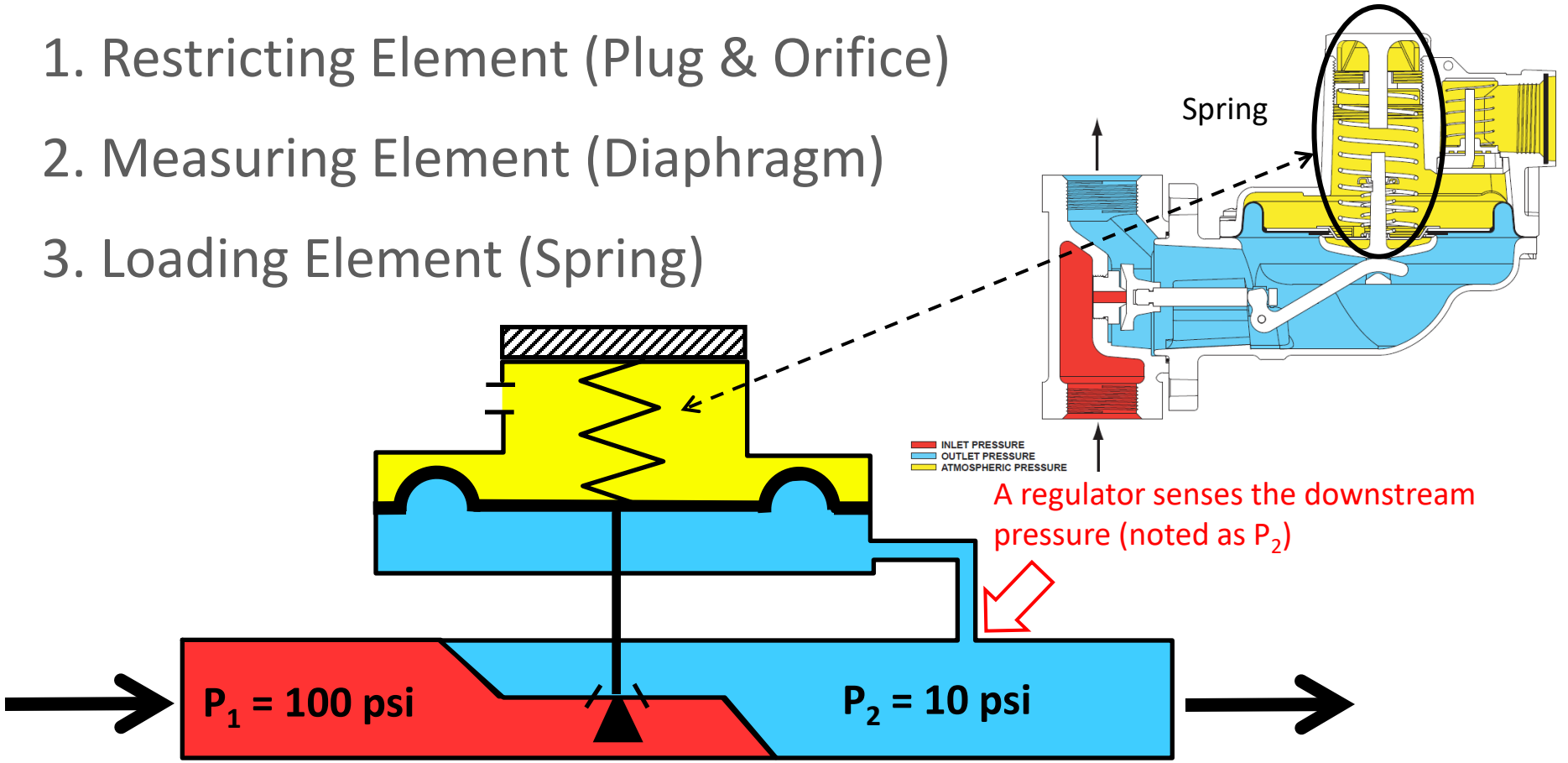
Spartan Controls, Application Specialist

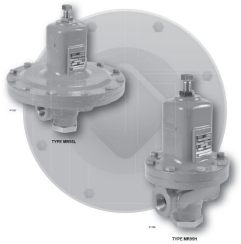
Direct Operated Regulators

1. Restricting Element (Plug & Orifice)
2. Measuring Element (Diaphragm)
3. Loading Element (Spring)

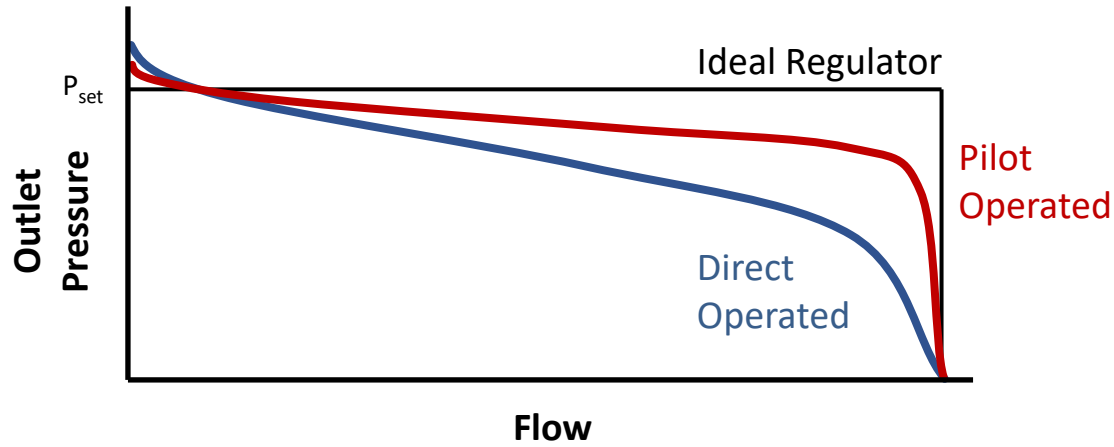


Direct Operated versus 2-path Pilot Operated

Direct Operated



- Low cost
- Simple construction
- Smaller line sizes
- Decent accuracy (10-20% droop)
- Extremely fast speed of response



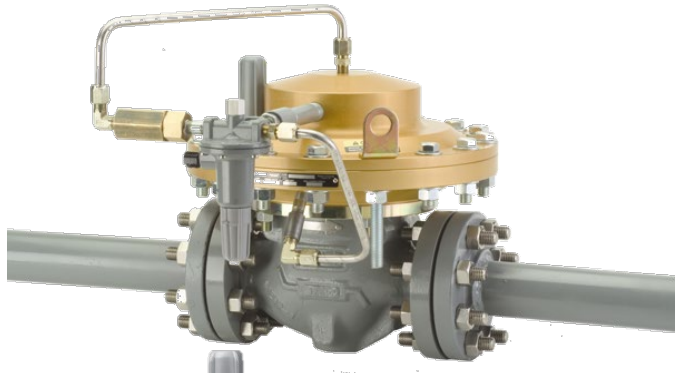
Pilot Loading Operated

- Good rangeability
- High accuracy (1-2% droop)
- High capacity
- Lower lockup tail
- Control/Tune gain of the system
- More complex installation
- Slower speed of response than self op

Rule of Thumb:
Pilot Ops trade speed of response for accuracy with less droop and smaller lockup tails compared to Direct Ops

Types of Pilot-Operated Regulators

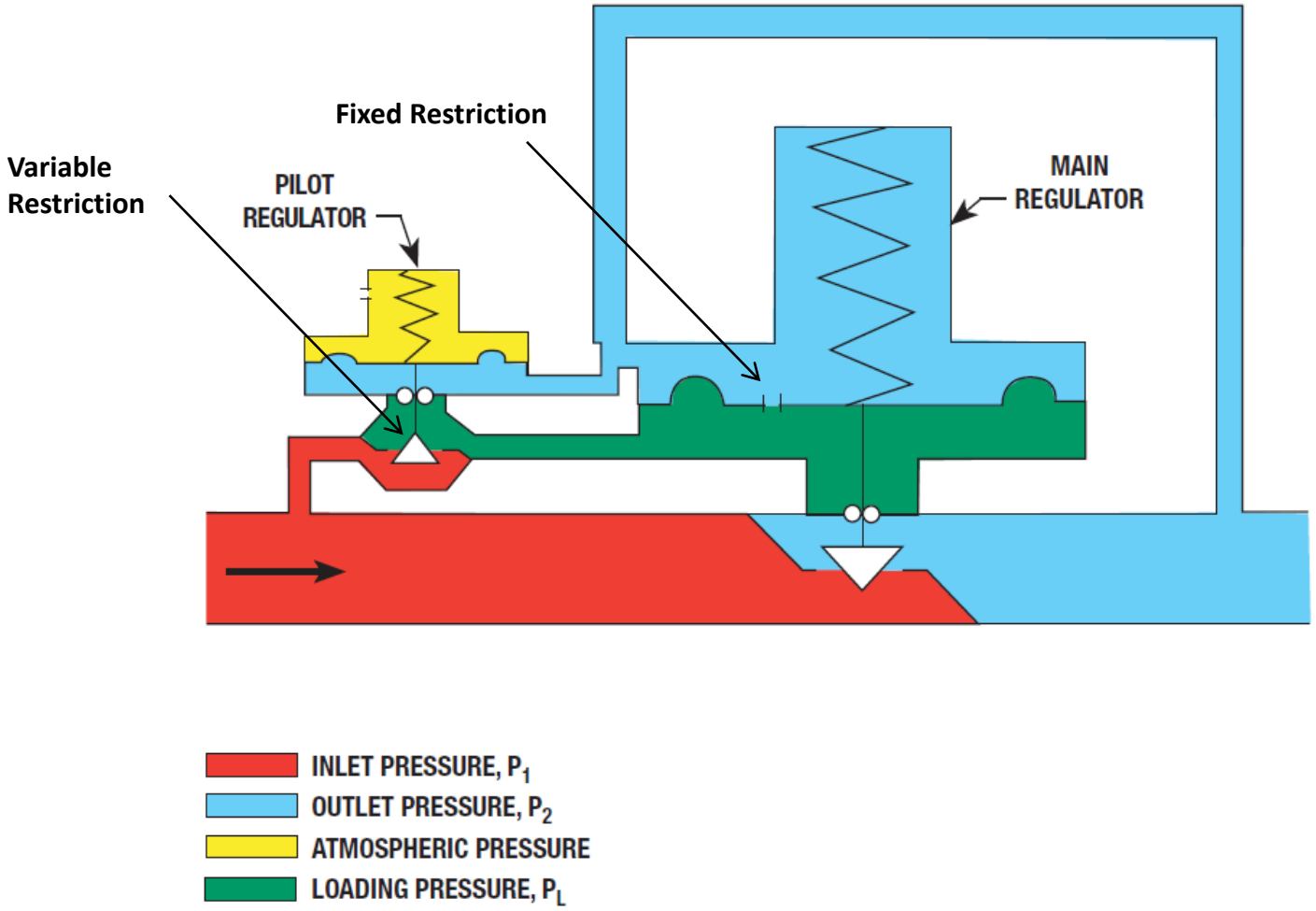
- Pilot Loading – “2-path Control”
  - Sample models include Fisher 99, 299H, EZH, EZL

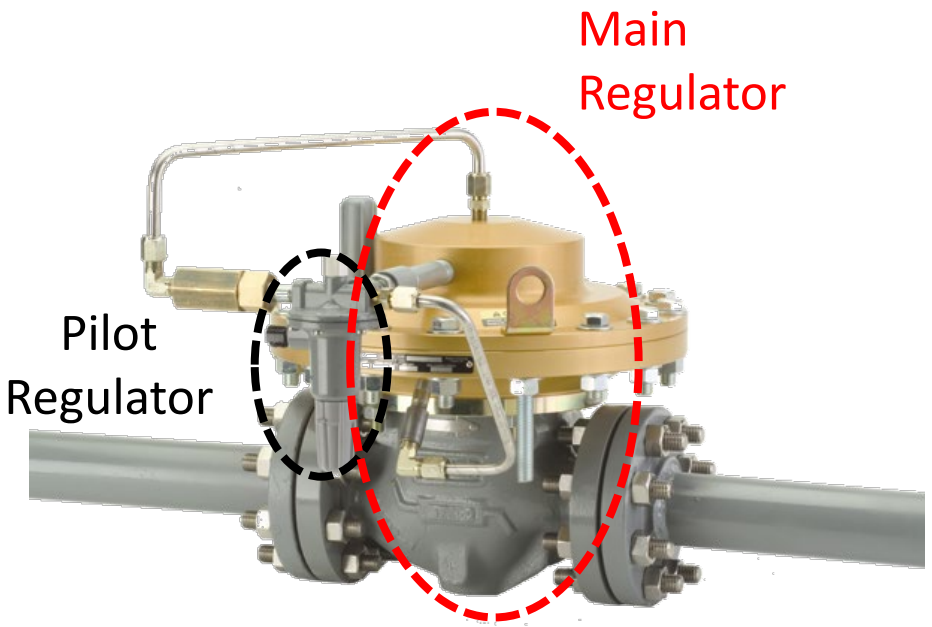


- Pilot Unloading – “Flexible Element, Boot-style”
  - Sample models include Fisher EZR

- Pressure Loaded
  - Sample models include Fisher CP200, CP400

Pilot Loading – “2-Path Control”



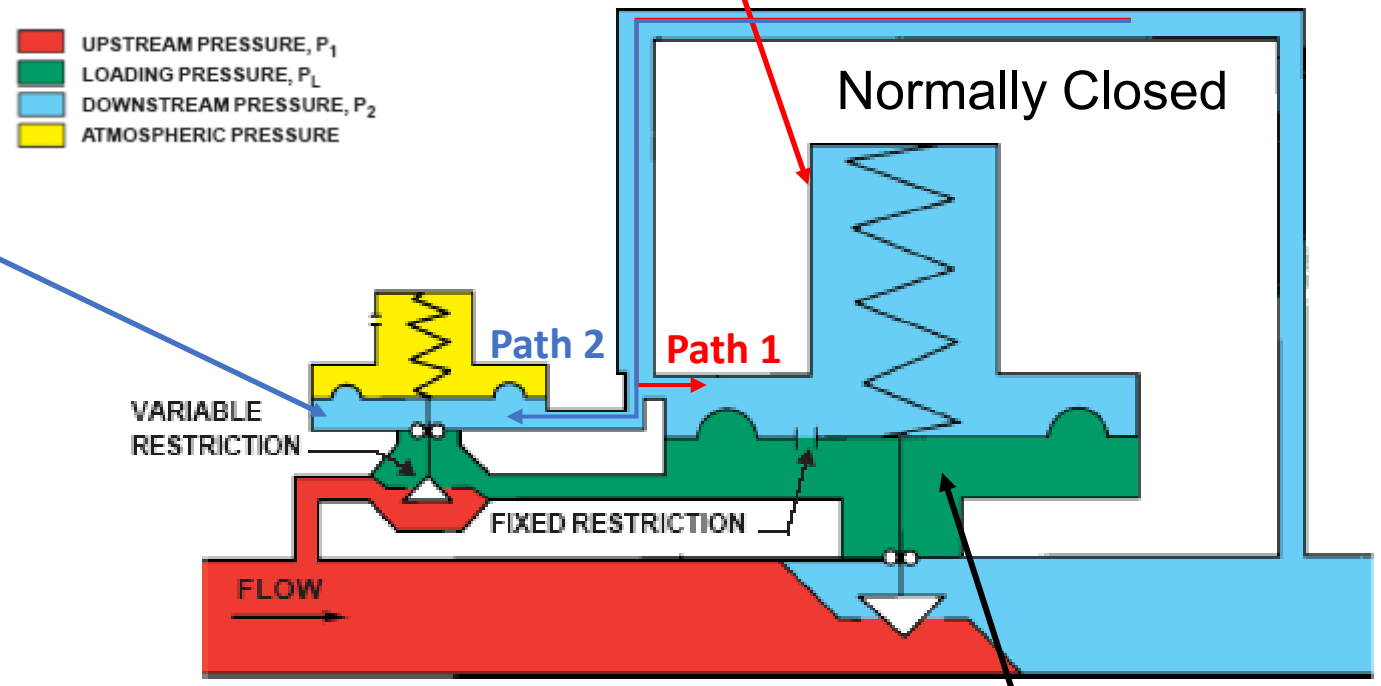


Pilot Loading – “2-Path Control”

Outlet Pressure (P2)
Chamber Sensed by
Main Valve and Pilot → Main Regulator

Pilot

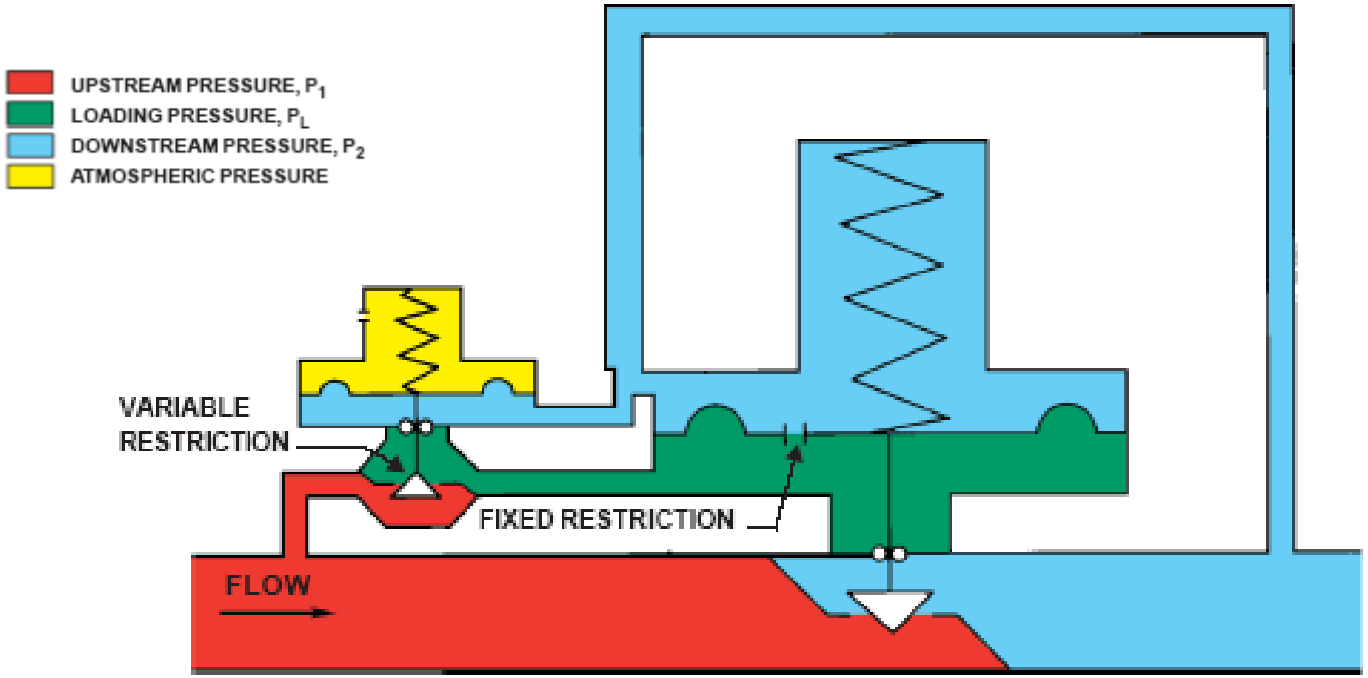
(self-op)



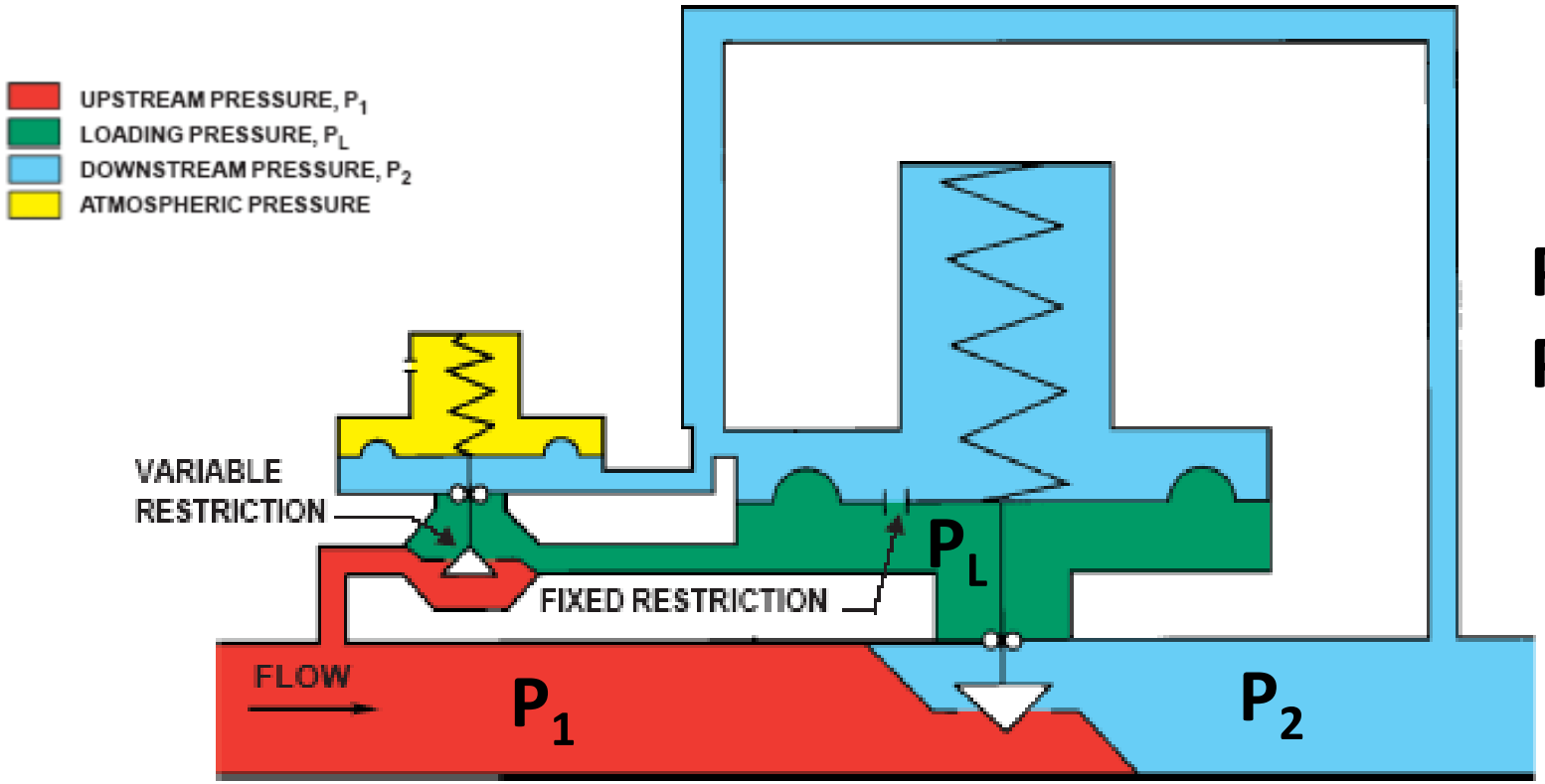
Loading Pressure (P_L)
- Chamber pressure from Pilot

Basic Operation of 2-Path Control

- When $P_L = P_2$, regulator is closed
- P_1 (Red) must be greater than P_2 (Blue) to open the valve
- All pilot operated regulators require a **Minimum Differential Pressure** to open
  - the pressure difference ($P_L - P_2$, Green-Blue) required to stroke the main valve open
  - P_L equalizes with P_2 (Green=Blue) for lock-up through fixed restriction



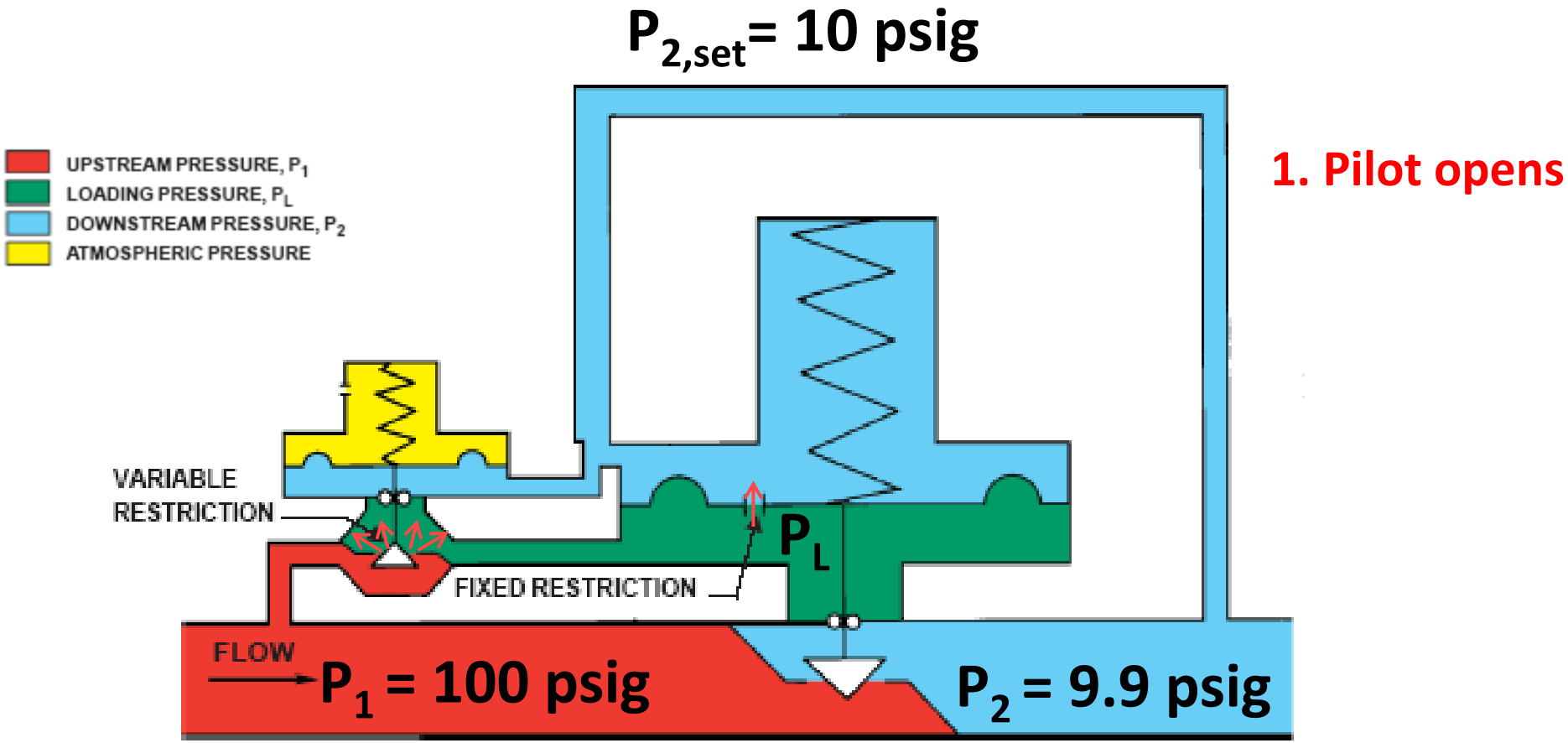
Process Conditions



P_1 = 100 psig

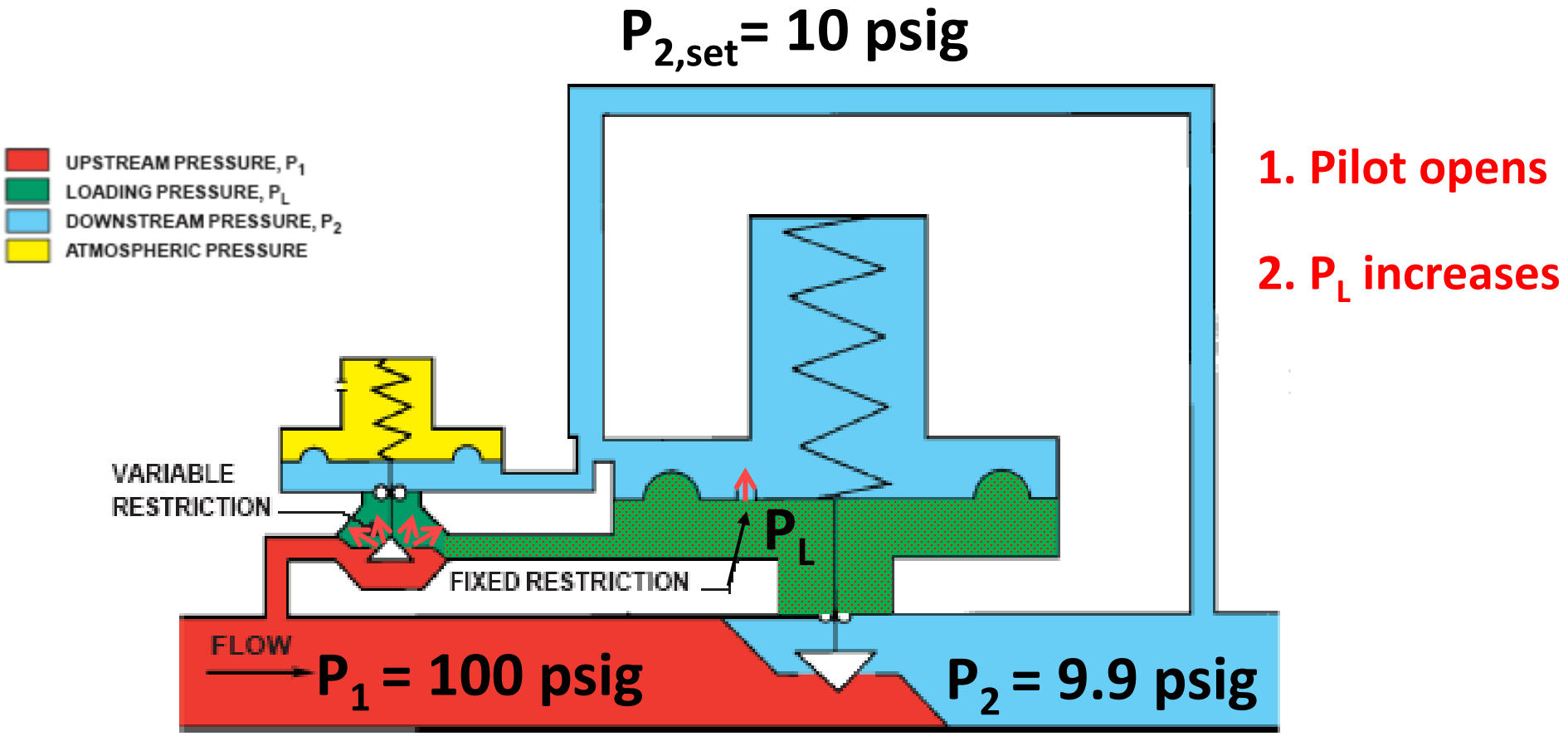
$P_{2,set}$ = 10 psig (Ideal)

Scenario: Downstream Demand Increases



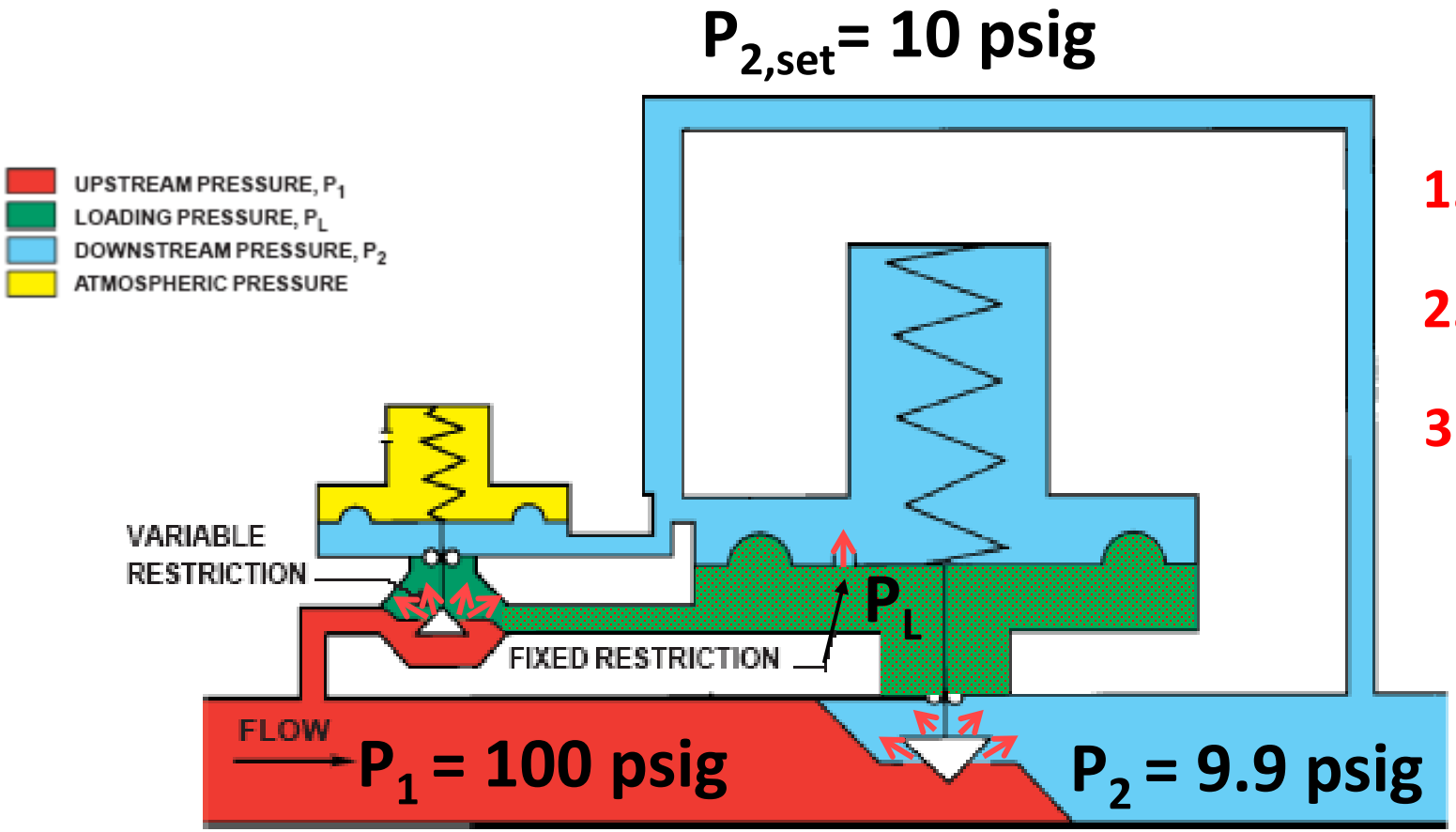
1. Pilot opens

Scenario: Downstream Demand Increases



1. Pilot opens
2. P_L increases

Scenario: Downstream Demand Increases



1. Pilot opens
2. P_L increases
3. Main Valve opens

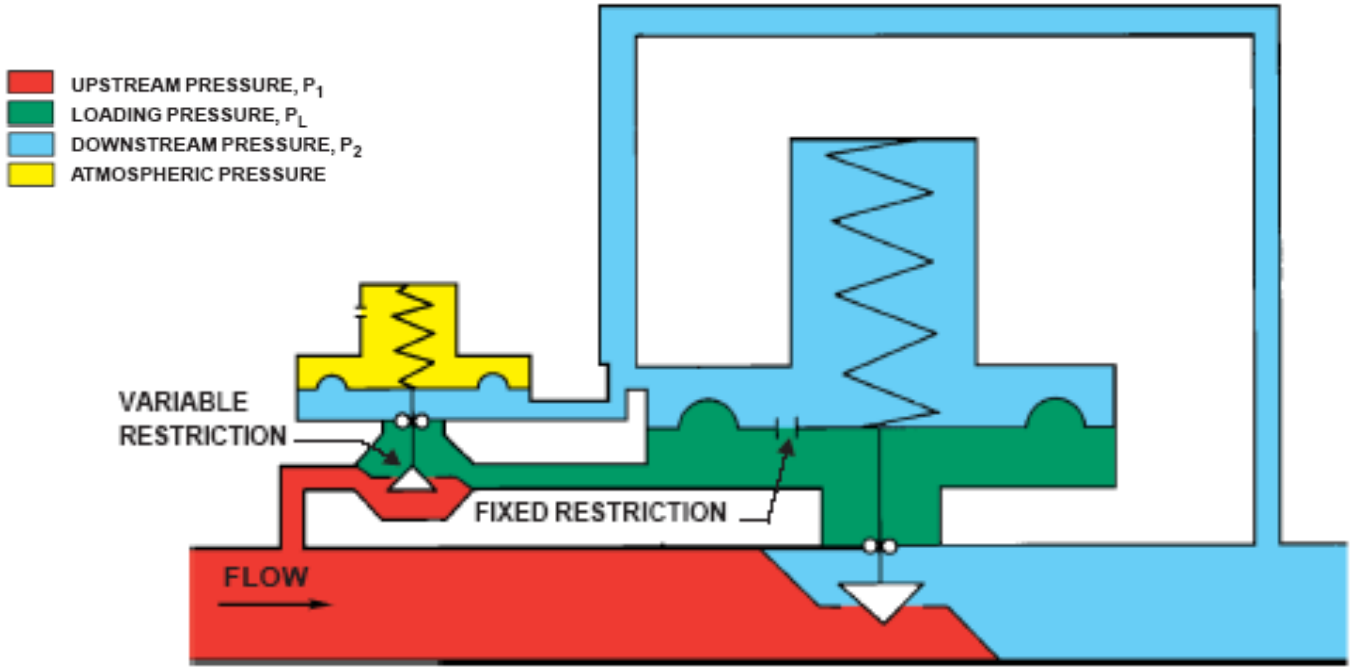
Why is a Pilot-Operated Regulator More Accurate?

The Pilot is the Key to Accuracy

Variable Restrictor

Pilot gain determines accuracy

- Gain = $\Delta P_L / \Delta P_2$ as regulator droops/opens

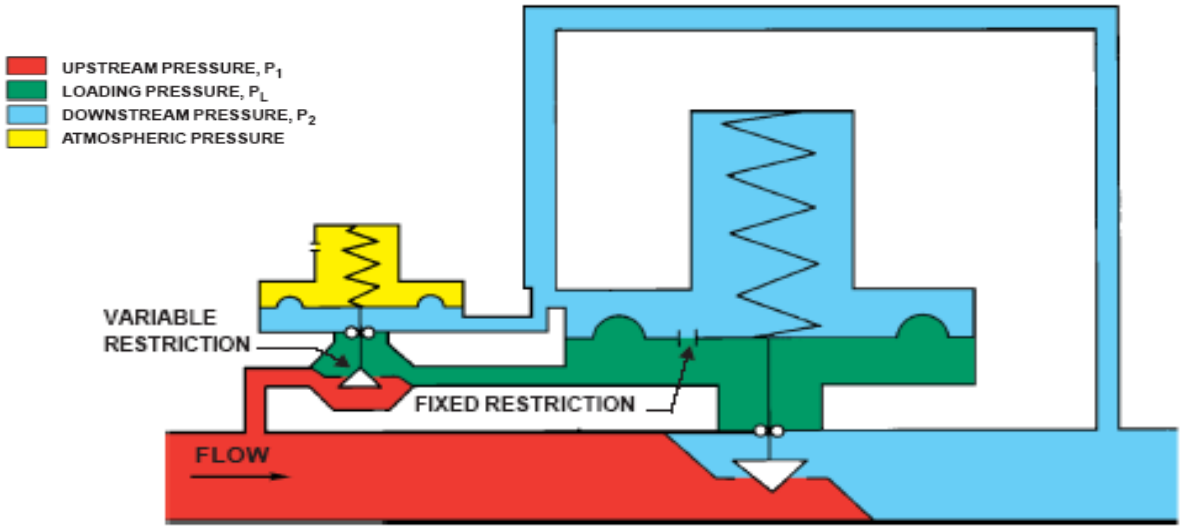


Change in P_L

Pilot Gain Effects on Accuracy (2 Path Control)

P_1 = 100 PSIG
P_2 = 10 PSIG
Q = 0 SCFH

Suppose the load increases to 10,000 scfh
P_2 goes to 9 PSIG and the pilot opens
P_L loading pressure goes to 30 PSIG



Pilot gain determines accuracy
• Gain = $\Delta P_L / \Delta P_2$ as regulator droops/opens

$$\frac{\Delta P_L}{\Delta P_2} = \frac{30 - 10 \text{ PSIG}}{10 - 9 \text{ PSIG}}$$

$$\frac{\Delta P_L}{\Delta P_2} = \frac{20 \text{ PSIG}}{1 \text{ PSIG}} = 20{:}1 \text{ Gain}$$

Restrictions, Response Time, and Gain

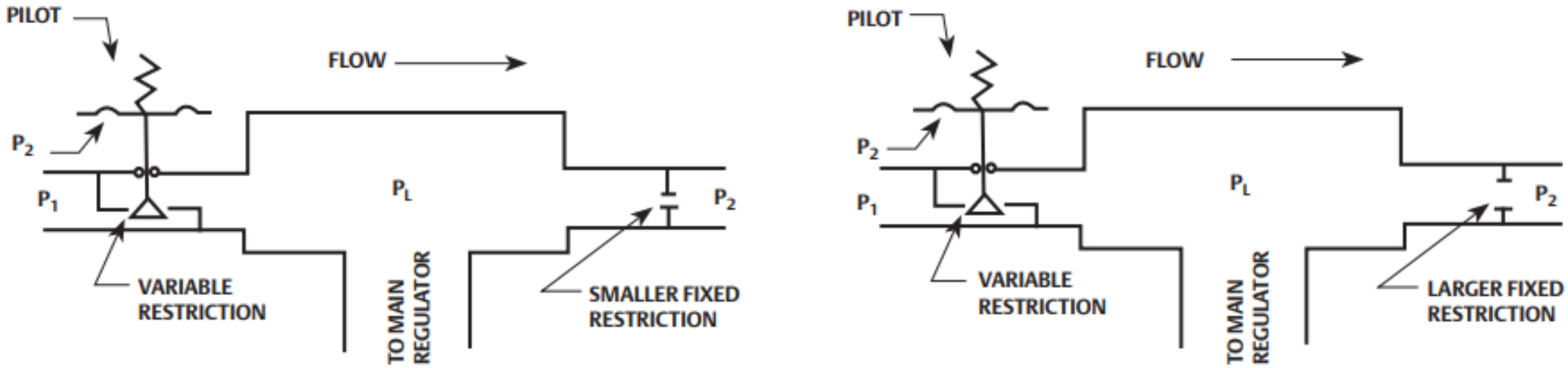


Figure 2. *Fixed Restrictions and Gain (Used on Two-Path Control Systems)*

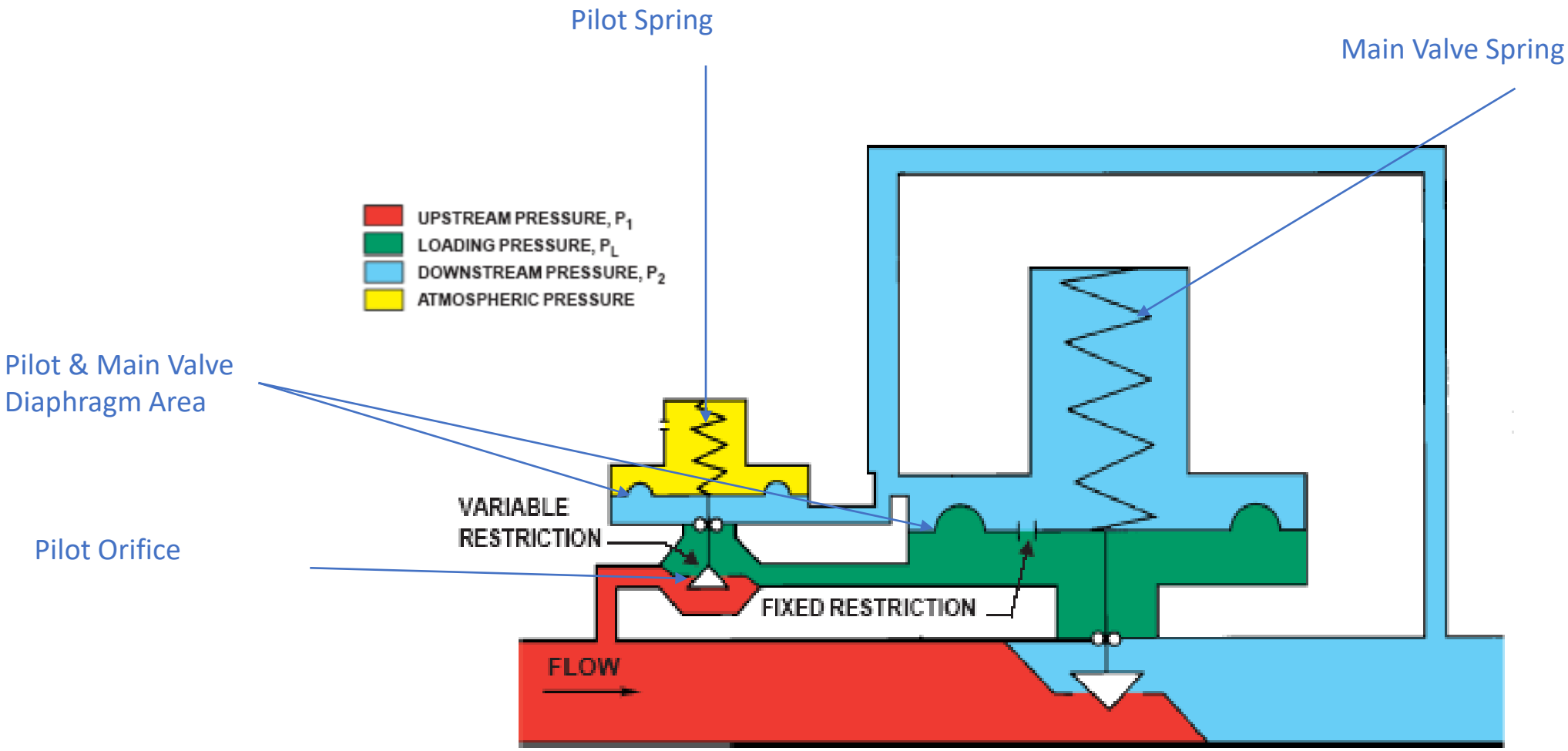
High Gain = Quick to open,
Slow to close

Low Gain = Slow to open,
Quick to close

Pilot Considerations

- Allows for gain adjustments
  - Gain = $\Delta P_L / \Delta P_2$
  - Adjustments to detune when unstable
  - Adjustable restrictions
  - Pre-pilots
- Minimum differential pressure requirements to fully stroke main valve
- Speed of response is slower if the differential pressure across the regulator is low

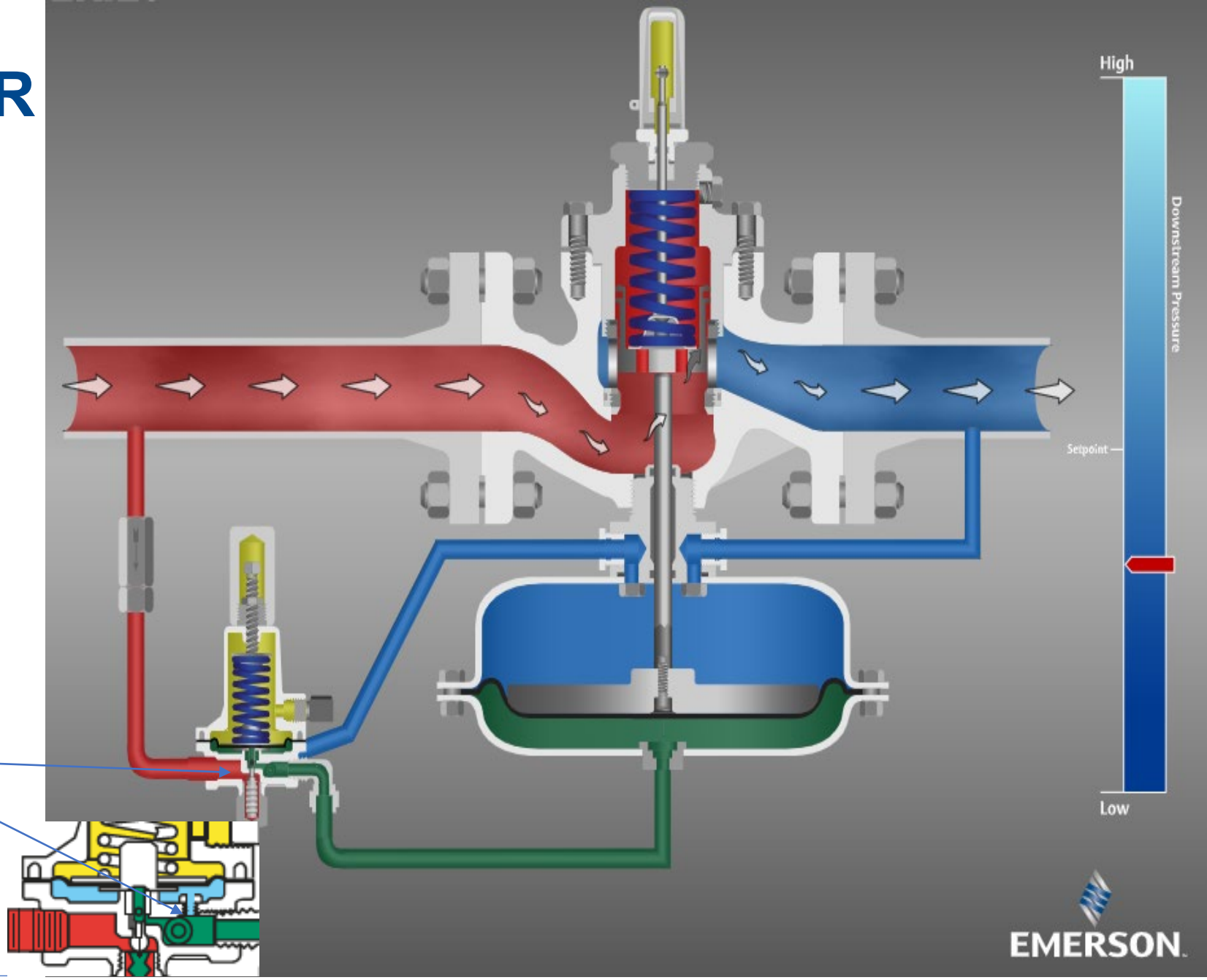
Other Issues Affecting Accuracy



Fisher Type 1098EGR

Fixed Restriction

INLET PRESSURE
LOADING PRESSURE
OUTLET PRESSURE
ATMOSPHERIC PRESSURE



Fisher Type 299H

Fixed Restriction

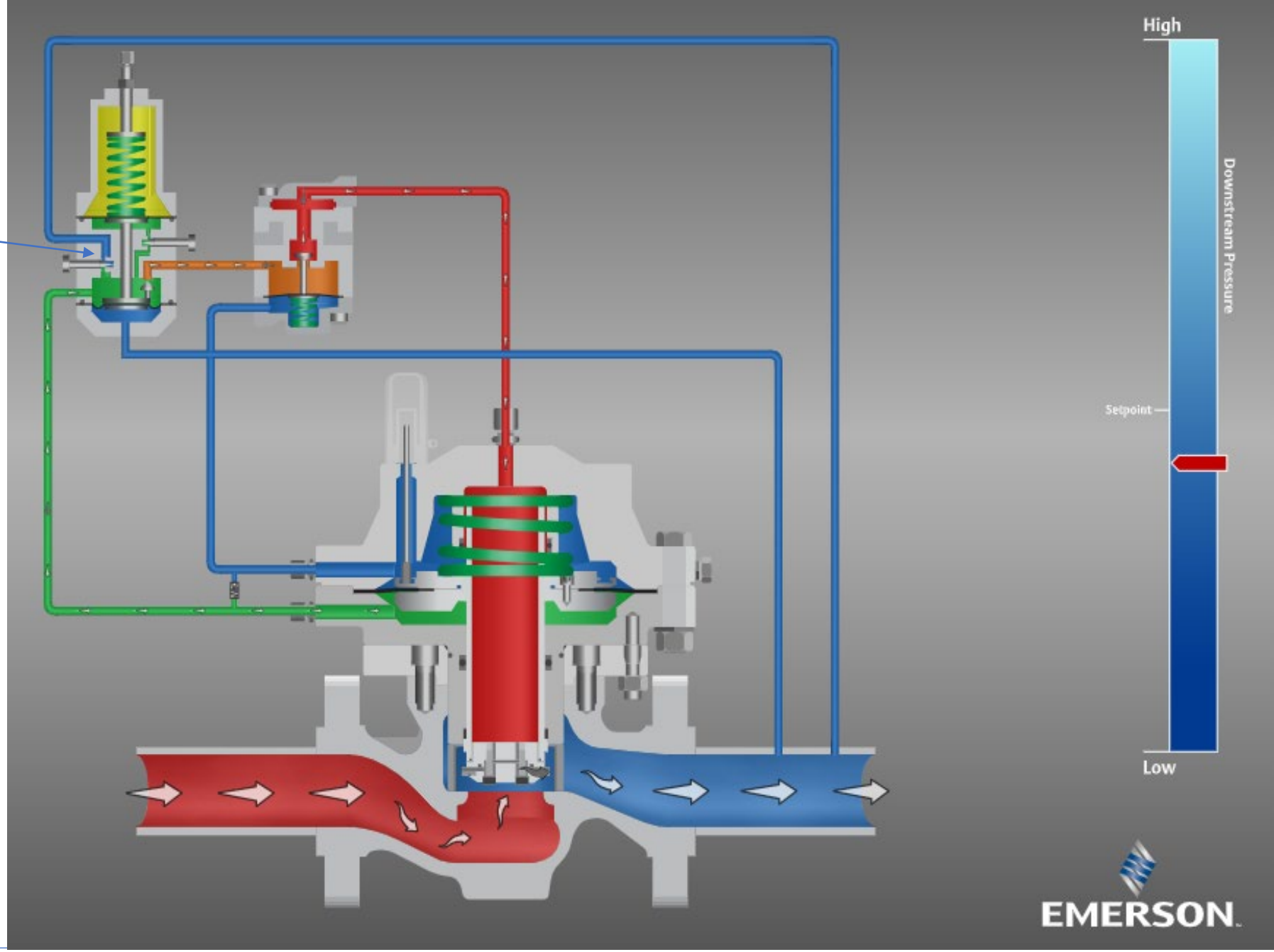
INLET PRESSURE
LOADING PRESSURE
OUTLET PRESSURE
ATMOSPHERIC PRESSURE

High
Downstream Pressure
Setpoint
Low
Downstream Demand
EMERSON

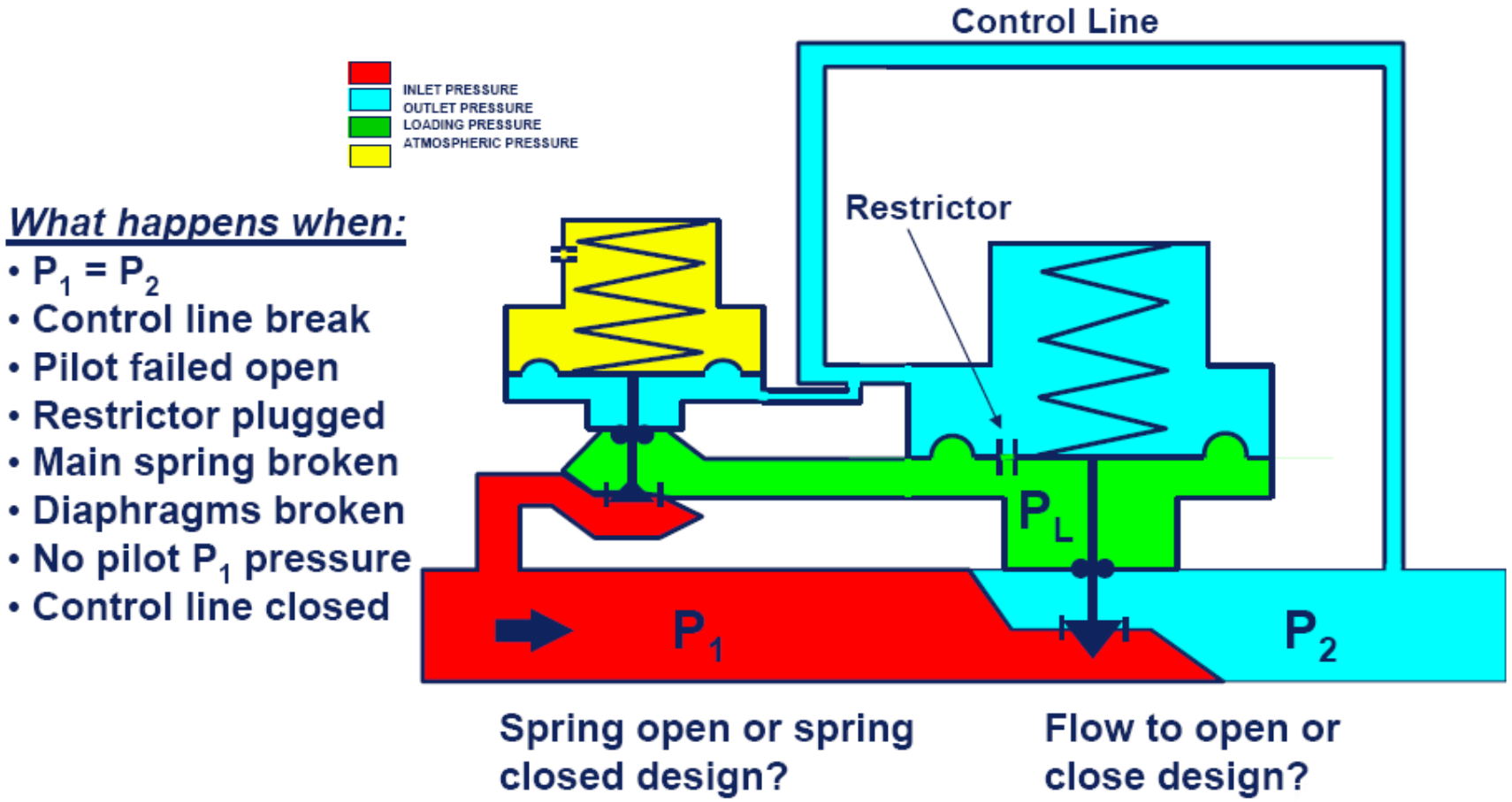
Fisher Type EZH

Fixed Restriction

INLET PRESSURE
LOADING PRESSURE
OUTLET PRESSURE
ATMOSPHERIC PRESSURE



2-Path Pilot Operated Regs – Failure Modes



What happens when:

- $P_1 = P_2$
- Control line break
- Pilot failed open
- Restrictor plugged
- Main spring broken
- Diaphragms broken
- No pilot P_1 pressure
- Control line closed

Spring open or spring closed design?

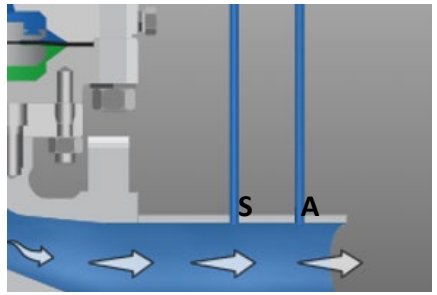
Flow to open or close design?

Different Ways a 2-Path Control Regulator Can FAIL

PART NAME	CONDITION	CAUSE	EFFECT	REGULATOR REACTION Type FL w/ PRX+SA2+252
Filter	Filter blocked / Clogged	Debris or aromatics present in the gas	Decrease of supply pressure gives decrease of loading pressure	Close
Pilot disk	Pilot cannot be closed	Debris or aromatics present in the gas	Increase loading pressure	Open
Pilot lower diaphragm	Pilot cannot control	Debris or aromatics present in the gas	Decrease loading pressure	Close
Pilot upper diaphragm	Pilot cannot feed the regulator	Debris or aromatics present in the gas	Decrease loading pressure	Close
Regulator diaphragm	Poor performance of the loading pressure chamber	Debris or aromatics present in the gas	Balancing of Pressures and charge or discharge of the loading pressure chamber	Close
Pilot	Frozen pilot or SA2 not working	Moisture in the gas, high pressure drop	SA/2 loading upper casing of regulator, Pilot not supplying loading pressure to lower casing	Close
Inlet pipeline low	Pipeline pressure decreases below pilot set pressure	Upstream pipeline pressure low	Loading pressure is present and will partially hold FL Open	Hover (Last)

Custom Tubing Options

- Downstream lines to be installed in the order of **BLEED (S)**, then **SENSE (A)**



- Recommended to use **½" tubing** on the downstream sense line
- Minimize tubing elbows, nice clean and as straight as possible design
- If longer than 20ft away, upsize to ¾" or 1" pipe
- Do not share taps, by DOT 192 or CSA Z662 code (special exception available, needs review)
- All taps that have isolation use **full port** ball valves

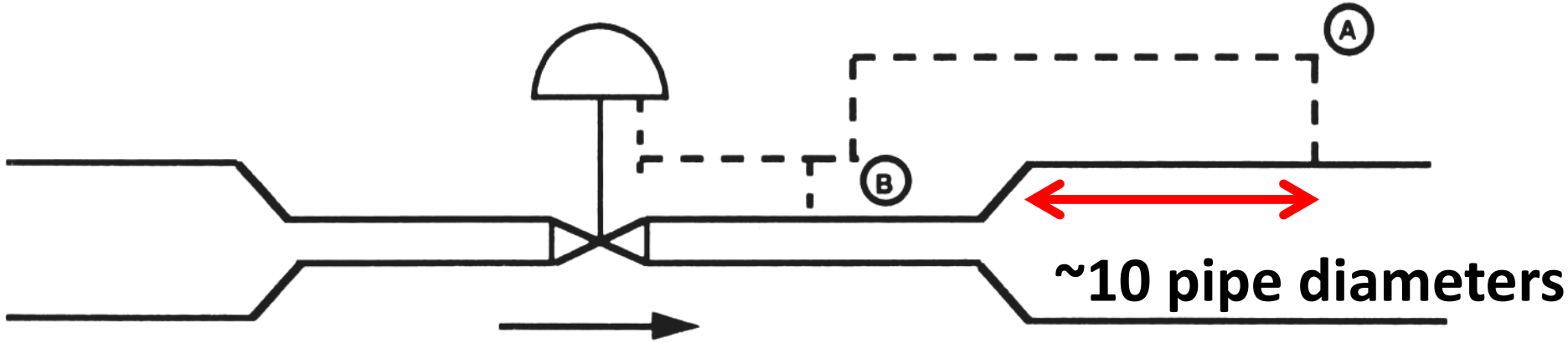
Control Line Placement

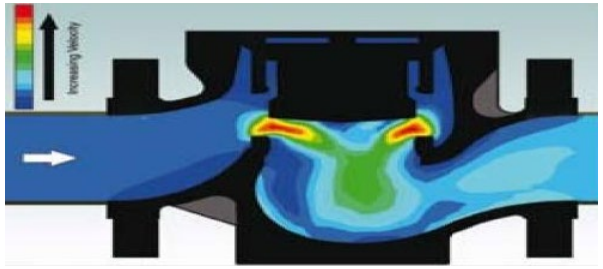
- **What is the best location?**

✓ Install control line piping tap at TOP or SIDE of piping and not in the bottom

✓ Consider control line diameter based upon distance and setpoint

✓ Piping almost always expanded size once pressure reduction happens

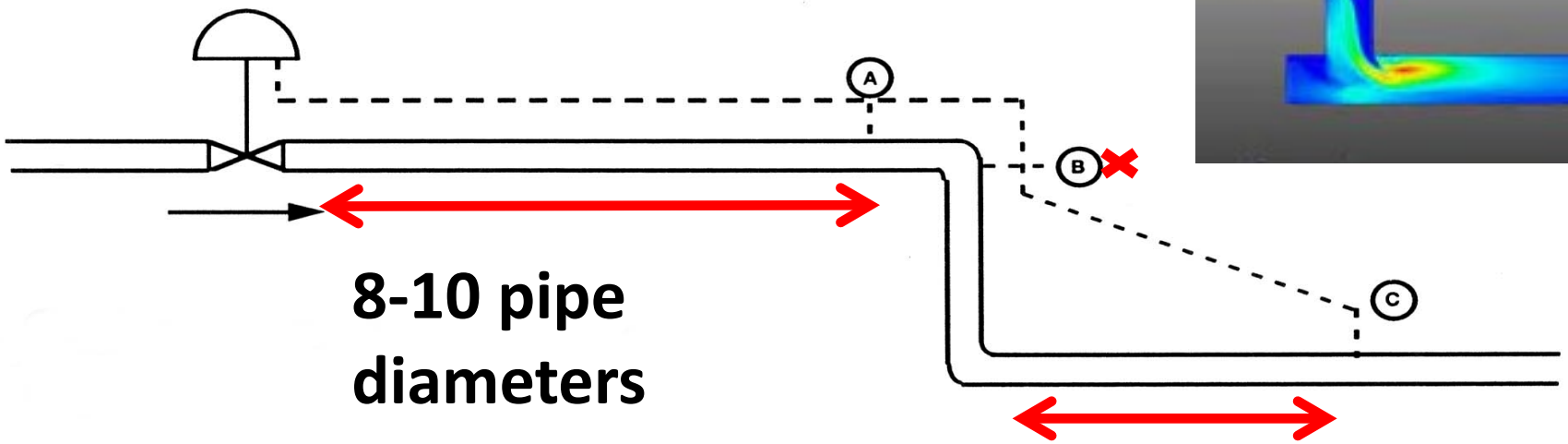


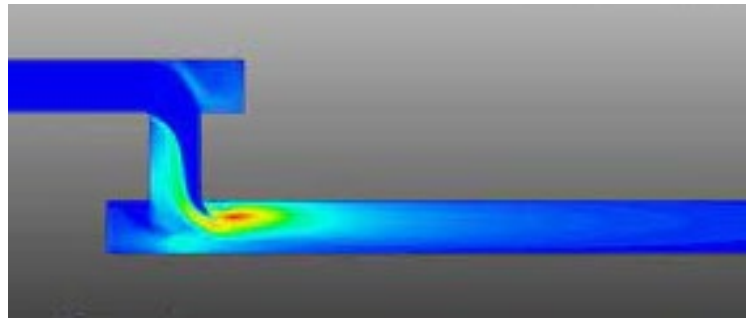


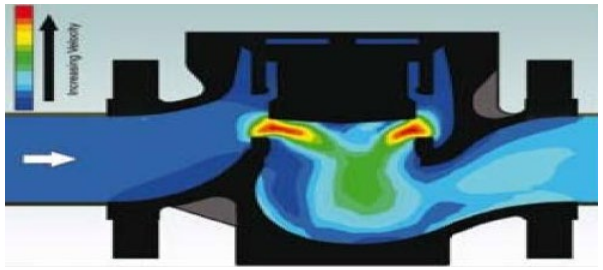
Not stable at outlet

Control Line Placement

- What is the best location?

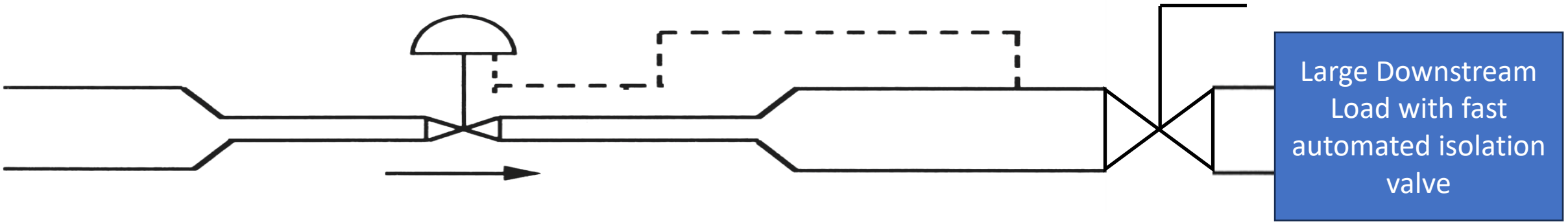






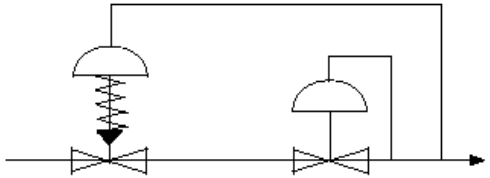
Do I have enough Pipe Volume of Gas of Instantaneous Demand?

- A fast pilot-op regulator takes about 0.3 to 0.5 sec to respond on average
- Do you have at least 0.5 to 1 .0 sec volume of gas between the regulator and the load?
  - If you don't, move the regulator back from the load to provide more gas volume to the load



Forms of Over Pressure Protection

Regulator with Slam-shut



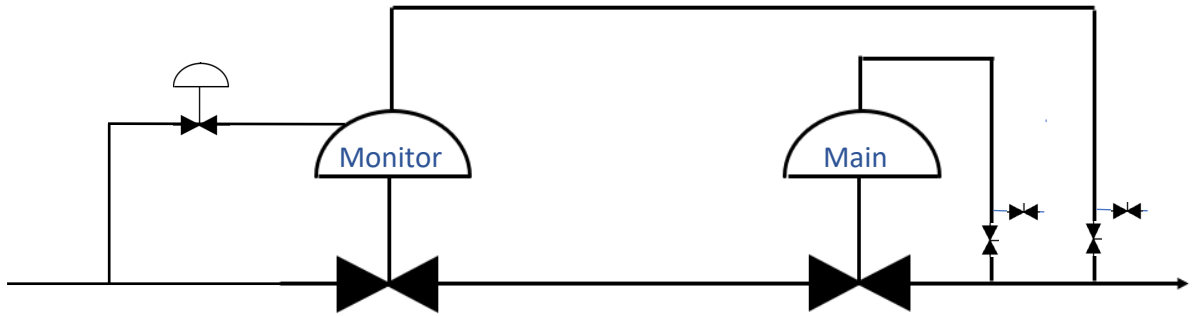
Shut-Off Regulator Set @ 40 psig

Pressure Regulator Set @ 30 psig

Shutoff devices provide overpressure protection by containment (no venting); however service is disrupted during an upset until manual reset occurs.

Wide-Open Monitor System

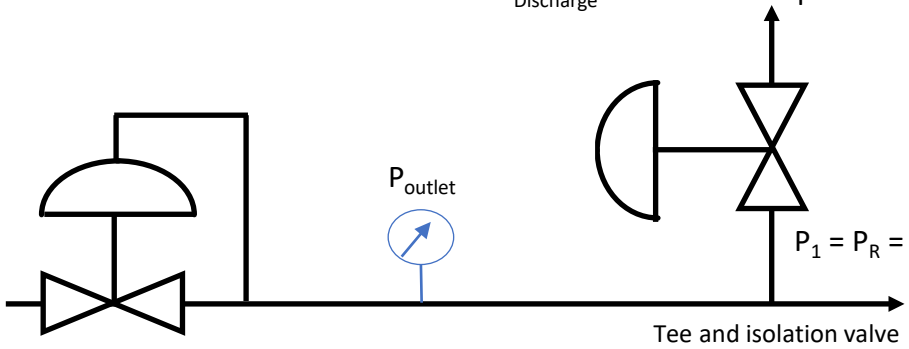
P_{inlet} = 80# $P_{intermediate}$ = 80#-(permanent pressure loss) P_{outlet} (set)



"False Sense" the upstream regulator so that it always thinks it needs more and stays wide-open until an upset event occurs

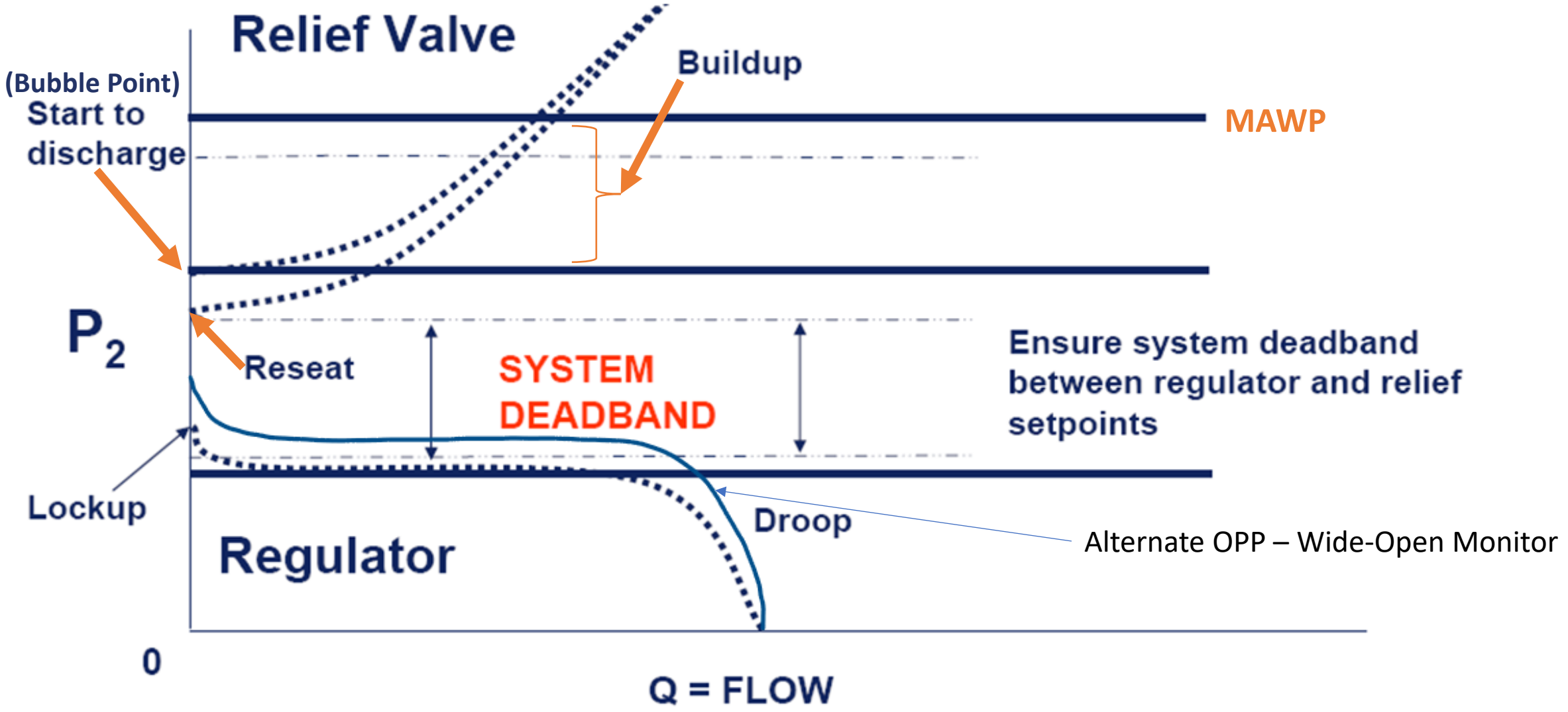
Regulator and Relief (internal or external relief)

$P_{Discharge}$ = Either Atmosphere or a safe discharge place lower than P_R



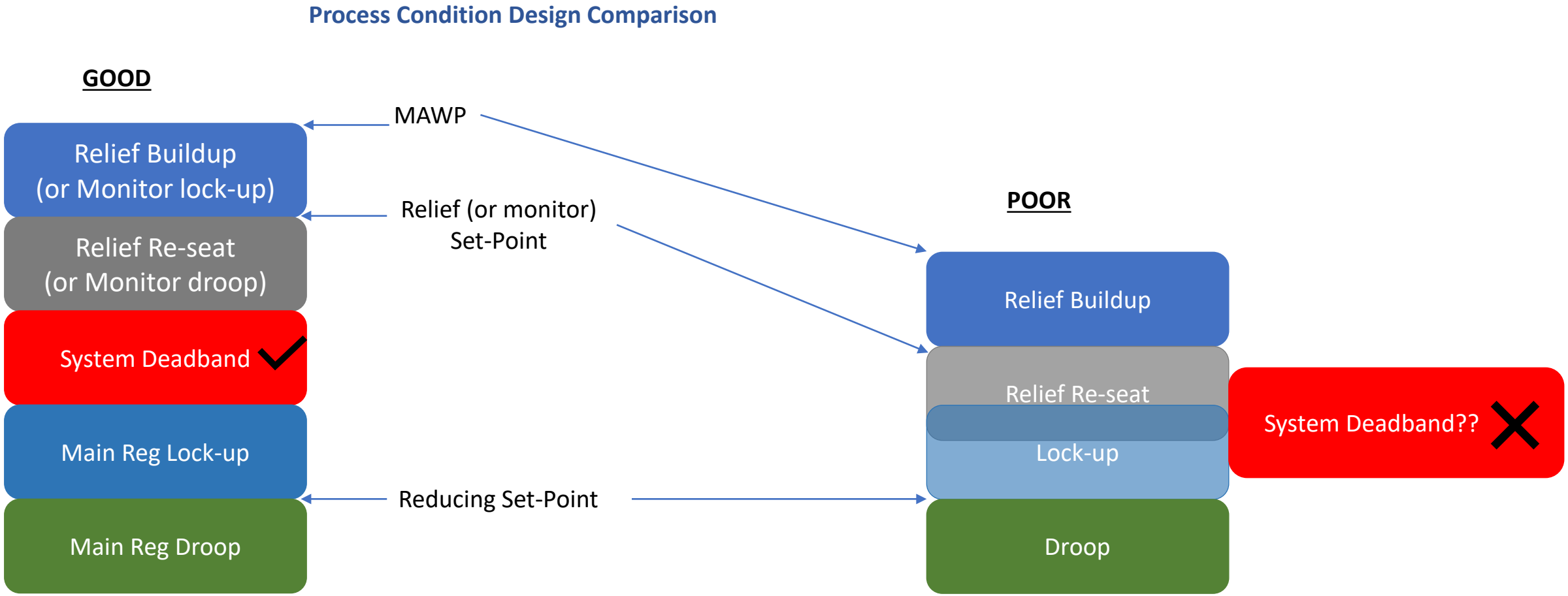
$P_1 = P_R$ = Set Pressure (start to discharge) > P_{outlet}

Regulator with Over-Pressure Considerations



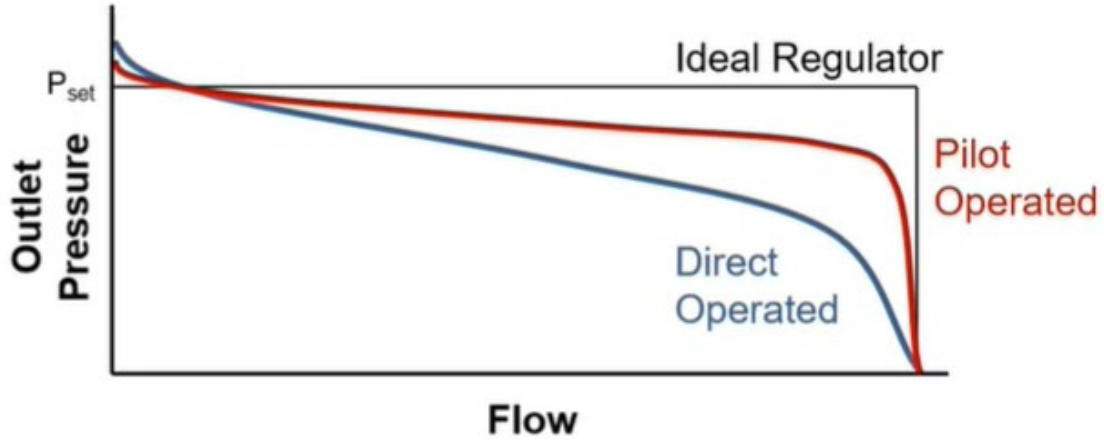
Importance of Pressure Set-up during Design

- Is the **system deadband** large enough?



Why Use A Pilot Loading Regulator?

- Ease of maintenance
- Capacity/line sizes
- Various applications
  - Large volume flows
  - Continuous duty
  - Gate stations, transmission lines
  - Dead-End service
  - Single end-user stations
  - Large pressure drops



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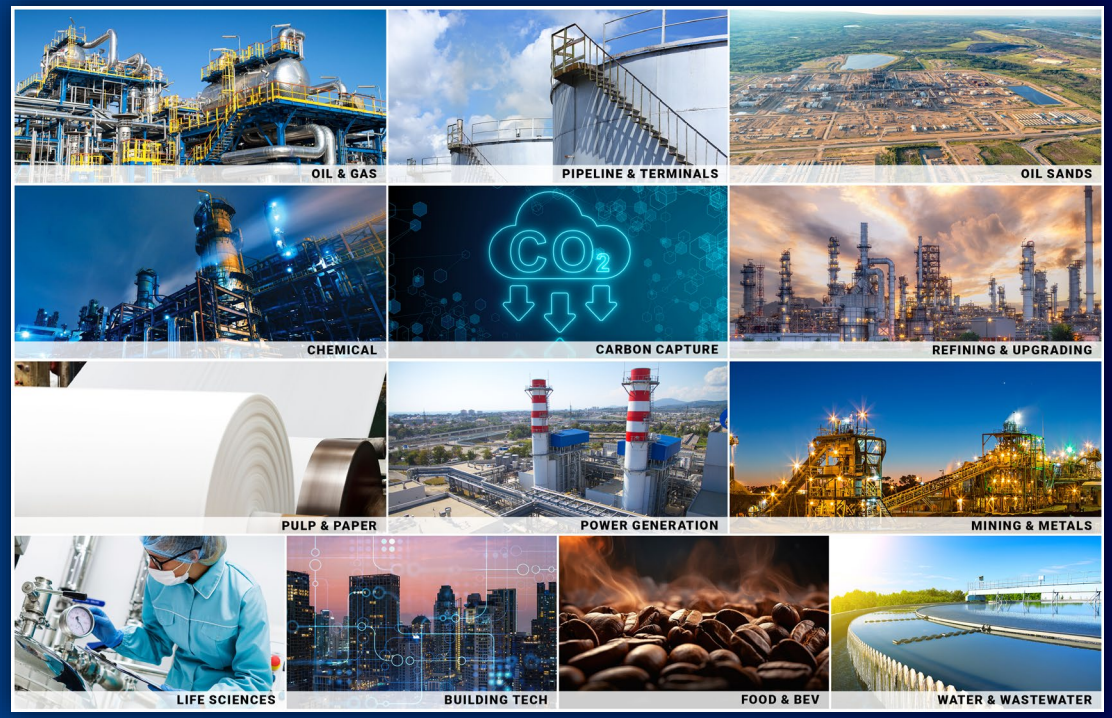

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