FLEXIBLE ELEMENT REGULATORS

2026 WESTERN GAS MEASUREMENT SHORT COURSE

Principle of Operation

Advantages & Disadvantages

Monitor & Single Cut Relief

Sizing

Installation & Maintenance

Best Practices

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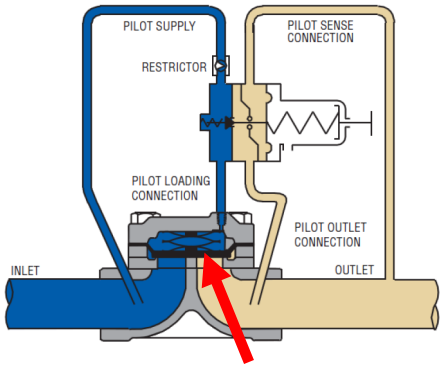
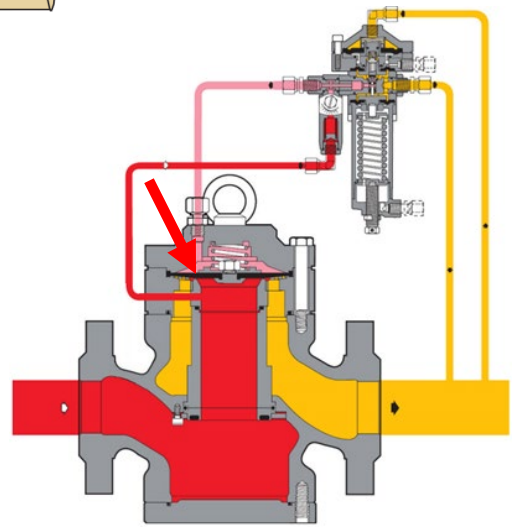
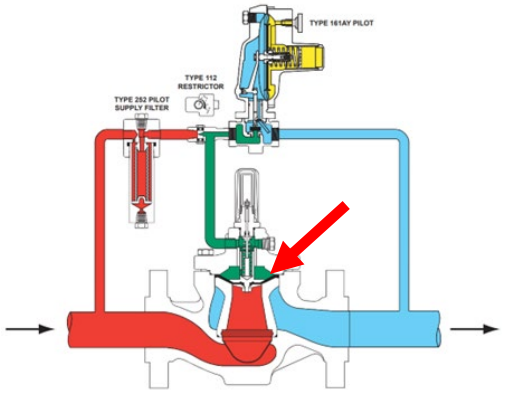






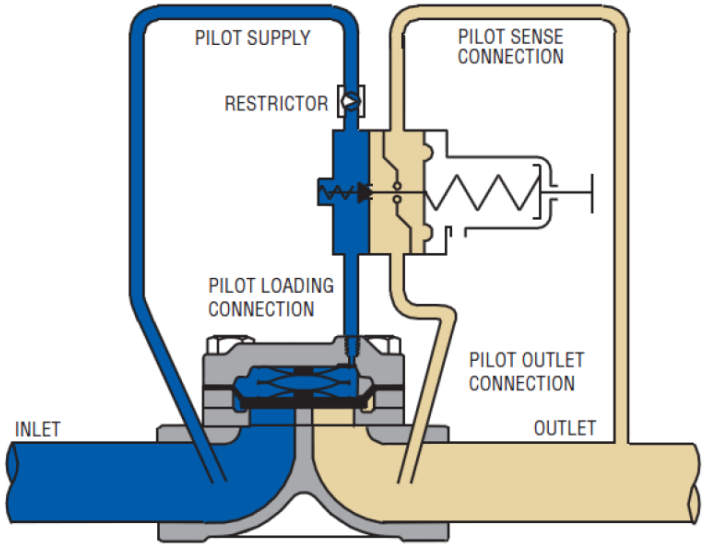
Pilot Unloading Regulators

Combines the function of an actuator and throttling element into a single component, the *flexible element*

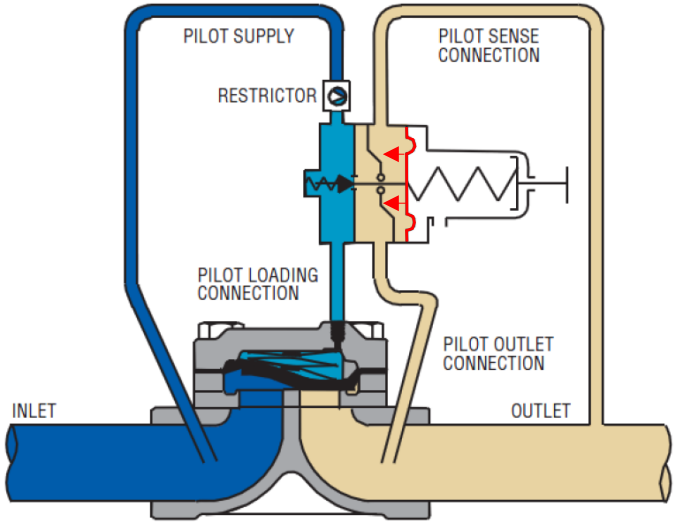
Flexible Elements

Fabric reinforced elastomer that allows the element to flex but not stretch (e.g. Nitrile, Viton, or Vulcanized Rubber)

PRINCIPLE OF OPERATION

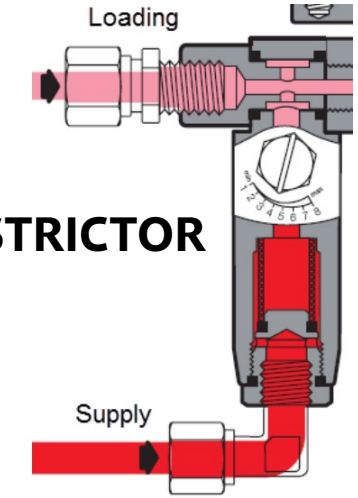


CLOSED

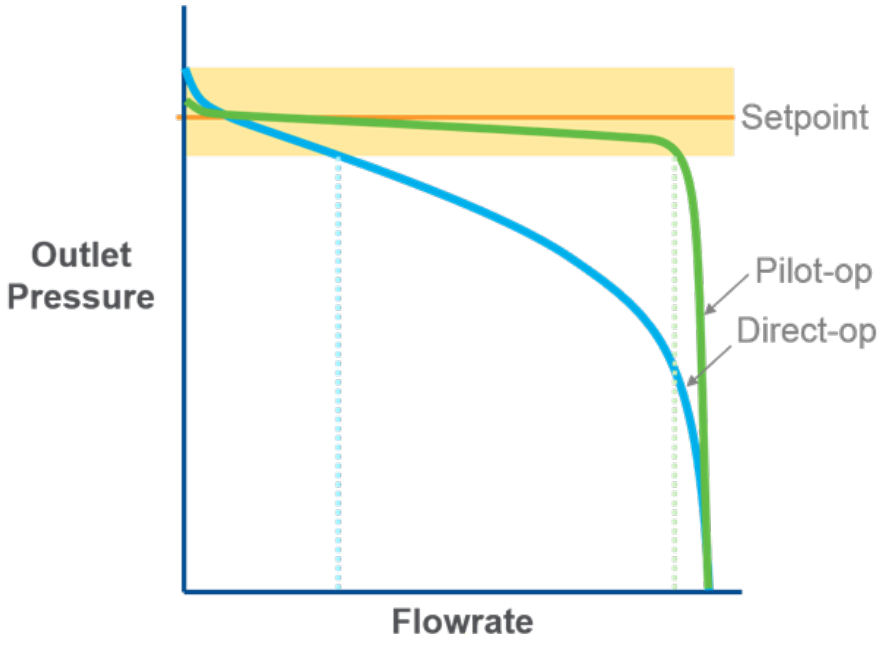


OPENING

- Upstream pressure loads *flexible element* (provides shut-off force)
- *Pilot unloads* allowing *flexible element* to open
  - Fixed restrictor on pilot supply ensures gas can not load faster than it can unload through the variable restriction within the pilot
  - Larger orifice provides faster shut-off & better stability
  - Smaller orifice provides more responsiveness & sensitivity



ADVANTAGES & DISADVANTAGES



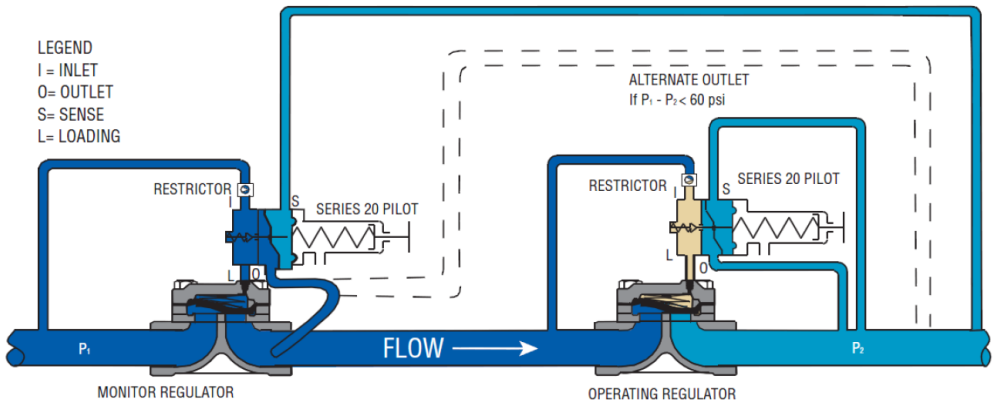
Advantages

- High flow rate capability
- Good set point accuracy
- Wider range of inlet & outlet pressures
- In-line maintenance: Typically, do not require unbolting & removing the regulator from the line due to top entry designs

Disadvantages

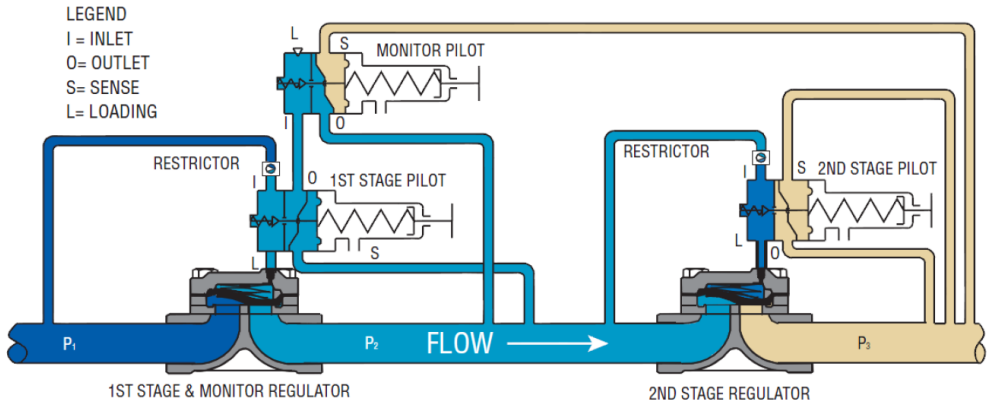
- Response not as fast as other regulator types (e.g. spring operated)
- Pilot unloading requires adequate differential pressure to maintain proper control
- Vulnerable to debris, sulfur, & liquids

MONITOR & SINGLE CUT RELIEF APPLICATIONS



Standby Monitor

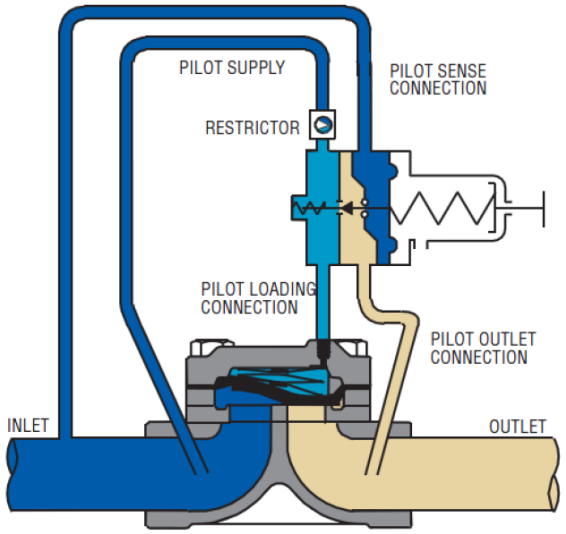
- Normally open monitor installed in addition to working regulator
  (can be installed upstream or downstream of working regulator)
- Monitor pilot set point above working regulator set point
  - Monitor pilot spring keeps gas unloading off flexible element which keeps the monitor open
  - Monitor pilot spring becomes engaged if downstream pressure rises. At this point the monitor comes into control



Working Monitor

- Working monitor installed upstream of working regulator
  (must be installed upstream of working regulator)
- Two pilots
  - 1st stage pilot is actively controlling the monitor regulator
  - 2nd monitor pilot remains open & inactive
  - 2nd monitor pilot comes into control if downstream pressure rises. 1st stage pilot goes open & inactive.
- Working monitors make use of both regulators & distributes the pressure cut across both regulators

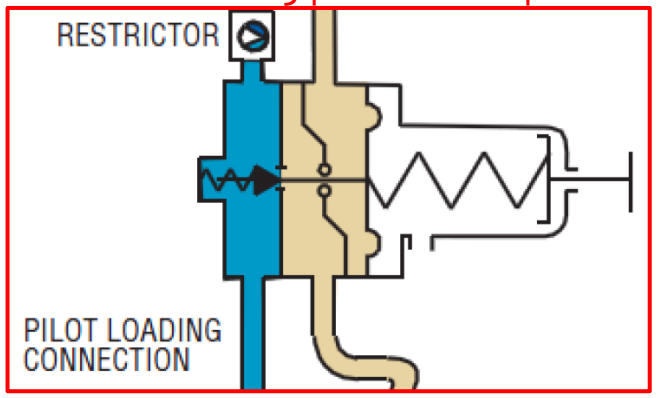
MONITOR & SINGLE CUT RELIEF APPLICATIONS



Single Cut Relief

- Pilot sense on the upstream
- Different pilots or modifications are required to function in back pressure/relief application
- Pilot spring keeps inlet gas loaded on flexible element which keeps the regulator closed
- Pilot spring becomes engaged if upstream pressure rises. At this point the flexible element unloads and regulator opens

Pressure reducing pilot for comparison



SIZING

Rule-of-thumbs:

- Target Percent Utilizations within 20-80%
- ΔP > 30 psid

Consider multiple operational scenarios

- Max. flow required @ min. inlet pressure
- Min. flow @ max. inlet pressure
- Percent utilization should be considered for scenarios [e.g. (Max. or Min. Flow / Regulator Capability) x 100]
- Sizing can be done with manufacturer provided charts, tables, or software

Turndown Ratio = Max. Flow Capability/Min. Controllable Flow

- Example: 100:1 turndown ratio means regulator should provide stable control down to 1% of it's max. flow capability.
- Periods of operation at a flowrate not covered by turndown ratio could have unstable control (i.e. hunting/oscillating)

Minimum pressure differential (ΔP):

- Flexible element regulators have minimum ΔP requirements (make/model dependent)
- Some material/spring types available for low differential applications

Max. Pressure Reduction & Velocity:

- Limit max. pressure reduction and velocity through regulator body per manufacturer
- Minimizes wear on flexible element, avoid hydrate formation, reduce noise & mechanical vibration

Outlet Pipe:

- Significant pressure drop in outlet pipe where sense lines are located can cause control issues
- Consider increasing outlet pipe size (e.g. velocity < 100 ft/s)

INSTALLATION & MAINTENANCE

Flexible Element Material

- Different material types are available for some manufactures based on temperature, pressure drop, gas quality

Pilot Filters

- Basic dry particle filtration (at a minimum)
- Sulfur filtration
- Liquid filtration

Catalytic Heaters or Alcohol Injection

- Reduce risk of internal freezing due to ambient temperature &/or Joule-Thomson effect
- Heat can be applied to pilot supply lines or mainline but not applied towards flexible element due to risk of damage

Sense Line Tap Location

- Install away from sources of turbulence (e.g. valve, tee, reducer, or similar fitting)
- Per manufacturer or industry guidance (e.g. 5-10 pipe diameters away)

Filter + Inlet & Outlet Block Valves

- Filter for first layer of defense against debris
- Block valves for maintenance and lockup testing

Cleanliness

- Take care during installation & construction activities to prevent debris
- Borescoping can be utilized to help find debris before it presents an issue

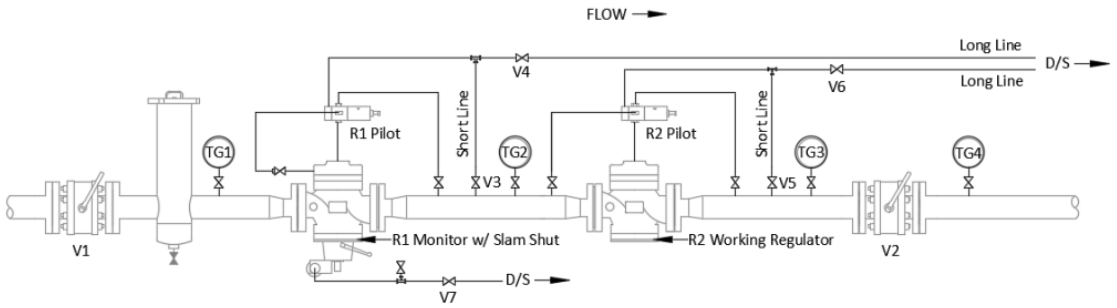
INSTALLATION & MAINTENANCE

1. Lock-Up Test (less invasive)

- External diagnostic test
- Can be conducted more frequently

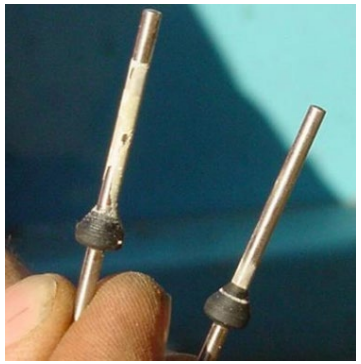
Testing for Set Point and Lock-Up

Regulator and Monitor Configuration Technique (Pilot Unloading)



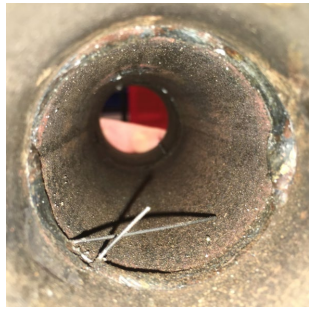
2. Internal Inspection (more invasive)

- More valuable insight on internal conditions (e.g. sulfur, liquids or debris)
- Flexible element & parts can be replaced proactively



3. Internal Inspection + Borescope (most invasive)

- Useful in finding debris further from regulator body



Regulator No. 1 through Regulator No. 2
Loose debris

BEST PRACTICES

- **Avoid oversizing**: Size for actual pressure parameters before considering abnormal operating conditions or speculative growth

- **Slam shuts**

- **Token reliefs** for smaller dead-end systems or customers with hard stops. Also, for thermal expansion.

- When limiting parameters are encountered with Flexible Element Regulators (**pilot unloading**), consider the "more complicated" **pilot loading** regulator which offers the following benefits:
  - Better control at lower differential pressures
  - Better speed of response & regains control better if inlet pressure drops below set point
  - Some have higher turndown ratios (maximum flow capability/minimum controllable flow)

OPEN FORUM

Reference Materials

- Mooney (Baker Hughes)
- Pietro Fiorentini
- Fisher (Emerson)