

PICTURE THE POTENTIAL

Process Safety Approach to Preventing Gas Over-Pressurizations and Releases at Pressure Regulating Stations

*An educational tool developed by
AGA's Process Safety Working Group*

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Scope and Objectives

This information is intended to be used as an educational tool and leverages AGA's technical paper, "[Leading Practices to Reduce the Possibility of a Natural Gas Over-Pressurization Event](#)." Case studies are highlighted to help with identification, prevention, mitigation and measurement of risks within the context of gas pressure regulating station operations.

The target audience for this guidance document is those involved in the design, operation and maintenance of pressure regulating stations.

The objectives include:

- Identifying and describing key risks that exist at gas pressure regulation stations
- Discussing approaches to effectively manage these risks
- Proposing key performance indicators that can be used to help with improving risk management

Note: The terms "*process safety management*" and "*PSM*," as used throughout this document, refer to the systems used to manage process safety within an organization. They do **NOT** refer to a specific regulation (such as 29 CFR 1910.119 in the United States).

Risk Assessment

- Risk: “How likely is it that something bad could happen, and how bad could it be?”
- Risk is calculated as a function of consequence severity and the likelihood of occurrence.
- Risk is calculated for each individual hazard for individual risk receptors and can be summed to determine total risk.



Why is Risk Assessment Important?

Risk assessments help to **identify areas where the pipeline may be at risk of a catastrophic failure** which could result in undesirable consequences for the company and put the public safety at risk.

Risk assessments **provide a systematic approach to identifying these risks** and **enable a structured analysis to identify the most effective risk reduction and management methodologies** to bring the pipeline safety risk to within an acceptable level.

The risk assessment process is the heart of both the process safety and the pipeline safety management systems because if you do not know what your risks are, it is very difficult to manage them.



Hazard vs. Consequence

HAZARD

A condition or property that has the potential for causing damage or harm.

Examples:

- Toxicity
- Flammability
- Explosivity
- Live electrical equipment
- Heavy/fast-moving parts or objects
- Sharp edges

CONSEQUENCE

Damage or harm caused to a receptor.

Examples:

- Health impacts– e.g., fatality
- Environmental harm– e.g., water contamination
- Reputation damage– e.g., making the local news
- System and/or equipment damage

Hazard Scenario

To assess risk, first identify the hazard for which we will build a scenario.

- **Hazard Scenario:** The situation that has the potential to cause harm or damage to people, property, or the environment.

A hazard scenario is initiated with a fault or cause.

- **Cause:** The initiating event that started the hazard scenario. The three major types of causes include equipment failure, external events, and human factor failures.

To prevent a scenario from escalating to its worst possible consequence, a number of safeguards are accounted for.

- **Safeguards:** Active or passive engineering or administrative controls that reduce the probability or the consequences associated with a hazard scenario.

Bowtie Diagram

One way to show the relationship between cause, safeguard, event, and consequence is to use a bowtie diagram. The bowtie provides an overview of the hazard scenario.



The bowtie can then be used to assess the risk of potentially undesirable consequences and events for the analyzed assets. It can also be used to identify risk management and reduction strategies to help reduce the probability or severity of potential undesirable consequences.

Key Performance Indicators

The process safety and risk management performance of a company is measured using Key Performance Indicators (KPI). Each company typically defines its own KPI but selecting the right metric can be a challenging task.

KPIs fall under one of two categories:

- **Leading Indicators:** A forward-looking set of metrics which indicate the performance of the key work processes, operating discipline, or protective barriers that prevent incidents. They are designed to give an indication of potential problems or deterioration in key safety systems early enough that corrective action can be taken to prevent an incident. [Adapted from API RP754]
- **Lagging Indicators:** A retrospective set of metrics that are based on incidents that have already occurred and can indicate potential recurring problems. [Adapted from API RP754]

Example Case Studies

The following set of slides review case studies that are intended to provide ideas on risks that have materialized in gas regulating stations and the approaches that can be taken to identify, assess, address and measure these risks. These are explored using the bowtie methodology.

While only three examples are analyzed in depth, additional examples are included in the appendix for your reference [here](#).



Case Study Format

Please note that each case study is not meant to be comprehensive in nature.

Hazard Scenario describes the situation that has the potential for causing damage to people, property, or the environment. In this training program, we are focusing on the potential to cause safety consequences.

Cause explains the initiating event that started the hazard scenario. There are three major types of causes: *equipment failure, external events, or human factor failures*. Specific examples of these types are shown.

Safeguards identify active or passive equipment controls or administrative controls that reduce either the probability or the consequences associated with a hazard scenario.

Recommended Leading Key Performance Indicators (KPI) suggest metrics that could provide performance information and give an organization time to take corrective action before a potentially catastrophic event occurs.

Case Study #1

Hazard Scenario: Gas pressure regulating station's working regulator fails open due to equipment-related failure and allows higher pressure gas to flow into downstream piping with the potential to have a gas release and possible ignition.

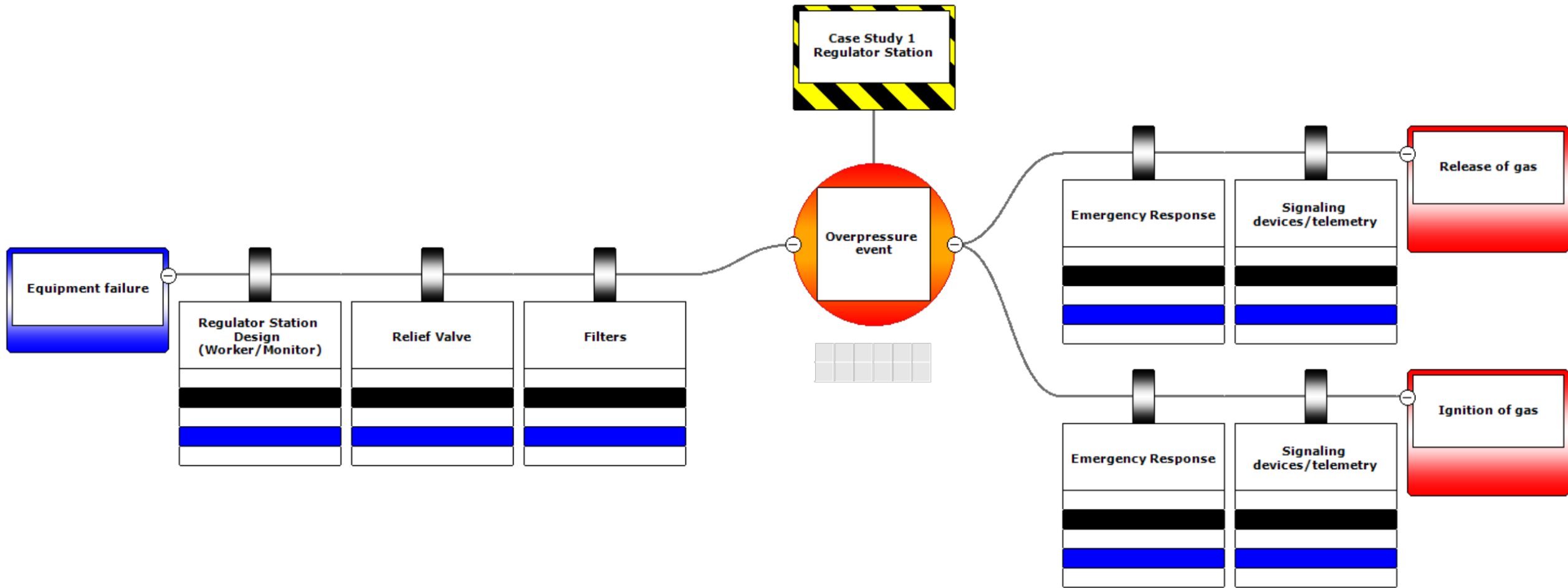
Cause: Singular Event-Equipment failure

Safeguards:

- Use of in-line monitor regulator that controls pressure upon failure of the primary control regulator.
- Use of relief devices that vent excess gas pressure to the atmosphere.
- Use of automatic-shutoff devices, such as positive shut-off valves or fail-close regulators to interrupt the supply of gas.
- Deployment of signaling devices that notify operating personnel of equipment failure or abnormal operating conditions (AOCs).
- Use of telemetry and transducers that are monitored remotely with corresponding alarm set points.

Recommended Leading Key Performance Indicators (KPI):

- % of regulators with on-time completion of the inspection, testing, and maintenance.
- % of regulators with deferred maintenance.
- Number of stations with no remote pressure monitoring.
- Number of stations where a single failure can result in over-pressurization.



Case Study #2

Hazard Scenario: Gas pressure regulating station's regulator fails open due to pressure regulator being forced to remain open by external mechanical means (ice accumulation, flood, debris, wildlife) with potential for release of gas and ignition.

Cause: Several External Events (foreign material preventing correct operation)

Safeguards:

- Use of in-line monitor regulator that controls pressure upon failure of the primary control regulator.
- Use of pressure relief devices that vent excess gas pressure to the atmosphere.
- Use of automatic-shutoff devices, such as positive shut-off valves and fail close regulators to interrupt the supply of gas.
- Deployment of signaling devices that notify operating personnel of equipment failure or abnormal operating conditions (AOCs).
- Use of telemetry and transducers that are monitored remotely with corresponding alarm set points.
- Inspection and cleaning of pressure regulation stations before returning to service or on the indication of non-operability or as weather conditions improved.

Recommended Leading Key Performance Indicators (KPI):

- The time between discovery and inspection/remediation.
- The number of stations with no remote monitoring (pressure, regulator, or valve position).
- Number of stations where a single failure can result in over-pressurization.
- Number of stations per year where a regulator was found to be compromised due to external means.
- Number of regulator failures reported by a third party.

Case Study #3

Hazard Scenario: Gas pressure regulating station's regulator fails open due to external fire around the pressure regulator with potential for release of gas and ignition.

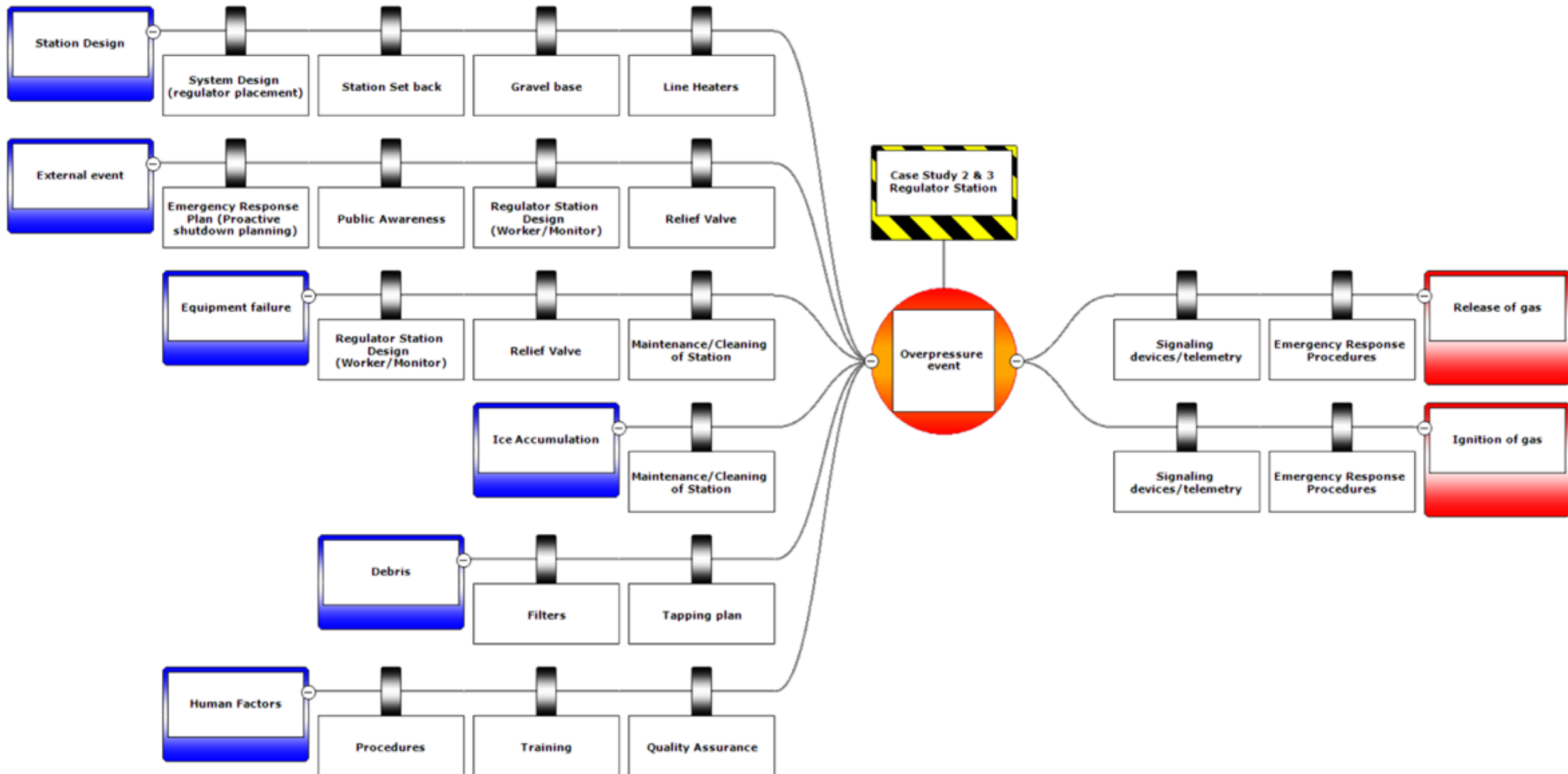
Cause: External Event (Fire)

Safeguards:

- Use of in-line monitor regulator that control pressure upon failure of the primary control regulator. Separate layers of over-pressure protection so that a single fire cannot compromise all layers of over-pressure protection.
- Use of pressure relief devices that vent excess gas pressure to the atmosphere.
- Use of automatic-shutoff devices, such as positive shut-off valves and fail close regulators to interrupt the supply of gas.
- Deployment of signaling devices that notify operating personnel of equipment failure or abnormal operating conditions (AOCs).
- Use of telemetry and transducers that are monitored remotely with corresponding alarm set points.
- Inspection of pressure regulator stations and combustible material removal.

Recommended Leading Key Performance Indicators (KPI):

- The time between discovery and inspection/remediation.
- The number of stations where a single failure can result in over-pressurization.
- Number of station inspections completed on time.
- Number of stations that do not have an adequate separation between over-pressure protection devices to prevent a single point of failure from an external fire.
- Number of remediations outstanding to minimize exposure to external fires.



Concluding Remarks

This information was meant to raise your awareness of the importance and usefulness of risk assessments in quickly communicating and identifying risks of your pipeline assets.

It was also intended to:

- Identify and describe key risks that exist at gas pressure regulating stations
- Discuss approaches to effectively manage these risks
- Propose key performance indicators that can be used to help with improving risk management

The value of this information comes from the discussions you will have with your colleagues and peers on the types of risks that exist in your business and the effectiveness of measures in place to manage them. Risk Management is a team initiative, and it takes everyone to make it work.



Appendix

Case Study #4

Hazard Scenario: Pressure relief device fails due to blockage (debris, ice, water, closed valve) in the outlet resulting in no pressure relief capacity during an overpressure event with the potential for release of gas and ignition.

Cause: External Event (foreign material preventing correct operation)

Safeguards:

- Inspection and testing of pressure relief devices.
- Use of drain holes in the discharge piping.
- Use of screens over the outlet of the discharge piping.
- Establishing capability to lock the isolation valve positions.
- Discharge reactive forces controlled to prevent inlet piping from pinching off.
- Operational controls – Pressure relief device isolation valves are locked in the open position.

Recommended Leading Key Performance Indicators (KPI):

- % of pressure relief devices inspected.
- % of inspected pressure relief devices with blockage.
- Number of outstanding pressure relief outlets not remediated to prevent ice or debris build-up.

Case Study #5

Hazard Scenario: Pressure sensing instrumentation signal failing from external event causing signal output failure (disconnect at instrument or transmitter, communication line break) resulting in either over-pressurization or gas release.

Cause: External Event (Communication interruption)

Safeguards:

- Barricades (fencing, Jersey barriers) around pressure sensing instrumentation and regulators to protect communication equipment.
- Minimize instrumentation communication (tubing, wiring) length.
- Ensure instrumentation communication is contained within barricaded areas, hardened (buried) and/or clear line of sight for telecommunications.
- Inspection of pressure sensing instrumentation, status of barricades, and communication protections.
- Testing the continuity of pressure sensing instrumentation.

Recommended Leading Key Performance Indicators (KPI):

- % of inspections done on time.
- % of equipment testing done on time.
- Number of reported equipment failures due to loss of signal.

Case Study #6

Hazard Scenario: Gas pressure regulating station receives high-pressure gas from upstream supply that results in overpressurization of the downstream pipeline with potential for release of gas and ignition.

Cause: External Event (upstream/ supplier problem)

Safeguards:

- Use of pressure sensing device, pressure control regulator, alarms and piping design matches supplier's design at the interface with supplier.
- Use of automated alarm and shutdown of the overpressurized supplier.
- Ensure pressure regulator station design incorporates overpressure supply in design (piping MAOP, regulator pressure differential capacity, etc.).
- Isolation of supplier during an overpressure event or manual pressure control during an overpressure event. Communication with supplier about overpressurized supply and actions.
- Training of scenario.

Recommended Leading Key Performance Indicators (KPI):

- % of overpressure training scenarios tested on time.
- % of instrument and alarm tests completed on time.
- Number of completed emergency plans tested vs. plan on upstream supply abnormal conditions.
- Number of reported MAOP exceedances at various gradients.

Case Study #7

Hazard Scenario: A vehicle strikes above ground piping or sensing or control line at the pressure regulating station causing certain types of regulators to potentially fail open and allows higher pressure gas to flow into downstream piping with the potential to have a gas release and possible ignition.

Cause: External Event

Safeguards:

- Bollards or guard rails protect any above-ground portions of pressure regulator stations.
- Monthly visual inspections of station equipment.
- Use of in-line monitor regulator that control pressure upon failure of the primary control regulator.
- Use of relief devices that vent excess gas pressure to the atmosphere.
- Use of automatic-shutoff devices, such as positive shut-off valves and fail close regulators to interrupt the supply of gas.
- Deployment of signaling devices that notify operating personnel of equipment failure or abnormal operating conditions (AOCs).
- Use of telemetry and transducers that are monitored remotely with corresponding alarm set points.

Recommended Leading Key Performance Indicators (KPI):

- Number of stations where a single failure can result in over-pressurization.
- Number of stations without bollards or guardrails.
- Number of reported external damages to above-ground piping or control lines.

Case Study #8

Hazard Scenario: A 3rd party damages a sensing or control line at a pressure regulating station causing certain types of regulators to potentially fail open and allows higher pressure gas to flow into downstream piping with the potential to have a gas release and possible ignition.

Cause: External Event

Safeguards:

- Dig safe process for mark outs and company personnel onsite when 3rd parties are excavating nearby pressure regulator stations.
- Signage posted at the regulator station with the local Gas Control phone number advising Contractors and the public to call before they dig.
- Using independent/separate control and sensing lines for each regulator and lines are kept within a vault or protected area.
- Monthly visual inspections of station equipment.
- Use of in-line monitor regulator that control pressure upon failure of the primary control regulator.
- Use of relief devices that vent excess gas pressure to the atmosphere.
- Use of automatic-shutoff devices, such as positive shut off valves and fail close regulators to interrupt the supply of gas.
- Deployment of signaling devices that notify operating personnel of equipment failure or abnormal operating conditions (AOCs).
- Use of telemetry and transducers that are monitored remotely with corresponding alarm set points.
- Add marker balls to existing below-grade sensing equipment to enhance locating accuracy.
- Record and retain the as-built location of underground communication equipment with facility records.

Recommended Leading Key Performance Indicators (KPI):

- Number of Dig Safe violations.
- Number of stations where a single failure can result in over-pressurization.
- Number of stations with single control or sensing lines for multiple regulators.
- % of stations with non-locatable below-grade sensing equipment.

Case Study #9

Hazard Scenario: Operator inadvertently puts valve to a sensing or control line at a pressure regulating station in the wrong position causing certain types of regulators to potentially fail open and allows higher pressure gas to flow into downstream piping with the potential to have a gas release and possible ignition.

Cause: Human Factors

Safeguards:

- Operators receive initial and refresher training on the written procedures for operating a pressure regulator station.
- Labeled valves and station schematic available at the station.
- Use of 3-way communication between Operator and Gas Control before operating equipment.
- 2nd Operator onsite peer checking operator who is operating equipment.
- Use of in-line monitor regulator that control pressure upon failure of the primary control regulator.
- Use of relief devices that vent excess gas pressure to the atmosphere.
- Use of automatic-shutoff devices, such as positive shut-off valves and fail close regulators to interrupt the supply of gas.
- Deployment of signaling devices that notify operating personnel of equipment failure or abnormal operating conditions (AOCs).
- Use upstream and downstream pressure gauges to verify proper operation before leaving a site.
- Use of telemetry and transducers that are monitored remotely with corresponding alarm set points.
- Lock valves in a safe position and distribute keys to only qualified personnel.

Recommended Leading Key Performance Indicators (KPI):

- Number of Operators who are not current on training.
- Number of stations where a single failure can result in over-pressurization.
- % of stations where valves are not labeled or are improperly identified.

Case Study #10

Hazard Scenario: Operator incorrectly sets control regulator at a pressure regulating station incorrectly causing the regulator to potentially fail open and allows higher pressure gas to flow into downstream piping with the potential to have a gas release and possible ignition.

Cause: Human Factors

Safeguards:

- Operators receive initial and refresher training on the written procedures for operating a pressure regulator station.
- Use of 3-way communication between Operator and Gas Control before operating equipment and Gas Control verifies station outlet pressure as part of station adjustment.
- 2nd Operator onsite peer checking operator who is operating equipment and local gauges are used.
- Use of in-line monitor regulator that control pressure upon failure of the primary control regulator.
- Use of relief devices that vent excess gas pressure to the atmosphere.
- Use of automatic-shutoff devices, such as positive shut-off valves and fail close regulators to interrupt the supply of gas.
- Deployment of signaling devices that notify operating personnel of equipment failure or abnormal operating conditions (AOCs).
- Use of telemetry and transducers that are monitored remotely with corresponding alarm set points.
- Physically tag regulators with set-point and position (worker/monitor).

Recommended Leading Key Performance Indicators (KPI):

- Number of Operators who are not current on training.
- Number of stations where a single failure can result in over-pressurization.
- Number of events where failure to set correct pressure was due to instrument error.

Case Study #11

Hazard Scenario: Operator incorrectly opens bypass valve at a pressure regulating station allowing higher pressure gas to flow into downstream piping with the potential to have a gas release and possible ignition.

Cause: Human Factors

Safeguards:

- Operators receive initial and refresher training on the written procedures for operating a pressure regulator station.
- Bypass valves are labeled and locked in a normally closed position.
- Use of 3-way communication between Operator and Gas Control before operating equipment and Gas Control verifies station outlet pressure as part of station adjustment.
- 2nd Operator onsite peer checking operator who is operating equipment and local gauges are used.
- Use of relief devices that vent excess gas pressure to the atmosphere.
- Deployment of signaling devices that notify operating personnel of equipment failure or abnormal operating conditions (AOCs).
- Use of telemetry and transducers that are monitored remotely with corresponding alarm set points.

Recommended Leading Key Performance Indicators (KPI):

- Number of Operators who are not current on training.
- Number of stations where a single failure can result in over-pressurization.
- Number of bypass valves that are not chained and locked closed.

Case Study #12

Hazard Scenario: Operator inadvertently does not follow all steps in the SOP correctly allowing higher pressure gas to flow into downstream piping with the potential to have a gas release and possible ignition.

Cause: Human Factors

Safeguards:

- Operators receive initial and refresher training on the written procedures for operating a pressure regulator station.
- Written SOPs are prepared for jobs that interrupt the flow of gas and are reviewed by subject matter experts prior to performing the SOP.
- Use of 3-way communication between Operator and Gas Control before executing steps of the SOP and Gas Control verifies station outlet pressure as part of station adjustment.
- 2nd Operator onsite peer checking operator who is operating equipment and local gauges are used.
- Use of in-line monitor regulator that control pressure upon failure of the primary control regulator.
- Use of relief devices that vent excess gas pressure to the atmosphere.
- Use of automatic-shutoff devices, such as positive shut-off valves and fail close regulators to interrupt the supply of gas.
- Deployment of signaling devices that notify operating personnel of equipment failure or abnormal operating conditions (AOCs).
- Use of telemetry and transducers that are monitored remotely with corresponding alarm set points.

Recommended Leading Key Performance Indicators (KPI):

- Number of Operators who are not current on training.
- Number of stations where a single failure can result in over-pressurization.
- Number of critical SOPs that have not been reviewed as per company procedure/policy.