ethos OPERATIONAL EXCELLENCE Practice	Pipe and Hose Restraints
Owner: USA Division Safety **Revision No:** 00	**Date last revised:** 08/14/2013

1.0 Applicability

This practice applies to all Encana Oil & Gas (USA) Inc. (Encana) staff and service providers who work under contract for Encana at all facilities owned or operated by Encana.

2.0 Scope

The purpose of this practice is to establish the minimum requirements for restraint of pressurized piping and hoses for the Business Units (BUs) and Sub-Business Units (SBUs) at Encana. The risk assessment methods and scoring are based on the Ethos Restraint Committee research and experience. Based on site-specific conditions, an SBU may elect to develop more comprehensive operational procedures in order to further reduce hazards and risks associated with a work location.

2.1 Restraint Planning Checklist

This checklist summarizes the steps in determining whether restraints are appropriate for a particular operation. There may be multiple temporary piping installations on a site, each with varying risks. Each can be assessed separately.

☑	Step	Activity
☐	1	Determine the anticipated forces (Table 4) and stored energy (Table 5) in the piping planned to be in operation. This can be done quickly using these two tables.
☐	2	Perform a Risk Assessment utilizing the Ethos Risk Assessment form. • Utilize the example Risk Assessment in Table 1 and 2 to guide your selection of probability and impact. • Consider the performance record of the service provider in assessing whether additional risk is present in their conducting the planned operations.
☐	3	Identify risk mitigation measures needed to reduce or eliminate risk. • Determine whether no-go zones can be utilized. • Determine if restraints are appropriate. • If required, select the appropriate restraint level (Table 3) for the operation as determined by the Risk Assessment form.
☐	4	Implement any appropriate mitigation methods in accordance with the No-Go Zones and Pipe and Hose Restraints Ethos Practices.

3.0 Core information and requirements

The core information and requirements of this practice include the following:

3.1 Applicable Operations

This Ethos Restraint Practice is applicable to all Encana operations involving temporary installations of pressurized piping and hoses. This includes, but is not limited to, drilling, pump down operations, cementing, well preparation, hydraulic fracturing (including remote hydraulic fracturing), wireline, coiled tubing, snubbing, workovers, and flowback. This is applicable only to temporary installations. Please see section 8.2 for documents governing restraint of permanent piping and production equipment.

3.2 Purpose of Restraints

Restraints function to reduce movement of pipe and hoses in the event of a pipe, hose or fitting failure. They are a mitigation tool that can be used to minimize or restrict damage to personnel and equipment from piping, but they are not capable of restraining every fitting that may break free during a failure event.

Restraints are not a substitute for good integrity management practices including proper design, iron management, proper pipe support, and pressure testing. Even with excellent integrity management practices, risks must be identified by each operation prior to starting work, and tools used to mitigate risk must be in place.

Where mitigation steps are appropriate to reduce the risk associated with a particular operation or procedure, restraints can be used as part of an overall plan which uses other mitigation tools such as No-Go Zones. The end result of using a combination of tools is to eliminate the risk or reduce it to as low a level as practically feasible.

When this practice is used correctly, the following questions should be able to be answered:

- What forces will be generated by a pipe failure and will the force be sustained or momentary?
- What risk level does the operation pose?
- Does the service provider's track record add additional risk?
- What mitigation steps can be used to reduce risk?

3.3 Risk Assessment

This restraint practice is designed to be used in conjunction with [Encana's Risk Assessment].

To better inform the group conducting the risk assessment, this document provides a sample assessment specifically around the use of restraints and no-go zones to mitigate risks from pressurized piping. The sample clarifies which causes and mitigations affect "frequency" or "impact" ratings in the assessment. It also provides recommendations for assigning severity levels based on operating conditions and forces. During each operation, the company representative must determine which category of restraint is required.

TABLE 1. RISK ASSESSMENT Example

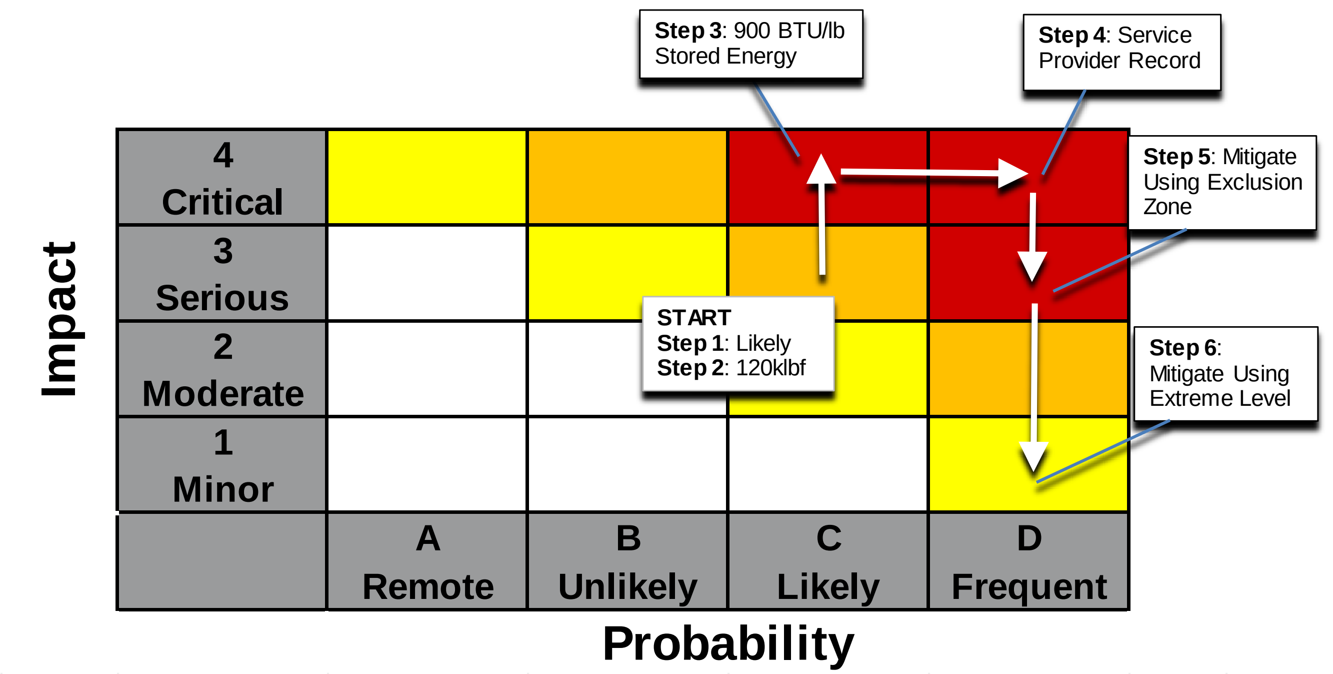


Table 1 provides an example of how risks can be assigned and then mitigated using the guidelines in Table 2. It shows Example 1 results. A second example is also provided in Table 2 showing an operation where restraints were not required.

Example 1: Nitrogen frac at 8,000 psig utilizing 4 inch ID pipe and Good service provider.
Example 2: Water frac at 6,000 psig utilizing 3 inch ID pipe and Excellent service provider.

Table 2: Risk and Mitigation Level Assignments

Step 1: Determine Probability of Iron Failure

Probability	A – Remote	B – Unlikely	C – Likely	D – Frequent
Likelihood	Once in the life of the facility	One occurrence every 5 - 20 yrs	One occurrence every 1 – 5 years	One or more occurrences / yr

Example 1 Result: C - Likely. Encana and Industry have experienced failures in the last 5 years. (box C)
Example 2 Result: C - Likely. Encana and Industry have experienced failures in the last 5 years. (box C)

Step 2: Determine Risk Posed by Forces in the Line (Table 4)

Force (lbf)	0-50k	50k-100k	100k-150k	150k+
Risk Ranking	1 Minor	2 Moderate	3 Serious	4 Critical

Example 1 Result: 3 - Serious. 150klbs. Generally classed as serious in Encana operations. (box 3C)
Example 2 Result: 2 - Moderate. 60klbs. Generally classed as moderate in Encana operations. (box 2C)

Step 3: Determine if Fluid Potential Energy Increases Risk (Table 5)

Stored Potential Energy (BTU/lb)	0-100	100-450	450-850	850+
Added Level of Impact	0	1	2	3

Example 1 Result: 800 BTU/lb. Add 2 to Impact level. Raises impact level from 3 to 4 (max value). (box 4C)
Example 2 Result: 21 BTU/lb. No addition to Impact Level. (box 2C)

Step 4: Service Provider Considerations (affects Probability)

Safety Record	Excellent	Good	Fair	Poor
Iron Integrity Mgt Program	Excellent	Good	Good	Good
Std Operating Procedures	Comprehensive	Partial	Partial	None
Track Record	Excellent	Good	Fair	Fair
Increased Level of Probability	0	1	2	3

Example 1 Result: Good track record. Higher than avg fitting failures. Add 1 to Probability Level.(box 4D)
Example 2 Result: Excellent track record and safety. No addition. (box 2C)

Step 5: Mitigate Risk Using Exclusion Zone (affects Impact) (See Encana Restricted Access Standard)

Pad Size	Any Size	Any Size	Large	Remote Operation*
No-Go Zone Imposed	No	Yes, Red Zone	Yes, Red Zone	Yes, Red Zone
Strict Zone Enforcement	No	Yes	Yes	Yes
Line-of-Fire Exclusions	No	Yes	Yes	Yes
Reduced Level of Impact	0	1	2	3

Example 1 Result: Midsize wellpad, no-go, line of fire strictly enforced. Reduce Impact level by 1.(box 3D)
Example 2 Result: Midsize wellpad, no-go, line of fire strictly enforced. Reduce Impact level by 1.(box 1C)

*Remote Operation – see Section 8.3 Definitions

Step 6: Mitigate Risk Using Restraints (affects Impact)

Restraint Level	LOW	MEDIUM	HIGH	EXTREME
Reduced Level of Impact	0	1	2	2

Example 1 Result: Reduce Impact level by 2 by utilizing EXTREME level restraints. (box 1D)
Example 2 Result: No restraints required. Risk already reduced below low level. (box 1C)

3.4 Restraint Levels

Encana categorizes restraint requirements into four levels – Low, Medium, High, and Extreme based on the risk level assigned during a risk assessment (RA).

TABLE 3. Restraint Levels

<table>
<tr><th colspan="2">RA Results</th><th>LOW</th><th>MEDIUM</th><th>HIGH</th><th>EXTREME</th></tr>
<tr><th rowspan="2">Allowable Restraint Types</th><th>Hoses</th><td>-</td><td>Whipsock, Whipcheck</td><td>Whipsock, Whipcheck</td><td>Whipsock</td></tr>
<tr><th>Piping</th><td>-</td><td>Sling, Cable/Shackle</td><td>Sling</td><td>Sling</td></tr>
<tr><th colspan="2">Un-Allowable Restraint Types</th><td colspan="4">• Whipchecks or whipsocks which are not specifically engineered for the anticipated failure forces.
• Cable/Shackle systems which are not specifically designed for anticipated failure forces.</td></tr>
<tr><th colspan="2">Recommended Practices</th><td colspan="4">• Although not required, whipsocks are recommended for all hoses regardless of operating pressure.
• Carefully consider where pipe or hose vibration may cause premature failure of cable/shackle restraints or where concrete blocks may rub on piping and wear through pipe wall.
• Verify that restraints are engineered for the anticipated failure forces.</td></tr>
</table>

3.5 Practices to Avoid

Some restraint practices should be avoided completely. They only appear to be safe but do not provide sufficient protection or are not designed for the application. You do not want to create a false sense of security by using the wrong restraint equipment. These include:

- Don't use whipchecks on pipe, regardless of the pressure. They are designed only for hoses.
- Don't use stakes only (without pipe clamp) crossed over pressurized pipe. They can easily separate from the pipe in a failure event.
- Don't use T-posts with some kind of attachment to pressurized pipe. They can easily separate from the pipe in a failure event.
- Don't use concrete block anchors that do not have a channel for the piping. This results in elevation of the concrete block on wood shims, which negates their restraining effect. If you are using concrete blocks on wood shims, utilize a restraint to secure the block to the piping.
- Don't stack items on top of concrete block anchors as these items can become projectiles in the event of a line separation.
- Don't use chains, as they are not designed for use as restraints (exceptions exist, but design of chain for application must be verified).

3.6 Types of Restraints

<u>When restraints are utilized</u> on pressurized piping and hoses, they must be engineered to withstand the anticipated force encountered during a failure. They must also be attached to equipment and/or supports that can withstand the forces that will be put on them. Users of restraints should be careful to avoid assuming that their restraint systems are sufficient merely because they resemble other restraints seen in the oilfield. For the reasons listed above in Section 3.5 there are many practices that do not enhance safety and would not withstand the forces they would encounter.

<u>Location Requirements:</u> On straight pipe runs, restraints must be installed across each hammer union or other connection. On each 90 degree turn, a restraint must be across each turn, and anchored to the nearest solid anchor point to minimize lateral movement if a failure of the targeted tee should occur. Restraints are permitted to be anchored to the flanged connection on the frac tree or wellhead. Slack in restraints must be minimized as much as practical while still allowing for assembly of the hammer union or other connection covered.

Below is a description of types of restraints, their intended applications and distinguishing aspects.

3.6.1 Sling Type (Soft)

Sling restraints are intended for use with high pressure systems including energized applications. Depending on the specific design, these restraints include soft slings that wrap around the pressured piping, and anchor points, and may utilize sling connections or spines. The two major types are rib-and-spine (Figure 2) or an ongoing link-to-link (Figure 1).

Sling restraints are designed to absorb the kinetic energy from moving pipe where rigid systems would otherwise break. Critical

aspects include:

- Intended for hard pipe, not for use with hoses.
- Must be specifically engineered for system pressures and forces.
- Correct installation of the system is crucial, and sling slack must be minimized throughout the system.
- Maintenance program for sling quality is critical.
- Chemical corrosion of slings should be avoided.

Figure 1 Link-to-Link

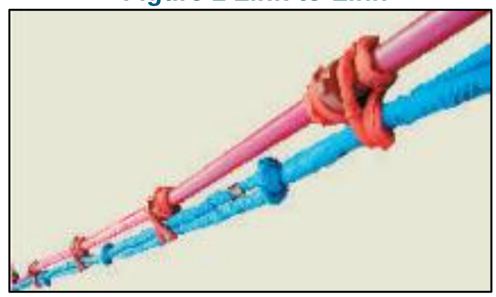


Figure 2 Spine

3.6.2 Cable and Shackle (Wire and Clamp)

Cable and shackle restraints consist of a “shackle” or clamp located on both sides of a pipe connection, with a cable or wire rope securing the two shackles together (Figure 3). Critical aspects of this type of restraint include:

- In order for the shackle/clamps to work correctly, they must be tightened adequately onto the pipe to prevent the clamp from sliding.
- They are designed for specific force/pressure ratings. If used beyond their rating they actually increase risk by becoming potential projectiles in the event of a pipe or fitting failure. The manufacturer’s intended design must be confirmed in order to use.
- A point for regular tie down is also prefereable, as seen in the pipe bolt down in the picture to the right (Figure 4).

Figure 3 Cable and Shackle

Figure 4 With Bolt Down

3.6.3 Whipsocks

Figure 5 Hose to Hose

Figure 6 Hose to Pipe

Whipsock restraints consist of twisted strands of metal wire that wrap around a pressured hose (like a sock) with eyes hooks on the connection end that secure to anchor points. The sock diameter reduces when the hose is forced away from the anchor points (coupling failure), tightening around the hose and restraining it from movement. Critical aspects include:

- Intended for use with pressured hose lines.
- Require anchor points for the whipsock eyes.
- They can be used on hose to hose connections (Figure 5) or hose to pipe connections (Figure 6).
- Whipsocks are preferable to whipchecks as they can significantly reduce the area of potential movement of a hose during failure compared to a whipcheck.
- Whipsocks are preferable to whipchecks as they can restrain a separation of the hose from an end fitting. A whipcheck may not restrain in this scenario.

3.6.4 Whipcheck

Whipcheck restraints consist of a steel cable with loops on each end that are positioned on both sides of a hose connection (Figure 7) in case of coupling failure. Critical aspects include:

Figure 7 Whipcheck

- Intended for use with pressured hose lines. Not intended for use with hard pipe.
- Installation must minimize the amount of slack in the cable as much as possible.
- Although whipchecks minimize the area which the hose can whip around upon failure of a coupling, they do not completely restrict movement. This may result in injury to personnel located along side it during an event.
- Whipchecks are typically designed with a 5 to 1 safety ratio, which often limits them to lower pressure operations.
- Whipchecks must be used for their designed purpose and rating, and the whipcheck design specification must be documented.

3.6.5 Anchors

Anchors are intended to be used in conjunction with restraint systems. Common designs include deadmen anchors, clamped-stakes anchor, concrete blocks, and helical anchors. They should be installed and placed based on spacing from engineering calculations or guidelines for the expected forces to be encountered.

Figure 8 Deadman

5.3.6.1 Deadmen anchors (Figure 8) normally have 3-4 expandable wings with a pointed-end structure that bites into the soil for maximum grip. Deadmen anchors shall be installed in accordance with API and IADC recommendations and applicable state and federal laws.

5.3.6.2 Clamped-stakes anchors (Figure 9) are made of two stakes that are connected together via a clamp fitted around the pipe that is being secured. Stakes alone do not suffice as anchors. Engineering calculations should be performed to ensure they will truly counteract the movement being anticipated.

Figure 9 Clamped-stakes

5.3.6.3 Concrete block anchors (Figure 10) must be designed to straddle or bolt onto the flowback iron and must be of sufficient weight to prevent movement of the anchor in case of a line failure. Because concrete block applications are often not designed but simply mimic other local convention, they may pose a particular hazard. All anchors, including concrete block, must be appropriately engineered for the potential static and dynamic forces in the case of a failure. Don't use concrete block anchors that do not have a channel for the piping. This results in elevation of the concrete block on wood shims, which negates their restraining effect

Figure 10 Concrete Block

5.3.6.4 Helical anchors (Figure 11) consist of one or more helix-shaped bearing plates attached to a central shaft, which is installed by rotating or "torqueing" into the ground. Each helix is attached near the tip, is generally circular in plan, and formed into a helix with a defined pitch. Helical anchors derive their load carrying capacity through both end bearing on the helix plates and skin friction on the shaft.

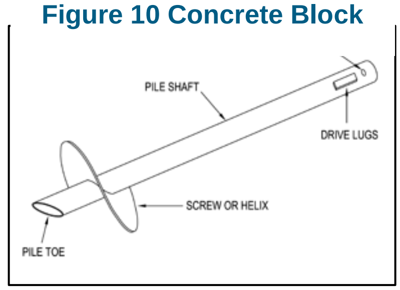


Figure 11 Helical

It should be noted that pipe restraint and anchor examples provided above are not all inclusive and other types of systems may be appropriate for use.

Any damaged pipe safety restraint or anchor must be taken out of service immediately.

3.7 Restraint Concepts

Design and use of restraints should take into account the following key variables: forces needing to be restrained, the amount of potential energy in the system, and effect of vibration on restraint systems.

3.7.1 Restraint Forces

Forces from a failure of a pipe or pipe fitting can be highly destructive, depending on the pressure, line size and type of failure.

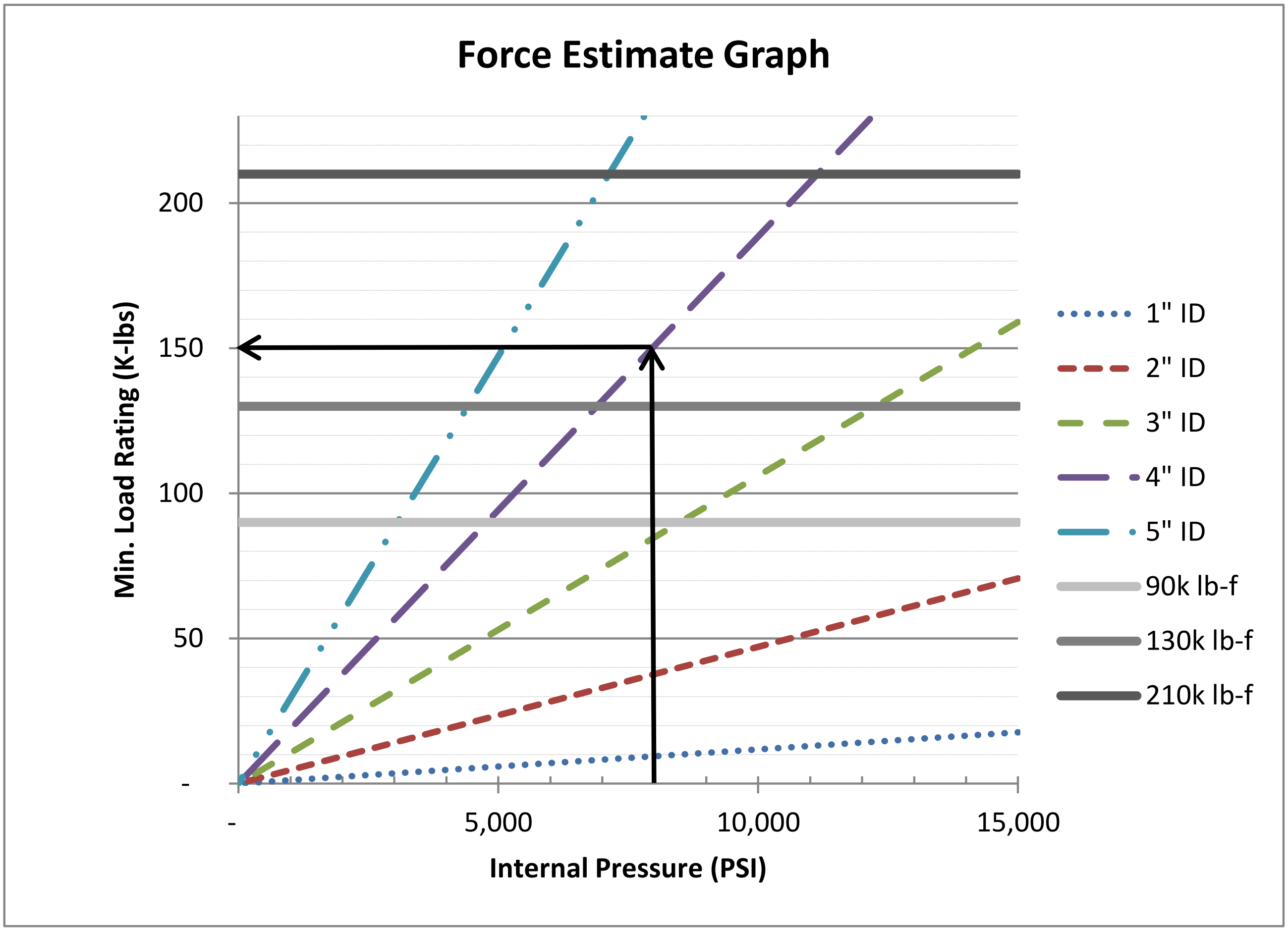
- Restraints must be designed and engineered to account for these high forces.
- Generally speaking, the initial rupture forces are very similar for non-compressible and compressible fluids. The forces can be determined using the table below for a number of different pipe sizes and pressures.

Table 4 below depicts total initial forces for a pipe that contains either a compressible or non-compressible fluid. The forces shown include a 1.5 safety factor and are a function of the pressure and inside pipe diameter.

[Pressure (*psig*) X Area (3.14 x $(ID/2)^2$ (in^2)] X 1.5 (Safety)

Example: 8,000 psig in a 4 inch nominal pipe – [8,000 X 3.14 X $(4/2)^2$] X 1.5 = **150k-lbs**

Table 4: Initial Rupture Forces for Sizing Restraints (Compressible and Non-compressible fluids)



3.7.2 Stored Energy

Anyone who has witnessed the failure of an energized pipe (one filled with gas or a gas/liquid mixture) has observed that the line moves for an extended period of time as the fluid jet exiting the pipe whips it around (when unrestrained). In lines filled with non-compressible fluids there is a sudden release of pressure during failure and resulting jerk of the piping, but it almost immediately settles down.

After the initial point of rupture, the energy available for continued release in a compressible fluid line is significantly greater than that in a non-compressible line. The force keeps coming. This is why energized fluids need special consideration.

- For a line containing compressible fluids it is critical to limit movement of the pipe in the event of a failure, and that the restraint system used is engineered to absorb the energy from line movement.

Table 5 shows the dramatic difference in stored energy in a line containing a compressible fluid versus a non-compressible fluid. These values are based on change in enthalpy of the fluid from a standard state (atmospheric pressure and temperature) to an elevated state of operating conditions (increased pressure and temperature). This additional energy must be dissipated during a pipe failure, and the restraint system has to hold onto the pipe or hose until it is completed.

Table 5: Stored Energy for Compressible and Non-Compressible Fluids

	Estimated Energy in Line (BTU/lb)		Ratio of Energy: Compressible to non-Compressible
PSIG	Gas (N_2)	Liquid (H_20)	
500	306	2.0	153 Times Greater
1,000	407	4.0	102 Times Greater
2,000	525	8.0	66 Times Greater
3,000	608	12.0	51 Times Greater
5,000	728	20.0	36 Times Greater
10,000	922	39.0	24 Times Greater
15,000	1061	59.0	18 Times Greater

3.7.3 Vibration

Installation of restraints on vibrating piping and hoses can result in unwanted consequences. While these are not reasons to avoid restraints, some care must be taken to learn from the past mistakes of others. In areas of high vibration soft restraint systems are often used to avoid wear or impact points. Further, where concrete blocks are used, they can be padded with foam to reduce movement and impact of the vibrating line in order to minimize wear on exterior of the pipe and degradation of the block.

3.8 Staffing Requirements

Encana Completion supervisors must ensure that there is adequate and experienced personnel on location at all times to safely monitor and operate equipment during operations.

4.0 Roles and responsibilities

USA Division EH&S	Responsible for developing, implementing, communicating, evaluating, maintaining, and improving this practice. Implementation consists of making this practice available to all staff through Encana's intranet and providing appropriate training materials and system tools for use by the business units (BUs). Evaluation consists of, at a minimum, the performance of Ethos audits within the BUs or sub-business units (SBUs) on a routine basis. Based on the results of audits and requests from staff for modifications, USA Division EH&S will make appropriate changes to the practice to maintain and improve it.
BU EH&S	Responsible for helping implement this practice within their respective BU and SBUs.
BU leadership	Responsible for implementation of this practice in their BU or SBU through providing adequate resources to support the practice.
BU staff	Responsible for following this practice and incorporating its requirements into their work.

5.0 Goals, objectives, and performance measures

The goal of this practice is to prevent incidents and mitigate risk by providing a systematic method for restraint selection and use where appropriate.

Performance measure includes the following:

1. BU implementation of this practice,
2. Ethos audit for implementation of this practice; and
3. Number of incident casual factors or root causes related to missing or inadequate restraints.

6.0 Training

Encana field support and field operations employees subject to this practice shall successfully complete training in restraint selection and use aligned with this practice as follows:

1. Upon hire;
2. Upon major modification or revision to this practice; and
3. Every three years (at a minimum).

Contractors shall receive training on key elements of this practice during the contractor orientation delivered at each SBU.

7.0 Resources

BUs shall identify, allocate, and verify appropriate resources to communicate and implement this practice.

8.0 Associated forms, documents, and references

8.1 Forms

Encana Risk Assessment Form

8.2 Documents/references

Encana Ethos Practice for Temporary Pipe Installation

Encana Ethos Practice for Restricted Access

Encana Specification for Piping and Valves

Encana Specification for Pressure Vessels

Encana Recommended Practice for Pressure Safety Valves

API 54 - Recommended Practice for Occupational Safety for Oil and Gas Well Drilling and Servicing Operations

API Spec 7 - Specification for Rotary Drill Stem Elements, Fortieth Edition

29 CFR 1910.147 - The control of hazardous energy (lockout/tagout).

30 CFR § 56.13021 U.S. Department of Labor Mine Safety and Health Administration 30CFR 56/57.13021 High-Pressure Connection (100 psi and up)

8.3 Definitions

Term	Definition
Early Life Cycle	**The early stages of a well from rig release to initial production.**
Contractor	**A company Encana has selected to perform a service. The individual performing the service is specified (e.g., site representative or site supervisor) as acting as an agent for Encana.**
Service Provider	**A company Encana has selected to perform a service without specifying the individuals who provide the service (e.g., Ensign Drilling or Halliburton).**
Onsite Service Providers	**Service providers that perform work for Encana on an Encana field site (e.g., wellsite, pipeline, seismic line, road, and facility).**
Restraint System	**Nylon Sling, Cable and Shackle, Whipcheck, Whipsock, etc.**
Staff	**Includes all Encana employees and contractors hired to conduct work on Encana's behalf.**
Remote Operation	**An operation in which the working crew remains at a considerable distance from equipment, NOT that the equipment is at a distance from part of the operation (such as a remote completion where equipment is a distance from the wellhead).**

8.4 Decision Record and Implementation Plan

The Decision Record documents how this practice was developed and pertinent decisions made during the development. The Implementation Plan documents the purpose and audience of the practice as well as changes that were made either from the previous version of the practice or from standard operations. These records can be located by clicking on the links below:

- Decision Record for the Pipe and Hose Restraints Practice
- Implementation Plan for the Pipe and Hose Restraints Practice