INTRODUCTION TO OVER-PRESSURE PROTECTION

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Introduction

This paper covers options for over-pressure protection equipment utilized in natural gas distribution networks based on requirements of United States Department of Transportation 49 CFR Part 192 (with acknowledgement of Canada's CSA Z662). Requirements vary by country, though it is widely accepted that over-pressure protection is a required element for safe Natural Gas delivery. Recommendations for design and use are based on utility standard practices, but are not considered to be an authority on design requirements.

Definitions and Acronyms

49 CFR Part 192 – The United States' Code of Federal Regulations Part pertaining to the Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards. All CFR code sections referenced in this paper are from Title 49 (i.e. §192.195 → 49 CFR 192.195).

CSA Z662 – The Canadian Standards Association standard for Oil and Gas Pipeline Systems.

Lock-Up – The state in which a regulator has fully sealed and shut off flow between different pipeline pressures.

Maximum Allowable Operating Pressure (MAOP) – The maximum pressure at which a pipeline or segment of a pipeline may be operated.

OPP – Over-Pressure Protection

Over-pressure – The state at which the internal pressure of a pipeline exceeds its MAOP.

Set Point – The sensed downstream pressure limit at which a regulator begins to feed.

The Need for Over-Pressure Protection

All pressurized systems must be designed to control the forces induced by the containment of its pressure. Natural gas is moved through pipelines by using the natural forces pushing pressure gradients from high pressure to low pressure. In natural gas pipelines, each ladder of transmission, distribution, and service pipelines are designed to operate at different pressures.

At junctions between pipelines operating at different pressures, precautions must be taken to ensure that each pipeline MAOP is protected. The risk of downstream over pressurization is an unacceptable risk to life and property, which must be addressed.

Pipeline regulations – 49 CFR Part 192 (in the USA) and CSA Z662 (in Canada) have established minimum requirements for when, where, and what OPP must be installed. 49 CFR Part 192, sections 195-201 specifically cover over-pressure protection requirements and are summarized below. See the most recent revision of the code for official requirements.

§192.195 – Protection against accidental overpressuring – covers the general requirements for ensuring that a pipeline's pressure is always regulated and/or protected from any upstream source that could cause the MAOP to be exceeded. Distribution systems must have pressure regulation devices designed for the pressure, capacity, and load of the system during normal operation.

§192.197 – Control of the pressure of gas delivered from high-pressure distribution systems – covers the requirements for protecting customer facilities from distribution pressures. If the MAOP of the distribution system is 60 psig or less, operators may either install service regulators with specific characteristics from paragraph (a), or include "suitable protective devices" to prevent over pressure in the event of service regulator failure.

Per paragraph (c), if the distribution MAOP is 60 psig or greater, additional upstream regulation and OPP must be installed to ensure the inlet to the service regulator does not exceed 60 psig. In other cases, service regulators with monitors, reliefs, or shutoffs can be used to maintain safe pressure values delivered to the customer. See more on the options outlined in 192.197(c) below in Types of OPP.

§192.199 – Requirements for design of pressure relief and limiting devices – cover specific design requirements for OPP equipment. These are primarily manufacturing-based requirements for the equipment. Paragraph (h) notes security requirements that the pressure limiting devices must be designed "to prevent unauthorized operation of any stop valve that will make the [device] inoperative."

§192.201 – Required capacity of pressure relieving and limiting stations – covers requirements on OPP capacity. For systems with multiple regulated pressure stations, OPP must be installed at each station. Paragraph (a)(2) defines the allowable "build-up" over MAOP an OPP device can control the pipeline pressure to.

§192.739 Pressure limiting and regulating stations: Inspection and testing – defines an inspection interval for pressure limiting stations and OPP devices not to exceed 15 months, but at least once each calendar year. Though this CFR section addresses OPP inspection intervals, it is less prescriptive regarding maintenance practices of the OPP device.

These regulations establish **minimum** requirements. It is the pipeline operator's obligation to ensure that public safety is considered when designing, installing, and maintaining pipelines, and to ensure the OPP is adequate and reliable for each scenario.

Causes of Over-Pressure Events

Pressure regulation failure is the most common cause of an over pressure event. Other causes include valve passing, equipment contamination, and human error. If a pressure regulation device fails, it could flow more gas than intended to the downstream system. Common causes of pressure regulation device failure are:

Pipeline Contamination – debris or liquids in the gas stream can become lodged between the orifice and the sealing element, preventing shut-off. In pilot operated regulators, debris can also get into the small orifices in pilots or restrictors and disrupt operation. Pilot and regulator filters are often installed to limit the risk of contamination failures.

Orifice or Sealing Element Damage – The orifice surface in a regulator is designed to extremely tight tolerances. Large or persistent debris impacts can erode the orifice surface and prevent a bubble-tight seal. The sealing element can also be damaged if a regulator experiences higher than specified pressure differentials, excessive cycling (sometimes called “chatter”), or if the regulator previously experienced an over-pressure event.

Hydrates or Particulates – Small particulates can precipitate out of the gas stream and build up in pilots and orifices as pressure drops and gas temperatures change. Typically, these consist of sulfur-based compounds, or sulfur scrubbing agents added during gas production. Moisture, or “hydrates” can condense and freeze in small orifices and block gas sensing lines.

Lever Disconnect – many regulator designs rely on a lever to link the spring and orifice stem operation. If this lever becomes disconnected, the orifice stem could be pushed open by the inlet pressure.

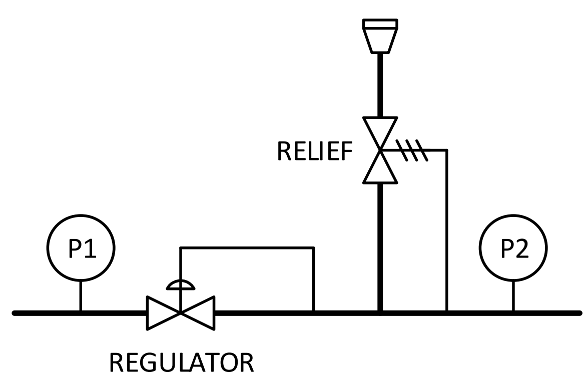
High Lock-Up or Low Gain – while not technically a failure of the equipment, a sharp decrease in downstream demand can cause over pressure if the regulating device cannot respond quickly enough to keep the outlet below MAOP. Set points close to MAOP can increase this risk.

Sense Line Damage or Shut-Off – also not technically a failure of the equipment itself, but rather due to accidental damage or human error, an incorrectly implemented sense line can cause over pressure. If a sense line is damaged or otherwise loses pressure, the regulating equipment will open to satisfy an erroneous low pressure signal. Any break in the pressure sensing loop back to the pressure regulating device may prompt a wide-open condition.

Types of OPP

Relief – a pressure relief valve functions by venting the excess gas pressure above MAOP to atmosphere. A relief is always installed on the downstream side of the pressure regulating device. A relief valve is often a preferred form of OPP due to its low cost and ability to maintain service while preventing an overpressure event. Some jurisdictions disallow relief valves due to venting concerns in populated areas, or methane emission regulations.

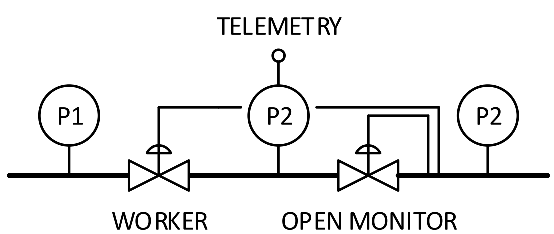
In its simplest form, a relief valve is a spring-operated regulator that seals a vent point until pipeline pressure overcomes the set force of the spring and begins to open the valve. Spring operated reliefs do not reach full capacity immediately, so this style of relief must be set well below MAOP fully open before the downstream reaches MAOP.

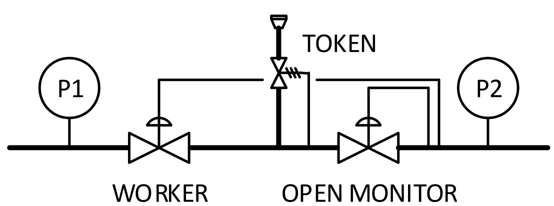


A relief valve can also be a pilot operated regulator that senses line pressure and is configured to open once a specified line pressure is detected. This style of relief valve can typically be set near or at MAOP as the pilot increases relief response time to achieve full-capacity much faster than a spring-operated relief.

Relief capacity must equal or exceed the total full-open failure capacity of the largest upstream pressure regulating device. Some regulators and control valves can be configured with reduced ports or restrictor plates to provide a physical reduction in capacity to lower the required relief size.

Worker-Monitor – a secondary "monitor" regulator can be installed in series with a primary regulator, known as the "worker" regulator. The monitor regulator provides redundant regulation in case the worker fails.





Worker-Monitor regulator configurations may be preferred in a station with capacity requirements where an appropriately sized relief valve would be disruptive. Jurisdictional requirements or environmental initiatives also encourage the use of this type of OPP.

There are many configurations for worker-monitor designs. Operator preference often determines the orientation of the monitor with respect to the worker (upstream or downstream). Additionally, operators decide whether the monitor should be a regulating "working monitor" or an idle "wide-open monitor".

Worker-monitor stations should implement a notification to operators when the monitor regulator is controlling (i.e. the worker regulator has failed). Notification is cued by an increase in station outlet pressure consistent with the setpoint of the monitor setpoint. Small "token" reliefs may be configured to vent a small amount of gas, allowing the gas odor to be detected by the surrounding public. Instrument telemetry systems can monitor system pressure and trigger alarms to operators when pressure exceeds a certain value.

An important design consideration for a worker-monitor regulator configuration is the inherently tortuous path for gas passing through two regulators in series. The extra regulator reduces the maximum theoretical capacity of gas through the regulator station. As a rule of thumb, the capacity of a worker-monitor configuration is 70% of the capacity of the smaller regulator.

As noted in Types of Regulation Failure, the monitor must react fast enough to overcome a wide-open failure of the worker before MAOP is reached. For worker-monitor control valves, it's recommended that the monitor be two to four times faster at closing than the worker valve.

Shut-off "Slam Shut" Valve – These valves are designed to sense downstream pressure and automatically close when the pressure reaches a designated maximum pressure. Typically, shut-off valves cannot be re-opened remotely and require a technician to service the valve in person and reset it to the open state.

Shut-off valves come in many different forms (e.g. actuated valves, rupture disks, spring operated trip valves) and are available as standalone inline components, or built into a regulator body. Shut-off valves are useful in designs where downstream service can be temporarily interrupted to prevent over pressure

OPP Selection – Regulation Failure Mode

When selecting an OPP solution for a scenario, it is important to understand the failure mode of the pressure regulating device. Most regulators are designed to fail-open when experiencing one or more of the failure causes mentioned in this paper.

Many control valves and regulators can be designed to fail-closed. A fail-closed regulator by itself does not constitute a level of over-pressure protection. Additionally, in its failure state, a fail close regulator may only become partially closed.

For operators utilizing a worker monitor OPP configuration, it can be beneficial to install a fail-open device for the worker, and a fail-closed device for the monitor. In this case, if the redundancy provided by the monitor fails, it is designed to close as a last resort.

Levels of Over Pressure Protection

Operators sometimes characterize their OPP selections in “levels” or “layers”. The number of OPP layers implemented depends on operator risk assessments and project design criteria.

One-Layer OPP – The operator chooses one of the above-mentioned devices to establish OPP. This protects against one equipment failure (required by code).

Two-Layer OPP – This configuration uses two OPP devices to be installed such that the second protects against the first device failing. An example would be a relief installed in addition to a worker-monitor, in the case that both the worker and the monitor fail.

Three-Layer OPP – This configuration uses three OPP Devices. An example would be a shut-off valve installed in addition to a worker-monitor and relief, such that the shut-off valve will close in the case where the worker, monitor, and relief fail.

While more than three layers of OPP can be implemented, it begins to provide diminishing returns for most systems. For extremely sensitive or critical infrastructure, operators may choose to implement more OPP as demanded by the conditions.

Maintenance Considerations

With the variety of equipment in the field, most operators determine and document their own maintenance plans with the help of manufacturer recommendations. Maintenance plans must decide where to operate between run-to-failure maintenance versus preventative maintenance.

Preventative maintenance is the most conservative method to ensure OPP devices are always functional. Operators may choose to replace some or all sealing components (flexible elements, O-rings, orifice seats) during each visit to a regulation site to ensure reliable operation. Operators define replacement criteria based on experience and manufacturer recommendations. Most operators will align their OPP inspections and maintenance with remaining station asset inspections to streamline their maintenance activity.

Running to failure maintenance plans give operators flexibility with both budget and resources. Though the pressure limiting and OPP devices are still inspected for sound operation per the CFR code, internal sealing elements may not be replaced as often as with preventative maintenance strategies. This method introduces more risk than a full preventative maintenance plan. In the case of using a run to failure strategy, the operator must ensure they have redundancies and notifications systems available, with personnel available to respond quickly to alarms.

Future (USA) Regulations

In 2020, the USA passed the PIPES act which directed PHMSA to increase oversight and safety directives for pipeline infrastructure, with impacts to Natural Gas distributors. Of particular interest and impact to this paper is PHMSA's 2023 **proposed rulemaking** RIN 2137–AF53.

This rulemaking aims to reduce the potential for common mode of failure incidents from overcoming OPP devices. A 2018 incident in Merrimack Valley, Massachusetts unveiled the risks of operator error leading to complete failure of a code-compliant worker-monitor regulator station. Incorrectly installed sense lines on the worker and monitor regulator caused high pressure natural gas to enter a low-pressure distribution system which immediately caused explosions and fires in as many as 40 homes, leading to one death.

The proposed rulemaking would modify §192.195 and require that operators serving low-pressure distribution systems install "at least two methods of overpressure protection" (two levels of OPP). Federal Regulations define low-pressure distribution systems as systems which distribute gas at pressures "substantially the same as the pressure provided to the customer." In this type of system, the district regulator station is the last line of defense for maintaining safe pressure to customers. If enacted, this rule will require operators of low-pressure distribution systems to retrofit new and changed regulator stations.

If Overpressure Occurs

If a pipeline becomes over-pressurized, the first course of action is always to protect life and property. This can constitute many different actions depending on the severity of the over-pressure event. This paper will only discuss the gas operations and compliance perspectives of the recovery process.

Make Safe – Operationally, the goal is to isolate the source of the unregulated gas flow and remove the excess downstream gas to return the pipeline to safe operating pressure.

Get the Facts – Take notes, timestamp steps taken, and document decisions. Initial key data points might include: the peak pressure reached, duration of over-pressure, area and extent of over-pressure, time of notification, time of mobilization, and time to isolation.

Determine which component(s) failed and remediate all potential failure points before putting the failed pipeline back in service. Depending on the findings, consider if the failure type is a risk at other points in the system.

Reporting – §191.23 on reporting safety-related conditions, mentions in paragraph (a)(6) the need to report malfunctions or errors that cause the pressure in a pipeline to rise above MAOP; but additional reporting requirement specifics are largely jurisdiction-dependent.

Minimally, operators should be prepared to report, as mentioned above, the peak pressure reached, the percent over-pressure of MAOP, the duration of the over pressure, the extent of the impacted pipeline(s), any associated damages, and the recovery and recertification plan for the pipeline.

Leak Survey – As a means of both assessing damage to and proving strength of the pipeline, it is recommended that at least one leak survey should be performed after an over-pressure event. The leak surveys should include all above and below ground facilities believed to have experienced the over-pressure condition. Document the survey times, pressure during the survey, scope, and findings.

Re-Pressure Test – In cases where the pipeline was over-pressured above the original pressure test pressure, increased significantly in %SMYS, or if there were any pipe repairs made because of the over-pressure, a pressure test may be necessary to ensure the pipeline is fit for service.

Conclusion

Federal regulations provide design and location guidance for OPP devices. Operators must develop maintenance plans and redundancy criteria that ensure safe and reliable delivery of gas to their customers. Operators must follow jurisdictional requirements, and consider industry best practices and manufacturer recommendations to maintain safety and operability of the gas distribution system. With proper OPP solutions implemented, operators can be assured that their distribution systems will safely deliver natural gas to their customers.

Acknowledgement: The original draft of this paper is credited to the 2019 & 2022 Over Pressure Protection presenters (Peter Cathcart & Chanda Cross of NW Natural) and portions are used with permission.