OVERPRESSURE PROTECTION

Equipment Options
Advantages and Disadvantages

ALABAMA NATURAL GAS ASSOCIATION

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Elster American Meter
OVER PRESSURE PROTECTION

- KNOWLEDGE, PLANNING AND IMPLEMENTING REDUCES RISK

- KNOW THE TYPES OF OVERPRESSURE PROTECTION OPTIONS AVAILABLE IN THE INDUSTRY AND UNDERSTAND THEIR CAPABILITIES AND LIMITATIONS

- PLAN / DESIGN YOUR SYSTEM FOR THE BEST PROTECTION YOU CAN PROVIDE

- PROPERLY INSTALL, AND MAINTAIN YOUR EQUIPMENT WITH REGULAR INSPECTION INTERVALS
Federal Regulations

- **§ 192.195 Protection against accidental overpressuring.**
  - (a) *General requirements.* Except as provided in § 192.197, each pipeline that is connected to a gas source so that the maximum allowable operating pressure could be exceeded as the result of pressure control failure or of some other type of failure, must have pressure relieving or pressure limiting devices that meet the requirements of §§ 192.199 and 192.201.
  - (b) *Additional requirements for distribution systems.* Each distribution system that is supplied from a source of gas that is at a higher pressure than the maximum allowable operating pressure for the system must—
    - (1) *Have pressure regulation devices capable of meeting the pressure,* load, and other service conditions that will be experienced in normal operation of the system, and that could be activated in the event of failure of some portion of the system; and
    - (2) *Be designed so as to prevent accidental overpressuring.*
Federal Regulations

- § 192.197 Control of the pressure of gas delivered from high-pressure distribution systems.
  - (a) If the maximum actual operating pressure of the distribution system is 60 p.s.i. (414 kPa) gage, or less and a service regulator having the following characteristics is used, **no other pressure limiting device is required**:
    - (1) A regulator capable of reducing distribution line pressure to pressures recommended for household appliances.
    - (2) A single port valve with proper orifice for the maximum gas pressure at the regulator inlet.
    - (3) A valve seat made of resilient material designed to withstand abrasion of the gas, impurities in gas, cutting by the valve, and to resist permanent deformation when it is pressed against the valve port.
    - (4) Pipe connections to the regulator not exceeding 2 inches (51 millimeters) in diameter.
    - (5) A regulator that, under normal operating conditions, is able to regulate the downstream pressure within the necessary limits of accuracy and to limit the build-up of pressure under no-flow conditions to prevent a pressure that would cause the unsafe operation of any connected and properly adjusted gas utilization equipment.
    - (6) A self-contained service regulator with no external static or control lines.
Federal Regulations

- (b) If the maximum actual operating pressure of the distribution system is 60 p.s.i. (414 kPa) gage, or less, and a service regulator that does not have all of the characteristics listed in paragraph (a) of this section is used, or if the gas contains materials that seriously interfere with the operation of service regulators, there must be suitable protective devices to prevent unsafe over pressuring of the customer's appliances if the service regulator fails.
Federal Regulations

- (c) If the maximum actual operating pressure of the distribution system exceeds 60 p.s.i. (414 kPa) gage, one of the following methods must be used to regulate and limit, to the maximum safe value, the pressure of gas delivered to the customer:
  
  1. A service regulator having the characteristics listed in paragraph (a) of this section, and another regulator located upstream from the service regulator. The upstream regulator may not be set to maintain a pressure higher than 60 p.s.i. (414 kPa) gage. A device must be installed between the upstream regulator and the service regulator to limit the pressure on the inlet of the service regulator to 60 p.s.i. (414 kPa) gage or less in case the upstream regulator fails to function properly. This device may be either a relief valve or an automatic shutoff that shuts, if the pressure on the inlet of the service regulator exceeds the set pressure (60 p.s.i. (414 kPa) gage or less), and remains closed until manually reset.
  
  2. A service regulator and a monitoring regulator set to limit, to a maximum safe value, the pressure of the gas delivered to the customer.
  
  3. A service regulator with a relief valve vented to the outside atmosphere, with the relief valve set to open so that the pressure of gas going to the customer does not exceed a maximum safe value. The relief valve may either be built into the service regulator or it may be a separate unit installed downstream from the service regulator. This combination may be used alone only in those cases where the inlet pressure on the service regulator does not exceed the manufacturer’s safe working pressure rating of the service regulator, and may not be used where the inlet pressure on the service regulator exceeds 125 p.s.i. (862 kPa) gage. For higher inlet pressures, the methods in paragraph (c) (1) or (2) of this section must be used.
  
  4. A service regulator and an automatic shutoff device that closes upon a rise in pressure downstream from the regulator and remains closed until manually reset.
§ 192.199 Requirements for design of pressure relief and limiting devices.

Except for rupture discs, each pressure relief or pressure limiting device must:

(a) Be constructed of materials such that the operation of the device will not be impaired by corrosion;

(b) Have valves and valve seats that are designed not to stick in a position that will make the device inoperative;

(c) Be designed and installed so that it can be readily operated to determine if the valve is free, can be tested to determine the pressure at which it will operate, and can be tested for leakage when in the closed position;

(d) Have support made of noncombustible material;

(e) Have discharge stacks, vents, or outlet ports designed to prevent accumulation of water, ice, or snow, located where gas can be discharged into the atmosphere without undue hazard;

(f) Be designed and installed so that the size of the openings, pipe, and fittings located between the system to be protected and the pressure relieving device, and the size of the vent line, are adequate to prevent hammering of the valve and to prevent impairment of relief capacity;

(g) Where installed at a district regulator station to protect a pipeline system from overpressuring, be designed and installed to prevent any single incident such as an explosion in a vault or damage by a vehicle from affecting the operation of both the overpressure protective device and the district regulator; and

(h) Except for a valve that will isolate the system under protection from its source of pressure, be designed to prevent unauthorized operation of any stop valve that will make the pressure relief valve or pressure limiting device inoperative.
§ 192.201 Required capacity of pressure relieving and limiting stations.

(a) Each pressure relief station or pressure limiting station or group of those stations installed to protect a pipeline must have enough capacity, and must be set to operate, to insure the following:

1. In a low pressure distribution system, the pressure may not cause the unsafe operation of any connected and properly adjusted gas utilization equipment.

2. In pipelines other than a low pressure distribution system:
   - (i) If the maximum allowable operating pressure is 60 p.s.i. (414 kPa) gage or more, the pressure may not exceed the maximum allowable operating pressure plus 10 percent, or the pressure that produces a hoop stress of 75 percent of SMYS, whichever is lower;
   - (ii) If the maximum allowable operating pressure is 12 p.s.i. (83 kPa) gage or more, but less than 60 p.s.i. (414 kPa) gage, the pressure may not exceed the maximum allowable operating pressure plus 6 p.s.i. (41 kPa) gage; or
   - (iii) If the maximum allowable operating pressure is less than 12 p.s.i. (83 kPa) gage, the pressure may not exceed the maximum allowable operating pressure plus 50 percent.

(b) When more than one pressure regulating or compressor station feeds into a pipeline, relief valves or other protective devices must be installed at each station to ensure that the complete failure of the largest capacity regulator or compressor, or any single run of lesser capacity regulators or compressors in that station, will not impose pressures on any part of the pipeline or distribution system in excess of those for which it was designed, or against which it was protected, whichever is lower.

(c) Relief valves or other pressure limiting devices must be installed at or near each regulator station in a low-pressure distribution system, with a capacity to limit the maximum pressure in the main to a pressure that will not exceed the safe operating pressure for any connected and properly adjusted gas utilization equipment.
Simple Spring Loaded External Relief

- Spring
- Diaphragm
- Pitot tube
- Exhaust Port
- Seat
- Adjusting Screw
- Diaphragm Plate
Spring Loaded External Relief Valve
Principal of Operation

When \( F_p > F_s \), Spring yields and Relief Opens
## Spring Loaded External Relief Valve

<table>
<thead>
<tr>
<th>ADVANTAGES</th>
<th>DISADVANTAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Cost</td>
<td>Set pressure accuracy can be limited due to manufacturing limitations of springs</td>
</tr>
<tr>
<td>Simple to operate and maintain</td>
<td>Additional space needed in pipeline / meter set.</td>
</tr>
<tr>
<td>Automatic reclosing when system returns to normal pressure</td>
<td></td>
</tr>
<tr>
<td>Permits continued gas use by customer</td>
<td></td>
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</table>
Pilot Operated Relief Valves

### Advantages
- Excellent set pressure accuracy
- Greater capacities
  - Not limited to spring solid height limitations for lift
- Auto reclose when system pressure returns to normal

### Disadvantages
- Greater cost than spring loaded relief
- Pilot line can be susceptible to dirt & contaminants
- Re-seat can be slightly higher than spring loaded reliefs
Pilot Operated Relief Valve
Internal Relief Valves

Note: Relief start to discharge occurs when pressure overcomes the relief spring and the main spring.
# Internal Relief Valves

<table>
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<tr>
<th>ADVANTAGES</th>
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<tr>
<td>Space saving – RV integrated into regulator</td>
<td>Accuracy can be limited to manufacturing capabilities of springs</td>
</tr>
<tr>
<td>Cost savings – not a separate external device</td>
<td>Capacity limitations – internal space constraints of regulator</td>
</tr>
<tr>
<td>Automatic reclose when system pressure returns to normal</td>
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<td>Permits continued service to customer</td>
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The 3 Methods of Testing Internal Relief Valve Capacity

Method 1: “LEVER DISCONNECT” – disconnect link and leave it loose during test

Method 2: “Blocked Open” – Rod installed through seal cap to stop diaphragm stem from rising during over pressure condition.

Method 3: “Ø.125 Obstruction” – Rod adhered to seat disc to hold it open a small amount.

Conservatism Levels:
- LEAST CONSERVATIVE
- MODERATELY CONSERVATIVE
- MOST CONSERVATIVE
Alternate Methods of Testing Relief Valves Yield Different Results

Relief - Alternate Test Methods

MODEL: 1813B
VB SIZE: 2" x 2" NPT
SPRING: 71424P018
RANGE:

SET P1: 20.0 psi
SET P2: 7.0 inches w.c.
ORIFICE: 1/2" 

DATE: 10/1/2008
RAN BY: T. Peter

LEVER DISCONNECT
BLOCKED OPEN
Ø.125 OBSTRUCTION ON SEAT DISC
Overpressure Shut Off

Pressure Sense
Integrated OPSO
# Over Pressure Shut-Off

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<td>Shuts off gas from downstream with no release of gas to the environment (no greenhouse gases)</td>
<td>Shuts off customer service (customer inconvenience)</td>
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<tr>
<td>No additional downstream pressure buildup once shut-off is achieved</td>
<td>Doesn’t automatically reset. Have to roll a truck to reset the shut-off (cost/resources)</td>
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<tr>
<td>Provides mechanism for human inspection before pressurizing the service line again (opportunity to solve root cause)</td>
<td>Cost is generally slightly greater compared to relief valve in some cases</td>
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Under Pressure / Over Pressure
Shut Off
Under Pressure / Over Pressure
Combined Shut Off

NEUTRAL PIN

TRIP LEVER

UPSS PIN
Under Pressure / Over Pressure
Combined Shut-off
## Under Pressure / Over Pressure Combined Shut-Off

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</tr>
<tr>
<td>Combined overpressure and under pressure capability in one device (no additional equipment to maintain)</td>
<td></td>
</tr>
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Over Pressure Slam Shut

1 - Increasing pressure pushes diaphragm up, lifting the ball bearing cage with it.

2 - Bearing cage lifts, allowing bearings to move radially outward, allowing shaft collar clearance to pass by.

3 – Spring force pulls shaft downward past ball bearings.

4 – Main stem moves down, releasing valve disc, allowing it to close under spring load.
# Over Pressure Slam Shut

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Sliding Orifice
Principle of Operation
Wide Open Flow

Main Seat
Main Orifice
Principle of Operation
Main Orifice Seat Lock-up
Principle of Operation
Safety Orifice Seat Lock-up
Sliding Orifice vs Fixed Orifice Relief Curves

Relief - Blocked Open

MODEL: 1873B
VB SIZE: 2"x2"
SPRING: 71424P018
RANGE: 5.5"-8"w.c.

SET P1: 30.0 psi
SET P2: 7.0 inches w.c.
SET FLOW: 58 cfm
ORIFICE: 3/4"

DATE: 12/4/2012
RAN BY: D. Allen

Relief curves for sliding and fixed orifices are shown. The graph compares the outlet pressure at different inlet pressures for both types of orifices. The models and specifications are also listed.
## Sliding Orifice

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<tr>
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</thead>
<tbody>
<tr>
<td>No release of gas to the environment (no greenhouse gases)</td>
<td>Not affective if regulator mode of failure is linkage disconnect.</td>
</tr>
<tr>
<td>Automatically returns to normal operation when system pressure returns to normal (no manual reset required)</td>
<td>May have reduced capacities for same size orifice compared to a fixed orifice (requires going up in orifice size)</td>
</tr>
<tr>
<td>No additional downstream pressure buildup once shut-off is achieved</td>
<td></td>
</tr>
<tr>
<td>Device is integrated into regulator so no additional component to purchase (cost savings)</td>
<td></td>
</tr>
</tbody>
</table>
Worker / Monitor

Example:
Worker: set pressure = 10#
lock-up = 10.5#
Monitor: Set pressure = 13#
OPSO Set pressure = 15#
Downstream Equip MAOP = 20#
Pipe MAOP = 60#

If both regulators fail to lock-up, the worker relief or the monitor OPSO is the next layer of over pressure protection.

Monitor operates “wide open” unless Worker fails to maintain downstream pressure.

Set pressure should be above the lock-up pressure of the Worker.
## Worker / Monitor

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<tr>
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<tr>
<td>No release of gas to the environment (no greenhouse gases)</td>
<td>Cost – duplication of functionality that is only utilized under failure conditions</td>
</tr>
<tr>
<td>No manual reset required</td>
<td>Additional piping space required</td>
</tr>
<tr>
<td>Maintains continued service to customers</td>
<td></td>
</tr>
<tr>
<td>Complete duplication of all regulator operational capabilities (ie, seemless continued operation)</td>
<td></td>
</tr>
</tbody>
</table>
Vent Piping

• Rule#1: Try to avoid adding vent piping whenever possible.
  – Adds backpressure to the relief outlet which reduces the flow capacity!

• When necessary follow this rule of thumb:
  – Increase by one pipe size for every 10 feet
  – 3 elbows count as 10 feet of pipe length
Sizing of Pressure Relief Valves

• Must First Know:
  – Inlet pressure of the upstream regulator, $P_u$
  – Maximum flow capacity of the upstream regulator at wide open, $Q_{\text{max}}$ (SCFH)
  – System Layout = Account for any pressure drop conditions between the relief valve and regulator (length/size of pipe, elbows, etc.), $\Delta P_{\text{pipe}}, \Delta P_{\text{elbows}}$
  – Outlet Pressure on the discharge side of the relief valve (atmospheric pressure, 14.7psi unless there is discharge piping), $P_o$
  – If discharge piping, then backpressure must be accounted for (3 elbows = 10psig, increase one pipe size with 10 feet of pipe length)
Sizing of Pressure Relief Valves

• Calculate the actual inlet pressure at the relief valve:
  \[ P_i = P_u - P_{\text{pipe}} - P_{\text{elbows}} - P_{\Delta d} \]

• **NEVER** decrease pipe size between the service line and the relief valve

• Flow equation for Relief Capacity:
  - Subcritical flow:
    • \( Q_{rv} = C_v \sqrt{P_o (P_i - P_o)} \), \( \frac{P_i}{P_o} < 1.894 \)
  - Critical flow:
    • \( Q_{rv} = C_v P_i / 2 \), \( \frac{P_i}{P_o} > 1.894 \)

• \( Q_{rv} = \text{max capacity of relief valve at wide open in SCFH of 0.6 specific gravity of Natural Gas} \) (\( C_v \) must be for Natural gas or must be adjusted for 0.6 specific gravity)

• \( Q_{rv} > Q_{\text{regulator}} \)
  - at failed wide open (recommend at least \( Q_{rv} = 2 \times Q_{\text{regulator}} \))
Pressure Drop in Pipe

• Darcy-Weisbach Equation:

\[ h_L = \left( \frac{fL}{D} \right) \left( \frac{v^2}{2g} \right) \]

  • \( h_L \) = head loss
  • \( f \) = friction factor (based on pipe roughness)
  • \( L \) = Length of pipe
  • \( D \) = Inside Diameter of pipe
  • \( v \) = fluid velocity
  • \( g \) = gravitational coefficient (32 ft/s\(^2\))

• Determine \( f \) (friction factor) from Moody Diagram......
Pressure Drop in Pipe

- **Reynolds Number,** \( Re = \frac{DV \rho}{\mu} \)

- **Moody Diagram**

<table>
<thead>
<tr>
<th>Pipe Material</th>
<th>Roughness, ( \varepsilon )</th>
</tr>
</thead>
<tbody>
<tr>
<td>drawn brass or copper</td>
<td>0.000005</td>
</tr>
<tr>
<td>PVC pipe</td>
<td>0.000005</td>
</tr>
<tr>
<td>commercial steel</td>
<td>0.000150</td>
</tr>
<tr>
<td>wrought iron</td>
<td>0.000150</td>
</tr>
<tr>
<td>asphalted cast iron</td>
<td>0.000400</td>
</tr>
<tr>
<td>galvanized iron</td>
<td>0.000500</td>
</tr>
<tr>
<td>cast iron</td>
<td>0.000850</td>
</tr>
<tr>
<td>concrete</td>
<td>0.001 - 0.01</td>
</tr>
</tbody>
</table>

\[
H = f \frac{L}{D} \frac{v^2}{2g} \quad \nu = \frac{Q}{A} \quad A = \frac{\pi D^2}{4} \quad Re = \frac{VD}{\nu}
\]

If laminar flow (\( Re < 4000 \) and any \( \frac{\varepsilon}{D} \)) then \( f = \frac{64}{Re} \)

If turbulent flow (\( 4000 \leq Re \leq 10^8 \) and \( 0 \leq \frac{\varepsilon}{D} < 0.05 \)) then Colebrook Equation:

\[
\frac{1}{f} = -2.0 \log \left( \frac{64}{3.7} \frac{Re}{1.7} \frac{2.51}{Re^{1/2}} \right)
\]

If fully turbulent flow (\( Re > 10^8 \) and \( 0 < \frac{\varepsilon}{D} < 0.05 \)) then:

\[
f = \left[ 1.14 - 0.369 \ln \left( 2.51 \frac{Re^{1/2}}{1.7} \frac{\varepsilon}{D} \right) \right]^{-2}
\]
THANK YOU
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