Pressure Regulators
Agenda

• Theory of Regulators
• Pressure Regulator Performance
  • Lock-up
  • Droop
  • Choked Flow
  • Creep
  • Supplied Pressure Effect
  • Joule Thompson
Theory of Regulators
Theory of Regulators: Types of Regulators

Pressure-reducing regulators control pressure to process by sensing outlet pressure.

Back pressure regulators control pressure from process by sensing inlet pressure.
Theory of Regulators: Regulator Basics

Sensing mechanism (diaphragm or piston)

Loading element applies a downward force

HIGH PRESSURE

LOW PRESSURE

The poppet & seat ‘bleed’ the high pressure to low pressure side of the regulator
Theory of Regulators: Balance of Forces

\[ F_1 = \text{Loading Force} \]
\[ F_2 = \text{Inlet Spring Force} \]
\[ F_3 = \text{Outlet Pressure Force} \]
\[ F_4 = \text{Inlet Pressure Force} \]

\[ F_1 = F_2 + F_3 + F_4 \]
Pressure Regulator Performance

- Lock-up
- Droop
- Choked Flow
Regulator Performance: Flow Curves

Nitrogen Flow, std L/min

Outlet Pressure, psig

Inlet Pressure
2200 psig (151 bar)

500 psig (34.4 bar)

1000 psig (68.9 bar)

Outlet Pressure, bar

Nitrogen Flow, std ft³/min

500 psig (34.4 bar)

1000 psig (68.9 bar)

2200 psig (151 bar)

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Regulator Performance: Lockup

- The difference in pressure between a flowing and non-flowing condition.
  - As flow decreases, the poppet will move closer to the seat and outlet pressure will rise.
  - The final rise in pressure is needed to fully stop flow.
  - This pressure must be released before flow can start again.

![Graph showing nitrogen flow and outlet pressure](image-url)

- **Inlet Pressure**: 500 psig (34.4 bar)
- **Outlet Pressure**: 100 psig (6.8 bar)
Regulator Performance: Droop

- Droop is the reduction of outlet pressure as flow increases.
Why is droop important?:
Perceived Problem

Need a specific pressure at a specific flow

Pressure

Flow

pressure set point
Why is droop important?:
Actual Problem

Need a specific pressure at a range of flows.
Why is droop important?:
Flow Curve vs. Need
Why is droop important?:
Flow Curve with Outlet Pressure set at Lowest Flow
Why is droop important?:
Flow Curve with Outlet Pressure set at Highest Flow
Why is droop important?:
Flow Curve with Outlet Pressure set at Nominal Flow

Pressure

desired pressure

actual pressure

Flow
Regulator Performance: Choke Flow Range

- When a regulator is in the full open position and no longer regulating pressure.
  - Acting as a restricting orifice
Regulator Performance: Optimal Flow Range

• The portion of the flow curve in which a regulator should operate for best performance

![Diagram showing nitrogen flow and outlet pressure for optimal flow range, lock-up, and choked flow conditions.](image-url)
Pressure Regulator Performance

- Creep
- Supplied Pressure Effect
- Joule Thompson
Creep

- If the poppet does not fully seat in the orifice, inlet pressure may continue to bleed through the orifice.
- Over time this leakage can increase the outlet pressure until it equals the inlet pressure
Creep

• Causes:
  - Contamination of the seat
    • Upstream filtration critical
  - Damage to the poppet or seat
  - Misalignment of the poppet to the seat
• Relief valves provide protection
• A regulator is not a shut-off device!
SPE- Supply Pressure Effect

Change in outlet pressure due to change in inlet pressure

What would cause a change in inlet pressure?

3600 psig

50 psig
F1 = F2 + F3 + F4

F1 = Spring Force
F2 = Inlet Spring Force
F3 = Outlet Pressure Force
F4 = Inlet Pressure Force

F1 and F2 are constant.

As inlet pressure drops, F4 decreases

To maintain a balanced equation, F3 will increase
1. Upstream pressure decreases as cylinder is depleted

\[ P_{\text{inlet}} \text{ decreases from 3600 to 2600} = 1000 \text{ psig} \]

\[ 1\% \text{ of 1000 psig} = 10 \text{ psig} \]

\[ P_{\text{outlet}} \text{ increases 10 psig} \]

2. Downstream pressure increases 1\% of the inlet decrease
SPE- Supply Pressure Effect

3600 psig

500 psig

50 psig

1%
SPE- Supply Pressure Effect

Down 2000 psig

Up 20 psig

Down .2psig

(3600 psig)

(500 psig)

(520 psig)

(49.8 psig)

1%

1%

1600 psig

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SPE- Supply Pressure Effect
The temperature of a high pressure gas can drop when there is a pressure drop where the gas expands.

For example:
With natural gas, the average temperature drop will be approximately 1°C Celsius for every 2 bar drop in pressure.

How can we compensate for this?
By:
• Heating the gas

or

• Using a two-stage pressure drop
Joule-Thomson Effect

• When a compressed gas is taken from high to low pressure (inlet to outlet of a pressure regulator or valve), the temperature will also decrease. This is the Joule-Thompson effect.

• At room temperature, most gases **COOL** upon expansion by the Joule-Thomson Process.
  • Hydrogen, Helium, and Neon **HEAT** up.

• Average temperature drop is 1 degree Celsius for every 2 bar pressure drop
  ~2 degree F for every 30 psi.
Joule-Thomson Effect

• What does J-T mean to me?
  - Cooling of your system fluid may cause constituents to drop out, changing the composition.
  - Liquid in the fluid stream may freeze, impairing or damaging the regulator.
  - Even if your fluid is a ‘pure gas’ the decrease in temperature may damage elastomeric seals.