DACC
DRILLING AND COMPLETION COMMITTEE

IRP 29: Temporary Pipework, Securement and Restraint

An Industry Recommended Practice (IRP)
for the Canadian Oil and Gas Industry

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CANADIAN ASSOCIATION OF ENERGY CONTRACTORS
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29.0 **Preface**

29.0.1 Purpose

This document defines temporary pipework, establishes minimum standards for its selection, implementation and use in the oil and gas industry. It also outlines safety measures, including consideration of dynamic forces that may occur during a failure, and provides guidance to manage these risks through appropriate controls.

IRP 29 takes a risk-based approach to managing temporary pipework, empowering users to assess specific operational hazards and select controls that align with the specific risk level of each application. These controls may include, but are not limited to, restraints, exclusion zones, inspections, and procedures.

Key principles of this approach include:

- Not one-size-fits-all: Operators assess site-specific risks rather than applying blanket controls.
- Control selection: A variety of controls–restraints, exclusion zones, procedures, and inspections–may be applied based on the nature of the risk.
- Emphasis on prevention: Proactive design, inspection, and planning are emphasized to reduce the likelihood of failure events.

For more on this approach, see “Risk-Based Approach” in section 29.2 Definitions and the bow-tie analysis example in section 29.3.4 Evaluating Risk and Choosing Controls.

The recommendations in this IRP align with current industry practice and standards for temporary pipework. They also account for jurisdictional differences to support consistent, practical guidance where regulatory requirements may be unclear or vary across jurisdictions.

29.0.2 Audience

The audience includes those involved in the planning, setup and use of temporary pipework. This applies to completions, workovers, well servicing and decommissioning operations.

It is assumed the reader has a basic understanding of wellsite terminology and practices.

29.0.3 Scope and Limitations

The scope of IRP 29 includes land-based operations in western Canada. It covers the selection, implementation and use of temporary pipework systems, including securement, restraint, and anchoring.

IRP 29 covers a broad range of pumping services, from a pump truck injecting methanol to the large multi-well pad hydraulic fracturing operations. The basic principle of protection of the worker, protection of the public and the environment is essential to all operations that utilize temporary pipework.

For this IRP, a temporary pipework system meets the following two conditions:

1. The pipework is used to deliver a pressurized medium:
    a. from a pumping unit into the wellhead or
    b. from the wellhead to an atmospheric or pressurized holding container (e.g., a recovery vessel, tank, flare, holding tanks/C-rings) or temporary surface pipeline.
2. The pipework is used on a temporary basis with the intention of disassembly when the operation is complete.

    Note: The term “temporary” is intentionally not defined by a specific duration in this IRP. Its meaning may vary depending on the context of the operation, jurisdiction, or organizational requirements. It is the responsibility of the Prime Contractor and/or Owner to determine whether the pipework in use qualifies as temporary for the purposes of applying this IRP.

Due to inherent risks, operational similarities and frequent overlap with simultaneous operations, water transfer systems are included in this IRP. See sec. 29.11 Water Transfer Systems.

29.0.3.1 Out of Scope

This IRP does not apply to piping used on a drilling rig mud circulation system, primary or secondary well control, such as blowout preventer (BOP) system, underbalanced drilling (UBD) lines, managed pressure drilling (MPD) or emergency shutdown (ESD) systems. These systems are governed by other codes and regulatory requirements (e.g., CSA B51, ASME B31.3, API 16C) that already establish controls and requirements. While such systems may incorporate piping similar to that described in this IRP, their function, risk profile, and oversight fall outside the intended scope of this document. See 29.2 Definitions for a definition of Temporary Pipework, for further clarification.

29.0.4 Revision Process

IRPs are developed by the Drilling and Completions Committee (DACC) with the involvement of both the upstream petroleum industry and relevant regulators. Energy Safety Canada acts as administrator and publisher.

Technical issues brought forward to the DACC, as well as scheduled review dates, can trigger a re-evaluation and review of this IRP in whole or in part. For details on the IRP creation and revisions process, visit the Energy Safety Canada website at www.EnergySafetyCanada.com.

A complete list of revisions can be found in Appendix A.

29.0.5 Sanction

The following organizations have sanctioned this document:

Canadian Association of Oilwell Energy Contractors (CAOEC)

Canadian Association of Petroleum Producers (CAPP)

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Explorers & Producers Association of Canada (EPAC)

29.0.6 Range of Obligations

Throughout this document the terms ‘must’, ‘shall’, ‘should’, ‘may’ and ‘can’ are used as indicated below:

Table 1. Range of Obligation

Term	Usage
Must	A specific or general regulatory and/or legal requirement that must be followed. Statements are bolded for emphasis.
Shall	An accepted industry practice or provision that the reader is obliged to satisfy to comply with this IRP. Statements are bolded for emphasis.
Should	A recommendation or action that is advised.
May	An option or action that is permissible within the limits of the IRP.
Can	Possibility or capability.

29.0.7 Background

IRP 29 establishes best practices for temporary pipework (also called temporary flow piping).

Temporary pipework is mobilized to various well operations and subjected to dynamic conditions, pressure changes and other stresses during storage, transport, and operation. Tracking the impact of these conditions on pipework and components is difficult without a consistent pipework management system.

There is no single temporary pipework design standard and regulatory requirements vary across western Canadian jurisdictions, which creates the potential for failure. For example, connections may be physically compatible but designed to operate at different working pressures than other components of the system. In addition, WorkSafe BC mandates the use of engineered restraint systems to secure temporary flow piping at worksites.

This Industry Recommended Practice provides a uniform, risk-based approach to enhance safety when using a temporary pipework system. The IRP outlines design, assembly, and potential failure contributors as factors to consider during a site-specific risk assessment for the use of temporary pipework.

29.1 Introduction

IRP 29 provides guidance to industry to identify the risks associated with pipework systems used in temporary applications within the oil and gas sector. The IRP outlines the methodology to identify risk scenarios, components and operations; it also provides a risk register to assist industry in implementing controls (exclusion zones, restraints, procedures) to ensure the protection of workers, the public and the environment. The IRP defines what constitutes temporary pipework to help employers focus on these systems and provides guidance for components that fall outside the definition but still benefit from management (i.e., mounted pipework components).

29.1.1 Original Equipment Manufacturer (OEM)

The Original Equipment Manufacturer (OEM) uses standards of engineering and manufacturing such as those provided by the American Petroleum Institute (API) and the American Society of Mechanical Engineers (ASME). These standards outline the requirements for the following:

- Design
- Materials
- Welding
- Factory acceptance testing
- Certification
- Documentation
- Servicing/maintenance
- Repairs

29.2 Definitions

For this IRP, and to assist the user, the following definitions will be used throughout IRP 29:

Competent Person

The term “competent person” is used throughout the IRP when no specific job title applies. In these cases, the individual performing the task must be adequately qualified, properly trained, and have enough experience to carry out the work safely. It is the employer’s responsibility to ensure workers are competent for their assigned tasks. When the IRP refers to “a competent person or professional engineer” it means a professional engineer is not strictly required–the task may be performed by a competent person who meets the above criteria.

Restraint Owner

The Restraint Owner could be the OEM restraint manufacturer, a service company that provides restraints for use with their temporary pipework, a third-party rental company or the prime contractor.

Risk-Based Approach

A risk-based approach involves identifying potential hazards, assessing the likelihood and consequences of failure and applying appropriate controls to reduce the risk to an acceptable level. In the context of IRP 29, this approach allows operators to evaluate the specific conditions and configuration of temporary pipework systems and implement controls such as restraints, inspections or exclusion zones based on the level of risk, rather than a one-size-fits-all solution. This method supports flexibility while maintaining safety by aligning controls with the hazard potential of the operation, the consequences of failure and industry best practices. See Section 29.3.4 Evaluating Risk and Choosing Controls for more details.

Temporary Pipework

Temporary pipework, also referred to as temporary flow piping, is the system of pipes and associated components temporarily assembled at the wellsite to pump fluids into or out of a wellbore (wellhead). This includes but is not limited to services such as swabbing, well flowback, cementing, well servicing and well stimulation. Temporary pipework typically includes

- connections (e.g., hammer unions, flanged connections),
- joints, valves, tees, swivels and

- components used to adjust orientation or elevation.

Pipework

Pipework is the complete system of pipes, restraints and anchoring.

Securement

Securement is the anchor point where restraints are attached.

Restraint

Restraint is a safety system designed to control the release of stored energy if temporary pipework fails.

Mounted Pipework

Mounted pipework is pipe systems that are permanently attached to a skid or trailer, such as trailer-mounted or truck-mounted piping, and separator skid packages.

Ancillary Piping

Ancillary piping is pipe systems that do not qualify as temporary pipework. Common examples include the following:

- Hydraulic hoses for actuating components (e.g., accumulator lines for BOPs, lubricator pack-off/grease injection, ball launcher systems)
- Steam/glycol lines (hard or flexible piping) not pumping into the wellhead
- Hydraulic, electrical, or pneumatic lines connected to wellhead components like emergency shutdown device (ESDs)
- Chemical injection lines
- Fuel lines (e.g., natural gas, propane, diesel) that supply engine-driven equipment
- Permanent production piping or flowlines tied to facilities that are not disassembled after use.

Water Transfer

Water transfer is moving water with pumps using layflat hoses or other means, excluding tank trucks. Water transfer does not include tying to a wellhead, test package, or pressure vessel. Water transfer can occur on lease or off lease. See Section 29.11 Water Transfer Systems.

29.3 **Planning**

29.3.1 Objectives

The primary objectives when planning a temporary pipework system are to ensure the following:

- Protection and safety of workers and the public
- Protection of the environment
- Protection of equipment and property
- Mitigation of the risks of a temporary pipework failure through use of controls

29.3.2 Roles and Responsibilities

Temporary pipework is used for a variety of services, ranging from large-bore, high-pressure piping for hydraulic fracturing to flowback piping, service rig piping connected to the wellhead, pressure trucks and hot oilers.

IRP The Owner and/or Prime Contractor shall verify the operation complies with local jurisdictional regulations.

IRP The Owner and/or Prime Contractor shall provide any service company connecting to a well with the expected operating pressures, wellbore fluid composition and maximum working pressures.

IRP The Service Company shall ensure that equipment and piping meet the scope of work requirements and is responsible for producing the necessary Process Flow Diagram and/or Process and Instrumentation Diagram (P&ID) for the piping installation. See IRP 04: Well Testing Design Considerations for information on Process Flow Diagrams.

IRP The Service Company shall keep records of temporary pipework meeting the minimum requirements specified in Section 29.3.3 Pipework Management System.

IRP The Restraint Owner shall ensure the restraint system meets dynamic force requirements and is properly installed, maintained and repaired.

29.3.3 Pipework Management System

The Pipework Management System, also known as an Iron Management System, monitors the condition of temporary pipework (including flexible hoses) to prevent failures.

IRP All temporary pipework components shall be managed and tracked using a pipework management system. Tracking records shall be maintained for each component throughout its operational life or as specified by the company's record retention policy.

IRP At a minimum, the pipework management system should include

- identification and tracking system,
- maintenance schedule tracking,
- certification and recertification records and requirements,
- documented inspections and repairs, and
- manufacturer's operational specifications, or the Owner's and/or Prime Contractor's operating procedures if manufacturer's specifications are unavailable.

29.3.3.1 Storage Requirements

IRP The following storage procedures should be followed:

- Clean, lubricate, and coat components with OEM-approved products to prevent rust and maintain performance.
- Store in a manner that prevents damage to threads, sealing faces, or body.
- Flush components exposed to corrosive fluids to prevent rust.
- Protect elastomers from ultraviolet rays.

29.3.3.2 Transport Requirements

IRP The following transportation procedures should be followed:

- Transport in a manner to protects threads and seals and prevents anything from entering the pipe.
- Transport in a manner that prevents components from impacting each other, which can cause wear or damage.
- Transport with proper load securement to meet local jurisdictional regulatory requirements.

29.3.4 Evaluating Risk and Choosing Controls

Temporary pipework systems present many potential hazards. These hazards need to be controlled based on a risk assessment of their likelihood and potential severity. The complexity of the operation determines the level of risk assessment required.

IRP A risk assessment of potential hazards shall be completed and documented for an individual job or by job type. The IRP 29 Risk Register

(see energysafetycanada.com) provides examples of common risks associated with temporary pipework for reference.

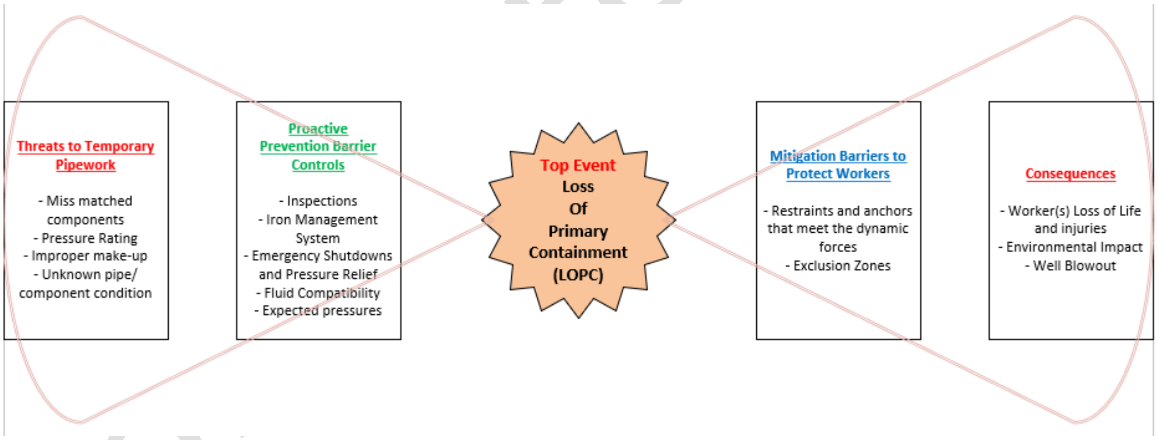
IRP **A Management of Change (MOC) process shall be used to document and manage the risks associated with changing operating conditions. Changes shall be communicated to the appropriate parties involved in the work.**

IRP **Risk assessments and controls shall not be used to bypass local jurisdictional requirements without the proper regulatory variance application.**

Various controls can be used to reduce the risks to workers, the public and the environment in the event of a temporary pipework system failure. These controls may include engineering controls, such as restraint systems and administrative controls such as procedures or establishing an exclusion zone. Controls are identified based on the risk assessment.

To support users in applying this risk-based approach, the following bow-tie diagram (Figure 1) illustrates how threats, preventative barriers, the top event (e.g., loss of containment) and mitigation barriers work together to reduce the likelihood and impact of failure.

Figure 1. Risk-Based Approach Illustrated in Bow-Tie Risk Diagram



This example shows how temporary pipework failure can be assessed using a bow-tie model:

- Top Event: Loss of primary containment
- Threats: Improper pipe selection, overpressurization, poor connections
- Preventative Barriers: Pipework management systems, inspection protocols
- Mitigation Barriers: Exclusion zones, emergency response, restraint systems

The diagram reinforces that IRP 29 does not emphasize restraints as the only solution but rather encourages layered, effective, independent and auditable controls tailored to each situation.

Key inputs to the risk assessment are as follows:

- Pipework system design: considerations and risks related to the pipework design, including
  - review of the IRP 29 Risk Register,
  - pipework management: maintenance and certifications,
  - component selection: pipe, connections, other components, mounted components, restraints, anchor points, and
  - pressure source (e.g., wellbore, pump truck, gas cylinder),
- Pipework system assembly, including
  - Inspections, and
  - assembly practices,
- Pipework system potential equipment failure factors, including
  - fluid types,
  - pressures,
  - temperature,
  - erosion, and
  - pipework system parting (dynamic) forces.

IRP A risk assessment shall be completed for each of these inputs to determine the appropriate controls for the specific application.

IRP Completed risk assessments shall be documented and communicated to the appropriate parties involved in the work.

IRP Dynamic force calculations shall be used during the design phase to determine the expected forces and the required strength of restraints when pipe restraint systems are used.

IRP Consideration should be given to the pressure source's maximum pressure output as it may limit the forces the system could experience.

29.3.5 Understanding Dynamic Forces Related to Restraint Design

Understanding dynamic forces caused by pipe breaks or connections parting is essential when designing and selecting restraint systems for temporary pipework. These forces occur when a pipe system fails, releasing fluid or gas under pressure.

IRP The applicable dynamic forces shall be determined by a competent person to select a restraint system capable of withstanding those forces, ensuring safe operation.

Traditionally, industry has estimated the force that a restraint must resist using simplified equations such as Force = 2PA, where a thrust coefficient of 2.0 is applied to account for dynamic effects like pipe acceleration, slack and system response. This approach provides a conservative estimate of the working load and has been widely adopted for its simplicity.

However, this simplified method does not distinguish between the two main pipe break scenarios: those driven by a constant pressure source (e.g., wellbore flowback) and those driven by a constant pump rate source (e.g., pumping operations). As a result, it may not accurately reflect the dynamic forces present in either scenario.

IRP 29 addresses this limitation by introducing equations tailored to each scenario. These equations are based on principles of momentum and energy conservation and incorporate physical variables such as pipe mass, restraint stiffness and free pipe length. The resulting calculated force ($F_{restraint}$) provides a more realistic estimate of the peak dynamic load that a restraint system may experience.

Temporary pipework connected to a well is usually used to either flow fluid from the well or pump fluid into the well. For potential pipe break situations related to restraint system design and selection, two scenarios are described below:

1. Constant Pressure Source Scenario (Wellbore Model), where fluid flows from the well
2. Constant Pump Rate Source Scenario (Pump Model), where fluid is pumped into the well

Table 2 summarizes the simplified formulas for calculating thrust forces and restraint loads for both pipe break scenarios and highlights the key differences between them. See Sections 29.6.1 Restraint System Design and 29.6.2 Restraint Force Equations for further details.

Note: The equations provided below and in Section 29.6.2 Restraint Force Equations are not mandatory but are offered as an alternative when no other method is available.

Table 2. Summary of Thrust and Restraint Loading Formulas

Scenario	Thrust Force	Force on Restraint	Symbols

Constant Pressure Source (Wellbore Model)	$F_{thrust-CP} = 2\,P_{AOF}\,A$	$F_{restraint-CP} = 2\,P_{AOF}\,A$	• **$F_{thrust-CP}$**: Thrust force under constant pressure conditions • **$F_{restraint-CP}$**: Restraint force under constant pressure conditions • **P_{AOF}** : Operating pressure at area of flow • **A**: Internal cross-sectional area of the pipe
Constant Pump Rate Source (Pump Model)	$F_{thrust-CF} = P_{pump}\,A$	$F_{restraint-CF} = \frac{P_{pump}\,A\,L_{pipe}}{a}\sqrt{\frac{k_{restraint}}{m_{pipe} + m_{fluid}}}$	• **$F_{thrust-CF}$**: Thrust force under constant flow conditions • **$F_{restraint-CF}$**: Restraint force under constant flow conditions • **P_{pump}**: Pump discharge pressure • **A**: Internal cross-sectional area of the pipe • **L_{pipe}**: Unanchored length of pipe segment • **a**: Speed of sound in the fluid • **$K_{restraint}$**: Restraint system stiffness • **m_{pipe}**: Mass of the pipe segment • **m_{fluid}**: Mass of the fluid within the pipe segment

29.3.5.1 Constant Pressure Source Scenario (Wellbore Model)

IRP The thrust coefficient of 2.0 should be applied for all constant pressure source applications, including both incompressible and compressible flow situations. Lower thrust coefficients should only be used after a Professional Engineer’s assessment for the specific installation or operation.

IRP For the Constant Pressure Source Scenario (Wellbore Model), the pipe pressure should be selected based on the maximum sustained wellhead pressure that could occur during unrestricted flow to surface.

Note: This pressure could be impacted by the charged or induced pressure from fracturing operations, resulting in a potential flowing pressure higher than the native reservoir pressure.

IRP For the Constant Pressure Source Scenario (Wellbore Model), the restraint should be designed to withstand at least the full thrust force generated by the fluid jet from the parted pipe.

Note: The calculated thrust force will act on the unanchored pipe segment at the break, causing it to move and stretch the restraint. The restraint will carry the load until the force matches the full thrust, which will persist until the flow is shut off.

IRP The Owner and/or Prime Contractor shall provide the highest anticipated wellhead pressure to determine potential restraint loads.

29.3.5.2 Constant Pump Rate Source Scenario (Pump Model)

If temporary pipework parts while pumping into a well (i.e., Pump model), the initial flow will be at a constant rate.

Note: The Pump Model is applicable only for incompressible fluid flows.

IRP As described further in Section 29.6.1 Restraint System Design, the following parameters shall be considered when calculating the maximum force applied to the restraint

- magnitude of the transient thrust force applied to the pipe with time (i.e., impulse load), which depends on the initial pressure and pipe area,
- length of the pipe that is free to move (L_{pipe}), which affects how much the pipe will move,
- duration of the thrust force impulse, which is proportional to L_{pipe},
- mass of the pipe that is free to move, which is also proportional to L_{pipe}, and.
- restraint spring factor, a property of the restraint product.

Note: In most cases, temporary piping systems will be pressure tested before operations. If a pipe break occurs during such a test, the Pump Model scenario applies for thrust and restraint force calculations.

29.3.5.3 Restraint Design Considerations for Wellbore and Pump Models

Both the Wellbore and Pump models involve rapid loading of the restraint system, which needs to be factored into the design. These scenarios, in which a full pipe break or separation is assumed, represent worst-case conditions for potential restraint loading.

IRP The end user should account for restraint forces under both constant pressure and constant flow rate scenarios, and should base restraint design and selection on the larger of the two forces.

In hydraulic fracturing, both models can occur during a single pipe break event. Initially, the pipe is pressurized and fed by a constant pump rate source, causing the restraint across the break to experience impulse loading (with a peak thrust force of Fthrust-CF = Ppump x A). If the well is not secured, it may flow back, leading to a constant pressure scenario with a steady-state thrust force (Fthrust-CP = $2P_{AOF}$ x A). The forces acting on the restraint may differ in magnitude and duration, and both need to be considered in the restraint design.

Long-duration flowback, especially if unrestricted, can place greater demands on a restraint system due to sustained loading. This potential impact needs to be considered during hydraulic fracturing and well testing operations.

Table 3 identifies what field operations would apply the wellbore and pump models.

Table 3. Field Examples of Wellbore and Pump Model Application

Operation	Constant Pressure Source (Wellbore Model)	Constant Flow Source (Pump Model)
Pumping or injecting into a well	X	X
Kill operations	X	X
Hydraulic fracturing	X	X
Cementing operations	X	X
Flow testing operations	X	

29.4 Pipework System

The pipework system includes piping connection and premanufactured components such as valves, tees and swivel joints. The supplier and OEM are responsible for meeting the applicable codes and standards for the pipework system.

IRP **The end user shall provide the operating conditions to the supplier/OEM to determine a temporary pipework system that meets the requirements for pressure, temperature, sour service, fluid erosion potential and fluid/material compatibility.**

29.4.1 Piping

The piping for temporary pipework falls into two categories: hard and flexible. Hard piping is constructed from rigid materials such as steel, fiberglass, plastics or other alloys. Flexible piping is constructed from materials such as polyurethane, rubber or braided hose. The flexible hoses discussed in this section are layered high-pressure hoses.

Note: Ancillary hoses not connected directly to the wellhead are not part of the scope for this IRP (See Section 29.2 Definitions). However, considerations for water transfer lines are discussed in Section 29.11 Water Transfer Systems.

Note: Connections and components are used for both hard and flexible piping.

29.4.1.1 Sour Service Requirements

IRP **All pipework used in sour service applications shall meet the requirements of NACE MR0175/ISO 15156 (Metals for Sulphide Stress Cracking and Stress Corrosion Cracking Resistance in Sour Oilfield Environments), published by NACE International (now the Association for Materials Protection and Performance, AMPP).**

Figure 2. Hydraulic Fracturing Pipework System Before Restraint Application

Figure 3. Temporary Flowback

Figure 4. Restraints Used During Fracture Operations

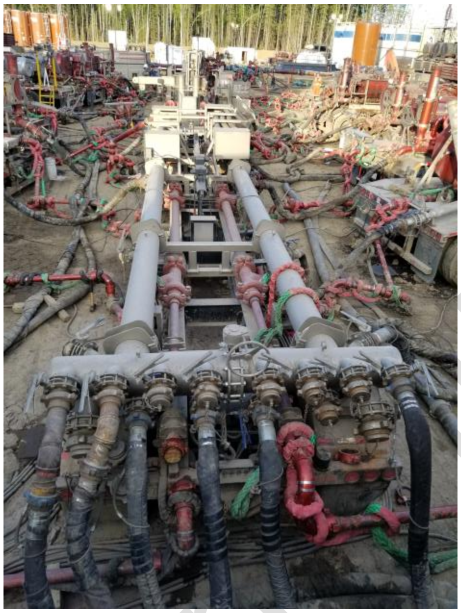
Figure 5. Large Bore Fracture with Restraints

Figure 6. Discharge Iron from Fracture Pumpers to Manifold Trailer with Restraints

Figure 7. Discharge Iron from Fracture Pumpers to Manifold Trailer with Restraints

Figure 8. Discharge Iron from Fracture Pumpers to Manifold Trailer with Restraints

Figure 9. Discharge Iron from Fracture Pumpers to Manifold Trailer with Restraints



29.4.1.2 Potential Pipework Hazards

Consider the following hazards in the hazard assessment:

- Characteristics of the flow stream
- Temperature variations, both internal and external
- Chemical compatibility with OEM requirements (e.g., hydrogen sulphide (H_2S), carbon dioxide (CO_2), acids)
- Potential energy in hose ends during assembly and disassembly from trapped pressure
- Static buildup and electrical continuity of hoses (See IRP 04: Well Testing and Fluid Handling)

- Radiant heat from surfaces during hot flow or pumping (e.g., hoses in the tank farm area during flow back)
- Line of fire hazards may create contact with the following:
    - Pressurized fluids that may penetrate the skin and inject fluids into the body
    - Steam that may cause burns
    - Chemicals that may cause adverse health effects
    - Unintended hose movement (e.g., whipping or flailing of lines)
    - Ice plugs or hydrates that may form during pressure bleed-off in winter operations
- Release hazards may include the following:
    - Flammable fluids that may ignite
    - Hazardous vapors that may pose inhalation risks
- Uncontrolled movement of components (e.g., hydraulically powered pumps, coiled tubing reels)
- Triggers that can cause pressure to be released, including the following:
    - Exceeding pressure limits
    - Hammering on pressurized connections or components
    - Failing to follow proper procedures
    - Using improper or deficient equipment
    - Changing conditions in work processes
    - Failure to communicate changes to original rig-in or operational procedures
- Inadvertent releases (e.g., due to unknown trapped pressure) may occur due to the following:
    - Ice plugs or valves/check valves without proper bleed off points, and
    - Failure to understand the full fluid path.

29.4.2 Hard Piping

IRP-29 does not provide information for the manufacturing or assembly of connections used in hard piping. This IRP focuses on steel seamless pipe manufactured under the following standards:

- ASME B31.3 Process Piping
- API 6A Specification for Wellhead and Christmas Tree Equipment

29.4.2.1 Certification Requirements

IRP At a minimum, hard pipe shall be certified by a competent person in accordance with the OEM's specifications and local jurisdictional regulations for pressure safety equipment. If OEM specifications are unavailable, the Owner's and/or Prime Contractor's operating procedures shall be used.

Certification requirements for hard pipe may include the following:

- Annual ultrasonic testing (UT) (non-destructive)
- Annual magnetic particle inspection
- Periodic UT testing for higher loading operations (e.g., high sand volumes or high-velocity pumping/flow with increased erosion risk)
- Visual inspections before and after each job for signs of wear (e.g., washing, pipe segments, wings, O-rings, sealing faces)
- Confirmation that pipe selection considers operating conditions such as ambient temperature, pressure, and fluid type
- Verification through the Certificate of Compliance that pipe specifications are suitable for the intended service conditions
- Review of traceable documentation, including Material Test Reports, to confirm that the material meets required standards (e.g., chemical composition, mechanical properties, Charpy testing).

29.4.3 Flexible Piping

Flexible piping can safely be used in high-pressure pumping with appropriate controls in place and may provide both operational and safety benefits. Services include mud and cement hoses, choke and kill lines and well stimulation hoses. The applicable API specification hose manufacture depends on the intended service.

Figure 10. Flexible Fracture Hose

Figure 11. Flexible Fracture Hose

Figure 12. Flexible Fracture Hose

29.4.3.1 Codes and Standards

The following codes and standards are referenced in this section:

- API Specification 7K Drilling and Well Servicing Equipment, Sixth Edition, December 2015
- API Specification 16C Choke and Kill Equipment, Third Edition, March 2021
- API Specification 17J Specification for Unbonded Flexible Pipe, Fourth Edition, May 2014
- API Specification 17K for Bonded Flexible Pipe, Third Edition, August 2017
- API Recommended Practice 17B for Recommended Practice for Flexible Pipe, Fifth Edition, May 2014, Reaffirmed, March 2021

29.4.3.2 Construction and Connections

Flexible piping is designed to fail differently from hard piping. The body of flexible piping is constructed in multiple layers to meet requirements for pressure, temperature, fluid type and external environment. These layers are typically comprised of the following:

- One or more inner rubber liners providing the sealing membrane
- Reinforcement cables or textiles providing pressure strength
- An outer rubber cover protecting the reinforcement from the external environment

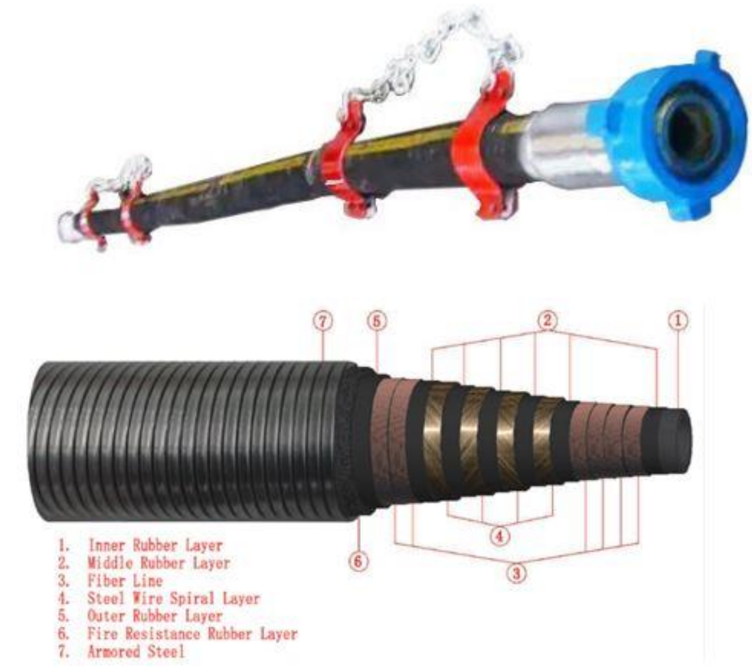
Depending on the service for which the flexible pipe will be used, the construction may include the bonding of the reinforcement layers as defined in API Specification 17K Specification for Bonded Flexible Pipe or unbonded reinforcement layers as defined in API Specification 17J Specification for Unbonded Flexible Pipe. The operator and/or service company may specify additional certifications.

Flexible piping connections are available with hammer union, hub/clamp or flange connections.

IRP High pressure mud and cement hoses meeting API Specification 7K Drilling and Well Servicing Equipment shall not be used for gas service, air drilling or completions/intervention/workover if exposed to wellbore hydrocarbons. Hoses identified under API Specification 7K are designated for pumping drilling liquids (mud) or for pumping cement slurries.

IRP Owners and/or Prime Contractors shall ensure the selected flexible hose type is compatible with the intended service.

Figure 13. Flexible Piping Examples (high pressure)



29.4.3.3 Transport Requirements

IRP **Flexible piping shall not be transported in a manner that exceeds the bend radius specified by the OEM.**

IRP **Flexible piping shall be supported in accordance with OEM recommendations during transport.**

29.4.4 Connections

The following are commonly used temporary connections on hard and flexible piping. This section does not cover all connection types.

- Hammer unions
- Threaded unions
- Flanged connections
- Clamp/hub connections

Other connection types are available but are not commonly used.

IRP Inspections should include, at a minimum, a visual inspection by a competent person for obvious connection damage such as the following:

- Abnormal wear
- Visible cracks
- Impact damage
- Erosion and/or corrosion
- Other, including
    - Corrosion, pitting, percentage of wall loss
    - Thread damage or damage to bolts or receptacles

IRP **Connections shall be evaluated to ensure there are no mismatches or potential failure mechanisms.**

IRP **If the size, style or pressure rating of a connection cannot be confirmed, the component shall be removed from service and clearly marked as out of service.**

IRP **If at any time the condition or integrity of the connection is in doubt, it shall be removed from service and marked as out of service.**

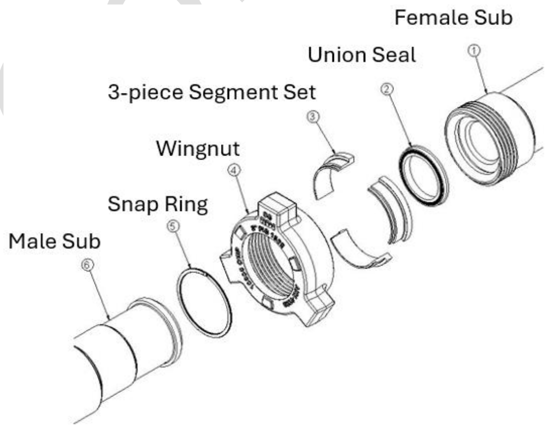
29.4.4.1 Hammer Unions

Hammer Unions, also known as “hammer-seal” unions, are common in oilfield applications due to their quick assembly and broad working pressure range. A hammer union consists of a threaded female sub, a male sub and a hammer/wing nut.

The sealing element (metal-to-metal, elastomer, or a combination) is energized when the wing nut is hammered tight, creating the pressure seal. The threads are used for mechanical assembly only and are not relied upon for pressure containment.

For elastomers used in temporary pipework, see IRP 02 Completing and Servicing Sour Wells.

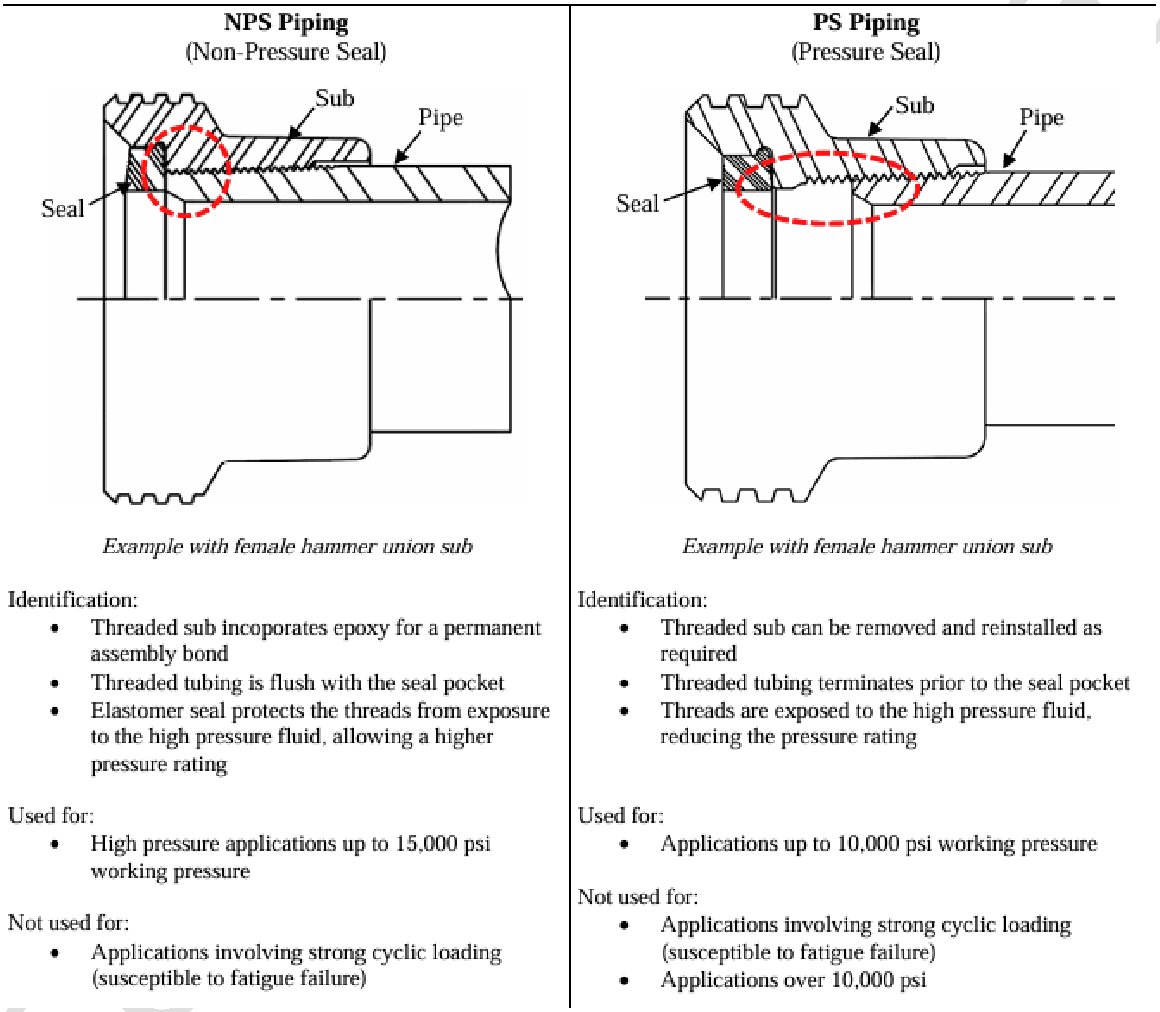
Figure 14. Hammer Union Cutaway



29.4.4.1.1 Hammer Union Pipe-End Thread Types

Hammer unions may be manufactured with different pipe-end thread types for attaching the union sub to pipe:

Figure 15. Hammer Union NPS Piping (Non-Pressure Seal) and PS Piping (Pressure Seal)



NPS Piping (Non-Pressure Seal)	**PS Piping** (Pressure Seal)
Example with female hammer union sub	*Example with female hammer union sub*
Identification: • Threaded sub incoporates epoxy for a permanent assembly bond • Threaded tubing is flush with the seal pocket • Elastomer seal protects the threads from exposure to the high pressure fluid, allowing a higher pressure rating	Identification: • Threaded sub can be removed and reinstalled as required • Threaded tubing terminates prior to the seal pocket • Threads are exposed to the high pressure fluid, reducing the pressure rating
Used for: • High pressure applications up to 15,000 psi working pressure	Used for: • Applications up to 10,000 psi working pressure
Not used for: • Applications involving strong cyclic loading (susceptible to fatigue failure)	Not used for: • Applications involving strong cyclic loading (susceptible to fatigue failure) • Applications over 10,000 psi

29.4.4.1.2 Hammer Union Identification

Hammer unions are designated by size, figure type and rated Cold Working Pressure (CWP). These designations are typically stamped or cast into the male sub, female sub and wing nut.

Figure 16. Example Hammer Union Identification

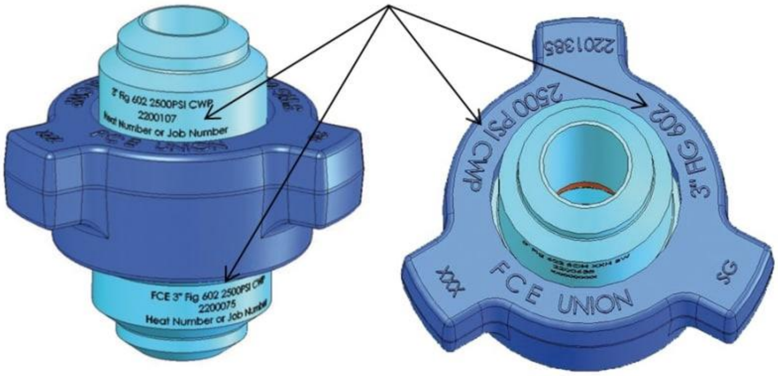


Table 4 identifies types and pressure ratings for commonly used hammer unions.

Table 4. Hammer Union Specifications

Hammer Union Specification Type	Standard Service Pressure Rating Working/Test (psi)	Sour Service Pressure Rating Working/Test (psi)
100	1,000 / 1500	NA
200	2,000 / 3,000	NA
206	2,000 / 3,000	NA
207	2,000 / 3,000	NA
211	2,000 / 3,000	NA
400	2,500 / 3,750	2,500 / 3,750
600	6,000 / 9,000	NA
602	6,000 / 9,000	6,000 / 9,000
1002	10,000 / 15,000	7 500 / 11,250
1003	10,000 / 15,000	7 500 / 11,250
1502	15,000 / 22,500	10,000 / 15,000
1505	15,000 / 22,500	NA
2002	20,000 / 30,000	NA
2202	NA	15,000 / 22,500

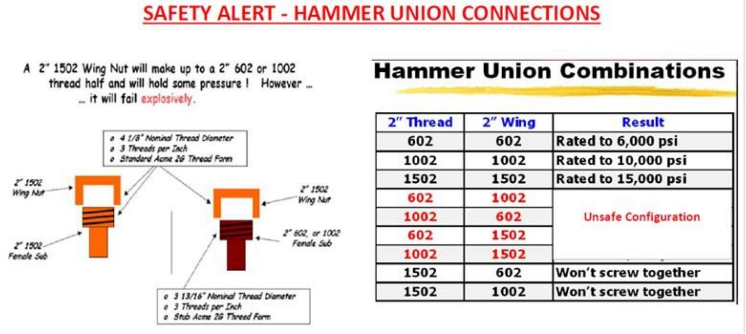
29.4.4.1.3 Hammer Union Potential Hazards

API Recommended Practice 7HU1, Safe Use of 2-Inch Hammer Unions for Oilfield Applications, highlights a severe hazard: the interchangeability of a two-inch (2”) Figure 1502 wing nut with female subs of 402, 602 and 1002. These mismatches may appear to fit but will fail catastrophically under pressure.

IRP Hammer union connections shall be figure-matched.

Figure 17 illustrates mismatched unions that can lead to failure and Figure 18 shows a tool used to ensure no mismatched unions for 1502 combinations.

Figure 17. Mismatched Unions



SAFETY ALERT - HAMMER UNION CONNECTIONS

A 2" 1502 Wing Nut will make up to a 2" 602 or 1002 thread half and will hold some pressure ! However … … it will fail explosively.

Hammer Union Combinations

2" Thread	2" Wing	Result
602	602	Rated to 6,000 psi
1002	1002	Rated to 10,000 psi
1502	1502	Rated to 15,000 psi
602	1002	Unsafe Configuration
1002	602	
602	1502	
1002	1502	
1502	602	Won't screw together
1502	1002	Won't screw together

Figure 18. 1502 Go-No-Go Tool

29.4.4.2 Threaded Unions

Threaded unions join two pipe segments using male and female threaded ends. In threaded unions, the threads themselves provide the pressure seal through contact and compression.

Common thread types include the following:

- NPT
- National Pipe Taper Fuel (NPTF)
- Short-Thread Coupling
- Long-Thread Coupling

IRP NPT fittings must be rated for the Maximum Allowable Working Pressure (MAWP) of the system in accordance with ASME B31.3 Process Piping. See ASME B31.3 for applicable limits by pipe schedule and fitting type.

Figure 19. Threaded Unions

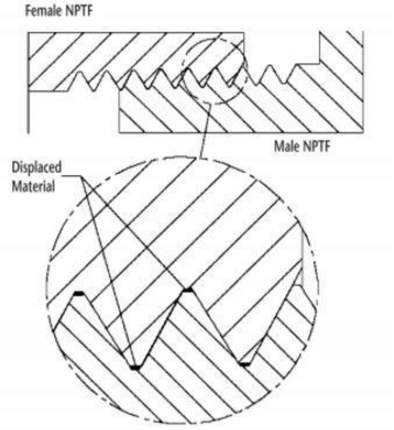


Figure 4 – NPTF, Fully Engaged (hand tight plus 1 turn)

29.4.5 Flanged Connections

Flanged connections are assemblies of flanges, gaskets and bolting brought together to form a pressure-containing connection. The governing standards for flanged connections typically seen on temporary piping are API Specification 6A Specification for Wellhead and Tree Equipment and ASME B16.5 Pipe Flanges and Flanged Fittings.

29.4.5.1 API Specification 6A Flanged Connections

API 6A defines the pressure ratings for flange material, gaskets and bolts/nuts. API Specification 6A governs the design requirements for 6B and 6BX flange types as shown below. All API 6A flanges use a ring-type gasket to achieve a metal-to-metal seal between the mating flanges. This seal is achieved by compressing the ring gasket into the groove by torquing the bolting.

29.4.5.2 Flange Identification

IRP All API 6A flanges shall be marked, at a minimum, with the following information:

- Nominal bore size
- End/outlet connector size(s)
- Rated working pressure
- Ring groove type and number

Table 5. Adapted from API 6A Rated Working Pressures and Size Ranges of Flanges

Rated Working Pressure		Flange Size Range			
		Type 6B		Type 6BX	
MPa	psi	mm	in	mm	in
13.8	2000	52 - 540	2 1/16 – 21 1/4	679 – 762	26 ¾ - 30
20.7	3000	52 - 527	2 1/16 – 20 ¾	679 – 762	26 ¾ - 30
34.5	5000	52 - 279	2 1/16 - 11	346 – 540	13 5/8 – 21 ¼
69.0	10,000			46 – 540	1 13/16 – 21 ¼
103.5	15,000			46 – 476	1 13/16 – 18 ¾
138.0	20,000			46 - 346	1 13/16 – 13 5/8

Equipment needs to be designed to operate in one or more specified temperature classes (See Table 6) or to minimum and maximum temperature ratings as agreed by the purchaser and manufacturer.

Table 6. Adapted from API 6A Table 2 Temperature Ratings

Temperature Class	Temperature Range			
	Minimum (lowest ambient temperature the equipment can be subjected to)		Maximum (highest temperature of the fluid that can directly contact the equipment)	
	°C	°F	°C	°F
K	-60	-75	82	180
L	-46	-50	82	180
N	-46	-50	60	140
P	-29	-20	82	180
S	-18	0	60	140
T	-18	0	82	180
U	-18	0	121	250
V	2	35	121	250

API 6A states that equipment used at temperatures more than 121°C (250°F) may need to have its rated working pressure (RWP) derated to account for a loss in material strength. An engineering analysis can be completed to determine the allowable pressure of the equipment at these temperatures or, alternatively, the RWP of the API 6B flanged connections can be derated as per Table 7.

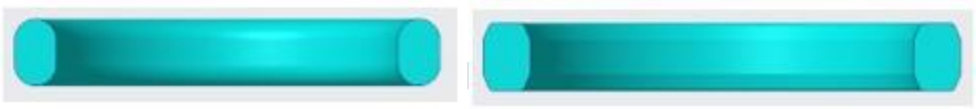
Table 7. Adapted from API 6A Table G.2 Optional Pressure-Temperature Ratings for 6B Flanges

Pressure Rating for Classes K to U		Derated Pressure			
		Class X		Class Y	
MPa	psi	MPa	psi	MPa	psi
13.8	2000	13.1	1905	9.9	1430
20.7	3000	19.7	2860	14.8	2145
34.5	5000	32.8	4765	24.7	3575
138.0	20,000			46 - 346	1 13/16 – 13 5/8

29.4.5.3 Ring Gasket Types

IRP A new ring gasket shall be used every time a flange is made up. For API 6A flanges, an API 6A monogrammed ring gasket shall be used.

Figure 20. R Gaskets



This R ring gasket is used in flanges up to 5,000 psi. It fits into 6B flanges and is available as either an octagonal or oval cross-section. This gasket has the same nominal pitch diameter as the groove it sits in. When placed into the groove it should contact, or nearly contact, the groove on both its Outside Diameter (OD) and Inside Diameter (ID). When properly assembled, there will be an S Ref between the two flange faces of approximately 3/16” (see Figure 21).

Figure 21. API 6A Type 6B Flange with ‘R’ Gasket and S Ref = 3/16”

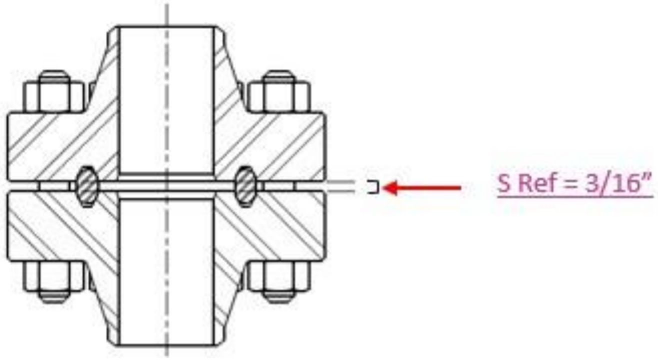


Figure 22. RX Gaskets

RX gaskets are pressure-energizing versions of an R gasket. This gasket is interchangeable with R gasket grooves and fits into 6B flanges. RX gaskets have a slightly larger pitch diameter than the groove they fit into. When placed into its groove, the gasket contacts the OD firmly and fits loosely at the ID. This fit compresses the gasket vertically and radially, storing more energy and creating a higher contact load on the OD of the seal. The S Ref between flanges is approximately a half an inch (½”) (See Figure 23).

Figure 23. API 6A Type 6B Flanges with ‘RX’ Gasket and S Ref = ½”

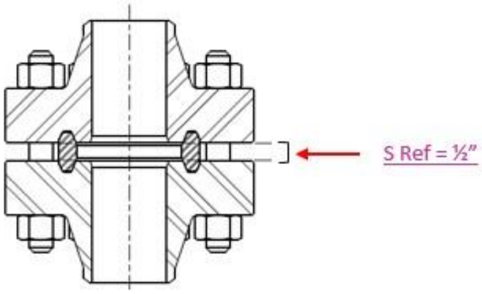
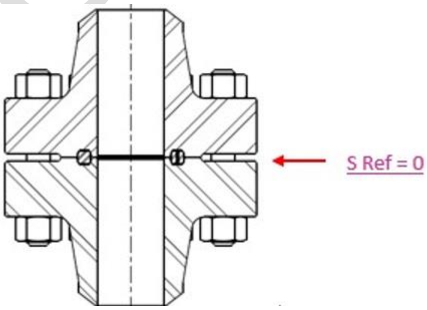


Figure 24. BX Gaskets

BX gaskets are used in flanges up to 20,000 psi. These fit into 6BX flanges and the design requires at least one of the joining flanges to have a raised face. BX gaskets fit only into BX-style ring grooves, and face-to-face contact is required between flange faces when properly made up (S Ref=0, See Figure 25). The BX gasket contacts both the ID and OD of its mating groove but is designed to primarily seal on the OD. They also have a pressure-balancing hole through the cross section.

Figure 25. API 6A Type 6BX Flange with ‘BX’ Gasket and S Ref = 0 (flanges face to face)



29.4.5.4 Bolting

The final component in a flanged connection is the bolting, which provides the necessary compression for proper sealing of the ring gasket. ASTM standards apply to bolting for 6B and 6BX flanges (e.g., ASTM A193/A320 for studs and ASTM A194 for nuts).

Proper torque provides two effects:

1. Coning: When two metal surfaces of different harness contact, the softer material plastically deforms to match the harder surface finish
2. Intimate Contact: Adequate clamping force eliminates gaps at the interface

Both effects are achieved by applying the correct bolt torque. See API 6A for bolt make-up patterns.

29.4.5.5 Recommended Make-up Torque

The torque values given in API 6A Annex H correspond to the desired tension required in the bolting to achieve proper flange sealing and functionality, and induce a stress in the bolt of 50% of the bolt yield. To use these tables, it is necessary to know the nominal stud size and the yield strength of the bolt material. The nominal size of the stud is the measured outside diameter of the stud. The bolt material grade is stamped on the end of the studs to identify its material.

The following are the common stud grades used in Canada:

- B: High temperature/high-pressure service
- L: Low-temperature, outdoor service
- M: Sour service

The yield strength of these common stud grades is as follows:

- ASTM A193/A193M Grade B7M: 550 MPa (80,000 psi)
- ASTM A320/A320M Grade L7M: 550 MPa (80,000 psi)
- ASTM A193/A193M Grade B7: 720 MPa (105,000 psi)
- ASTM A320/A320M Grade L7: 720 MPa (105,000 psi)

IRP The following flanges should not be made up beyond 275 MPa (40 000 psi) bolt stress due to potentially high flange stresses:

- 346 mm (13 5/8 in): 13.8 MPa (2,000 psi)
- 425 mm (16 3/4 in): 13.8 MPa (2,000 psi)
- 540 mm (21 1/4 in): 13.8 MPa (2,000 psi)
- 346 mm (13 5/8 in): 20.7 MPa (3,000 psi)

- 425 mm (16 3/4 in): 20.7 MPa (3,000 psi)
- 527 mm (20 3/4 in): 20.7 MPa (3,000 psi)

Table 8 shows the recommended torques when bolting flanges. Two coefficients of friction are shown. A coefficient of friction of 0.13 approximates the friction with threads and nut bearing surfaces being bare metal and well lubricated. A coefficient of friction of 0.07 approximates threads and nut face coated with fluoropolymer material. Proper torque and S Ref based on ring gasket type, (see Figures 21, 23 and 25) are key to ensuring the flanges are made up properly. Table 8 provides an example. Refer to API and/or manufacturer's documents for friction factors, etc.

Table 8. Adapted from API 6A Table H.1 Recommended Torques for Flange Bolting

Stud Diameter	Threads per Inch	Studs Sy = 550 MPa Bolt Stress = 275 MPa			Studs Sy = 720 MPa Bolt Stress = 360 MPa			Studs Sy = 655 MPa Bolt Stress = 327.5 MPa		
		Tension (F)	Torque (f = 0.07)	Torque (f = 0.13)	Tension (F)	Torque (f = 0.07)	Torque (f = 0.13)	Tension (F)	Torque (f = 0.07)	Torque (f = 0.13)
Inches	**1/in.**	**kN**	**N-m**	**N-m**	**kN**	**N-m**	**N-m**	**kN**	**N-m**	**N-m**
0.500	13	25	36	61	33	48	80			
0.625	11	40	70	118	52	92	155			
0.750	10	59	122	206	78	160	270			
0.875	9	82	193	328	107	253	429			
1.000	8	107	288	488	141	376	639			
1.125	8	140	413	706	184	540	925			
1.250	8	177	569	981	232	745	1,285			
1.375	8	219	761	1,320	286	996	1,727			
1.500	8	265	991	1,727	346	1,297	2,261			
1.625	8	315	1,263	2,211	412	1,653	2,894			
1.750	8	369	1,581	2,777	484	2,069	3,636			
1.875	8	428	1,947	3,433	561	2,549	4,493			
2.000	8	492	2,366	4,183	644	3,097	5,476			
2.250	8	631	3,375	5,997	826	4,418	7,851			
2.500	8	788	4,635	8,271	1,032	6,068	10,828			
2.625	8							1,040	6,394	11,429
2.750	8							1,146	7,354	13,168

Stud Diameter	Threads per Inch	Studs Sy = 550 MPa Bolt Stress = 275 MPa			Studs Sy = 720 MPa Bolt Stress = 360 MPa			Studs Sy = 655 MPa Bolt Stress = 327.5 MPa		
		Tension (F)	Torque (ƒ = 0.07)	Torque (ƒ = 0.13)	Tension (F)	Torque (ƒ = 0.07)	Torque (ƒ = 0.13)	Tension (F)	Torque (ƒ = 0.07)	Torque (ƒ = 0.13)
Inches	1/in.	kN	N-m	N-m	kN	N-m	N-m	kN	N-m	N-m
3.000	8							1,375	9,555	17,156
3.250	8							1,624	12,154	21,878
3.750	8							2,185	18,685	33,766
3.875	8							2,338	20,620	37,293
4.000	8							2,496	22,683	41,057

Table 9. Adapted from API 6A Table H.2 Recommended Torques for Flange Bolting (U.S. customary units, USCS)

Stud Diameter	Threads per Inch	Studs Sy = 80 ksi Bolt Stress = 40 ksi			Studs Sy = 105 ksi Bolt Stress = 52.5 ksi			Studs Sy = 95 ksi Bolt Stress = 47.5 ksi		
		Tension (F)	Torque (ƒ = 0.07)	Torque (ƒ = 0.13)	Tension (F)	Torque (ƒ = 0.07)	Torque (ƒ = 0.13)	Tension (F)	Torque (ƒ = 0.07)	Torque (ƒ = 0.13)
Inches	1/in.	lbf	ft-lbf	ft-lbf	lbf	ft-lbf	ft-lbf	lbf	ft-lbf	ft-lbf
0.500	13	5,676	27	45	7,450	35	59			
0.625	11	9,040	52	88	11,865	68	115			
0.750	10	13,378	90	153	17,559	118	200			
0.875	9	18,469	143	243	24,241	188	319			
1.000	8	24,230	213	361	31,802	279	474			
1.125	8	31,618	305	523	41,499	401	686			
1.250	8	39,988	421	726	52,484	553	953			
1.375	8	49,340	563	976	64,759	739	1,281			
1.500	8	59,674	733	1,278	78,322	962	1,677			
1.625	8	70,989	934	1,635	93,173	1,226	2,146			
1.750	8	83,286	1,169	2,054	109,313	1,534	2,696			
1.875	8	96,565	1,440	2,539	126,741	1,890	3,332			
2.000	8	110,825	1,750	3,094	145,458	2,297	4,061			
2.250	8	142,292	2,496	4,436	186,758	3,276	5,822			
2.500	8	177,685	3,429	6,118	233,212	4,500	8,030			
2.625	8							233,765	4,716	8,430
2.750	8							257,694	5,424	9,712

Stud Diameter	Threads per Inch	Studs Sy = 80 ksi Bolt Stress = 40 ksi			Studs Sy = 105 ksi Bolt Stress = 52.5 ksi			Studs Sy = 95 ksi Bolt Stress = 47.5 ksi		
		Tension (F)	Torque (ƒ = 0.07)	Torque (ƒ = 0.13)	Tension (F)	Torque (ƒ = 0.07)	Torque (ƒ = 0.13)	Tension (F)	Torque (ƒ = 0.07)	Torque (ƒ = 0.13)
Inches	1/in.	lbf	ft-lbf	ft-lbf	lbf	ft-lbf	ft-lbf	lbf	ft-lbf	ft-lbf
3.000	8							309,050	7,047	12,654
3.250	8							365,070	8,965	16,136
3.750	8							491,099	13,782	24,905
3.875	8							525,521	15,208	27,506
4.000	8							561,108	16,730	30,282

Note: Sy denotes specified yield strength.

29.4.5.6 Nuts

The common nut grades used in Canada are ASTM A194 Grades 2H, 2HM, 7 and 7M.

Note: Recommended torque values are not determined by the nut’s yield strength. They are based on achieving a target preload in the stud and on assumed friction/lubrication. Nuts still need to be of adequate grade for the service to prevent thread damage or embedding.

IRP Lubrication shall not contain lead, tin, antimony or bismuth when used for applications above 260°C (500°F).

29.4.5.7 Loading Limitations

The capabilities of API flanges under combinations of loading are published in the following API Technical Reports:

- API TR 6AF Technical Report on Capabilities of API Flanges Under Combinations of Loading
- API TR 6AF1 Technical Report on Temperature Derating of API Flanges under Combinations of Loading
- API TR 6AF2 Technical Report on Capabilities of API Flanges Under Combinations of Loading - Phase II

IRP API TR 6AF2 should be used as the resource for flange loading limitations.

29.4.5.8 Flange Failure

Flange failure is not always due to the ring gasket. The condition of the flange faces and bolting can lead to leakage. A small leak can quickly grow as high-pressure fluid erodes the gasket, ring groove and/or flange.

Figure 26. Example Flange Failure

29.4.5.9 Restraint Recommendation

For API 6A flanged connections, the bolting provides the restraint that prevents complete separation; therefore, no additional restraint is required unless local jurisdictional regulations specify otherwise.

Note: Based on rigorous design and quality requirements, and the engineering work done for the API Technical Reports (See API TR 6AF2 Technical Report on Capabilities of API Flanges Under Combinations of Loading - Phase II), API 6B and 6BX flanges will leak at the ring gasket before there is a catastrophic failure of the bolting. Therefore, no further restraint is necessary. Non-API flanges must be evaluated to understand their failure modes and failure potential (e.g., destructive test, Finite Element Analysis).

IRP Flanged pipework is a combination of flanges connected by hard piping. If proper tracking and identification of the flange is not verifiable, then the component shall be removed from service.

29.4.5.10 Recommended Assembly

IRP API flanges shall be assembled in accordance with API 6A Annex H: Recommended Assembly of Closure Bolting, and the manufacturer's specifications for the flange configuration, sealing element and pressure/ temperature rating.

IRP Torque equipment shall be calibrated in accordance with the manufacturer's specifications. Workers performing torquing or calibration shall be competent.

29.4.5.11 ASME Flanges

ASME Flanges designed for piping applications come in many configurations and materials and fall under several codes and standards. For this reason, this IRP does not concisely define their requirements; however, some recommendations are provided.

Within the ASME standards, multiple carbon steels, low-alloy steels, high-alloy steels and nonferrous metals can be used to make flanges.

IRP Pressure–temperature ratings are maximum allowable working gauge pressures and shall be referenced in the appropriate ASME flange standard tables. The ASME flange class and construction material identify the operating pressure and temperature.

29.4.5.12 ASME Flange Identification

IRP All ASME/ANSI flanges should be marked with the following:

- Manufacturer’s name or trademark
- Material of construction designation
- Flange pressure rating designation (Class)
- Conformance (e.g., ASME B16 series, ASME B16.5 Pipe Flanges and Flanged Fittings: NPS ½ through NPS 24; ASME B16.47 Large Diameter Steel Flanges: NPS 26 through NPS 60; ANSI/MSS SP-44 Steel Pipeline Flanges)
- Nominal Pipe Size (NPS) or Diameter Nominal (DN)

29.4.5.13 ASME Flange Type and Use

ASME flange types are differentiated by size and class in the various ASME standards. The combination of the flange class and size define the physical geometry of the flange. The common ASME flange types are covered in the following standards:

- ASME B16.5-2020: Pipe Flanges and Flanged Fittings NPS ½ through NPS 24 Metric/Inch Standard
  - Flanges sized NPS ½ through 24
  - Classes 150, 300, 400, 600, 900, 1500 and 2500
- ASME B16.47-2020: Large Diameter Steel Flanges NPS 26 through NPS 60 Metric/Inch Standard
  - Flanges sized NPS 26 through 60
  - Classes 75, 150, 300, 400, 600 and 900
- ANSI/MMS-SP-44-2019: Steel Pipeline Flanges
  - Flanges sized NPS 12 through 60
  - Classes 150, 300, 400, 600, 900

The class refers to the ASME B16.5 designation for pressure/temperature ratings (e.g., Class 150, 300, 400, 600, 900, 1500, 2500). The higher the class number, the heavier the flange.

ASME flange sizes are based on Nominal Pipe Size (NPS), which corresponds to a reference nominal diameter. International standards use DN. Table 10 shows NPS-DN equivalencies.

Table 10. Relationship Between NPS and DN (Adapted from ASME)

NPS	DN
½	15
¾	20
1	25
1 ¼	32
1 ½	40
2	50
2 ½	65
3	80
4	100

Note: For NPS ≥ 4, DN = 25 x NPS.

29.4.5.14 ASME Flange Assembly

IRP ASME flanges shall be assembled in accordance with the manufacturer's specifications for the flange configuration, sealing element and pressure/temperature rating to ensure proper makeup.

29.4.6 Clamp/Hub Connections

Clamp/hub connections are assemblies consisting of a hub, seal ring, clamp and bolting.

Hub and clamp-style connectors are an alternative to ASME B16.5 or API 6A/16A flanges. They are rated from 13.8 MPa to 138.0 MPa (2,000 psi to 20,000 psi), require fewer bolts and eliminate bolt-hole alignment issues. The four-bolt design allows the clamp to be rotated for installation in tight spaces, and the assembly is lighter and more compact.

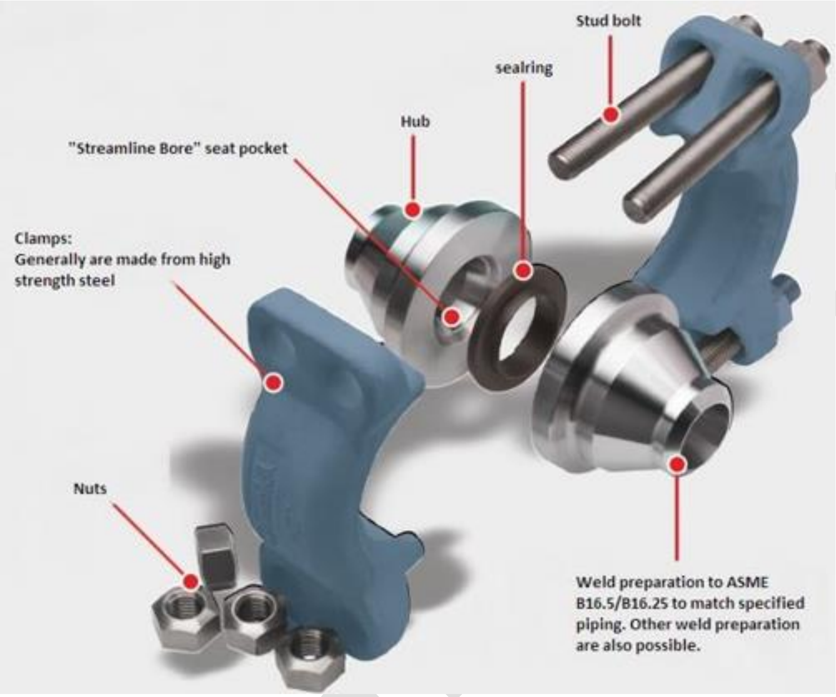
This type of connector includes the following three basic components:

1. Hub
2. Sealing ring (elastomeric, standard API ring gasket or proprietary mechanically energized seal)

3. Clamp ring with bolting and, potentially, spherical washers or nuts

Hub and clamp connectors provide a metal-to-metal seal (sometimes with an elastomeric backup) between the seal ring and the machined seat pockets of the two hub faces. The seal ring design is also pressure-energized. This style of seal allows for lower bolting torque when compared to a ring-gasket flange, which relies on bolt torque to energize the seal.

Figure 27. Hub/Clamp Connector Four Bolt Design



Some hub clamps use a standard ring gasket energized by clamp force. This style is non-directional, unlike other versions that require orientation.

29.4.6.1 API Specifications 6A and 16A

API 16A provides the design requirements for clamps used with 16B and 16BX hubs. Clamps are assigned a clamp number based on hub size and pressure rating, as referenced in API 16 Pressure Ratings and Size Ranges for Type 16B and 16BX Hubs.

29.4.6.2 Hub/Clamp Potential Hazards

IRP **Clamps shall be inspected to verify manufacture in accordance with API 6A or 16A. Prior to the adoption of these API standards, non-API clamps may not be interchangeable with hubs, seal rings or other clamps manufactured to the API standards.**

IRP The correct clamp shall be used with the appropriate hub for the application. Incorrect hub ID or pressure rating may cause failure. Incorrect clamp selection (undersized or oversized) may cause complete connection failure due to loss of mechanical engagement with the hub.

Hub clamp connections present the following concerns:

1. Clamp sections are mated pairs; do not swap individual clamps
2. The orientation of clamp sections may be important; consult manufacturer specifications
3. The integrity of the seal depends on proper clamp torque
4. Avoid side loading when using this connection style.

IRP Clamp make-up should follow the manufacturer's specifications for bolt/nut type, tightening pattern, incremental torque steps, final torque values and required re-check intervals.

IRP Hub and clamp-style connections are not considered self-restraining and shall be evaluated for restraint.

Some manufacturers designate a required flow path. Ensure that connections are installed accordingly to prevent failure from erosive fluid flow in the wrong direction.

29.4.6.3 Special Considerations

IRP High-load surfaces where the clamp engages the hub should be inspected for galling (adhesive wear) after each use. If galling or scoring is found, the hub should be removed from service until repaired per the manufacturer's recommendations.

IRP Hub mating surfaces should be inspected for corrosion or damage that may prevent full contact. Damaged hubs should be removed from service and repaired per manufacturer specifications.

IRP Elastomeric hub seals should be inspected for condition and orientation. Abnormal wear may indicate incorrect installation. Follow the manufacturer's specifications to replace seals.

29.4.7 Other Piping Components

Other piping components–such as joints, valves, burst disks, chokes, laterals, wyes, elbows and crosses–provide flexibility, orientation and functionality within the pipework system. These components can alter flow dynamics, may experience substantial forces and are more prone to wear. For instance, Figures 28 and 29 show wear observed on a swivel.

IRP Other piping components shall be inspected and maintained in accordance with OEM recommendations.

IRP If the condition or integrity of a component is in doubt, it shall be removed from service and clearly marked as out of service.

Figure 28. Washed Out Swivel

Figure 29. Washed Out Swivel

29.4.8 Mounted Pipework and Manifold Components

Mounted pipework and manifold components are permanently installed on equipment (e.g., trailers, trucks, skids) to allow pressurized flow in or out. They are not typically removed when mobilizing between job sites. This mounted pipework utilizes the same components identified in this IRP. Examples of mounted pipework include the following:

- Manifold systems (e.g. choke manifold and pump manifold)
- Reel-iron assembly and rotating joint within a coiled tubing unit
- Piping contained within a trailer or attached to a skid
- Discharge-iron assembly on pumping units

The mounts supporting the pipework may be designed only for transport and not for the forces generated during a piping failure.

IRP The equipment owner and/or manufacturer should assess the potential for mounting hardware failure and associated worker safety risks. This may require installing restraints on the mounted equipment.

Figure 30. Example of Mounted Pipework

There may be situations where the temporary piping system and mounted pipework share the same design and therefore the same likelihood of failure. A restraint system may be considered as a control measure; however, in some cases, applying restraints to mounted pipework may be impracticable or could introduce additional risk. For example, the reel on a coiled-tubing unit contains hammer union piping inside the reel (i.e., the temporary piping system connecting to the reel). In such cases, the equipment owner may determine–based on worker safety or operational limitations–that installing restraints in the reel is unnecessary. Instead, they may choose to anchor the temporary piping system to the reel, recognize that the hammer union piping is already self-contained within the reel and implement an exclusion zone around the reel as sufficient mitigation to ensure worker safety.

It is the responsibility of the equipment owner and manufacturer to implement appropriate measures that ensure worker safety without introducing additional risk. See Appendix D: Case Study.

Figure 31. Hammer Union Connections Inside a Coiled Tubing Reel Unit

In another example, a pumping unit owner may find that the mounts on the hammer union pipework cannot withstand failure forces and may reinforce or modify them to handle the expected loads.

The following figures show mounted pipework with restraints.

Figure 32. High Pressure Piping on Twin Pumper with Restraints

Figure 33. Fracture Pump Bridle with Restraints

Figure 34. Fracture Pump Bracket

29.5 **Pipework System Assembly**

This section outlines recommended practices for assembling the pipework system. Details on the selection, use and handling of piping, components and connections are provided in Sections 29.4.1 Piping, 29.4.4 Connections and 29.4.7 Other Piping Components.

29.5.1 Pre-Rig In

Manufacturers specify recommended flow rates for components based on velocity to reduce wear, improve safety and extend component life.

IRP The maximum allowable fluid velocity shall be determined by the OEM and the Service Company based on the fluid type being pumped. Different velocity limits shall be applied for abrasive versus clean fluids.

Note: Pipework systems often include components from multiple manufacturers, which may not share the same recommended flow rates.

IRP Each component shall be marked with a unique identifier to enable tracking through service and maintenance cycles.

See Appendix D: Checklists for a sample Pre-Rig In Inspection Checklist.

29.5.2 Installation and Make Up

IRP All connection points shall be clean (i.e., free of ice, mud, dirt, debris) and lubricated.

IRP Components should be assembled in accordance with the Owner’s and/or Prime Contractor’s site plan (if available) or, at minimum, with the manufacturer’s specifications.

IRP All components shall be inspected during rig-in and rig-out (See Sections 29.5.3.1 Pre-Rig In and Rig Out Inspections and 29.5.3.2 Pre-Use Inspection).

Additional periodic inspections may be conducted depending on operating conditions (e.g., operating area, product line, job size, fluid rates, duration), operator procedures or OEM specifications. See Section 29.5.3.3 Periodic Inspections for more information.

IRP For pumping operations down the wellbore, the piping system shall have some flexibility to accommodate operational movement.

Swivels may be used to provide this flexibility. See Section 29.5.2.1 Considerations for Swivels in Pumping Operations for more information.

IRP Swivels shall not be used for flowback operations due to their limited lifespan in erosive environments. See IRP 04: Well Testing and Fluid Handling.

29.5.2.1 Considerations for Swivels in Pumping Operations

Swivels provide rotational flexibility that reduces external forces on the pipework system and helps dampen vibration. Using one three-way swivel or two two-way swivels provides three points of rotation to accommodate free movement of the lines in all planes. Using multiple three-way swivels may provide a means to avoid lockup (three points of rotation: up and down, left and right, horizontal).

IRP Swivels should be positioned between 45° and 100°.

Any angle outside these parameters may not work as designed and may allow too much freedom of movement. This also helps to avoid open swivels (which would no longer be able to rotate properly).

29.5.2.2 Considerations for Flanged Connections

Proper flange alignment is critical to achieve rated temperature and pressure limits.

IRP Flanges shall be aligned in a manner that avoids applying additional forces on the pipework system.

IRP When assembling ring gasket connections, the ring grooves shall be thoroughly inspected to verify they are clean, undamaged and free from corrosion.

IRP Ring gaskets shall be new and undamaged when assembling.

29.5.2.3 Considerations for Hub/Clamp Connections

IRP The following steps should be completed to ensure hub/clamp components are clean and in good operating condition:

- Ensure seals are not cracked or worn (replace if necessary)
- Lubricate bolts with an approved lubricant (as defined by the manufacturer)
- Insert the seal ring into one of the bores and ensure it is clean and lubricated with an approved lubricant (as defined by the manufacturer)

When using hub/clamp connections the following steps are typically followed:

- Assemble components and lubricate the flange surfaces and seal ring:
    - Pull flange faces together
    - Position clamps and hand-start bolts (minimum two full turns) to avoid cross-threading
- Ensure surfaces are flush and seated before tightening clamps
- Torque bolts in accordance with manufacturer's specifications and verify final assembly

29.5.2.4 Considerations for Threaded Unions

Sealing compounds need to be compatible with the ambient temperature rating and fluid service.

29.5.2.5 Considerations for Flexible Hoses

IRP Only OEM-approved end connections rated for the intended service shall be installed.

IRP The bend radius specified by the OEM shall not be exceeded and may require brackets or slings for support.

IRP End connections shall be completely clean (i.e., free of ice, mud, dirt, debris) and free from mechanical damage (e.g., burrs).

IRP Seals shall be fitted as per OEM specifications.

IRP Flexible hoses should be protected from potential abrasion, cutting or impact damage.

IRP OEM specifications shall be followed for handling, transport, storage, rig in/out, installation (including support, securement, twisting limits, bend radius, temperature and fluid compatibility), maintenance, inspection and testing.

IRP Options for an engineered system to secure flexible hoses should be evaluated.

29.5.3 Inspections

Inspections are an integral part of safe and effective use of temporary pipework. Visual inspections can identify existing or potential damage. Types of inspections include the following:

- Inspections as part of the Pipework Management System (Section 29.3.3)
- Pre-rig in/rig out inspections
- Pre-use inspection after assembly (rig in)

- Periodic inspections after assembly.

IRP Inspections shall be completed by a competent person.

IRP If the condition or integrity of hard or flexible piping is in doubt, it shall be removed from service and marked accordingly.

IRP Inspections should include, at a minimum, a visual inspection of all hard or flexible piping for damage such as the following:

- Abnormal wear
- Visible cracks
- Impact damage
- Erosion
- Flexible hose connections, including the crimp/compression make-up between the hose and the end connection

29.5.3.1 Pre-Rig In and Rig Out Inspections

Pre-rig in/rig out inspections for hard and flexible piping may include the following:

- Visual inspection
- Ultrasonic thickness test
- Borescope inspection
- Magnetic particle analysis (if required)
- Pressure test to confirm the component and/or system is in suitable condition.

IRP Components that fail the initial visual inspection shall be removed from service until they pass reassessment for service.

IRP Before use, documentation for new temporary pipework components shall be reviewed, a visual inspection completed and identification bands installed.

29.5.3.1.1 Union-Equipped Hard Piping

IRP A rig-in or rig-out visual inspection should include the following for hard piping:

- Ensure the union is complete, in good condition and free of defects
- Ensure all threads are in good condition and clean (use a wire brush or cleaning fluid and scrub brush)
- Lubricate the threads on both threaded and wing halves

- Ensure the elastomer is present, properly installed and not warped or cracked

- Confirm unions are not mismatched. See Section 29.6.9 Potential Hazards for more information on mismatched unions.

Note: See Section 29.4.5 Flanged Connections for further details.

29.5.3.1.2 Flexible Piping

IRP A rig-in or rig-out visual inspection should be conducted in accordance with the OEM's recommendations and API 574 Inspection Practices for Piping System Component and include the following for flexible piping:

- Confirm certification for the intended service
- Inspect the hose along its full length, including end fittings, paying particular attention to high-risk areas (e.g., near equipment, or previous hose body repair areas)
- Check for cuts, abrasions or other visible damage
- Inspect the outer cover for looseness, kinks, bulges, soft spots, abrasion, cuts or gouges

IRP Flexible hoses shall be inspected annually and tagged with a new inspection record.

IRP Cuts or gouges shall be assessed for failure risk. If reinforcement is exposed, the hose shall be replaced immediately. Minor cuts or abrasions may be repairable.

IRP Repairs, service and maintenance shall be performed by a competent repair person in accordance with OEM specifications (See IRP 07: Competencies for Critical Roles in Drilling and Completions).

29.5.3.2 Pre-Use Inspection

IRP A pre-use inspection should confirm all segments are secure and inserts are correctly placed and in good condition.

IRP A pre-use inspection for installed flexible hoses should include checking:

- the outer cover looking for signs of looseness, kinks, bulges, soft spots, signs of abrasion, cuts or gouges,
- the hose body behind the hose end fitting for signs of overbending,
- areas of the hose that are near other steel or equipment edges,
- end couplings for signs of leakage, corrosion, erosion, or cracking of the steel end,
- for an inspection tag (e.g., steel band) and/or record of inspection (based on stamped serial numbers).

29.5.3.3 Periodic Inspections

IRP OEM specifications and local jurisdictional regulatory requirements for periodic inspections and testing of hard or flexible piping must be followed. If unavailable from the OEM, utilize the Owner's and/or Prime Contractor's operating procedures.

Note: API Recommended Practice 574 Inspection Practices for Piping System Component, may be a useful resource.

29.5.3.4 Post-Installation Inspections and Testing

IRP Prior to pressure testing, a supervisor shall walk the line to verify correct assembly (e.g., proper component installation, sufficient swivels for line movement).

IRP The Restraint Owner shall ensure the pipe restraint system is appropriately installed and anchored.

29.5.4 Pressure Relief and Emergency Shutdowns

This section provides guidance for pressure relief and emergency shutdowns used to prevent a component from being exposed to pressures above its design rating. The requirements apply to piping components only and do not address pressure vessels.

IRP Pressure relief and emergency shutdown devices should follow two strategies: primary de-pressuring and secondary de-pressuring, as described below:

- Primary de-pressuring involves shutdowns such as electronic trips that shut down equipment
- Secondary de-pressuring relies on pressure relief components:
    - Pressure Relief Valve (PRV)/Pressure Safety Valve (PSV): These devices reclose once the pressure drops below the set point
    - Pressure Relief Devices (e.g., burst disks): These do not reset or reclose after activation

Activation of pressure relief devices can result in significant release and de-pressurization if large amounts of stored energy are present. Associated hazards need to be identified and controlled.

IRP During pressure pumping operations, pressures should be managed in real time within the implemented treatment pressure range, using electronic sensors to trigger emergency shutdowns of equipment.

IRP All equipment and operating parameters must be set within the MAWP of the surface and wellhead equipment.

IRP The pressure relief system shall be designed to protect the lowest-rated component in the piping system.

29.5.4.1 Pressure Relief and Shutdown

IRP Consideration should be given to having more than one method of pressure protection, such as the following:

- Establishing the working pressure during pre-job planning
- Determining the lowest rated components in the system and ensuring they are suitable for the working pressure (unsuitable components may need to be changed or the pumping or flowback plan modified)
- Identifying electronic and mechanical controls required for pressure relief
- Setting electronic and mechanical controls within the limitations of the system

Below are examples for how pressure relief settings are established in various scenarios. Multiple layers of protection are used to stop a pumping operation or vent a vessel prior to an overpressure event. The examples illustrate a hierarchy of control and are not intended to be prescriptive.

29.5.4.2 Pressure Relief - Hydraulic Fracturing Example

Table 11. Pressure Relief – Hydraulic Fracturing Example

kPa	Settings	Action
69,000	Maximum Allowable Working Pressure	Tolerance Range for Pressure Relief Activation
60,000	Pump Trip 2	
58,000	Pump Trip 1	
53,500		Treatment Pressure Range
51,300		

The pressure relief strategy for the hydraulic fracturing shown in Table 11 above is as follows:

- The treatment pressure range determines the overall strategy for the pressure relief system
- The secondary protection for pump kick outs/shutdowns is determined. The pump kick outs are part of the pressure relief hierarchy, with the true intent of shutting down operations before relief through the pressure relief device

- The Maximum Anticipated Operating Pressure (MAOP) helps determine the selection of the primary pressure relief device set pressure, noting that device specifications include activation tolerances

29.5.4.3 Pressure Relief – Well Intervention

Well interventions include acid stimulations, cementing operations, abandonments and similar activities. These operations are more complex because pumping equipment ratings may exceed well pressure limits. As a result, pumping equipment may have pressure ratings that far exceed those of the components through which fluids are pumped. A thorough review of all components is required to establish the MAOP. Table 12 is an example of a Well Intervention.

Table 12. Pressure Relief – Well Intervention

kPa	Settings	Action
35,000	Pumping Equipment Maximum Allowable Working Pressure	
21,000	Well Maximum Allowable Working Pressure (Surface/Downhole)	Pressure Relief Activation Tolerance
19,600	Relief Pressure Setting for PRD	
18,200		
18,000	Pump Trip	
17,300	Maximum Anticipated Surface Pressure	Treatment Pressure Range
13,800		

The pressure relief strategy for Table 12 is as follows:

- In this example, the MAWP is established, which determines the relief system strategy

- The pumping equipment on location has a MAWP of 35,000 kilopascals (kPa); therefore the primary Pressure Relief Device (PRD) is set below this pressure

29.5.4.4 Pressure Relief – Well Testing

Well testing uses a combination of chokes and pressure staging to control higher pressures produced by the well for safe processing in lower pressure-rated equipment downstream. The following example illustrates a typical well testing application with a 9,927 kPa (1,440 psi) vessel.

Table 13. Pressure Relief – Well Testing

kPa	Settings	Action

9,927	Relief pressure setting for PRD	Pressure Relief Activation Tolerance
8,935	Simmer point setting for PRD	
7,942	Pressure Vessel High pressure shut down set point – typically 80% of Maximum Allowable Working Pressure	Secondary shutdown

The pressure relief strategy for Table 13 is as follows:

- In this example, the MAWP of the vessel establishes the set point for the PRD.
- The secondary shutdown device is set to 80% of the PRD to protect the vessel from nearing the MAWP.

29.6 Restraint Systems

Restraint systems are devices used to secure pipes and hoses, minimizing movement in the event of temporary pipework failure. They are one of several controls used to mitigate the impact of such failures. Guidance on anchors for restraints is provided in Section 29.7 Anchor Points.

Following this IRP's recommended practices for the proper design, selection, handling, installation, inspection and maintenance of restraint systems will help protect personnel, property and the environment.

Restraint systems are used in various applications involving different loads and environmental conditions. In some cases, restraints may last for years; in harsher conditions, they may degrade more quickly. Restraints of different sizes, materials or construction can also vary in durability within the same application.

IRP Restraints shall have a unique identifier for tracking usage, inspection and maintenance.

The following figures provide examples of different types of restraint systems. Depending on jurisdiction and specific use, the ratings and approved applications of the devices shown may vary.

Figure 35. Whip Check–Steel Cable Restraints (On Hose)

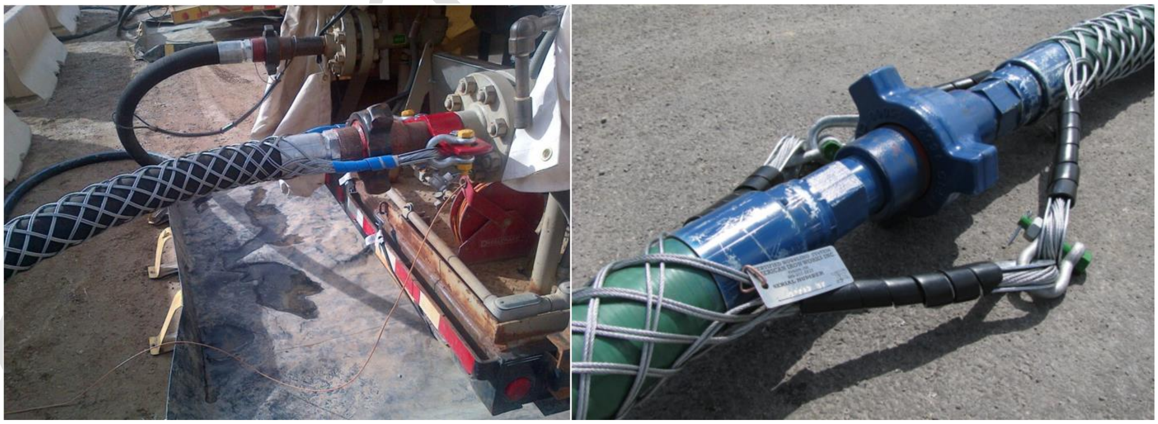


Figure 36. Whip Check–Synthetic Restraints (On Hose)

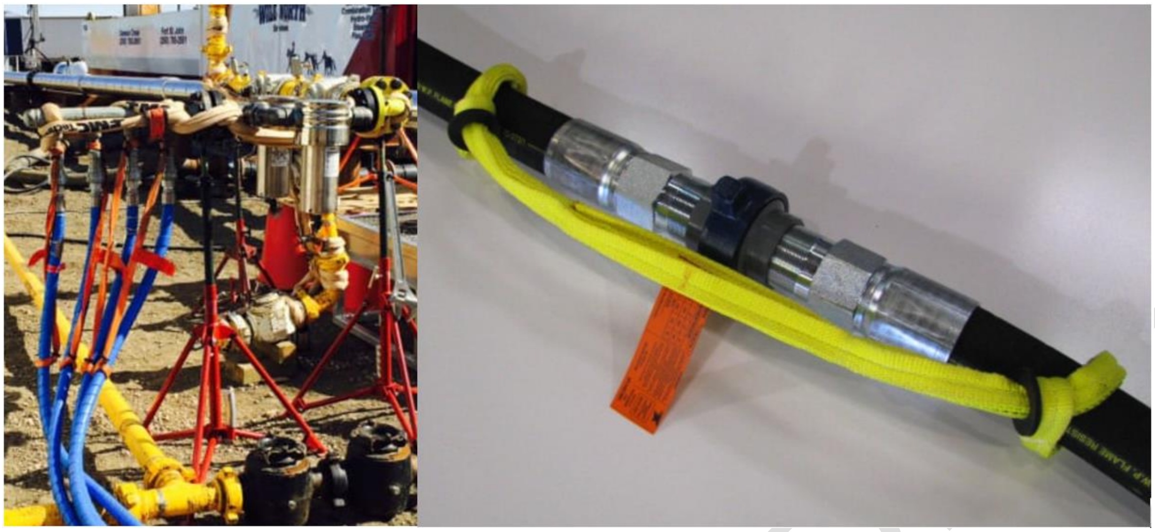


Figure 37. Hose Hobble Restraints (Whip Check Cable)

Figure 38. Anchor Line Tie-Off Restraint System (Spine and Rib)

Figure 39. In-Series, Half Hitch Restraint System

Figure 40. Large Bore Fracture Pipe Restraint

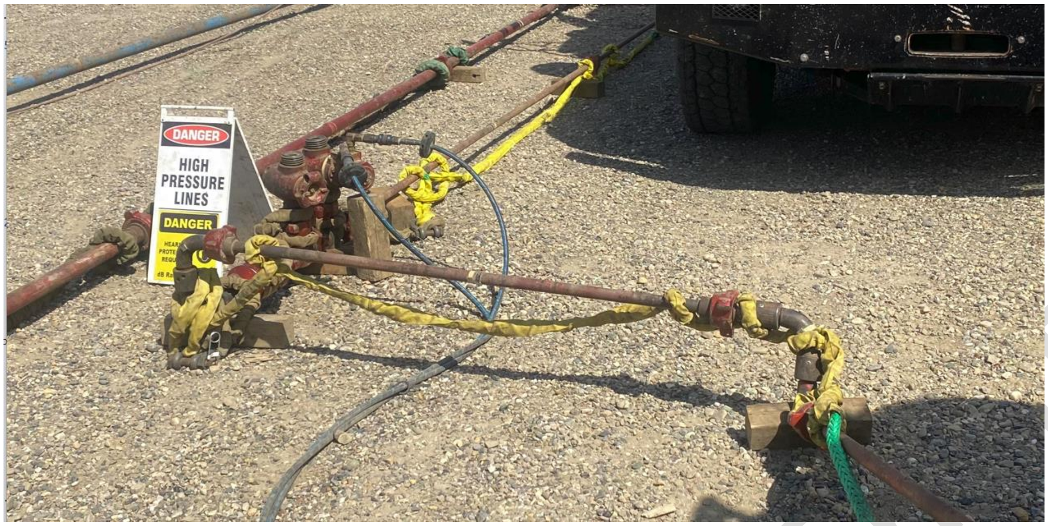
Figure 41. Twin Pumper Anchor

Figure 42. CT Reel Anchor

Figure 43. Fracture Anchor

Figure 44. CT Reel Anchor

Figure 45. Anchored N2 Low-Rate Line



29.6.1 Restraint System Design

The restraint system installed on a temporary piping system is designed to handle the energy released during a catastrophic failure and serves as a backup to other risk mitigation measures. As outlined in Section 29.3.5 Understanding Dynamic Forces Related to Restraint Design, restraint design and selection consider the energy source (i.e., constant pressure or constant flow rate) and operating pressure differential.

Additional factors considered in restraint design include:

- whether the fluid is compressible (e.g., gas, multiphase fluid) or incompressible (liquid, sub-cooled steam) and
- the jet impingement force exerted by the fluid jet discharged from the parted pipe.

In Constant Pressure Source Scenarios (Wellbore Model), theoretical and experimental work have found that incompressible fluids produce higher steady-state thrust forces than compressible fluids. Although some studies suggest a lower maximum thrust coefficient for compressible fluids (e.g., 1.26), IRP 29 recommends applying a conservative value of 2.0 for all applications unless an engineering assessment supports a lower value.

Note: See Appendix F: References and Resources for references to these theoretical assessments and experimental work.

IRP An engineering assessment should be performed and documented to justify the use of a thrust coefficient below 2.0 ($C_t < 2.0$) for compressible fluids flows to ensure conservative restraint design.

IRP For constant flow rate scenarios (Pump Model), the thrust force equation applies only to incompressible fluids. Restraint design in these cases should focus on impulse loading from incompressible flow. Applications involving compressible flow should be treated as Constant Pressure Source Scenarios (Wellbore Model).

In pipe break situations, the jet impingement force (F_{Imp}; See Figure 55) may increase the load on the restraint. However, sensitivity analyses show that jet impingement generally has little impact compared to fluid jet thrust forces, so it can often be ignored when calculating the restraint design force. See C-FER File: G310 Final Letter Report: Assessment of Restraint System Dynamic Loading in High-Pressure Temporary Pipe Installation Break Scenarios on Energy Safety Canada's website.

Typically, multiple parties are involved in the successful design and application of restraints on temporary pipework systems. The Restraint Owner could be the OEM restraint manufacturer, a service company that provides restraints for use with their temporary pipework, a third-party rental company or the prime contractor. Within industry, there are examples of purchasing and qualifying a restraint system using multiple products, and products not specifically designed as restraints.

IRP The Restraint Owner shall

- ensure the restraint system is designed according to this IRP, with documentation verifying it meets the application's loading requirements, and
- install, replace and maintain restraints according to the OEM's recommendations and the Restraint Owner's internal documentation.

IRP If the Restraint Owner assembles a system using products from non-restraint or restraint OEM sources, they shall calculate, evaluate and document the compatibility of those products as part of the restraint system. These systems shall be authenticated by a professional engineer.

IRP The Restraint Owner shall ensure that the design for the path/routing of the restraint system only applies loads through the intended piping anchor system. See Section 29.7 Anchor Points.

29.6.2 Restraint Force Equations

The sections below provide the restraint force equations for Constant Pressure Source Scenarios (Wellbore Model) and Constant Pump Rate Source Scenarios (Pump Model), respectively.

IRP The manufacturer shall provide specifications for the restraint so that end users can assess whether the restraint can withstand the predicted forces and is suitable for the intended application.

IRP The restraint manufacturer shall consider the restraint performance in both hot and cold weather conditions expected in Canada.

IRP The end user shall select an appropriate restraint for their piping application, taking into consideration the restraint product materials, construction and performance under high strain rates.

Since many factors and potential scenarios may influence maximum restraint forces for a particular application, selected sensitivity analyses may be prudent as part of the design process. See Appendix C: Restraint Force Equation Theory and Examples for details and sample calculations.

29.6.2.1 Force on a Restraint in a Constant Pressure Source Scenario

For restraint design and selection in a constant pressure scenario, it is assumed that the maximum force applied to the restraint can be calculated as follows:

Equation 1. Force on a Restraint in a Constant Pressure Source Scenario (Wellbore Model)

$$F_{restraint} = F_{thrust-CP} = 2\,P_{AOF}\,A$$

While transient loading will occur immediately following the pipe break in this scenario, steady state conditions are used in the design calculations. See Appendix C: Restraint Force Equation Theory and Examples, for further details.

IRP The thrust coefficient of 2.0 should be applied for all constant pressure source applications, including both incompressible and compressible flow situations. Lower thrust coefficients should only be used after a Professional Engineer's assessment for the specific installation or operation.

29.6.2.2 Force on a Restraint in a Constant Pump Rate Source Scenario

In a constant pump rate source scenario (Pump Model), the maximum force on a restraint can be calculated using the following formula in Equation 4 (i.e., applicable only to incompressible flow conditions):

Equation 2. Force on a Restraint in a Constant Pump Rate Source Scenario (Pump Model)

$$F_{restraint} = F_{thrust-CF}\,\Delta t_{thrust}\sqrt{\frac{k_{restraint}}{m_{pipe} + m_{fluid}}} = \frac{\Delta P A L_{pipe}}{a}\sqrt{\frac{k_{restraint}}{m_{pipe} + m_{fluid}}}$$

$$F_{thrust-CF} = \Delta P\,A$$

$$\Delta t_{thrust} = \frac{L_{pipe}}{a}$$

See Appendix C: Restraint Force Equation Theory and Examples, for further details.

IRP It should not be assumed that the thrust force applied to the pipe (i.e., $F_{thrust\text{-}CF} = \Delta PA$), has the same magnitude as the force exerted on the restraint in a constant flow rate scenario. The restraint force is the function of the energy imparted by the thrust force impulse to the pipe segment.

IRP For restraint design in a pump model scenario, the MAOP during operation or the rated MAWP of the temporary pipework system, should be used when deriving the restraint force.

IRP The end user should consider the maximum unanchored length of straight pipe where a break could occur when designing the restraint.

29.6.3 Pre-Rig In

IRP The following should be checked before installation of the restraint system:

- In-service date is current
- Restraints are suitable for expected temperature conditions (e.g., cold weather ratings on shackles/clevises or synthetic fibres, temperature of the pumped material)
- Load ratings shown on restraint tags meet or exceed the potential forces that the restraint system could experience
- Restraints are undamaged per OEM specifications (see Section 29.6.5.3 Inspection Criteria)
- Hardware (e.g., shackles/clevises) has all necessary, correctly sized components installed (e.g., safety pins, r-clips, nuts) and is undamaged

IRP These checks should be performed by someone familiar with the restraint system and the operational requirements of the job.

IRP Hardware and restraints shall not be used for purposes other than their designed scope.

See Appendix D: Checklists for a sample pre-job inspection checklist.

29.6.4 Installation and Make-Up

IRP A restraint system shall be installed by competent personnel in accordance with the manufacturer's installation specifications.

IRP All company Standard Operational Procedures (SOP), OEM recommendations, safety procedures and guidelines shall be followed during installation.

IRP Each piping section between two engineered anchors shall be restrained using the same brand and type of product, with an equivalent or higher rating.

Note: Mixing restraint system styles or brands may not meet the required pressure rating and can reduce overall integrity.

IRP The following should be confirmed during installation of the restraint system in accordance with the OEM's specifications:

- Restraints are installed so they do not interfere with operations (e.g., half-hitches or spines do not obstruct valve operation)
- Ribs are present on all connections and across each segment of the swivel when the spine-and-rib method is used
- The restraint system has adequate tension
- Restraints are anchored appropriately for the application (See Section 29.7 Anchor Points)

See Appendix E: Sample Checklists for a sample installation inspection checklist.

29.6.5 Post-Installation Inspections and Testing

The two types of post-installation inspections for restraints are

- frequent usage inspections and
- periodic inspections.

IRP If a restraint is exposed to any type of substance or chemical that could affect its integrity, it shall be removed from service, inspected and recertified in accordance with OEM specifications. Consult the OEM for chemical compatibility.

IRP Any restraint involved in an unplanned release or shock loading event shall be inspected. If not replaced, it may require load testing in accordance with OEM or restraint owner criteria.

29.6.5.1 Frequent Usage Inspections

Frequent usage inspections are similar to installation inspections (See Section 29.6.4 Installation and Make-Up). These are visual inspections that check for issues such as damage from pinch points or vibration, loose or missing components and loss of tightness.

IRP Inspections shall be performed by competent personnel (i.e., individuals familiar with visual inspection criteria).

IRP A visual inspection for damage shall be performed daily, or once per shift if multiple shifts occur within a day.

Written records are not required for frequent usage inspections.

29.6.5.2 Periodic Inspections

Periodic inspections are detailed inspections and may include load testing if specified by the OEM.

IRP Periodic inspections shall

- be performed by competent personnel,
- be performed annually, at a minimum,
- be based on criteria defined by the OEM and/or supplier,
- include a complete inspection for damage to the restraint (See Table 14 Restraint Inspection Criteria) and
- include records documenting the inspections and tests performed (e.g., load test).

IRP Each restraint shall be examined individually, taking care to expose and examine all surfaces.

IRP The inspection shall be conducted on the entire length of the restraint, including splices. Magnification may be required.

IRP Records of all periodic inspections shall be maintained.

Load testing may be required depending on the restraint type, operating conditions and OEM recommendations.

IRP Post-inspection load testing should be carried out in accordance with the Restraint Owner’s criteria, to a load that is reasonable and consistent with the maximum rating of the restraint.

29.6.5.3 Inspection Criteria

IRP The criteria in Table 14 should, at a minimum, be checked during frequent usage or periodic inspections.

Note: This is not an exhaustive list.

IRP OEM recommendations shall be followed.

Table 14. Restraint Inspection Criteria

Criteria	Notes
Missing or illegible restraint identification	• Working pressure • Flow line type and size • In service date • Serial numbers • Manufacturer
Abrasion, excessive wear or holes	• Most external abrasion is localized. • This may present as cut and/or frayed fibers. • Damage sufficient to degrade the restraint is usually obvious. • Jacketed restraints will show excessive wear on the sheath. The load bearing core should not be exposed
Cuts, tears or broken strands	• It is usually obvious where fibers have been cut, broken or torn sufficiently to degrade the restraint. • The severity and frequency of the cut(s) require the inspector to determine whether to remove the restraint from service. • For jacketed restraints where the jacket is not load bearing, a cut that does not expose the core probably doesn't degrade functionality. • Cuts to jackets may cause other adverse effects such as handling difficulties and inability to apply appropriate installation techniques.
Snags	• Individual strands and yarns can be snagged and pulled out or away from the restraint structure and construction. This can create uneven load bearing of fibers on the affected area of the restraint.
Chemical damage or discoloration	• Synthetic restraints can be weakened by chemical exposure with various fibres reacting differently.
Burns, melting or charring	• Melting, bonding of fibres and/or brittleness may be observed as a result of heat damage. These manifestations are not always present and, in some cases where present, may not affect the restraint's effectiveness.
Splice damage	• Ensure eye splices and end-to-end splices are as per OEM specification/instruction.
Loose or broken stitching	• Stitching may be present at termination eyelets or connections of material or fiber. Ensure stitch patterns, frequency and stitch density are as per OEM or supplier recommendations.
Evidence of crushing or stretching that compromises tensile strength	• Crushing and stretching will affect the cross-section diameter of the restraint. This can lead to a weak section of the restraint and a degraded strength.
Foreign matter that has permeated the rope	• Foreign matter such as dirt, sand and gravel can create internal abrasion and affect the tensile strength of the restraint. Examine each restraint for internal abrasion.

Criteria	Notes
Unintentional knots	• Unintentional knots can affect integrity of the restraint.

IRP **Restraints with unintentional knots shall not be used unless the working load is reduced to 50% of the published restraint strength, or specific data/testing is available to justify continued use.**

IRP **Restraints shall be retired if knots cannot be removed without causing structural damage to the restraint.**

29.6.6 Maintenance, Storage, and Transport Requirements

IRP **Any restraint that is altered in any way shall be load tested in accordance with OEM and Restraint Owner specifications.**

IRP **Restraint system maintenance shall be performed by competent personnel in accordance with OEM and Restraint Owner specifications.**

IRP **Restraint system storage, transport and handling shall follow OEM and Restraint Owner specifications.**

29.6.7 Potential Hazards

The following potential hazards are associated with restraint systems:

- Damage to the restraint system may result in failure
- Incorrect installation or operation (e.g., driving over restraints, pinch points, exposure to chemicals, exposure to extreme temperatures, mishandling) may result in failure
- Connecting restraints with different pressure ratings may not meet operational pressure requirements and may result in failure
- Use of non-approved hardware to connect the restraints or anchor points can compromise system integrity
- Restraint system failure can cause injury, property damage or environmental harm

29.6.8 Basis for Retirement

The basis for retirement establishes the parameters for removing a restraint from service.

IRP **The Restraint Owner shall establish retirement criteria for each restraint type, taking into account shelf life and conditions of use.**

IRP Retirement must reflect applicable local jurisdictional regulations for restraint systems.

IRP Restraints should be removed from service if there is any doubt about their reliability.

IRP Restraints shall be removed from service if continued use could create a hazard (See Section 29.6.7 Potential Hazards).

IRP Restraints taken out of service (e.g., during a pre-rig in inspection in the field) shall not be returned to service unless approved by a competent person.

Residual strength in a used restraint can only be verified through destructive testing methods (e.g., load testing).

29.7 Anchor Points

Anchor points absorb the forces transmitted by the restraint system when a temporary pipe fails.

Multiple temporary pipes of various sizes may be used, each with its own restraint system and specific anchor points.

IRP The anchor point's rating shall be established by a competent person.

IRP Anchor points shall have a rating that meets or exceeds the restraint system's requirements.

IRP Service providers, Owners and/or Prime Contractors shall identify anchor points for the temporary pipework or final restraint termination.

IRP The location of anchor points shall be considered during lease set up and lease inspection to ensure they are not placed in high-traffic areas.

It is important to consider the positioning of anchor points in the overall surface layout to eliminate or minimize risk exposure to persons and property. Other safety measures, such as safety zones and boundaries, can be used to control risk exposure.

The following figures are examples of various rated anchor points.

Figure 46. Coil Tubing Trailer Frame Mounted Anchor Points

Figure 47. Coiled Tubing Reel Mount Anchor Point

Figure 48. Nitrogen Pumper, Welded on Anchor Point, Top of Frame

29.7.1 Requirements

IRP The anchor point's load rating should be readily identifiable and accessible on a data plate to allow the end user to easily access and understand this information.

IRP Anchor points should be single-purpose only.

29.7.2 Inspections

Anchor points require regular inspections to ensure they remain functional even if they have not experienced a load. Factors such as age, corrosion or wear may affect their ability to serve as anchor points.

IRP **Anchor points shall be inspected periodically and/or after they have sustained a load, and before use, to ensure they are in good condition. Inspections shall follow the manufacturer's/Anchor Point Owner's instructions and be performed by a competent person.**

IRP **After sustaining a load, anchor points shall be removed from service until they are inspected and repaired. Any damaged or deteriorated anchor points shall be replaced or repaired and recertified by a competent person.**

29.7.3 Connecting Anchor Point to Restraint System

The Restraint Owner is responsible for connecting the restraint system to an anchor point and ensuring it functions correctly.

IRP **The Anchor Point Owner shall communicate the anchor point's rating to the Restraint Owner, and both shall ensure proper attachment.**

IRP **Restraint Owners shall specify connection requirements and necessary hardware for the restraint system. Any modifications shall be reviewed and recertified.**

29.7.4 Anchor Point Selection

Proper anchor point selection is essential to restraint system design. A restraint system is incomplete without secure anchor points at both ends of the temporary pipe system. Additional anchor points may be used in high-risk areas to prevent pipe movement. Overall, anchor point selection requires careful consideration. Due diligence is required when considering wells or wellheads as anchor points, taking into account well construction, history and potential loads.

Wells in the Western Canadian Sedimentary Basin vary in design, age and condition. Each well presents specific risks that need to be evaluated when determining suitability as an anchor point.

Connecting a restraint system to an anchor point introduces changes in load, equipment or hardware requirements, similar to a pipeline specification ("spec") break. These limitations need to be communicated to workers involved in installing, inspecting and certifying the system.

Anchor points may include the following:

- Mobile equipment with a rated anchor point
- Concrete blocks/skids with a rated anchor point
- Rated or pull-tested ground anchors that can be rated or tested to meet the required rating of the restraint system

IRP **The Anchor Point Owner shall ensure that any anchor points on their equipment are suitable for the intended loads.**

IRP **The integrity of the well is paramount. Anchoring to the well shall only be done if it can sustain the expected loads without compromising its integrity. Consider the following when using a well or wellhead as an anchor point:**

- Well and wellhead construction, including mechanical specifications
- Well integrity (e.g., corrosion, history, age)
- Cement integrity and placement
- Expected loads on the well or wellhead under various operating conditions (e.g., bending moments, axial loads, wellhead pressure, temperature effects, bolt specs)
- Anchor placement on the well or wellhead (consider failure modes and weak points)

Note: Other conditions may be added as needed by the well owner.

IRP **The well owner shall verify that a well or wellhead can be used as an anchor point before installation of any restraint system.**

Additional anchor point considerations include the following:

- Ground conditions (wet/soft, frozen/thawing, dry/loose, compaction)
- Practical and effective anchor placement that will not interfere with adjacent work activities
- The angle at which the load would be transmitted from the restraint system to the anchor
- One anchor used for multiple restraint systems
- Bending moments imposed on the anchor
- Limitations or restrictions of the anchor point

IRP **All anchor points shall be located within the exclusion zone to protect workers from line-of-fire hazards.**

29.7.5 Anchor Point & Hardware – Post Line Parting Incident

IRP **If a surface line parting event or an incident activates anchor points or hardware (e.g., uncontrolled pressure release), the restraint system, hardware and anchors shall be removed from service, tagged and either replaced or recertified before being returned to use.**

IRP Records shall be maintained and made available as proof of replacement or recertification.

IRP If the temporary pipework restraint system is activated by a pipe failure, the affected components, including hardware, shall be removed from service and either recertified or destroyed in accordance with the OEM’s/Anchor Point Owner’s/Restraint Owner’s guidance.

IRP Because structural damage may extend beyond the anchor, the entire load path should be inspected and either replaced or recertified.

29.8 Exclusion Zone

An exclusion zone is a predefined area with the potential for increased exposure to high-risk hazards where access is restricted to workers, or limited to only trained workers. Some form of approval is required for workers to enter the exclusion zone.

Exclusion zones may already be included in established, defined zones set out in company safe operating procedures and technical procedures. Exclusion zone boundaries are based on the type of equipment, piping and hosing, along with the fluid types and the maximum working pressure applied. The movement range of the restrained surface lines is also considered if a breech occurs, compromising the surface line assembly. Other safety variables, such as pressure relief valves, check valves barriers that offer additional layers of risk reduction or mitigation are also considered.

See Figures 49-51 for examples of exclusion zones.

IRP Exclusion zones shall be defined and identified to all on-site personnel.

IRP Exclusion zone boundaries shall be established through a site-specific hazard assessment. When defining the boundary, the assessment shall consider the type of fluid involved.

Examples of fluid types that will be pumped and the risks that each type will bring during pumping include the following:

- Fluids that change from liquid to gas (e.g., nitrogen or carbon dioxide): These can cause rapid changes in pressure and temperature at any point in the pumping system.
- Liquified gases (e.g., propane, natural gas): These behave like cryogenic fluids but also carry additional hazards such as like flammability and explosion.
- Petroleum-based products (e.g., crude oil, synthetic oils, kerosene, diesel): All carry inherent dangers such as flammability and explosion.
- Chemicals (e.g., acid blends, caustic blends, alcohols such as methanol): A wide variety of chemicals may be used, each with unique risks to workers and the environment if surface lines breach. Each type needs to be reviewed and assessed before use.
- Produced water: May contain chemicals, solids and bacteria. It is reused in various operations (e.g., diagnostic fracture injection tests, hydraulic fracturing, pump-downs, drilling, milling), and each batch can present different risks depending on its composition.

29.8.1 Approval to Enter an Exclusion Zone

It may be necessary to enter or pass through an exclusion zone during operations to perform short-duration tasks.

IRP **A process shall be in place to approve worker entry to the exclusion zone. This process shall minimize both the number of workers entering the zone and the duration of time they are in the zone.**

IRP **The number of workers entering or passing through the exclusion zone, and frequency of their entry, shall be kept to a minimum.**

The approval process will vary by site, Owner, Prime Contractor and/or Service Company, and may depend on local jurisdictional regulations.

Figure 49. Exclusion Zone Fracture Operations Example

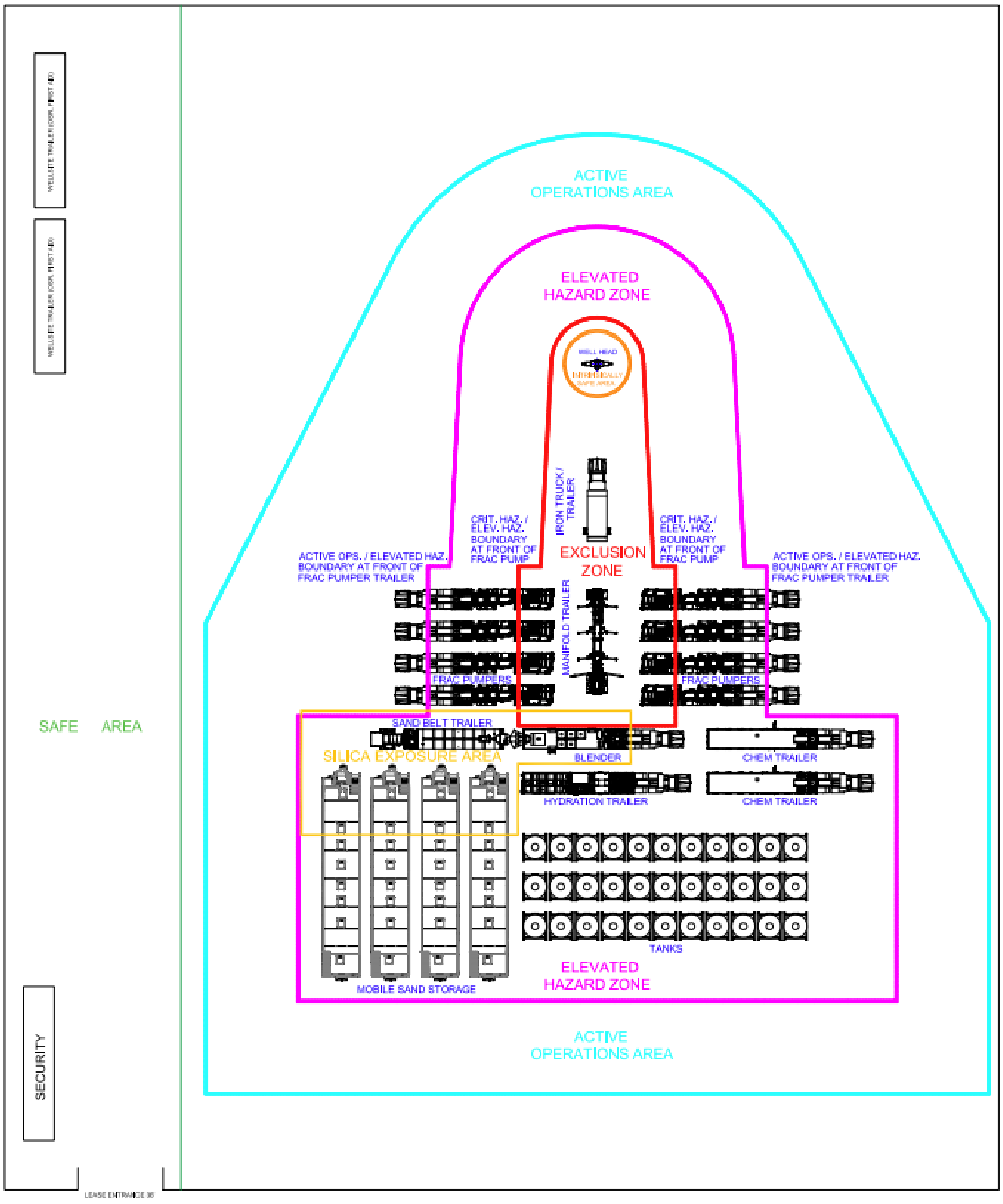


Figure 50. Exclusion Zone Coiled Tubing Operations Example

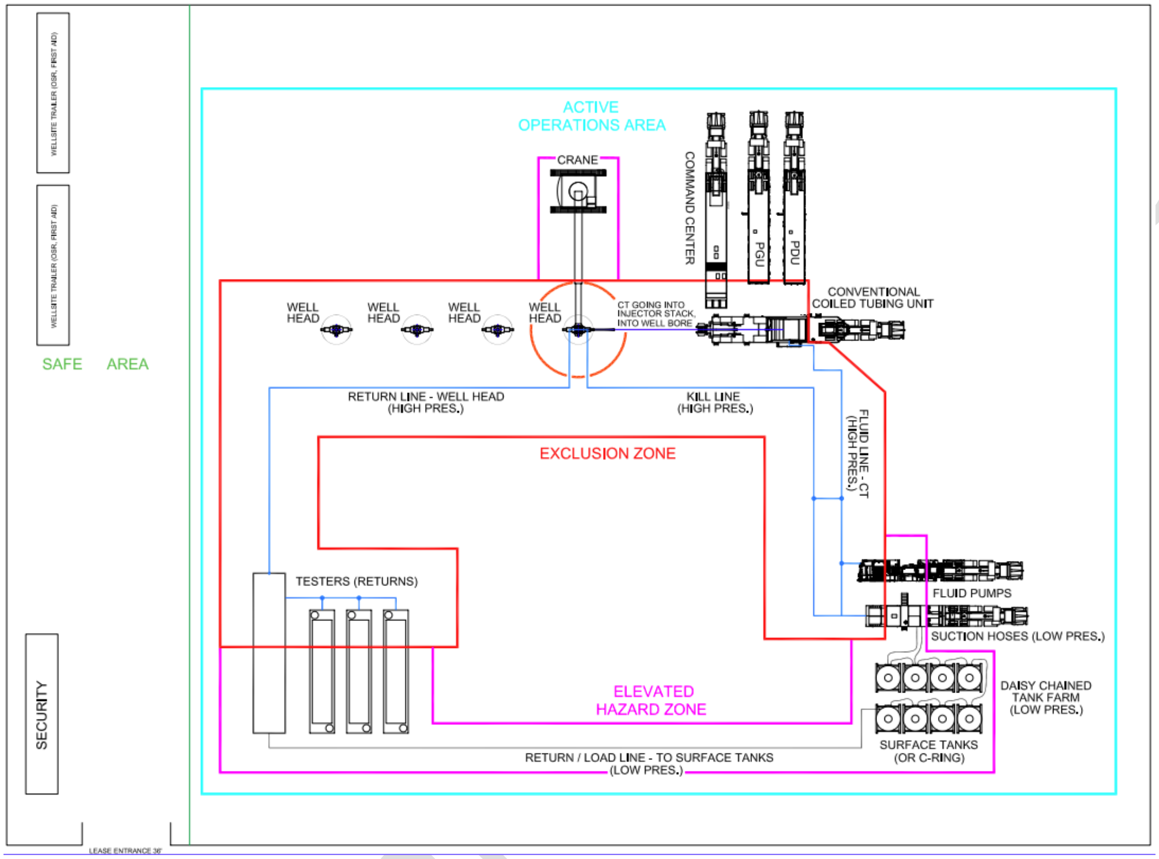


Figure 51. Well Testing Exclusion Zone Example

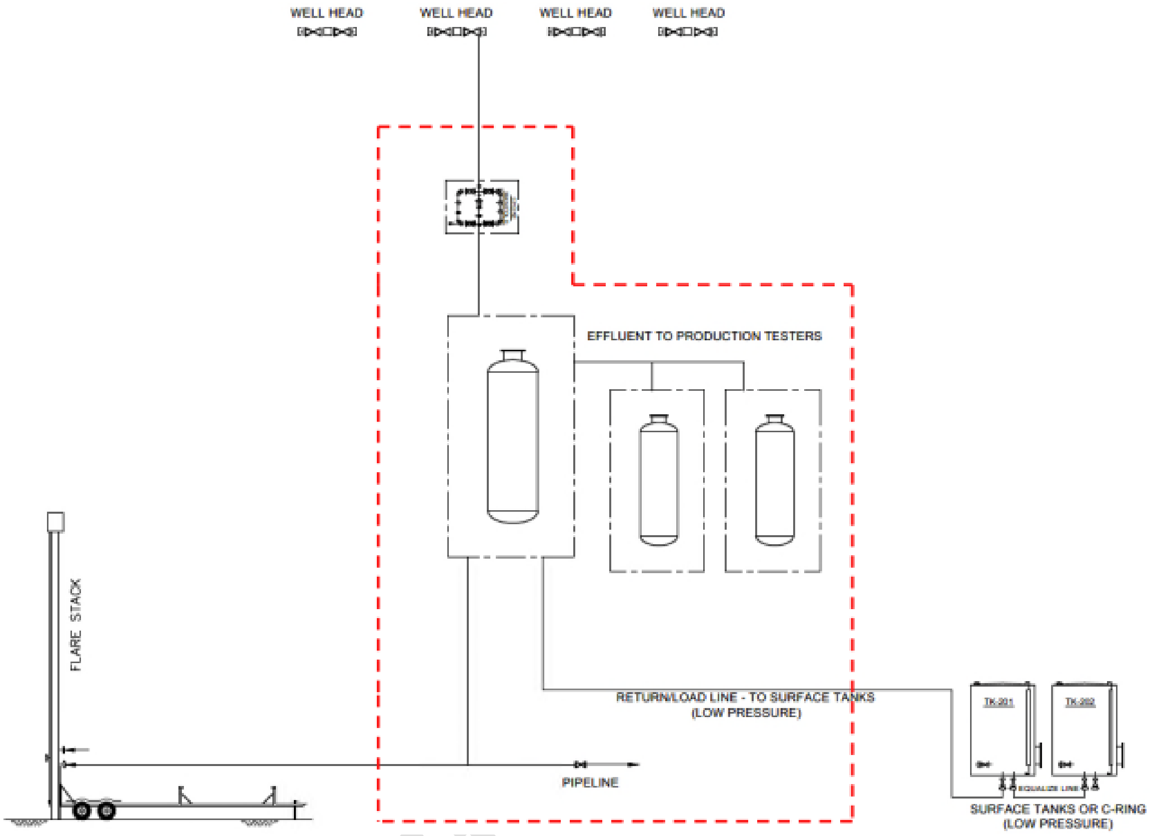


Figure 52. Service Rig Exclusion Zone Example

Figure 53. Service Rig Exclusion Zone Example

29.9 Pressure Testing

Pressure testing is a regulatory requirement to verify that the system's integrity is sufficient to proceed with operations.

IRP The temporary pipework system must be pressure tested before operation.

IRP Pressure tests shall be hydrostatic. If testing is conducted using compressible gas, a risk assessment for worker protection shall be completed, hazard zones established, and findings documented during the pre-job hazard assessment.

IRP Before pressure testing, the following shall be completed:

- A supervisor shall walk the line to confirm it is assembled correctly (e.g., proper component installation, adequate swivels for line movement)
- The maximum test pressure shall be established, communicated, and shall not exceed the MAWP of the lowest-rated component (lowest working pressure)
- The over-pressure shutdown system (i.e., trips) shall be set according to the pressure limits of all surface equipment, as determined by the service supervisor in consultation with the Prime Contractor.

IRP Before pressure testing, the trips should be function tested at a lower pressure, determined by the service supervisor in consultation with the Prime Contractor.

Initial pressure testing at a reduced pressure may be used to detect leaks in the system before increasing to the required test pressure.

IRP Temporary piping shall be pressure tested to a minimum of 10% above the MAOP of the operation, but not exceeding the MAWP of the lowest-rated component (lowest working pressure).

IRP In cold weather, temporary piping should be warmed before pressure testing.

IRP A pre-job safety meeting and hazard assessment shall be conducted, documented and communicated before pressure testing.

IRP At a minimum, the system should hold the test pressure long enough for the pressure to stabilize and for leaks to be detected. Test durations may vary depending on local jurisdictional requirements or the requirements of the Prime Contractor or Service Company.

IRP If temporary piping is disassembled and reassembled during operations, or between stages, the affected components shall be re-tested before use.

29.10 Disassembly

Consider the following when disassembling the pipework system:

- Obtain proper authorization to shut in and de-pressurize
- Ensure all pressure sources are isolated
- Confirm there is no conflict with simultaneous operations
- Inspect the line to ensure all valves are in the correct position and the line is fully depressurized
  - Confirm there is no trapped pressure

Note: Pressure can be trapped within valves.

- Verify there are no dead legs in the system that could contain an ice plug
- Remove and inspect restraints for damage or defects, and mark any damaged or defective restraints as out of service. Contact the manufacturer for recommended recertification or reassessment requirements
  - Store restraints as per OEM and Restraint Owner specifications
- Inspect piping for damage or defects, and mark any defective or damaged pipe as out of service. Contact the manufacturer for recommended recertification or reassessment requirements

29.11 Water Transfer Systems

Water transfer lines include layflat hoses or rigid pipes, commonly made from materials like thermoplastic polyurethane and nitrile, along with supporting equipment. These components are covered under the scope of this document.

Note: Fire hoses are out of scope for this document.

29.11.1 Pre-job Planning

Water transfer jobs can range from simple to complex, covering on-lease operations or spanning multiple kilometers, crossing roads and rivers, and dealing with significant elevation changes.

IRP The Operator and Service Company should work together to create a pre-job plan.

Key considerations in the planning process include the following:

- The fluid being transferred, including type and characteristics (e.g., fresh water, produced water, sour fluids, corrosive or abrasive properties)
- Expected rates and operating pressures, and associated pressure protection requirements (e.g., pressure relief devices, surge protection, pump bypass systems)
- Route selection, terrain, environmental conditions, weather, and total distance
- Type of piping or hoses used
- Fluid sourcing and delivery points (e.g. from ponds, rivers, tanks)
- Pump placement and elevation changes
- Hydraulic analysis requirements including expected operating pressures, friction losses and consideration of surge or transient conditions (e.g., pump trips, rapid valve closures, drop down spools)
- Impact on residents, businesses and the environment.

The objective of water transfer system design is to prevent spills and ensure safety for all involved. Proper planning ensures safe and efficient execution, helping maintain good relationships with residents, regulators, and businesses.

IRP **The Owner and/or Prime Contractor must ensure thorough planning and implementation of all safety measures for water transfer operations, in compliance with local jurisdictional regulations to protect workers, the environment and the public.**

29.11.2Route Selection

IRP The Owner and/or Prime Contractor should choose the most direct route while considering the following:

- Avoid unnecessary elevation changes and rough terrain
- Avoid exceeding the minimum bend radius
- Minimize road and water crossings
- Avoid sensitive areas, side slopes and natural or manmade hazards
- Minimize the impact of noise, light pollution and increased traffic on surrounding areas
- Minimize the impact on local water drainage to prevent excessive water accumulation due to pipeline routing (culverts are acceptable but they cannot obstruct existing drainage patterns)
- Determine how equipment will be drained, especially in low lying areas

IRP Where possible, water transfer lines should not be intentionally submerged (partially or fully) in any body of water.

IRP Where a water transfer line crosses a body of water (e.g., ditch, creek, drainage channel), the line shall be supported using floats, bridging or equivalent methods to prevent submersion and to comply with local jurisdictional requirements.

Note: For the purposes of this IRP, a body of water includes any natural or constructed surface water feature such as rivers, creeks, wetlands, ponds, sloughs, drainage ditches, stormwater channels or dry ephemeral water bodies.

IRP A leak detection method shall be in place.

29.11.3Water Transfer System Design

Water transfer systems can become complex due to high horsepower pumps, specification breaks, multiple connections, long distances, hydrostatic fluctuations, freezing conditions, pigging operations, line fill and many other factors.

IRP Where water transfer lines cross roads or access routes, the crossing must be designed and installed in accordance with local jurisdictional requirements.

IRP A competent person shall ensure the system is designed correctly and changes are managed through a diligent change management process. Engineering judgement shall prioritize primary containment and safety for workers, the environment and the public.

IRP Project changes that materially affect system design (e.g., pump placement, number of pumps, pump staging) should trigger an updated hydraulic analysis, that is reviewed by a competent person to confirm system integrity and operating efficiency.

IRP For high-risk areas or complex systems, a hydraulic analysis shall be performed by a competent person.

Low elevation points are subject to increased hydrostatic pressure and a higher risk of overpressure events that can cause injury, death or loss of containment.

IRP Low elevation areas shall be identified and all necessary precautions taken to mitigate risks and ensure system integrity.

IRP The hydraulic analysis report should be reviewed by the Owner and/or Prime Contractor (i.e., operator). See Section 29.11.4 Hydraulic Analysis Report.

Water transfer projects can undergo many changes throughout their lifecycle due to dynamic operating conditions such as start-up, fill-up, static conditions, changing flow rates, winter operations and pigging operations. These conditions can lead to pressure changes in the line, such as line creep, which may displace equipment, shift the line into unsafe positions, or put undue stress on equipment and couplings.

Significant pressure fluctuations can also occur during pigging and fill operations if not properly planned. Conducting hydraulic analysis, implementing a robust change management process and continuously monitoring the line are essential for safe and efficient water transfer operations.

IRP A line operating plan should be in place to continuously monitor equipment and operating parameters as conditions change. This includes monitoring for line or equipment displacement, equipment stress and ensuring operations stay within the MAWP of the system.

IRP Water transfer systems should include means of protection against pressure spikes or overpressure events. Acceptable measures may include high-pressure shutdowns, pressure relief valves, bypass systems, or equivalent protective controls suited to the system design and operating conditions.

29.11.4Hydraulic Analysis Report

IRP A hydraulic analysis report should include the following details:

- Route selection with topography and elevation changes
- MAWP of the system
- MAOP of the system

- Expected and maximum allowable flow rates
- Expected pressure along the route under normal operating and static conditions (no flow)
- Location of pumps along the route
- Identification of all equipment along the route with pressure and flow rate limitations
- Road crossings and equipment used at these crossings
- Identification of sensitive areas along the route
- Pigging equipment, operations and limitations

IRP Where system design or operating conditions create a credible risk of damaging pressures (e.g., long transfer distances, multiple pump stations, significant elevation changes), an engineered surge/transient analysis or equivalent protective measures should be applied and documented.

Note: Equivalent protective measures may include relief devices, pump soft-start controls, bypass loops, or operational procedures to control start-up and shutdown transients.

IRP System pressure shall always remain below the MAWP, including during startup, shut down, normal operations, static conditions, and any non-routine activities.

Note: Methods may vary depending on system design and operating risk. Common approaches include the following:

- Designing for an MAOP that does not exceed a specified percentage of MAWP (e.g., 90%)
- Installing high-pressure shutdowns, relief devices, or bypass systems to provide redundancy
- Implementing operating procedures that control pump ramp-up, valve sequencing and surge conditions.

IRP MAOP shall not exceed MAWP.

IRP A process flow diagram should be considered in the design process to show

- system connections,
- specification (spec) breaks,
- equipment specifications (sizes and pressure ratings),
- guidance on restraint systems and
- placement of pressure relief valves (PRV’s) and all valves used in the system (e.g., isolation, check, and control valves).

IRP Critical valves in the system should be identified and tagged according to the process flow diagram.

29.11.5Equipment Selection & Design

29.11.5.1 Road Crossings

IRP Road crossing design and maintenance should include the following criteria:

- Ensure adequate flow for the piping system
- Maintain structural integrity to handle expected traffic loads and provide vehicle clearance
- Limit interference with traffic flow while providing sufficient distance near intersections for safe turns without increasing collision risks
- Match the width of the road for optimal road crossing dimensions
- Establish a regular inspection frequency to maintain the crossing integrity and prevent progressive traffic disruptions
- Install signage to alert vehicles to the presence of a road crossing throughout the duration of the project
- Ensure the piping/equipment has an engineering pressure rating equal to or greater than the system MAWP where road crossings are designed as flow-through systems (e.g., coffin-style or flow-through crossing box)

29.11.5.2 Material Selection

Some operators and service companies may choose to move fresh or produced water through layflat hose or rigid piping.

IRP Before transferring produced water through layflat hoses or rigid piping, the OEM should be consulted for proper material selection. Aontaminants in the produced water that could impact the integrity of the layflat hose, rigid piping, or couplings should be disclosed to the OEM.

29.11.5.3 Couplings

Typically, layflat hose is the weakest part of the hose system, not the coupling. The most common failure point is where the layflat hose connects to the coupling. Field repairs, such as trimming and reattaching hose ends, can be performed in accordance with OEM instructions.

IRP Hose or couplings that cannot be repaired per OEM criteria shall be removed from service.

IRP Pump connections should be monitored during start-up to detect excessive stress and reduce the risk of catastrophic failure.

Line creep and water weight can induce excessive stress on the connection due to bending or axial stress if not adequately supported or accounted for.

29.11.6Risk Management

29.11.6.1 Modes of Failure for Temporary Layflat Hose System

Industry has observed many temporary water transfer line failures in recent years, emphasizing the need to understand their root causes and apply mitigations. Injuries have occurred around the pumps, particularly on the discharge side. Common causes of these failures include the following:

- Workers positioned in the line of fire
- Operating at pressures exceeding design limits
- Incorrect assembly of connections or hoses to couplings
- Unidentified and unmanaged specification breaks
- Poor communication and lack of competency
- Using improper tools or not following procedures when moving lines
- Exceeding equipment load limits (i.e. not accounting for bending or axial stress)
- Line creep due to expansion under various operating conditions

IRP To protect workers and the public, safety mitigations should be assessed through a risk-based approach. Potential safety measures include the following:

- Establishing exclusion zones in high-risk areas, such as around pump discharge and spec breaks, especially during start-up operations when stress on the line could lead to unexpected failures
- Installing visible barriers and signage to warn of danger in exclusion zones
- Placing pump controls in lower risk areas, such as the suction side
- Installing high-pressure shutdowns or PRV’s on the discharge side of pumps to prevent deadheading (i.e., Running pumps full of liquid while the outlet valves are closed), or to automatically stop pumps if pressure exceeds safe limits
- Installing a restraint system in areas frequented by workers

29.11.6.2 System Integrity Verification

Most water transfer operations cannot be pressure tested after assembly; instead, a leak inspection is used to verify the integrity.

IRP The initial leak test must be conducted in accordance with local jurisdictional requirements before operation.

IRP Because equipment is placed directly into service, additional mitigation measures should be implemented to protect workers and the environment.

IRP Hydraulic leak inspection shall be conducted throughout the entire water transfer system.

IRP The Owner and/or Prime Contractor shall identify areas where overpressure or abnormal pressures could occur. The operator shall evaluate risks and establish safeguards while protecting workers and the public.

Note: Transient pressure (e.g., water hammer) is a common cause of abnormal pressure events. Where credible surge conditions exist (e.g., long transfer distances, elevation changes, multiple pump stations, or rapid valve closures), companies are expected to evaluate risks and apply protective measures such as soft starts, bypasses, or relief devices.

IRP Pumps along the route shall have pressure monitoring devices installed on the discharge side and in any areas sensitive to overpressure (e.g., where elevation changes increase hydrostatic pressure or at choke points).

IRP Discharge pressure should be monitored from a safe location, such as a remote gauge, electronic pressure sensor with a local or remote display, or other remote monitoring system, to minimize the risk to workers in the event of failure.

29.11.6.3 Water Transfer Restraint Systems

IRP Restraint systems for water transfer should be designed in collaboration with the service provider and OEM.

While restraint systems cannot prevent catastrophic failures, they are intended to limit equipment movement and reduce the risk of injury or death.

IRP Proactive measures should be implemented to prevent catastrophic failures from occurring in the first place, including but not limited to

- conducting a hydraulic analysis of the operation,
- safeguarding against pipe separation (e.g. overpressure protection),
- ensuring competent personnel oversee system design and operation,
- selecting appropriate equipment and
- establishing a robust management of change protocol.

IRP The Owner and/or Prime Contractor should use a risk-based approach to implement mitigations against catastrophic failures and determine placement of restraint systems on water transfer lines. Exclusion zones should also be established in high-risk areas.

IRP Where high traffic areas interact with the public, proper warning signage should be installed.

IRP Service companies and layflat hose system owners should educate workers on the risks of layflat hose systems. Although operating pressures may be lower than in other industry applications, the large hose diameter can store significant energy and failures could result in serious injury or death.

IRP Discharge piping into storage tanks or pits (e.g., c-rings) shall be properly installed and secured, with additional restraints or anchoring as required.

IRP Restraint systems must comply with local jurisdictional requirements and be installed in accordance with OEM recommendations.

Note: Synthetic fibre-type restraints generally provide greater flexibility to choke and grip layflat hose effectively. However, other restraint methods may be used if they meet regulatory requirements, OEM recommendations and the MAWP of the line.

29.11.6.4 Layflat Hose Inspection and Repair

Wear and tear on layflat hoses may lead to failures, requiring either repairs or retirement from service.

IRP The service company should implement a hose inspection and repair program.

IRP The inspection program should include the following:

- Outline the minimum inspection frequency
- Identify key areas to inspect that are prone to wear and tear or common failure
- Outline conditions under which the hose should be retired from service

IRP All repairs shall be completed in accordance with OEM procedures by competent personnel.

IRP Layflat hose, couplings and associated equipment should be visually inspected for defects and proper assembly before operation.

29.11.6.5 Line Fill and Purge/Pigging Operations

Line-filling and purging are among the highest-risk operations in water transfer projects. Operators and service companies need effective procedures in place to perform these operations safely.

IRP System limitations during pigging operations shall be considered during project design.

IRP Pigging equipment shall be correctly sized and rated for the expected pressures, fitted with suitable connections suitable and supported by appropriate shutdowns to prevent overpressure.

IRP The discharge end of the hose assembly being pigged should be securely anchored to prevent uncontrolled movement. Open-ended or unrestrained discharges should be avoided.

IRP Pressure during pigging operations should not exceed the MAOP of the water transfer system.

Key risks to consider during line filling operations include

- line movement, such as rolling or twisting on uneven ground, creating additional stress and line-of-fire hazards,
- air discharge, which can cause pressure changes jacking on pumps as air circulates,
- solids exiting at slush points during winter operations and
- rapid line filling that compresses air and causes overpressure or failure.

IRP Proper line filling procedures should be followed to prevent overpressure and line failures.

Key risks to consider during purging operations include

- pigs entering inline pumps if positioning is not controlled,
- line pressure exceeding MAOP during purging,
- hose movement causing kinks, pig blockage or potential pressure spikes
- improper compressor sizing that leads to overpressure and
- workers exposed to line-of-fire hazards.

IRP Operators and service providers should consider the following during winter operations:

- Conduct pigging during daylight for visibility; provide lighting where workers are present, when necessary
- Manage storage volumes to ensure adequate capacity during hot water flushing operations
- Implement additional freeze protection measures (e.g., hot water pills, recirculation, insulation, or heating equipment)

- Ensure sufficient heating equipment is available to maintain effective freeze prevention practices
- Anticipate flash freezing on metal components when cold water contacts equipment below freezing
- Implement freeze protection for long-term shutdowns (e.g., hot water pills, re-circulation, purging, storage management)
- Recognize that pigging operations present a high potential for ice slugs, which can cause equipment damage, pressure spikes and line-of-fire exposure.

Appendix A: Revision Log

Edition 1

Edition 1 is the first edition of this new IRP sanctioned in 2025.

The following individuals helped develop Edition 1 of IRP 29 through a subcommittee of DACC.

Table 15. Edition 1 Development Committee

Name	Company	Organization Represented
Ernie Barker	TOPCO Oilsite	Enserva
Pam Blaney	Grimes Well Servicing Inc.	CAOEC
Adrian Campbell	ARC Resources	CAPP
Kevin Crumly	Trican Well Service Ltd.	Enserva
Matt Dagert	Treeline Well Servicing	CAOEC
Chad Dannish	Next Level Energy	CAPP
Jim Delsing	ConocoPhillips	CAPP
Glenn Doiron	Ideal Completion Services	Enserva
Rick Eckdahl	Chevron	CAPP
Kevin Elgert	Stream-Flo	Enserva
Corwin Gibbons	Isolation Equipment	Enserva
Kirk Grimes	Grimes Well	CAOEC
John Green	Ovintiv	CAPP
Daniel Harris	Canyon Rigging	Enserva
Kevin Holm	Precision Well Servicing	CAOEC
Nathan Kwasniewski	Stream-Flo	Enserva
Mike Nelson	Grant Production Testing Services Ltd.	Enserva
Greg Nichols	Trican	Enserva
Eric Plante	Calfrac Well Services Ltd.	Enserva
Andrew Robertson	AER	Regulator
Kris Sato	STEP Energy Services	Enserva
Trevor Schable	CNRL	CAPP
Craig Schroh	SMP Oil and Gas	Enserva
Bill Skea	Halliburton	Enserva
James Sloman	Iron Horse Energy Services	Enserva

Name	Company	Organization Represented
Doug Smith	Element Technical Services	Enserva
Dylan St. Germain	Safe-T-Whip	Enserva
Dave Thompson	Ovintiv	CAPP
Bob Toronchuk	STEP Energy Services	Enserva
Mike Uhryn	Safe-T-Whip	Enserva

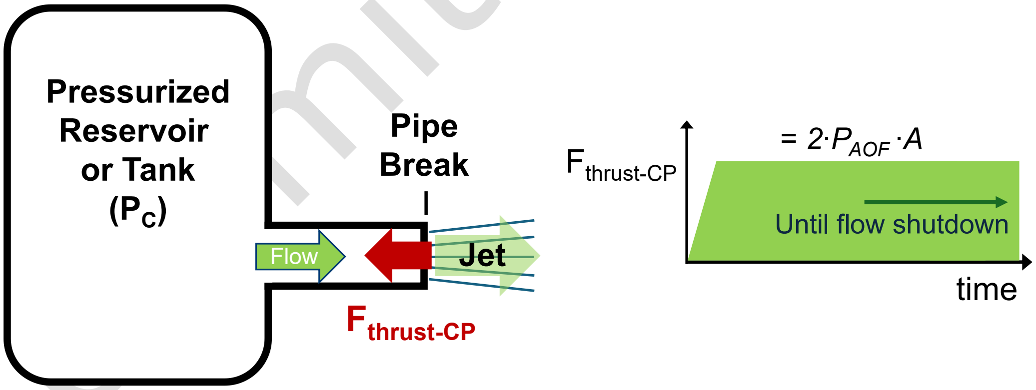
Appendix B: Dynamic Forces Equation Theory

This appendix outlines the fundamental dynamic force concepts that apply when temporary pipework fails during wellsite operations. Two fluid source scenarios are considered: the Constant Pressure Source Scenario (Wellbore Model) and the Constant Pump Rate Source Scenario (Pump Model). Understanding these force dynamics is critical for designing effective restraint systems.

Constant Pressure Source Scenario (Wellbore Model)

If temporary piping breaks while flowing fluids from the well (i.e., Wellbore Model), a fluid jet forms almost immediately, with the pressurized reservoir continuing to flow at a constant pressure until it is shut off. The shut-off could take seconds to hours depending on factors such as break location, shutdown systems (e.g., emergency shutdown devices) and personnel response time. The resulting thrust force acts immediately on the restraint system, which must handle the full force of the fluid jet. See Figure 54 Constant Pressure Source (Wellbore Model).

Figure 54. Constant Pressure Source Scenario (Wellbore Model)



In this case, the pipe segment near the break experiences a dynamic thrust force from the fluid jet. If the system is operating at full pressure when the break occurs, the thrust force peaks almost instantly and transfers to the restraint, depending on pipe end movement. If the broken pipe can move freely, the restraint bears the full force; if anchored, the anchor takes most of the load. Regardless, the thrust force continues until the flow is stopped, so the restraint must be designed to handle the maximum thrust force. In the Wellbore Model, the thrust force can be calculated using the following equation:

Equation 3. Thrust Force in Constant Pressure Source Scenario (Wellbore Model)

$$Fthrust - CP = Ct(Pc \times A)$$

Where

$F_{thrust-CP}$ (Thrust Force) is the thrust force applied to the pipe in Newtons (N).

C_t (Thrust Coefficient) is 2.0 for incompressible fluids. For compressible fluids (like gas or steam) the coefficient is typically 1.26.

P_C (Constant Pressure) is the constant pressure of the source feeding the pipe break. For restraint design, this can be assumed equal to the wellhead pressure (P_{AOF}) expected under sustained Absolute Open Flow (AOF) conditions for the well, or the maximum tank pressure if the flow originates from a surface vessel. Pressure is measured in Pascals (Pa).

A (Cross Sectional Area of Pipe) is the cross-sectional area of the temporary pipe bore in square metres (m^2).

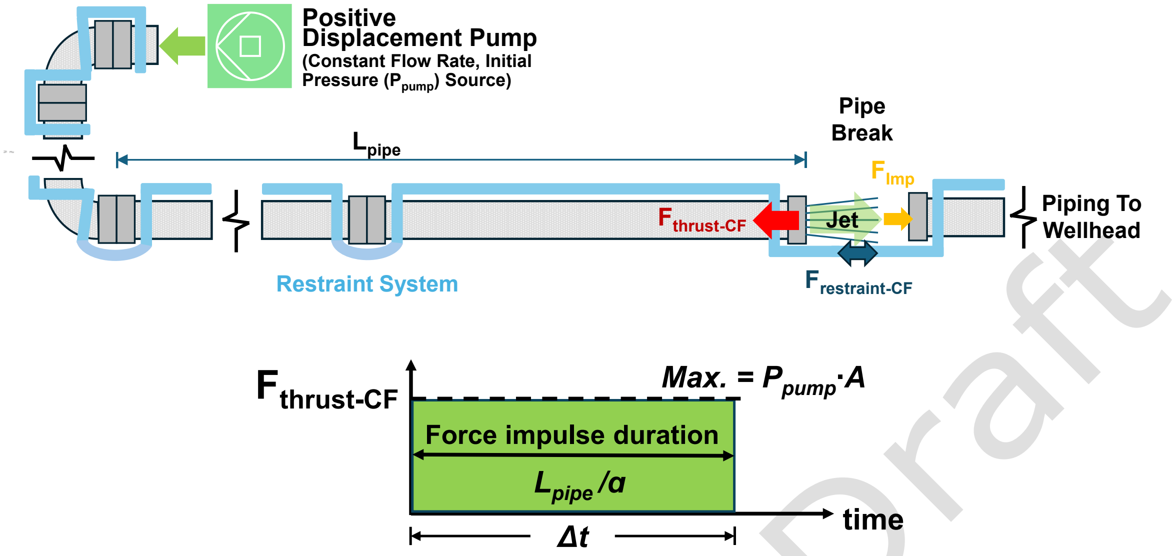
Note: The thrust coefficient of 2.0 applies to frictionless flow of incompressible fluids. For compressible flows (like gas or steam) or multiphase flow conditions, a lower thrust coefficient, typically 1.26, may apply.

Constant Pump Rate Source Scenario (Pump Model)

In this scenario, it is assumed that the parted pipe segment is connected by the upstream piping system to a positive displacement pump and therefore the pipe pressure at the break will be the pump pressure (Ppump), and the flow will continue until the pump is shut off. See Figure 55 Constant Pump Rate Source Scenario (Pump Model). After the break, the pipe depressurizes to atmospheric pressure, and a pressure wave travels through the system at the speed of sound (for the fluid), rapidly reducing the thrust load. The length of the pressure wave (Lwave) is proportional to the time required for the pipe to fully part during the break, typically one millisecond. Given the short depressurization time, where the load drops to zero as soon as the pressure wave reaches the end of the broken pipe, the forces on the pipe and restraint change rapidly, creating a transient condition before reaching a steady state. The restraint will absorb the thrust force until the flow stops. Due to the short transient loading conditions, both the thrust force and the forces acting on the restraint need to be derived from impulse theory. See Figure 55 Constant Pump Rate Source Scenario (Pump Model).

Note: A similar pressure wave will also travel from the break point through the piping on the other side toward the wellhead.

Figure 55. Constant Pump Rate Source Scenario (Pump Model)



In the Pump Model, the transient thrust force can be calculated using the following equation:

Equation 4. Thrust Force in Constant Pump Rate Source Scenario (Pump Model)

$$FthrustCF = Ppump \times A$$

Where

$F_{thrust-CF}$ (Thrust Force) is the transient thrust force in Newtons (N).

P_{pump} (Pump Pressure) is pump pressure at the time of the break in Pascals (Pa). For restraint design, this can be assumed equal to the maximum pump pressure required for the planned well operations, or for conservatism, the full pressure rating of the piping system.

A (Cross Sectional Area of Pipe) is a cross-sectional area of the temporary pipe in square metres (m^2).

> **Note:** Given the very short time required for pipe depressurization, a constant flow condition may also be assumed for installations employing a centrifugal pump source.

Appendix C: Restraint Force Equation Theory and Examples

This appendix explains how restraint systems respond to dynamic forces following a pipe failure. It summarizes the theory behind restraint force calculations and provides example for both the Constant Pressure Source (Wellbore Model) and Constant Pump Rate Source (Pump Model) conditions.

Restraint Force Equation Theory

To simplify how a restraint works, consider a spring loaded by an external force. For a linear spring, stiffness (spring constant) follows Hooke's Law: the force required to extend the spring by a distance 'x' is proportional to that distance.

Equation 5. Force Applied to Spring

$$F_{spring} = kx$$

Where

F_{spring} = force applied to the spring (N)

k = spring constant (N/m)

x = axial displacement of the spring (m)

When loaded, the spring lengthens and stores potential energy. Doubling the applied force doubles both displacement (stretch) and stored energy, until the elastic limit is exceeded (permanent deformation or failure). Similarly, when a dynamic force acts on a restraint during a temporary pipework failure, the restraint is expected to absorb energy in a spring-like manner.

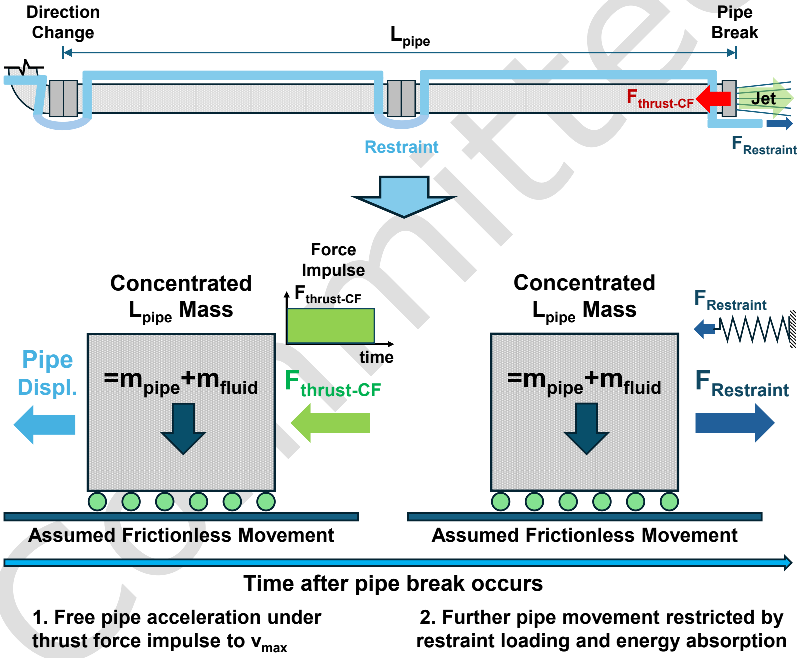
As described in Sections 29.3.5 Understanding Dynamic Forces Related to Restraint Design and 29.6.1 Restraint System Design, the fluid source needs to be identified–constant flow rate (Pump Model) or constant pressure (Wellbore Model)–to establish the force on the restraint.

For the constant flow rate (Pump Model) scenario, impulse and momentum principles apply (i.e., $F \cdot \Delta t = m \cdot \Delta v$): a short-duration thrust impulse accelerates the free pipe segment. The restraint engages, stretches, and absorbs the segment's kinetic energy until motion is arrested.

As illustrated in Figure 56, when a pipe parts in the Pump Model, a transient thrust force immediately acts on the unanchored pipe segment. This segment, with length L_{pipe} and total mass equal to the combined mass of the pipe (m_{pipe}) and contained fluid (m_{fluid}) will accelerate while the thrust force is applied.

Note: Force impulses of large magnitude and short duration (milliseconds) can occur. Under these rapid loading conditions, the unanchored pipe segment is assumed to start from rest and reach a peak velocity (v_{max}) as the force impulse ends, before the restraint system engages. Once engaged, the restraint stretches and absorbs the segment's kinetic energy ($KE = \frac{1}{2} m_{total} v^{2}_{max}$). Maximum loading and displacement occur when all kinetic energy has been converted to potential energy ($PE = \frac{1}{2} k_{restraint} x$), fully arresting the pipe. To achieve this outcome, the restraint must have sufficient capacity to safely withstand the dynamic peak load.

Figure 56. Thrust Force Impulse Loading of Unanchored Pipe Segment Followed by Restraint Engagement (Pump Model Scenario)



Note: For conservatism in restraint design and selection, in addition to frictionless fluid flow, it is assumed that the affected pipe segment remains intact, straight, and aligned with the thrust force during the impulse (See Figure 56), and no energy is dissipated through pipe friction, bending, or other load transfers.

The key factors affecting the kinetic energy transferred to the restraint include:

- magnitude and duration of the fluid-jet thrust and
- length and mass of the unanchored straight pipe segment (pipe + contained fluid).

For the Wellbore Model, the fluid-jet thrust force can persist much longer (minutes to hours). After initial engagement, the restraint reacts to the full thrust force until the flow is shut in. Thus, the maximum restraint force is assumed to be equal to the sustained thrust force (i.e., $F_{thrust\text{-}CP} = 2 \cdot P_{AOF} \cdot A$).

In compressible flow cases, the end user may justify a reduced thrust coefficient (see Section 29.6.1 Restraint System Design). For conservatism, it is assumed no energy imparted is dissipated through pipe friction, bending, or load transfers.

Constant Pressure Source Scenario (Wellbore Model)

For restraint design in a constant pressure scenario, the maximum force on the restraint is calculated as follows:

Equation 6. Force on a Restraint in a Constant Pressure Source Scenario (Wellbore Model)

$$F_{restraint} = F_{thrust-CP} = 2\ P_{AOF}\ A$$

where

***$F_{restraint}$* (Force on a Restraint)** is the sustained force on the restraint in an incompressible flow case (i.e., with $C_t = 2.0$), measured in Newtons (N).

***$F_{thrust\text{-}Cp}$* (Constant Thrust Force)** is the constant thrust force while flow continues, measured in Newtons (N).

P_{AOF} (Maximum Wellhead Pressure under Absolute Open Flow) is the maximum wellhead pressure under Absolute Open Flow (AOF) or tank operating pressure, measured in Pascals (Pa).

***A* (Cross Sectional Flow Area of Pipe)** is the cross-sectional flow area of the pipe, measured in square metres (m^2).

Although transient loading occurs immediately after the break, steady state conditions are used for design.

Constant Pump Rate Source Scenario (Pump Model)

In the case of a Constant Pump Rate Source Scenario (Pump Model), the maximum force on a restraint can be calculated using the following formula in Equation 7 (i.e., applicable only to incompressible flow conditions):

Equation 7. Force on a Restraint in a Constant Pump Rate Source Scenario (Pump Model)

$$F_{restraint} = F_{thrust-CF}\,\Delta t_{thrust}\sqrt{\frac{k_{restraint}}{m_{pipe} + m_{fluid}}} = \frac{\Delta PAL_{pipe}}{a}\sqrt{\frac{k_{restraint}}{m_{pipe} + m_{fluid}}}$$

$$F_{thrust-CF} = \Delta P\, A$$

$$\Delta t_{thrust} = \frac{L_{pipe}}{a}$$

where

***$F_{restraint}$* (Force on a Restraint)** is the force applied to the restraint, measured in Newtons (N).

***$F_{thrust\text{-}CF}$* (Thrust Force)** is the maximum thrust force applied to the pipe immediately after the break, measured in Newtons (N). The thrust force on the pipe in the Pump Model scenario is simply the assumed maximum pressure inside the pipe multiplied by the cross-sectional flow area of the pipe.

Δt_{thrust} (Time Thrust Force is applied to the Pipe) is the amount of time the thrust force is applied, measured in seconds (s). The amount of time the thrust force is applied to the pipe is dependent on the length of the pipe segment and the speed of sound in the fluid within the pipe.

ΔP (Change in Pressure) is the maximum operating pressure of the pipe minus the atmospheric pressure (this is equal to P_{pump} at gauge pressure), measured in Pascals (Pa). See Section 29.3.5 Understanding Dynamic Forces Related to Restraint Design.

***A* (Cross Sectional Flow Area of Pipe)** is the cross-sectional flow area of the pipe, measured in square metres (m^2).

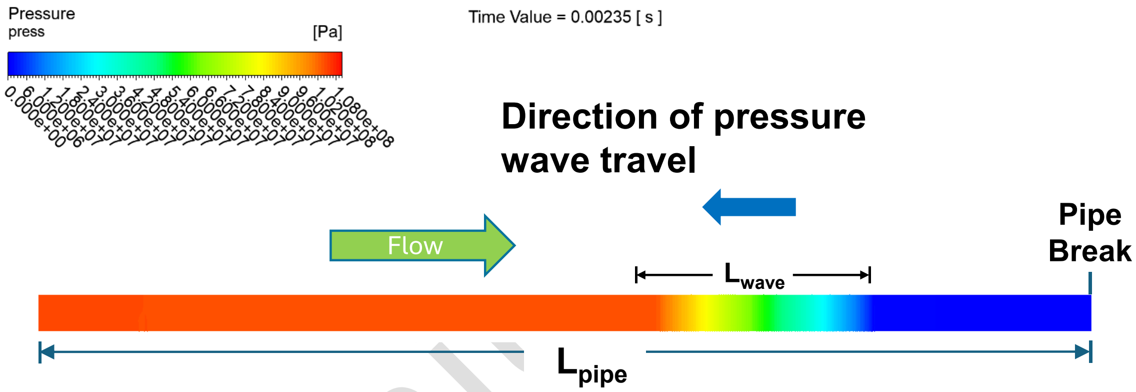
***L_{pipe}* (Length of Pipe)** is the length of the straight unanchored pipe segment that will move when subjected to the transient thrust force, measured in metres (m).

> **Note:** Typically, for restraint design, the longest straight section of unanchored piping will be selected for this parameter (e.g., it can be measured from the assumed break point at the end of the

straight segment to the first change of direction in the piping such as at an elbow or chicksan). The pipe length, L_{pipe}, is an important factor that needs to be defined in the design of the restraint system since it has a substantial impact on the restraint force magnitude in a constant flow rate scenario. This is because the pipe length directly impacts both the duration of the thrust force impulse, which acts to accelerate the pipe segment, as well as its total mass.

When the pipe parts, depressurization to atmospheric pressure starts at the break point. A pressure wave travels through the pipe at the fluid's speed of sound (See Figure 57). The thrust impulse duration is the time required for this wave to traverse the unanchored straight pipe. Longer pipe segments result in longer impulse duration and higher total restraint force.

Figure 57. Direction of Pressure Wave Travel vs. Direction of Fluid Flow



From the perspective of the thrust force impulse which acts on the pipe, the relevant segment length corresponds to the unanchored length of straight pipe extending from the break (i.e., the section of pipe that is assumed to be free to move under the thrust impulse loading). Typically, for restraint design, the longest straight section of unanchored piping will be selected for this parameter (e.g., it can be measured from the assumed break point at the end of the straight segment to the first change of direction in the piping such as at an elbow or chicksan). The duration of the force impulse corresponds to the time required for the pressure wave to traverse this straight pipe segment. Therefore, the longer the straight section of pipe, the longer the thrust force will be applied to the pipe.

α **(Speed of Sound)** is the speed of sound in the fluid, measured in metres per second (m/s). The pressure wave travels at the speed of sound in the fluid when the pipe breaks. For example, in the case of a 10 m section of pipe filled with fresh water at room temperature which parts at 103.4 MPa, it would take only 0.0066 seconds for the pressure wave to travel the full 10 m distance. With the same conditions in a 50 m section of pipe, the duration would be five times longer. In each case, this represents the time over which the thrust force impulse is applied to the pipe segment ($\Delta\mathbf{t}_{\mathbf{thrust}}$).

The speed of sound is a function of fluid density, decreasing with lower density fluids. However, as a default, one can use the speed of sound in fresh water at room temperature in their design calculations (i.e., 1,481 m/s at 20°C).

$k_{restraint}$ (Restraint Spring Constant) is the restraint spring factor or stiffness coefficient, measures in Newtons per metre (N/m). The restraint spring constant (or stiffness coefficient) reflects the rate at which the restraint absorbs energy as a function of its elongation. In a pipe break situation, the restraint is expected to effectively absorb substantial energy over a very short period (i.e., milliseconds).

Traditional restraint testing and qualifying has been performed using bench tests that load the restraint samples at low strain rates (stretch rates), which are not necessarily comparable to the loading rates that the restraints would experience in a pressurized temporary piping system failure situation. The restraint manufacturer is responsible for understanding the ability of the restraint product to withstand such dynamic loading conditions.

m_{fluid} (Mass of the Fluid) is the total mass of the fluid contained within the selected pipe segment, measured in kilograms (kg).

m_{pipe} (Mass of the Pipe) is the total mass of the straight unanchored pipe segment that will move when subjected to the transient thrust force, measured in kilograms (kg). Typically, the mass of fluid (m_{fluid}) contained within the selected pipe length will also be included in the calculation since it contributes to the total mass acted upon by the thrust force impulse.

Restraint Force Equation Examples

Example #1 - Pumping Operations

Scenario Description

Hydraulic fracturing operations will be conducted on a multi-well pad. Temporary piping runs from the fracture pumps to each wellhead. The longest straight, unanchored segment between pumps and a wellhead is 35 m.

- Pipe rating: 103.4 MPa (3”,15 ksi) pressure rated iron
- Pipe inside diameter (ID): 65.8 mm
- Pipe outside diameter (OD): 88.9 mm (76.2 mm nominal)
- Wellhead MAWP: 103.4 MPa (15 ksi)
- Maximum pump pressure: limited by casing burst (86 MPa), but pressure test to 95 MPa (13.8 ksi), approximately 10% above
- Fluid: produced water with a friction reducer (1,050 kg/m^3)

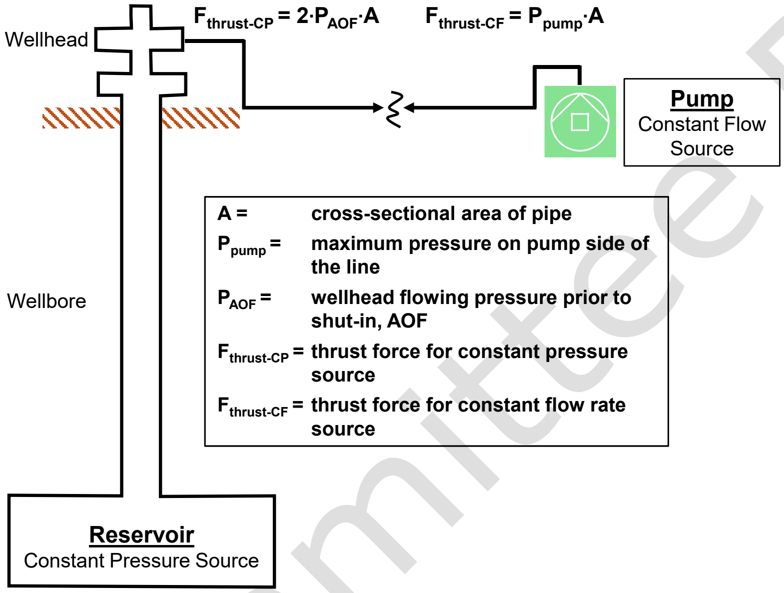
- Estimated absolute open flow (AOF) wellhead pressure through a parted leg: 25 MPa (3.63 ksi)

Note: Published casing burst capacities are derived from material yield strength formulas and include a safety margin; the actual burst pressure is typically higher. Without additional limits, a pump could exceed the nominal burst value before the casing actually fails.

Discussion of Scenario

Because the system can be fed by both pump and reservoir, restraint sizing needs to consider both the Constant Flow Rate (Pump Model) and the Constant Pressure (Wellbore Model), with the larger resulting restraint load used (See Figure 58).

Figure 58. Example 1 Pumping Operations



A = cross-sectional area of pipe
P_{pump} = maximum pressure on pump side of the line
P_{AOF} = wellhead flowing pressure prior to shut-in, AOF
$F_{thrust\text{-}CP}$ = thrust force for constant pressure source
$F_{thrust\text{-}CF}$ = thrust force for constant flow rate source

Table 16. Example 1 Assumed Parameter Values

Variable	Number	Units
Density of steel, ρ_{steel}	7,840	kg/m^3
Rated Working Pressure of Piping	103.4	MPa
Pipe OD	88.9	mm
Pipe ID	65.8	mm
Fluid density inside the pipe, ρ_{fluid}	1,050	kg/m^3
Speed of sound in fluid, α	1,481	m/s
L_{pipe}	35.0	m
Max pressure test	95.0	MPa
P_{AOF}	25.0	MPa

Key drivers for the pump model restraint load are

1. longest straight unanchored length of pipe,
2. maximum operating pressure during pumping,
3. speed of sound in the fluid,
4. pipe mass per unit length and
5. restraint stiffness.

For consistency, the speed of sound in freshwater at 20°C (1,481 m/s) is used unless better job-specific data are available. Peak pressure values are defined by the end user. This example uses 95 MPa (10% above casing burst).

> **Note:** The IRP allows engineering judgement for fluid parameters (e.g., density or speed of sound adjustments if well defined at operating conditions).

Example 1 Calculations

Constant Pump Rate Source (Pump Model):

For these calculations one assumes that the pipe system is fed by a constant displacement fracture pump when the break occurs. As a result, for the restraint design, the thrust force exerted on the parted pipe will be transient with a peak magnitude equal to the maximum pipe operating pressure multiplied by the internal cross-sectional area of the pipe.

The thrust force is calculated, as follows:

Equation 8. Thrust Force on Parted Pipe

$$A = \frac{\pi}{4} Pipe_{ID}^2$$

$$F_{thrust-CF} = P_{pump} A = P_{pump} \frac{\pi}{4} Pipe_{ID}^2$$

$$F_{thrust-CF} = (95{,}000{,}000\ Pa) \frac{\pi}{4} (0.0650\ m)^2$$

$$F_{thrust-CF} = 323{,}047\ N = 72{,}624\ lb_f$$

The next calculation is the time the thrust force is applied, Δt_{thrust}:

Equation 9. Time the Thrust Force is Applied

$$\Delta t_{thrust} = \frac{L_{pipe}}{a}$$

$$\Delta t_{thrust} = \frac{35m}{1{,}481 \frac{m}{s}}$$

$$\Delta t_{thrust} = 0.0236\ s$$

The total pipe/contained fluid mass (m_{pipe} + m_{fluid}) of the unanchored pipe segment can be calculated using the following formula:

Equation 10. Total Mass of Pipe and Fluid

$$m_{total} = \frac{\pi}{4}(Pipe_{OD}^2 - Pipe_{ID}^2)\rho_{steel}L_{pipe} + \frac{\pi}{4}Pipe_{ID}^2\ \rho_{fluid}L_{pipe}$$

$$m_{total} = \frac{\pi}{4}[(0.0889\ m)^2 - (0.0658\ m)^2]\left(7{,}840\ \frac{kg}{m^3}\right)(35\ m) + \frac{\pi}{4}(0.0658\ m)^2\left(1{,}050\ \frac{kg}{m^3}\right)(35\ m)$$

$$m_{total} = 895\ kg$$

Assuming the restraint system manufacturer has a restraint that has a $k_{restraint}$ factor of 2,918,780 N/m based on the product pull test characteristics listed in Table 17, then the total force that would be applied to the restraint can be calculated as shown below in Equation 11(i.e., due to the transient thrust force acting on the pipe segment).

Table 17. Example 1 Restraint Pull Test Results

Restraint Pull Test Results	Number	Units
Force Applied to Restraint	150,000	lbf
	667,233	N
Total Restraint Length Change	9.0	in
	0.23	m
$K_{restraint}$	2,918,780	N/m

Equation 11. Total Force on the Restraint

$$F_{restraint} = F_{thrust}\Delta t_{thrust}\sqrt{\frac{k_{restraint}}{m_{pipe}}}$$

$$F_{restraint} = (323{,}047\ N)(0.0236\ s)\sqrt{\frac{2{,}918{,}780\ \frac{N}{m}}{895\ kg}}$$

$$F_{restraint} = 435952\ N = 98{,}006\ lb_f$$

Constant Pressure Source (Wellbore Model):

As described in Section 29.3.5, during a hydraulic fracturing operation, the restraint spanning a break may see two sequential loadings. First, a short-duration impulse from the pump side (Pump Model). Second, a sustained thrust if the well subsequently flows across the parted connections (Wellbore Model). In the constant pressure case, thrust persists until the flow is shut in. The restraint load is taken as the fluid-jet on the pipe; it is implicitly assumed the wellhead-side pipe segment can displace axially enough to engage the restraint and transfer the full thrust load.

Equation 12. Thrust Force on Restraint from Wellbore Flow Event

$$A = \frac{\pi}{4} Pipe_{ID}^2$$
$$F_{restraint} = F_{thrust} = 2P_{AOF}A = 2P_{AOF}\frac{\pi}{4} Pipe_{ID}^2$$
$$F_{restraint} = F_{thrust} = 2(25{,}000{,}000\ Pa)\frac{\pi}{4}(0.0658\ m)^2$$
$$F_{restraint} = F_{thrust} = 170{,}025\ N = 38{,}223\ lb_f$$

In a continuous (constant pressure) loading scenario of this type, the maximum restraint force equals the fluid-jet thrust.

Example 1 Restraint Force Selection

The calculated pipe thrusts and corresponding restraint forces for the two load cases are summarized in the table below.

Table 18. Example 1 Summary of Calculated Restraint Forces

Energy Source	Thrust Force on the Pipe F_{thrust} (N/lbf)	Force on the Restraint $F_{restraint}$ (N/lbf)
Constant Flow Rate (Pump)	323,047 / 702,624	435,952 / 98,006
Constant Pressure	170,025 / 38,223	170,025 / 38,223

The peak force on the restraint would result from transient thrust force generated by the constant flow rate energy source, therefore the restraint should have a minimum capacity of 435,952 N (98,006 lb_f), plus an appropriate safety factor.

> **Note:** Based on the restraint stiffness value derived from the sample test, a restraint force of this magnitude would equate to a 0.149 m (0.49 ft) elongation of the restraint extending across the pipe break (this would need to be accommodated by commensurate pipe segment displacement).

Example 1 Results Discussion

This example shows that pipe thrust and restraint load differ significantly in transient flow. Using only P*A underestimates restraint requirements. Conversely, applying 2PA overestimates. Here test data provided a restraint capacity of 667,233 N (150,000 lb_f), giving a factor of safety of 1.59 (See Equation 13). The end user needs to decide if this is adequate for the dynamic conditions.

Equation 13. Factor of Safety

$$FoS = \frac{Pull\ Test_{max}}{F_{restraint}}$$
$$FoS = \frac{667{,}233\ N}{435{,}952 N}$$
$$FoS = 1.53$$

Example #2 – Flow Testing Operations

Scenario Description

A low-pressure well (shut-in 8 MPa) is being flow tested. Temporary 60.3 mm (2”) pipe rated for 34.5 MPa (5,000 psi) connects to a 9.93 MPa (1,440 psi) test vessel. The longest straight length of unanchored pipe between the wellhead and the tank manifold is 25 m (82 ft).

Discussion of Scenario

For this scenario, both reservoir and test vessel act as constant pressure sources (see Figure 59). The restraint design needs to consider both constant pressure sources, assuming the maximum operating pressures on either end of the potential break could be different.

Figure 59. Example 2 Flow Testing Operations

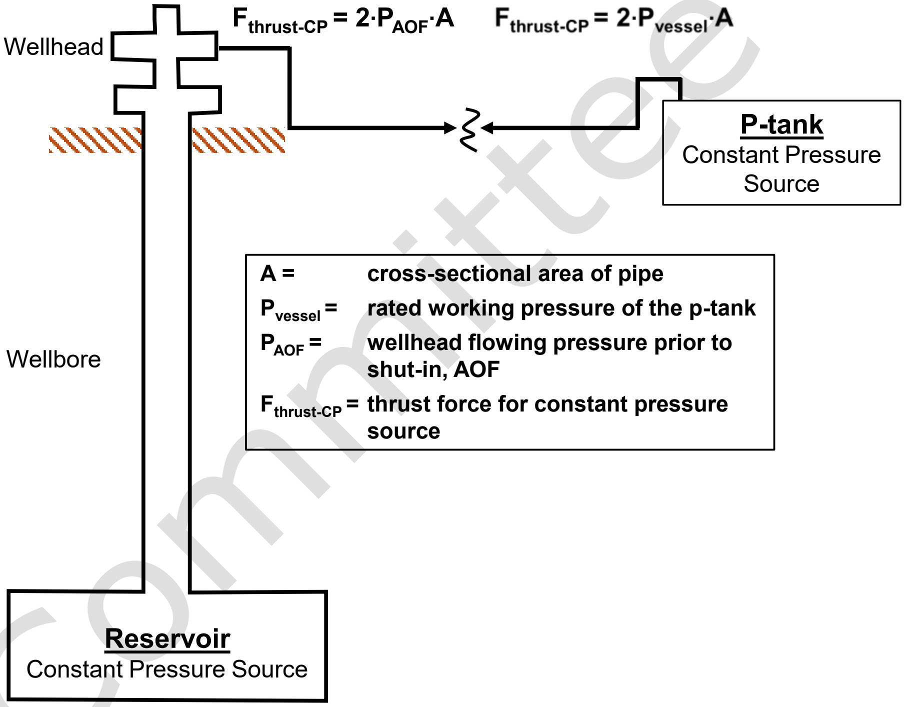


Table 19. Example 2 Assumed Parameter Values

Variable	Number	Units
Rated Working Pressure of Piping	34.5	MPa
Rated Working Pressure of Test Vessel	9.9	MPa
Pipe OD	60.3	mm

Pipe ID	43.7	mm
L_{pipe}	25	m
P_{AOF}	8	MPa

For this example, the analysis considers a break occurring at the maximum shut-in wellhead pressure of 8 MPa. In a real design evaluation, the assessment would also include the maximum pressure the system could experience in service. For example, the full line test pressure (typically at least 10% above the anticipated maximum operating pressure).

Example 2 Calculations

To determine the restraint force, evaluate the thrust force exerted on the parted pipe by the fluid jet from the constant pressure source (the reservoir). The estimated shut-in wellhead pressure of 8 MPA will be used. For this first part, assume the test vessel will not be exposed to any pressure higher than 8 MPa, so the vessel’s pressure rating (9.9 MPa) is not a factor in the initial restraint force calculation.

Having established this as a constant pressure scenario with the highest pressure being 8 MPa, the maximum thrust force on the piping system–and equivalently, the required restraint force–is calculated as follows:

Equation 14. Thrust Force on the Piping System

$$A = \frac{\pi}{4} Pipe_{ID}^2$$

$$F_{restraint} = F_{thrust} = 2P_{AOF}A = 2P_{AOF}\frac{\pi}{4} Pipe_{ID}^2$$

$$F_{restraint} = F_{thrust} = 2(8{,}000{,}000\ Pa)\frac{\pi}{4}(0.0437\ m)^2$$

$$F_{restraint} = F_{thrust} = 23{,}998\ N = 5{,}395\ lb_f$$

Without an automatic tank shut-off system, a second–possibly coincident–loading event can occur from the pressure vessel side if the pipe breaks. Since it has been assumed that the maximum tank pressure equals the 8 MPa shut-in pressure, both the pipe thrust and the restraint force on the vessel side will be the same as calculated above for the reservoir side.

Note: In this IRP, impulse loading analysis is only applied when a pressurized piping system is connected to a pump that maintains a constant flow rate. As described in Section 29.3.5, in those cases the piping system depressurizes from the break point back to the pump at the speed of sound in the fluid, even if the pump continues to operate at the same flow rate. The temporary pressure differential along the pipe gives rise to a transient thrust force on the pipe. While the same principle also applies to a pipe break in a Constant Pressure case, the key difference is that the fluid jet and pressure differential persist until flow is shut in. In the meantime, the thrust force acting on the pipe is fully reacted by the restraint (sling) as described above.

Example 2 Restraint Force Selection for Initial Assumptions

For the initial conditions considered (8 MPa on either side), the calculated restraint forces for the two constant pressure loading cases are equal. These forces are summarized in Table 20 below.

Table 20. Example 2 Summary of Calculated Restraint Forces

Energy Source	F_{thrust} (N/lbf)	$F_{restraint}$ (N/lbf)
Constant Pressure Reservoir	23,998 / 5,395	23,998 / 5,395
Constant Pressure Vessel	23,998 / 5,395	23,998 / 5,395

Example 2 Results Discussion

Based on these assumptions, both sources (reservoir and tank) produce the same peak sustained restraint force of 23,998 N (5,395 lb_f). Therefore, a restraint system rated for 44,482 N (10,000 lb_f) would be considered adequate, providing a factor of safety of roughly 1.85.

Example 2 Alternative Design Assumptions

It may be feasible to use an alternative approach that provides more consistency and flexibility by selecting a single, more robust restraint configuration. This approach uses the full pressure ratings of the pipe and connected equipment/vessels (rather than operation-specific pressures). While it can result in an oversized restraint for some applications, it avoids re-sizing for each operation using the same piping configuration.

In this extended example, the temporary pipe is rated at 34.5 MPa and the test vessel at 9.9 MPa. Both are treated as constant pressure sources for thrust and restraint force calculations.

First, calculate thrust assuming a maximum line pressure equal to the pipe's full rating of 34.5 MPa. In this case, it does not matter which side of the break the pressure source is on since a constant pressure source on either side produces the same thrust.

Equation 15. Thrust Force on the Pipe

$$A = \frac{\pi}{4} Pipe_{ID}^2$$

$$F_{restraint} = F_{thrust} = 2P_{AOF}A = 2P_{AOF}\frac{\pi}{4} Pipe_{ID}^2$$

$$F_{restraint} = F_{thrust} = 2(34{,}500{,}000\ Pa)\frac{\pi}{4}(0.0437\ m)^2$$

$$F_{restraint} = F_{thrust} = 103{,}491\ N = 23{,}266\ lb_f$$

Similarly, establish the thrust force and restraint load from the test vessel is established assuming operation at its maximum rating (9.9 MPa).

Equation 16. Thrust Force on the Restraint

$$A = \frac{\pi}{4} Pipe_{ID}^2$$

$$F_{restraint} = F_{thrust} = 2P_{vessel}A = 2P_{vessel}\frac{\pi}{4} Pipe_{ID}^2$$

$$F_{restraint} = F_{thrust} = 2(9{,}900{,}000\ Pa)\frac{\pi}{4}(0.0437\ m)^2$$

$$F_{restraint} = F_{thrust} = 29{,}697\ N = 6{,}676\ lb_f$$

Example 2 Alternative Restraint Force Selection

The restraint forces calculated for the two conditions are summarized in the table below.

Table 21. Example 2 Alternative Approach Restraint Forces

Energy Source	F_{thrust} (N/lbf)	$F_{restraint}$ (N/lbf)
Constant Pressure Reservoir (to full pipe pressure rating)	103,491 / 23,266	103,491 / 23,266
Constant Pressure Test Vessel (to vessel rated operating pressure)	29,697 / 6,673	29,697 / 6,673

Example 2 Alternative Results Discussion

A restraint selected based on the initial, operation-specific conditions would be under-designed compared with using full equipment ratings. At the pipe's rated pressure (34.5 MPa), the estimated maximum restraint force is 103,491 N (23,266 lb_f)–well above the 44,482 N (10,000 lb_f) capacity deemed adequate under the initial assumptions. The test vessel case (9.9 MPa) produces 24,881 N (5,593 lbf), also higher than the initial scenario. The alternate approach generally yields higher-capacity designs that can safely resist forces under more extreme–but plausible–conditions.

Conclusion

These two examples illustrate how restraints can be designed based on the assessment of various operating scenarios and underlying assumptions. One approach is to assess a piping and restraint system design specifically for an expected operating scenario with defined limits for pump and wellhead pressures as well as any pressure vessel ratings. However, if the operating conditions or equipment employed in the field change, the calculations need to be updated with the revised inputs. The risk is that a previously selected restraint system may be misapplied if the assumed equipment layout or operating conditions change materially. It can also be cumbersome for operators to continually update and track these calculations and to ensure that revised outcomes are implemented correctly at the field level.

The second example introduced a simpler approach that instead uses the specified pressure ratings of the piping and equipment to determine restraint capacity requirements, rather than estimates of the maximum operating pressures for a particular operation. While this alternate approach generally requires higher-capacity restraint systems–which may be over sized for many operations–the consistency it provides can create organizational and cost efficiencies. It also results in high factors of safety in most cases.

Appendix D: Case Study

Introduction

An organization is evaluating the need for restraints within its coiled tubing operations. The internal treating iron assembled inside coiled tubing (CT) reels connects the CT string to the rotating joint and typically includes chicksans, plug valves, tees, and pup joints–the same component types used in surface line pipework system from pumping units.

The internal CT reel manifold is supported by brackets and mounts designed to carry the weight and expected operating loads but not engineered to withstand forces from a pipework failure. The need for a pipework restraint system was therefore evaluated.

Figure 60. Coiled Tubing Unit

Figure 61. Coiled Tubing Reel Internal Manifold

Figure 62. Coiled Tubing Reel Internal Manifold

Risk Assessment

As part of the assessment, the organization evaluated operational factors relevant to its portfolio to characterize overall risk.

- Typical CT pumping rates are < 0.75 m^3/min, below OEM erosion-rate limits for the pipework system.
- Abrasives are not typically pumped through the system.
- The pipework system is certified annually.
- Operating pressure is typically 65 MPa; the pipework system is rated to 103.5 MPa.
- The CT reel is covered by the organization’s exclusion zone policy, limiting personnel presence nearby during operations.
- The CT reel shroud covers much of the internal manifold acting as a partial cage.

A significant risk was identified with synthetic sling-type restraints inside the reel. The reel is a rotating drum that feeds the CT string into the wellhead via an injector head. A sling could catch or bind on the reel during rotation, potentially causing severe damage to the reel, CT string, and wellhead, and escalating to crane collapse, well control events, and/or loss of life.

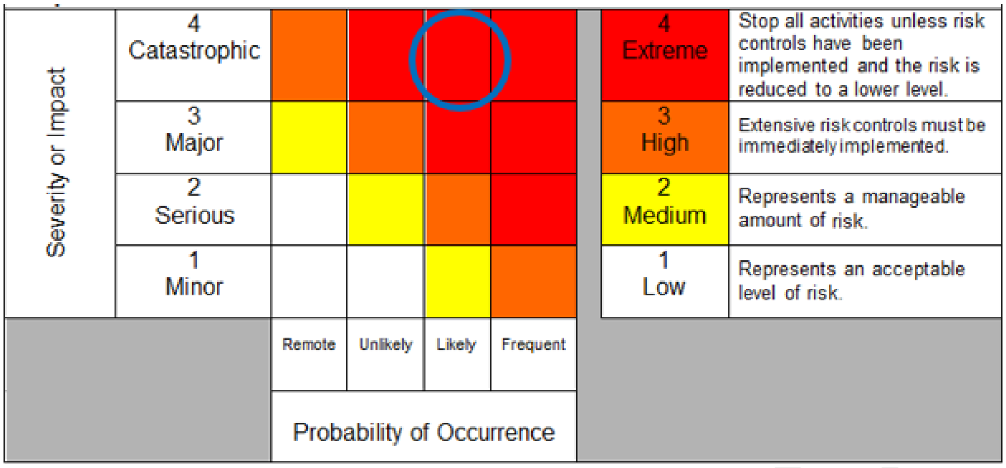
Given these considerations, the organization decided **not** to restrain the internal CT reel manifold.

A comparison of the risk profile is provided below:

A) Initial Risk Assessment: Utilize restraint inside CT reel (internal manifold)
Primary Hazard: Sling entanglement with the rotating drum

Potential Consequence: Catastrophic damage to surface equipment and wellhead; possible well control incident.

Figure 63. Initial Risk Assessment

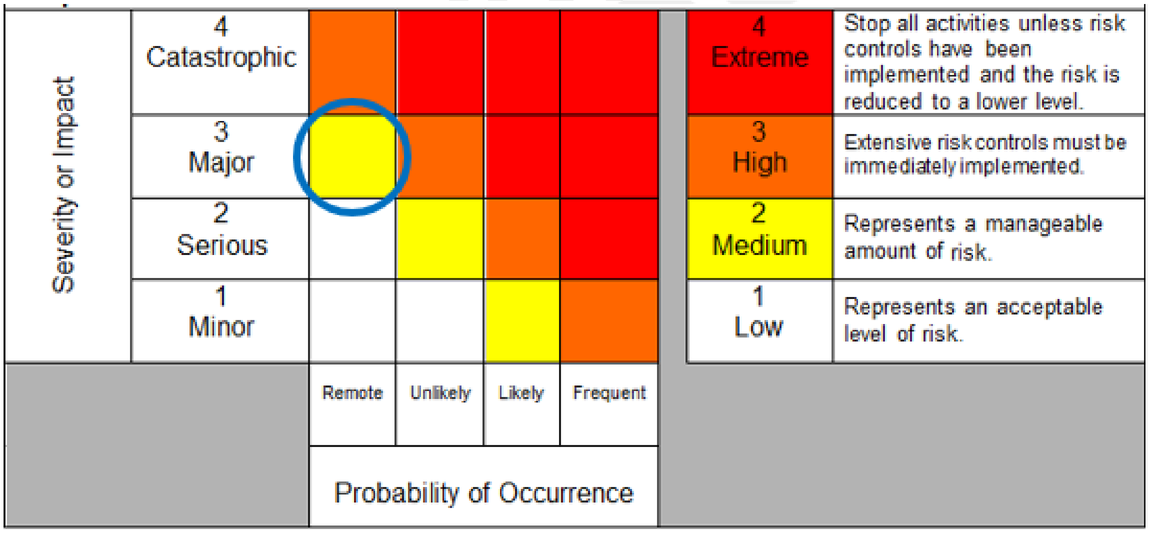


Severity or Impact	Remote	Unlikely	Likely	Frequent
4 Catastrophic	🟧	🟥	🟥	🟥
3 Major	🟨	🟧	🟥	🟥
2 Serious	⬜	🟨	🟧	🟥
1 Minor	⬜	⬜	🟨	🟧
	Probability of Occurrence			

🟥 4 Extreme	Stop all activities unless risk controls have been implemented and the risk is reduced to a lower level.
🟧 3 High	Extensive risk controls must be immediately implemented.
🟨 2 Medium	Represents a manageable amount of risk.
⬜ 1 Low	Represents an acceptable level of risk.

B) After Controls: Do not utilize restraint inside CT reel (internal manifold)
Primary Hazard: Overpressure leading to component separation and projectile risk.
Potential Consequence: Internal manifold pipework overpressures resulting in component separation and projectiles.

Figure 64. Risk Assessment After Controls



Severity or Impact	Remote	Unlikely	Likely	Frequent
4 Catastrophic	🟧	🟥	🟥	🟥
3 Major	🟨	🟧	🟥	🟥
2 Serious	⬜	🟨	🟧	🟥
1 Minor	⬜	⬜	🟨	🟧
	Probability of Occurrence			

🟥 4 Extreme	Stop all activities unless risk controls have been implemented and the risk is reduced to a lower level.
🟧 3 High	Extensive risk controls must be immediately implemented.
🟨 2 Medium	Represents a manageable amount of risk.
⬜ 1 Low	Represents an acceptable level of risk.

Additional Controls:

The external CT reel manifold is restrained with a synthetic sling because it is stationary and located away from the rotating drum. The external manifold is not mounted with engineered supports that would function as a self-restraint; therefore supplemental restraint is applied.

Appendix E: Sample Checklists

Pre-Rig In Inspection Checklist

Surface Location:				**Client:**		
Well UWI:				**Date (dd-mm-yy):**		
#	**Description**	**Checked**	**Corrected**	**Removed from Service**	**N/A**	**Comments**
1	Hard piping unions are in good condition, free of defects or damage and are not mismatched.					
2	Hard piping threads are in good condition, clean, and lubricated.					
3	Hard piping insert is present, properly installed and not warped or cracked.					
4	All three segments are present and the snap ring is in position.					
5	Flexible piping is free from cuts, abrasions, and other damage.					
6	The outer cover of flexible piping does not have signs of looseness, kinks, bulges, soft spots, abrasion, cuts or gouges.					
7	Restraint ‘in service’ date is current					
8	Restraints are appropriate to current or anticipated temperature conditions (e.g., cold weather ratings on shackles or synthetic fibres, temperature of pumped material)					
9	Tagged load rating of the restraint (tag) meets or exceeds rated maximum allowable					

	working pressure rating of the piping system.					
10	Restraints are free from damage					
11	Hardware has all necessary and appropriately sized/rated components installed and are free from damage					
Verifier Name:			**Verifier Signature:**			
Date Completed:						

Installation Checklist

Surface Location:				**Client:**		
Well UWI:				**Date (dd-mm-yy):**		
#	**Description**	**Checked**	**Corrected**	**Removed from Service**	**N/A**	**Comments**
1	High pressure iron P&ID has been provided and approved by appropriate representatives (optional)					
2	Hard piping unions are in good condition, free of defects or damage and are not mismatched.					
3	Hard piping threads are in good condition, clean, and lubricated.					
4	Hard piping insert is present, properly installed and not warped or cracked.					
5	Hard piping has all segments secured in place and the insert condition and placement is correct.					
6	The outer cover of flexible piping shows no signs of looseness, kinks, bulges, soft spots, abrasion, cuts or gouges.					
7	Flexible pipe shows no signs of overbending.					
8	Flexible pipe end couplings show no signs of leakage, corrosion, erosion or cracking of the steel end.					
9	Flexible piping end couplings have inspection tags with records of inspection.					
10	Restraint ‘in service’ date is current					
11	Restraints are appropriate to current or anticipated temperature conditions (e.g., cold weather ratings on shackles or synthetic fibres, temperature of the pumped material					
12	Restraints are free from damage					
13	Hardware has all necessary and appropriately sized					

	components installed and are free from damage					
14	Installation of the restraints does not interfere with operations					
15	Restraint system has adequate tension and no excessive slack					
16	Restraints are anchored appropriate to the application					
17	Installation of restraint system is as per manufacturer specification					
18	All company standard operating procedures, safety procedures and guidelines were followed during installation					
Verifier Name:			**Verifier Signature:**			
Date Completed:						

Appendix F: Glossary

See 29.2 Definitions and Regulations for additional definitions.

AER Alberta Energy Regulator

AMPP Association for Materials Protection and Performance

Anchor Point Owner The Anchor Point Owner could be the OEM of the Anchor, a service company that provide anchor points for use with their temporary pipework, a third-party rental company or the prime contractor.

API American Petroleum Institute

ASME American Society of Mechanical Engineers

ASTM American Society for Testing and Materials (now ASTM International)

BCER British Columbia Energy Regulator

Burst Disk Pressure Relief Device utilizing a disk that ruptures to relieve pressure. Pressure tolerances on pressure relief for disks need to be provided by the manufacturer.

CAOEC Canadian Association of Oilwell Energy Contractors

CAPP Canadian Association of Petroleum Producers

Competent Person A competent person is one that is adequately qualified, suitably trained and has sufficient experience to safely perform his/her work.

Compressible fluid A fluid that experiences large changes in volume or density when pressure is applied during flow.

CSA Canadian Standard Association

CT Coil Tubing

CWP Cold Working Pressure

DACC Drilling and Completions Committee

Dynamic Load Any force that changes over time in terms of size, direction, and position.

Elastomer Any natural or synthetic rubber material capable of recovering its original shape after being stretched. Elastomers provide permanent or temporary seals in a variety of situations and equipment, especially well control equipment, used in drilling operations.

EPAC Explorers & Producers Association of Canada

ESD Emergency Shut Down (valve)

Exclusion Zone Is a designated area of hazards with the highest risk and requires authorization to enter.

Finite Element Analysis A computerized simulation based on a numerical method used to predict how a product reacts to real-world forces such as vibration, heat, fluid flow, and other physical effects.

Galling The tearing of metal when two elements rub against each other, usually caused by lack of lubrication or extreme contact pressure.

H_2S Hydrogen Sulphide

High Pressure Containing Components A component which is exposed to and contains pressure.

HPCC High Pressure Containing Components

Incompressible fluid A fluid, either liquid or gas, whose density remains constant during flow.

Integral fitting A pressure-retaining component machined or forged from a single piece of material, with no welds or joined segments in the pressure-containing envelope. Integral fittings are used in high-pressure applications to minimize potential leak points and maximize structural integrity.

Iron Management System The purpose of iron management system is to ensure the integrity of the iron. They typically consider the potential for degradation of materials (e.g., erosion, corrosion, chemical/environmental degradation, temperature considerations, stress fatigue), pressure testing, material thickness testing, non-destructive testing, proper maintenance of materials and proper identification of tracking of information about the iron (e.g., in-service dates, inspections, manufacturer specifications). Refer to manufacturer recommendations for more detail.

IRP Industry Recommended Practice

Layflat Hose A flexible, lightweight hose that can lay flat when not in use and is used for the discharge and delivery of water.

LPT Line Pipe Thread

Maximum allowable working pressure The highest rated pressure that the system can withstand based on the maximum pressure of the lowest pressure rated component in the system.

Maximum anticipated operating pressure maximum pressure on the entire system during normal operations, static conditions, pigging operations and any other operating conditions the temporary pipework system is anticipated to be exposed to. MAOP shall not exceed MAWP.

MAOP Maximum Anticipated Operating Pressure

MAWP Maximum Allowable Working Pressure

MER Ministry of Energy and Resources

NACE National Association of Corrosion Engineers (NACE International)

> **Note:** NACE International merged with The Society for Protective Coatings to form the Association for Materials Protection and Performance (AMPP) in 2021.

NORM Naturally Occurring Radioactive Materials

NPT National Pipe Tapered

NPTF National Pipe Taper Fuel

NPS Non-Pressure Seal

NPST Non-Pressure Sealing Thread

OHS Occupational Health and Safety

Owner A trustee, receiver, mortgagee in possession, tenant, lessee or occupier of any lands or premises used or to be used as a place of employment and any person who acts for or on behalf of an owner as an agent or delegate. For the purposes of IRP 29, the owner is the person who possesses the worksite and/or product.

Pipework is the complete system of piping, restraints, and anchoring.

PPE Personal Protective Equipment

PPM Parts per Million

PRD Pressure Relief Device

Pressure Relief Device These are the primary pressure relief components. Devices include a pressure relief valve or a non-reclosing pressure relief device (burst disk).

Pressure Relief Valve are primary pressure relief valves that relieve excess pressure and reclose to prevent further flow after normal conditions have been restored.

Prime Contractor In relation to a multiple employer workplace, the directing contractor, employer or other person who enters into a written agreement with the owner of that workplace to be prime contractor or if there is no agreement, the owner of that workplace.

Process and Instrumentation Diagram (P&ID) A detailed diagram that shows all piping, equipment, valves, and instrumentation in a process system. It includes control logic, measurement points, and how components are interconnected for operation and safety**.**

Process Flow Diagram A simplified diagram that shows the major equipment and flow paths of a process system. It illustrates how fluids or gases move through the system but does not include detailed instrumentation or control information.

PRV Pressure Relief Valve

PS Pressure Seal

Relief Pressure Pressure that the PRD will open to de-pressure the system.

Restraint Safety system designed to control the release of stored energy if temporary pipework fails.

Restraint Owner The Restraint Owner could be the OEM restraint manufacturer, a service company that provide restraints for use with their temporary pipework, a third-party rental company or the prime contractor.

RWP Rated Working Pressure

SDS Safety Data Sheet

Securement Culmination of initial anchor point, restraint connections to individual temporary pipework sections and final anchor

Service Company Means a person, corporation or association who is contracted to supply, sell, offer, or expose for sale, lease, distribute or install a product or service to another company, usually the owner of the worksite.

Supplier a company that sells, rents, leases, erects, installs or provides equipment.

Swivel Joint (Chiksan) A series of short steel pipe sections that are joined by swivel couplings. The unit functions as a flexible flow line that provides a flow path between the control head and the floor manifold.

Temporary Pipework Temporary pipework, also called temporary flow piping, is the system of pipes used at wellsite for pumping into and out of wellbores (wellheads). It includes connections (e.g., hammer unions, flanged connections) and components like joints, valves, tees, and swivels that provide flexibility and adjust the system’s orientation and elevation. Temporary pipework is used in services, but not limited to, swabbing, well flowback, cementing, well servicing, and well stimulation.

Thermoplastic Polyurethane A category of plastic formed by injection molding, blow molding, and extrusion that can be melted and reformed, resulting in a highly flexible, durable, light weight and abrasion-resistant elastomer.

Tolerance During testing, actual pressure release of a PRD should be within +/- 1400 kPa (200 psi) of the required relief pressure. For burst disks the criteria will be met through the review of the manufacturers tolerance documentation for the specific disk installed in the relief system.

UT Ultrasonic Testing

Water Transfer Water transfer is moving water with pumps using layflat hoses or other means, excluding tank trucks. Water transfer does not include tying to a wellhead, test package, or pressure vessel. Water transfer can occur on lease or off lease. See 29.11 Water Transfer Systems.

Working Pressure Maximum pressure on the pressure control equipment that must never be exceeded during field operations.

Appendix G: References and Resources

DACC References

Available from www.energysafetycanada.com

- IRP 02: Completing and Servicing Sour Wells
- IRP 04: Well Testing and Fluid Handling
- IRP 07: Competencies for Critical Roles in Drilling and Completions

Local Jurisdictional Regulations and Information

Alberta

Available from www.alberta.ca:

- Occupational Health and Safety Code
- Safety Codes Act, July 2020

Available from www.aer.ca

- Directive 077: Pipelines – Requirements and Reference Tools
- Oil and Gas Conservation Act
- Oil and Gas Conservation Rules
- The Pipeline Rules
- The Pipeline Act
- Report 2009-A: Updates to Storage Requirements for the Upstream Petroleum Industry

British Columbia

Available from www.bclaws.gov.bc.ca:

- Energy Resources Activities Act
- Petroleum and Natural Gas Act

Available from www.bc-er.ca:

- Drilling & Production Regulation
- Oil and Gas Activity Operations Manual, Chapter 11 Pipeline Activity

Available from www.worksafebc.com

- Occupational Health and Safety Regulation, Part 23 Oil and Gas
- Workers Compensation Act

Manitoba

Available from www.gov.mb.ca:

- Drilling and Production Regulation, June 1994
- Workplace Safety and Health Regulations

Saskatchewan

Available from www.saskatchewan.ca:

- Directive PNG034 – Saskatchewan Pipelines Code
- Saskatchewan Ministry of Energy and Resources, The Oil and Gas Conservation Regulations
- Saskatchewan Occupational Health and Safety Regulations

Government of Canada Resources

Available from www.gc.ca:

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Other References and Resources

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- ANSI/MSS SP-44-2019: Steel Pipeline Flanges. 2020. USA: Manufacturers Standardization Society of the Valve and Fittings Industry Inc.
- API 6A, Specification for Wellhead and Christmas Tree Equipment, twenty first edition. 2018. Washington, DC, USA: API.

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- API 17K, Specification for Bonded Flexible Pipe, third edition. Reaffirmed 2022. Washington, DC, USA: API.
- API Recommended Practice 7HU1, Safe Use of 2-Inch Hammer Unions for Oilfield Applications, first edition. Reaffirmed 2020. Washington, DC, USA: API.
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- ASME B16, Standardization of Valves, Flanges, Fittings, and Gaskets. 2021. New York, NY, USA: ASME.
- ASME B16.5, Pipe Flanges and Flanged Fittings: NPS ½ through NPS 24, Metric/Inch Standard. 2020. New York, NY, USA: ASME.
- ASME B16.47, Large Diameter Steel Flanges: NPS 26 through NPS 60, Metric/Inch Standard. 2020. New York, NY, USA: ASME.
- ASME B31.3, Process Piping. 2022. New York, NY, USA: ASME.
- ASME PCC-2. Repair of Pressure Equipment and Piping. 2015. New York, NY, USA: ASME.
- ASTM A53/A53M-22, Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless. 2022. West Conshohocken, PA, USA: ASTM. https://doi.org/10.1520/A0053_A0053M-22.
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