**Proceedings of IPC 2004**
**International Pipeline Conference**
**October 4 - 8, 2004 Calgary, Alberta, Canada**

# IPC04-0395

## PRESSURE REDUCTIONS AND PIPELINE EXCAVATION

Robert I. Coote, Coote Engineering Ltd. J. Kyle Keith, TransCanada

### ABSTRACT

Pipeline companies often reduce the pressure while performing maintenance activities and integrity excavations on in-service pipelines. Despite this practice, pipeline design codes, regulations and industry publications offer little guidance on what factors should be considered to determine how much, if any, the pressure should be reduced from operating levels during excavation activities. Also, it is not commonly understood what level of safety is introduced with these reductions and what historical operating pressure level should be used as the basis for the reductions. A literature survey and an interview process with CEPA member companies summarized common industry practices and determined factors to be considered when assessing if and how much of a pressure reduction is appropriate while excavating an operating energy pipeline.

### INTRODUCTION

CEPA member companies safely perform over three thousand pipeline excavations in a typical year, including hundreds of excavations to investigate known or suspected pipeline damage. In order to safeguard workers involved in an excavation and people close to the pipeline, companies routinely take precautions to prevent pipeline damage or failure during excavation activities. Such precautions include

- rigorous procedures for locating underground facilities,
- hand probing before mechanical excavation,
- manual or hydro-vac exposure of underground facilities,
- prohibiting mechanical excavation close to the pipe, and
- use of personal protective equipment.

In certain circumstances, additional measures such as pressure reductions may also be appropriate to reduce the possibility of a pipeline failure and further limit the risks to workers or the public. Although pipeline failures associated with excavation activities are extremely rare, they are not unknown.

This study was performed to explore how CEPA member companies view the use of pressure reduction as an additional safety precaution in excavation situations that may include the presence of known or suspected pipe damage. Nine CEPA member companies participated in the study; six natural gas pipeline companies and three liquid hydrocarbon pipeline companies. They described their experiences of release incidents during excavation activities, the reasons for considering pressure reductions, and their pressure reduction practices for several common excavation situations.

### NOMENCLATURE AND ACRONYMS

CEPA is the Canadian Energy Pipelines Association representing twelve major Canadian transmission pipeline companies who are responsible for the transportation of over 95% of crude oil and natural gas produced in Canada.

HVP means high vapour pressure
LVP means low vapour pressure
MOP means licensed maximum operating pressure
ILI means in-line inspection

### INDUSTRY STANDARDS, REGULATIONS AND GUIDELINES.

CSA Standard Z662-2003 [1] requires that

- "Pipeline pressures shall be at safe levels when work is being performed on in-service pipelines." and that
- "Excavation of piping suspected of containing defects and, if required, the subsequent permanent or temporary repair of such piping shall be performed after the piping is depressurized as necessary to an operating pressure that is considered to be safe for the proposed work."

The CSA Standard includes a list of factors to consider, but does not provide guidance on how to determine a safe pressure.

The Canada Labour Code [2] and Provincial Occupational Health and Safety codes [3] contain requirements related to shoring, measures to protect workers from cave in or collapse of a trench and requirements related to locating and preventing excavation damage to pipelines, but contain no requirements about pressure during excavation.

The Federal pipeline regulations in Canada [4] and the US [5] and the provincial regulations in Alberta [6] contain requirements for locating and excavating pipelines that are mainly concerned with the prevention of pipeline damage by excavating equipment but contain no requirements about

 

pressure during excavation. The US regulations also contain requirements to protect personnel from the hazards of unsafe accumulations of vapor or gas. None of these regulations include requirements about pressure reductions during excavation.

A few publications [7,8] dealing with defect assessment and repair recommend a pressure reduction to 80% of the pressure that existed when the damage occurred or was discovered, to provide a minimum level of assurance that a failure will not occur during excavation and investigation. In some situations where pipe movement may impose unpredictable stresses on a defect, it is suggested that larger pressure reductions may be prudent.

## INDUSTRY FAILURE EXPERIENCE DURING EXCAVATION AND INTEGRITY EVALUATION.

Third party excavation damage, which generally occurs when excavation takes place without the precautions used by pipeline companies, is a known cause of failures that result in injuries and fatalities. In spite of precautions to prevent pipeline excavation damage, there have been rare occurrences of failures when a pipeline was being excavated for evaluation of suspected pipeline damage. Although such incidents are very rare, the authors are aware of one incident that occurred in Iowa and another in Argentina where loss of life was involved.

Although no published accounts of the Argentina incident were found, it is known that the incident involved excavation of an in-line inspection feature and the fatality of nine workers. The published accounts of the Iowa incident [9, 10] indicate that the rupture occurred as company inspectors were examining recent damage caused during the installation of drainage tiles. One worker was killed and another was seriously injured. It appears that the damage to the ten-inch diameter line occurred in the afternoon and that there was no gas release until the failure occurred several hours later just as the inspectors were examining the pipe. At present there are no reliable data about the pressure during the period between the time of the damage and the failure.

## CEPA MEMBERS' EXPERIENCE

### Excavation Incidents

The vast majority of excavations performed in Canada by CEPA companies are completed without incident. Although some of the companies have experienced incidents of a small release during their excavation activities, none of them resulted in serious injury or death.

Some release incidents involved attachments (i.e. branch/weldolet), whose presence was unknown, being broken by excavating equipment. Other small releases during excavations to investigate known damage were either discovered during the excavation, or were initiated by sandblasting to clean the pipe, or in one case, by removal of a wire in contact with the pipe. There had been no pressure reduction until the release occurred in some of these incidents. The pressure was subsequently reduced to zero for the repair operations in most cases.

## PRESSURE REDUCTION PRACTICES OF CEPA MEMBERS

### Reasons for Reducing Pressure

Most members ranked preventing injury to workers as the most important reason for a pressure reduction, followed by preventing injury to the public, and preventing environmental damage. Although preventing injury to the public was ranked highly, several members noted that the public is seldom present within the hazard zone. Additional reasons for a pressure reduction included planned repairs or welding operations on the pipeline.

### Potential Consequences of a Release During Excavation

The potential safety consequences of a product release range from insignificant for small leaks to serious injury and death for both liquid and gas pipelines. All members identified that the resulting overpressure wave and flying debris from a rupture and ignition of a large release of gas, HVP or LVP liquid could cause serious injury and death.

### Excavation Scenarios

Each participating company was asked to describe its normal pressure reduction practice for four relatively simplistic situations that are described below. In real situations there may be details and conditions specific to the situation that would result in a different decision, but the results described are based on the response considered to be most typical for each company.

The practices of some companies require a pressure reduction at the start of excavation for any situation that is not a routine line exposure. Other companies would not normally require a pressure reduction unless they determine from observations and analysis that serious damage is likely to be present that could cause a failure during the excavation.

### Routine Operational Exposures

When an excavation is planned, as part of a line crossing for example, all of the companies consider that their standard precautionary measures provide adequate safety, and they do not reduce the pressure unless there are unusual issues or circumstances, such as those shown in Table 1. This table describes some of the approaches used to address issues or circumstances beyond the scope of standard precautions.

**Table 1**
**Routine Operational Exposures**

| Issue | Approaches |
|---|---|
| Welding work on a live line. | • If welding is planned, a pressure reduction may be required to reduce the risk of burn-through or hydrogen cracking, and the pressure reduction may be maintained from the start of excavation until the welding work is completed. |
| Failure and damage history | • Reduce the pressure even though there is no specific knowledge of significant damage if there is a history of failures or significant damage in the pipeline section, due to corrosion, SCC, or slope movement, for example.<br>• Prevent any pressure increases during excavation but do not reduce the pressure unless significant damage is discovered during progressive examination of the pipe as it is exposed. |
| Machine Excavation close to pipe. | • Reduce the pressure if there is a need for machine excavation within 150 mm of the pipeline. |

**Excavation of ILI Features**

When excavating to examine features detected by in-line inspection, all of the companies would reduce the pressure when excavating a severe feature, with a calculated failure pressure close to the operating pressure or a large depth, however some companies reduce the pressure when excavating any features, regardless of severity. There are a range of severity criteria, assumptions about growth rates and sizing errors used by the companies that make a reduction decision based on the indicated severity of the feature.

Most of the companies that normally require a pressure reduction regardless of the indicated severity of the feature being excavated have had or are aware of others' experiences, which caused them to be concerned about:

- the presence of other defects such as stress corrosion cracks that are not detectable by the magnetic flux leakage tools that are being used, but which are sometimes associated with detected metal loss corrosion on some pipeline systems, and
- the possibility of a feature being much more severe than indicated by the inspection results, especially if inspection data is old or its accuracy is questionable.

Table 2 describes the range of approaches used to address such issues associated with excavation of ILI features.

**Table 2**
**Excavation of ILI Features**

| Issue | Approaches |
|---|---|
| Detected features may be more severe than indicated. | • Reduce pressure based on assumption that characteristics of features have not been judged correctly and the damage severity may be much worse than indicated. For example, narrow axial corrosion may not be recognized, or the dimensions may be underestimated.<br>• Assess the type of features known or expected to be present in the area of the planned excavation, and the types of errors that may have affected the ILI reporting accuracy for the features. Add an error allowance to the indicated dimensions to determine the failure pressure and the proximity to through wall depth, and reduce pressure if a leak is imminent or the failure pressure is less than about 1.25 times the excavation pressure.<br>• If the calculated failure pressure is more than 1.25 times the excavation pressure, and the depth is not close to through wall, prevent any pressure increases during excavation but do not reduce the pressure unless critical damage is found during progressive examination of the pipe as it is exposed.<br>• Prevent any pressure increases during excavation but do not reduce the pressure unless significant damage is discovered during progressive examination of the pipe as it is exposed. |
| Undetected damage, such as cracking, may be associated with detected features such as dents or corrosion. | • Assess the type of features known or likely to be present in the area of the planned excavation. If such undetected damage is considered to be a possibility, reduce pressure before excavation starts.<br>• If such damage is considered to be very unlikely, prevent any pressure increases during excavation but do not reduce the pressure unless critical damage is found during progressive examination of the pipe as it is exposed |

**Excavation of a Leak Site**

When excavating to investigate any known leak, liquids pipeline companies reduce the pressure to zero primarily to reduce the risk of vapour cloud ignition, and in some cases because of the possible presence of $H_2S$ in the crude oil, even though it is not considered to be "sour". Some gas pipeline companies require a pressure reduction from the level that existed at the time the leak was discovered for excavation of any leak, while other gas pipeline companies excavate without a pressure reduction if a leak is small or not considered to be a hazardous.

One gas pipeline company has excavated small leaks at line pressure because repeated experience showed that "pinhole" leaks in girth welds and seam welds could not be located at reduced pressures. In many cases, these small leaks remained undetectable until the pressure was raised in increments to full line pressure.

Table 3 describes some of the approaches used to address issues or circumstances associated with excavation of leaks.

**Table 3**
**Excavation of Leaks**

| Issue | Approaches |
|---|---|
| Vapour hazards. | • Reduce pressure to zero before excavation and examination begins if the vapour may contain hazardous levels of $H_2S$.<br>• Reduce pressure to zero before excavation and examination begins if there is a likelihood of an explosive vapour cloud forming. |
| Potential for rupture. | • Reduce pressure from the value when leak was discovered, based on assumption that rupture could occur, while exposing and examining the pipe<br>• Assess location and likely cause of leak (threaded fitting, flange, valve seals, pipe defect). If leak is most likely not related to a pipe defect, reduce pressure as much as possible, or prevent any pressure increases while manually exposing and examining the pipe.<br>• If leak is likely caused by a pipe defect, assess data about condition of pipe in the area. If pipe rupture is considered extremely unlikely, prevent any pressure increases while exposing and examining the pipe, but do not reduce the pressure unless critical damage is found during progressive examination of the pipe as it is exposed.<br>• Prevent any pressure increases during excavation but do not reduce the pressure unless significant damage is discovered during progressive examination of the pipe. |
| Sources of small leak indications cannot be located at low pressure. | • After examination at low pressure to ensure that pipe is free of any damage that may reduce its strength, temporarily remove workers from hazard area, increase pressure in increments, up to pressure when leak was initially indicated, until source of leak is located.<br>• Prevent any pressure increases during excavation but do not reduce the pressure unless significant damage is discovered during progressive examination of the pipe. |

**Excavation & Examination of Recent Damage**

When damage occurs to a line caused by a single event such as line contact by excavating equipment or sudden slope movement, most companies reduce the pressure from the level that existed at the time the damage was discovered before starting or continuing excavation and examination of the pipe. However, some companies only reduce pressure if evidence of critical damage is found during progressive examination of the pipe as it is exposed. Table 4 describes some of the approaches used to address issues or circumstances associated with excavation of recent damage.

**Table 4**
**Investigation of Recent Damage**

| Issue | Approaches |
|---|---|
| Severe equipment damage that is not visible without additional excavation may have occurred. | • Reduce pressure before additional excavation and examination begins, based on assumption that severe mechanical damage may be present that could fail.<br>• Perform an incident assessment that includes the pipe dimensions and properties, equipment characteristics (weight, power and shape of component that contacted pipe), and observations of workers to try do determine if significant damage is likely to have occurred. If significant damage is considered extremely unlikely, prevent any pressure increases while manually exposing and examining the pipe.<br>• Prevent any pressure increases during excavation and examination but do not reduce the pressure unless significant damage is discovered during progressive examination of the pipe as it is exposed. |
| High stress caused by pipe movement may cause failure of flaws that would otherwise be harmless | • Reduce pressure to zero before excavating pipe for examination.<br>• Perform engineering analysis to estimate the pipe movement, resulting stresses and the potential for existing weld flaws or other likely damage to fail. If pipe failure is considered extremely unlikely, reduce pressure as much as possible and cautiously expose the pipe to relieve soil-induced loading.<br>• Prevent any pressure increases during excavation but do not reduce the pressure unless significant damage is discovered during progressive examination of the pipe, or pipe movement occurs during exposure. |

## How is a Reduction Determined?

When a company determines that a pressure reduction is needed, it must determine the amount of the reduction, and the baseline from which the pressure is reduced. Some companies perform a detailed risk assessment to determine the appropriate pressure reduction for each excavation scenario, but most companies use a simpler approach.

Some of the liquids pipeline companies reduce the pressure to 50 % MOP. The reduction to 50% MOP seems to be based on historical practices and a desire for simplicity and consistency. However for pipe that seldom operates close to the MOP, the actual reduction achieved may be small or non-existent.

Most of the other companies consider that a 20% reduction from a recent peak pressure is appropriate because that provides the same safety margin accepted for new pipelines with a proven strength based on testing to 1.25 times the MOP.

However, the situation for an operating pipeline is more complicated than for a new line. For an operating pipeline, the current strength is established by the value of a recent peak operating pressure. The longer the time since the recent peak pressure the greater the likelihood that the strength may have decreased if the severity of the damage is increasing with time.

The maximum period used by CEPA member companies to determine the reference peak pressure varies from 28 days to 365 days. All companies believed that any loss of pipe strength (due to defect growth for example) in the period since the chosen peak pressure would be small, and would not encroach significantly on the 20% safety margin represented by the pressure reduction. The company that uses a 28-day maximum period will, in some cases, temporarily increase the pressure (nearer to MOP) prior to a planned excavation in order to obtain the desired reference peak pressure to provide the safety margin during excavation.

## Considerations for Larger Pressure Reductions

Several companies consider larger pressure restrictions based on the excavation method or the conditions at the excavation site.

### Excavation Method

The excavation procedures used by all companies include restrictions on the use of machine excavation near the pipe. One company increases the pressure reduction if it is necessary to use machine excavation within 0.6 m of the pipe.

### Terrain

In difficult terrain where pipe movement or equipment stability is a concern three companies consider an increased pressure reduction. The algorithm for calculating pressure reductions used by one of these companies includes a terrain term that may be up to 10 % MOP, depending on the slope and groundwater levels.

### Soil type

In areas of rock, for example in shot rock trenches where there is concern for dropping larger fragments of rock on the pipeline during excavation, some companies require that the pressure be no higher than 1900 kPa. The algorithm for calculating pressure reductions used by one company includes a soil term that may be up to 20 % MOP for excavations in rock. One company considers an increased reduction in areas of thixotropic clay, an unusual material that behaves like an extreme quicksand and causes unique problems when work is done in the area. One company that normally does not reduce pressure prior to excavation considers a reduction when excavating in areas with soil conditions known to be associated with SCC.

## Pressure Monitoring and Control during Excavation

Once an excavation operation begins it is essential that the pressure at the excavation site does not increase above the maximum approved value, and that communication be maintained between the crew at site and the operations control centre. The pressure at the excavation site is likely to vary from the pressure at the location of SCADA transmitters used for normal operational control, particularly under flowing conditions for liquids pipelines, so some method is generally needed to measure or estimate the pressure at the excavation site. The monitoring methods used by the CEPA members include:

- Pressure gauge installed at excavation site,
- Pressure gauge installed at closest valve site(s),
- SCADA monitoring & projection to excavation site, and
- SCADA monitoring at pump or compressor station.

## Impact of Pressure Reductions

In some situations, reducing the pressure for an excavation affects a pipeline company's ability to provide the expected service and causes restrictions of receipts or deliveries. Such restrictions can cause economic penalties for producers and shippers, who may be unable to deliver their product, for delivery customers who have no alternative source of supply. Measures used by all the companies to mitigate the impact of pressure reductions include:

- Scheduling the work to allow time for pre-delivery or alternative supply arrangements.
- Scheduling the excavations to coincide with other work to avoid or reduce the incremental impact.
- Using extra crews and equipment to reduce the period of the reduction.

Additional mitigative measures used or considered by some companies include:

- Accepting a smaller or no pressure reduction if engineering analysis indicates rupture is unlikely.
- Performing site preparation work in advance of the pressure reduction.
- Temporarily increasing the pressure when crews are not actually present on site.

- Using a mobile compressor to achieve the reduced pressure in the section while still maintaining an acceptable flow rate.
- Installing a stopple and bypass.
- Use of an internal device such as the SmartPlug to temporarily isolate the area.

## DISCUSSION

When a routine excavation is planned, the CEPA member companies consider that their standard precautionary measures provide adequate safety and they do not require a pressure reduction unless there are unusual issues or circumstances. Prevention of failure or damage incidents is managed by safe work practices that include rigorous procedures to locate all underground facilities, hand probing before mechanical excavation, manual or hydro-vac exposure of underground facilities, and manual excavation close to underground facilities.

When excavating pipe for integrity evaluation of any ILI indications, leaks or possible recent damage, some CEPA member companies reduce the pressure, to reduce the potential risk that a disturbance to the pipe might cause a failure. These companies requiring a pressure reduction include one company with a very new pipeline system, one with no history of ignited ruptures, and others with a range of failure and damage experience.

The CEPA member companies that do not normally require a pressure reduction for such integrity-related excavations are confident that in each situation, minor disturbance to the pipeline is unlikely to cause failure unless they determine from observations and analysis that the damage is serious. In one liquid pipeline company, that position is based on the absence of any rupture failures, significant corrosion damage or significant ILI features in over 50 years of operation.

The other companies that normally do not require a pressure reduction for such integrity-related excavations are also confident that in each situation, minor disturbance to the pipeline is unlikely to cause failure. Their experience of failures and serious damage may be fairly low, but not significantly different from the experience of the companies that normally do require a pressure reduction. The companies that normally do not require a reduction, often find it is very difficult to reduce pressure without restricting receipts or deliveries, and the disruptions associated with such restrictions are damaging to the customers and also to the pipeline companies. Unless there is strong evidence of critical damage, or a well-recognized integrity issue in the section being excavated, the risk reduction benefit associated with a pressure reduction is generally considered insufficient to justify the negative consequences of the disruption in service caused by a pressure reduction. The companies that normally do not require a pressure reduction for integrity-related excavations rely on progressive examination of the pipe, as it is exposed, to detect and assess any observed damage, and then determine if a pressure reduction is required for work to continue.

## CONCLUSIONS

The nine CEPA member companies that participated in this project safely perform over three thousand pipeline excavations in a typical year, including hundreds of excavations to investigate known or suspected pipeline damage. The member companies recognize the risks associated with excavating operating pipelines and implement precautions to prevent pipeline damage or failure that might cause harm to people or the environment. Most routine excavations to expose a pipeline are done without reducing the operating pressure. However, in some situations, particularly those to excavate and evaluate known or suspected pipeline damage, some CEPA members reduce the operating pressure to reduce the risk that a disturbance to the pipe might cause a failure.

The CEPA member companies have experienced minor releases during excavation activities. None of these incidents resulted in any serious injuries or fatalities; however the members are aware that failures resulting in fatalities have been known to occur in situations that involved excavation of an operating pipeline to investigate suspected pipeline damage.

Although some companies reduce the operating pressure when excavating pipe for integrity evaluation of any ILI indications, leaks or possible recent damage, other companies only reduce the pressure if the risk reduction achieved is considered to justify the resulting disruption in service and damage to customers.

The issues and considerations for each pipeline excavation depend on a number of factors related to the individual pipeline. The approaches described for identifying the need for pressure reductions, have been used to safely perform excavations on Canadian pipelines for many years, while the pipelines remain in service, transporting vital petroleum products to market.

## ACKNOWLEDGMENTS

The authors are grateful to the members of the CEPA Pipeline Integrity Working Group who sponsored, guided and participated in the original survey and report.

## REFERENCES


1. Anon, "Oil and Gas Pipeline Systems" CSA Standard Z662-03 Canadian Standards Association, June 2003.
2. Anon, "Oil and Gas Occupational Safety and Health Regulations SOR/94-165, s.2 (F)" Canada Labour Code Part II.
3. Anon, "Occupational Health and Safety Code", Province of Alberta, 2003.
4. Anon, "Onshore Pipeline Regulations, 1999, SOR/99-294 " Department of Justice Canada.
5. Anon, "Code of Federal Regulations 49CFR192 Sec. 192.605", U.S. Government Printing Office.
6. Anon, "Alberta Regulation 122/87 Pipeline Act Pipeline Regulation", Queen's Printer for Alberta, 1999
7. Kiefner, John F., Bruce, W.A., and Stephens, D.R., “Pipeline Repair Manual”, Pipeline Research Council International, 1994.
8. Cosham, Andrew, "Pipeline Defect Assessment" International Pipeline Conference Workshop, ASME, 2000.
9. Smith, L. Owen, T. "Oelwein pipeline break kills 1" Iowa Courier November 12, 1999.
10. Anon, Accident File 11/12/99, Oelwein IA, Underground Focus Magazine