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Review of Integrity Management For Natural Gas Transmission Pipelines

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ASC GPTC Z380, an ANSI Accredited Developer

ASC GPTC Z380 Secretariat

AGA American Gas Association

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The GPTC consists of members with technical expertise in research, design, construction, testing, operations, and maintenance of natural gas gathering, transmission, and distribution systems. The membership of this consensus-based committee is balanced between gas distribution operators, transmission companies, manufacturers, and general interest personnel including federal and state regulators. As an independent and consensus-based committee, the GPTC requires that published technical materials be written with the purpose or intent of advancing pipeline safety, not the views or positions of any particular organization that may sponsor participation of any of its members.

This report presents an approach for managing the integrity of steel natural gas transmission pipelines. It represents an accumulation of ideas and practices employed by operators in the natural gas industry regarding testing, repairing, and validating the integrity necessary to ensure safe and reliable natural gas pipeline systems. The report provides a general reference for developing or modifying integrity management plans. It is recognized that there may be other techniques existing or being developed to monitor threats to pipeline integrity and to confirm integrity that are not addressed in this report. It is also recognized that other approaches used by operators may result in plans that appear different from the examples described in this report.

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III. INTRODUCTION

Integrity management is an integral part of an operator's mission to provide safe and reliable delivery of natural gas through its pipeline systems. Integrity management is a process of identifying, assessing, evaluating, and mitigating threats to the integrity of a pipeline system. Integrity management planning begins during the pipeline development stage, which includes consideration of route selection, material selection, and design of the pipeline system. It is an integrated process and should not be viewed as a set of independent activities. Integrity management is an evolving process providing for the long-term integrity of a pipeline system. Integrity management considerations encompass new and existing technologies and methods, along with the changing conditions under which a pipeline operates. Whether the pipeline is engaged in the gathering, transmission, or storage of natural gas, the operator uses integrity management practices to maintain its serviceability. Mitigating actions for protecting a pipeline against factors affecting its integrity may be common to many pipelines; however, each type of operation: gathering, transmission, and storage presents unique integrity challenges to the operator. The focus of this report is to describe actions that operators consider in managing the integrity of transmission pipelines.

This report describes methods that can be used to define an integrity level for a pipeline. Ideally, segment information for the pipeline is established and recorded at the time of initial design and construction. However, in some cases pipeline parameters may be established after the facilities have been placed in service.

This report describes a framework that is useful in a written integrity management plan (IMP):

- Identification of integrity concerns and threats.
- Collection, integration, and evaluation of data.
- Identification and evaluation of risk.
- Establishment of integrity programs and mitigation techniques.
- Assessment of plan effectiveness for continuing improvement.

It is recognized that there may be other techniques that exist or are being developed to monitor threats to pipeline integrity and to confirm integrity issues that are not addressed in this report. It is also recognized that other approaches used by operators may result in plans that appear different from the one described here. This document is intended to provide examples that may be considered in developing a comprehensive pipeline IMP.

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A. Integrity Management Plan

An IMP is a written, systematic approach used to maintain the integrity of pipeline facilities at levels that provide safety and reliability. It helps operators to comprehensively evaluate an entire range of threats to pipeline integrity by integrating and analyzing available information about their pipelines. Although operators employ integrity management principles, not all of them take these actions within the framework of a formal written plan. A written plan provides a road map for the assessment, integration and analysis of data, and courses of action available in maintaining pipeline integrity. The data analyzed include information from existing sources such as:

- Inspections, surveys, and test results.
- Documentation of maintenance performed.
- Records of leaks and failures.
- Encroachment records.
- Records of excavation damage.

Available pipeline integrity information and assessment of relative risk can be considered to systematically define the actions needed to address pipeline integrity concerns.

B. Purpose of Integrity Management Plan

The purpose of an IMP is to maintain a safe and reliable pipeline system by monitoring and acting upon threats to pipeline safety in a systematic fashion. The plan provides for an initial pipeline integrity assessment and periodic confirmation of the pipeline's integrity through inspection, testing, and assessment of historical data. When an operator maintains the integrity of its pipeline system, it can provide reliable service for an indefinite number of years.

There are a number of reasons why maintaining the integrity of a pipeline is important to the operator. These include:

1. Protecting the public and employees. Where pipelines and people are in close proximity to each other, or where population development encroaches on areas where pipelines exist, maintaining pipeline integrity is important to reduce the probability of incidents that could affect the safety of the public and employees.

2. Protecting the environment. Although natural gas generally does not adversely affect the environment, ignition of leaking natural gas could produce adverse consequences.

3. Preventing interruption of service. Transmission pipelines are installed for the purpose of transporting natural gas from production areas to areas of consumption. The public relies on these pipelines to provide a reliable source of fuel. Effective integrity management reduces the unacceptable disruptions of service.

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4. Reducing liabilities. It is in the operator's best interest to ensure that compromises in pipeline integrity do not result in failure of the pipeline. The loss in public trust, the loss of revenues, and the potential liability associated with the consequences of failure are detrimental to the operator's business.

5. Protecting and preserving investment. Operators spend billions of dollars to construct, operate, and maintain the pipeline systems used to transport natural gas for consumption by the public. Operators follow industry standards that are based on good engineering principles in designing, testing, operating, and maintaining these pipeline systems. Maintenance of pipeline integrity will permit safe and reliable operation of pipeline systems for many years. Many pipeline systems in this country are over 50 years old and continue to operate safely. Continuous integrity management will provide safe and reliable gas supply to the public at a reasonable cost.

C. How Regulations Foster Integrity Management

It is no coincidence that pipelines have safely transported gas for so many years. Many of the pipelines in this country were designed, constructed, and operated under the American Society of Mechanical Engineers (ASME) B31.8 Code well before the promulgation of Federal Regulations, 49 CFR Part 192. The ASME B31.8 Code is a recognized integrity standard. Code provisions in this document include the key elements of an IMP. The B31.8 Code is the source document for the current 49 CFR 192. Since the adoption of 49 CFR Part 192 as the Federal Regulation in 1970, the Office of Pipeline Safety (OPS) has promulgated numerous additional requirements that deal with integrity issues (particularly in the areas of damage prevention and corrosion control.) The GPTC Guide contains accepted practices for complying with these regulations and is useful in establishing integrity management programs. Some states have requirements in addition to the Minimum Federal Safety Standards.

IMPs incorporate these established minimum standards for pipeline safety which require additional measures in areas of higher population density, areas subject to abnormal loading, and areas of harsher operating environments. The integrity of a newly installed pipeline is confirmed through the testing requirements of the regulations. Once in service, the regulations require monitoring to assess the impact that changing conditions may have on maintaining acceptable safety levels established by the regulations. Monitoring is required more frequently in areas with the highest potential consequence (e.g., in Class 3 and Class 4 location areas and at highway and railroad crossings). Threats to pipeline integrity are addressed on both a segment-by-segment basis and a system-wide basis. Segment issues are addressed by regulations that deal with specific issues such as: corrosion, material defects, and damage caused by excavation, natural hazards, and other outside forces. Systemic issues are identified as a result of the integration and analysis of the data developed by addressing the issues identified on a segment-by-segment basis. A failure investigation on a pipeline segment may also suggest a systemic

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problem. When the integrity of a pipeline is adversely affected, the regulations require replacement, repair, monitoring, or lowering the operating pressure of the pipeline.

Regulations require operators to monitor for conditions that may affect the integrity of the pipeline and to take remedial action whenever analysis indicates the need for corrective measures. Some of the threats to pipeline integrity that are monitored include:

- Excavation Damage. Excavation damage is the most common cause of pipeline "incidents" as defined by §191.3. Subpart L of 49 CFR Part 192 prescribes minimum requirements for the safe operation of pipeline facilities including provisions for preventing excavation damage to pipelines. The natural gas industry has focused considerable effort toward preventing excavation damage to pipelines. The industry through Common Ground, a study of one-call systems and damage prevention best practices, identified and validated best practices for preventing damage to underground facilities associated with excavation activities. Section 192.705 requires pipeline monitoring for excavation and construction activities affecting or possibly affecting integrity. Sections 192.614 and 192.616 require activities aimed toward preventing excavation damage through participation in damage prevention programs incorporating one-call systems, educating existing and potential excavators, and educating the public regarding the threat to pipeline safety from improper excavations. Section 192.614 also includes requirements for the operator to communicate the location of its pipeline(s) to excavators intending to excavate in the vicinity of the pipeline facilities. Significant progress toward reducing excavation damage has been accomplished through one-call systems and damage prevention legislation enacted by states with cooperation among pipeline operators and underground contractors.

- Corrosion. Corrosion is the second most common cause of pipeline incidents and the most common cause of leaks in gas pipeline systems. Operators are required to comply with Subpart I of Part 192 that prescribes minimum requirements for the protection of metallic pipelines from external, internal, and atmospheric corrosion. Operating and maintaining the pipelines in accordance with these regulations will reduce the chance of corrosion-related leaks and incidents along with the accompanying consequences. Sections 192.459, 192.465, 192.473, 192.475, 192.477, and 192.481 all address monitoring activities related to conditions that could lead to external or internal corrosion. Sections 192.705 and 192.706 require pipeline patrols and leakage surveys monitoring for evidence of a release of natural gas from the pipeline resulting from corrosion or other damage affecting pipeline integrity.

- Material Imperfections and Other Damage. Whenever the pipe is exposed, §192.459 requires examination of pipe for evidence of external corrosion. As part of this inspection an operator may find other conditions affecting the pipeline integrity. Aboveground facilities are also patrolled or inspected for evidence of conditions that may be detrimental to pipeline integrity under §§192.481 and 192.705. Subparts L and M of Part 192 provide requirements regarding detection and repair of leaks and cracks in pipelines.

- Environmental Hazards. Landslides, erosion, flooding, earthquakes, and other environmental hazards pose a threat to pipeline integrity. When patrolling in accordance with §192.705, the operator looks for evidence that these conditions may have affected or could potentially affect the integrity of the pipeline.

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Once a pipeline integrity concern is suspected or confirmed, the operator evaluates the degree to which integrity was affected and takes remedial measures. If corrosion is the cause, §192.485 is used as the basis for evaluating the impact on the integrity, and §§192.483 and 192.485 describe remedial measures. For other causes, §§192.703 and 192.713 are used as the basis for evaluating the impact on the integrity. §§192.703, 192.711, 192.713, 192.715, 192.717, and 192.719 describe actions to be taken to restore pipeline integrity.

In addition to monitoring for segment integrity issues, the operator may identify systemic issues in meeting the requirements of §192.613, Continuing Surveillance, and §192.617, Failure Investigation.

- Continuing Surveillance. Section 192.613 comes from Section 850.5 of the 1968 edition of the B31.8 Code. As described in the B31.8 Code, continuing surveillance is to be used by the operator "as a means of maintaining the integrity of its pipeline system." It is an integration and analysis of historical records of inspections, maintenance, patrols, surveys and tests conducted to detect whether unusual operating and maintenance conditions exist on the pipeline system that may not be evident through any individual inspection, maintenance, patrol, survey or test. To facilitate the analysis to detect these conditions, the regulation requires the integration of inspection, maintenance, patrol, survey and testing information regarding each segment of the pipeline system. The operator performs these analyses across the pipeline system to determine if there are any unusual operating and maintenance conditions and if they are isolated to specific segments or are systemic.

  Immediate hazards are addressed promptly. Where no immediate hazard exists, the regulation requires that the operator initiate a program to recondition or phase out segments that are found to be in unsatisfactory condition. If neither is possible, the maximum allowable operating pressure is reduced to a safe level.

- Investigation of Failures. Section 192.617 requires the operator to have procedures for analyzing accidents and failures for the purpose of determining the causes of the failure and minimizing the possibility of a recurrence. Like the analyses conducted under continuing surveillance, the failure analysis can identify if the problem is isolated to a specific site or if the problem is systemic. If the problem is not an isolated occurrence, the operator takes action to address similarly situated pipelines where conditions similar to those at the accident site or failure location are likely to exist.

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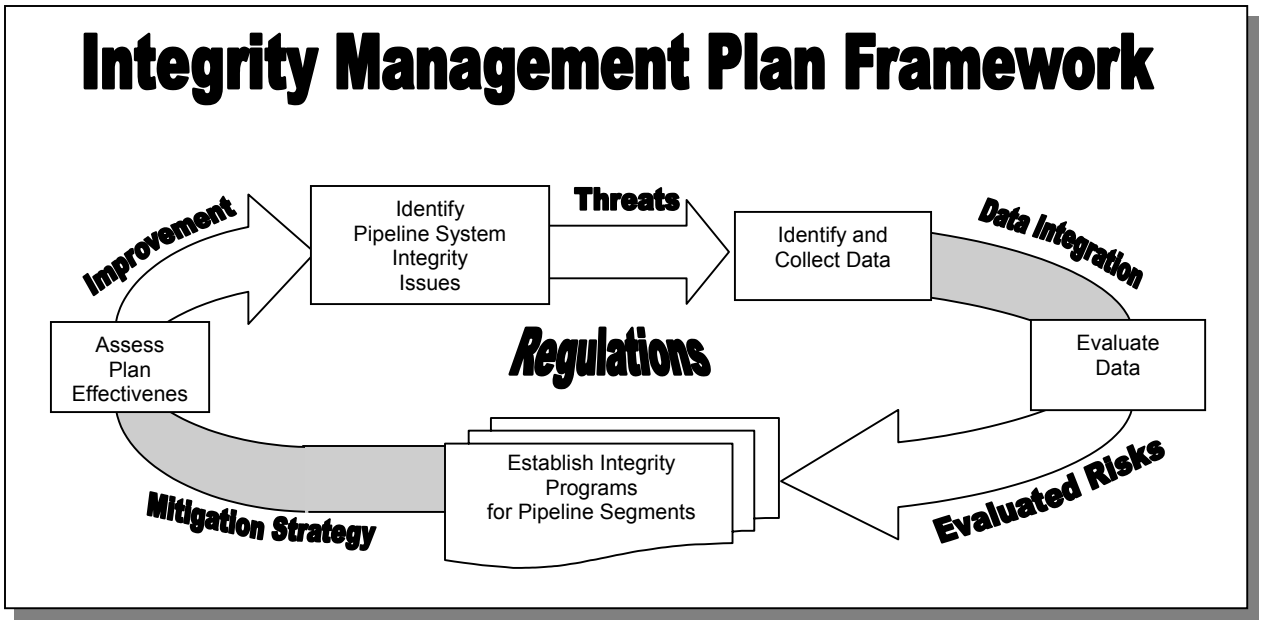
IV. OVERVIEW

This section presents an overview of how operators of natural gas transmission pipelines develop integrity management plans. A general framework for a pipeline integrity management plan (IMP) is shown in Figure 1.

Figure 1 - Framework for an Integrity Management Plan



The framework for an IMP often consists of a process of the following items, with pipeline safety regulations as a centerpiece:

- Identify pipeline system integrity issues leading to an understanding of the threats.
- Identify and collect data[1] leading to data integration.
- Evaluate data leading to an understanding of risks.
- Establishment of integrity programs leading to specific mitigation strategies.
- Assess plan effectiveness leading to improvements of the IMP.

The items in this framework are summarized below and described in detail in the following sections.

[1] Throughout this report the terms data and information will be used interchangeably to describe all information used in managing pipeline integrity ranging from operator personnel knowledge of the pipeline system to electronic databases.

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A. Identify Pipeline System Integrity Issues

There are many variables that operators examine when establishing an IMP. Operators review their systems and identify the integrity issues that must be considered within their IMP. These issues are examined considering the possible threats to each segment of the pipeline system.

B. Threats

The identification of threats to a pipeline and the management of those threats are integral parts of an IMP. The types of threats to a pipeline are numerous and the mechanics of failure can vary. Therefore, significant threats to particular pipeline segments and the risk they impose are considered in determining an overall approach to integrity management. Knowledge of the pipeline system; threats to the system; the tools that protect against, inspect for, and monitor those threats; and mitigation measures are necessary to develop an IMP addressing diverse and dynamic sets of threats and failure modes.

C. Identify and Collect Data

The identification, collection, and verification of data supporting the IMP are crucial. This includes gathering of available data, making efforts to define and gather additional data necessary to support the operator's risk assessment process, validating data, and taking steps necessary for data integration. Integrity data can be readily captured for new facilities. For existing pipelines this data may not be readily available. The IMP defines the process required to identify the methods to obtain required data to support the operator's risk assessment.

D. Data Integration

Integration of data is one of the keys to the implementation of an effective integrity management program. The data collected is assembled to provide a complete picture of the pipeline system, with special emphasis on key indicators selected by the operator. While the concept of data integration is simple, the implementation can be difficult.

E. Evaluate Data

Data and information are reviewed and analyzed to identify and assess risks. Quantitative analysis or qualitative review or both are used to identify factors that influence risk to pipeline integrity. The approach to assessing risks tends to be unique to the operator and to the operating environment of the individual pipeline segments. As more data and information become available, operators update their analysis. As results from the analysis become available,

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operators gain a greater understanding of the factors influencing pipeline integrity. This can lead to refinement of the risk assessment approach.

F. Evaluated Risks

Risk is an inherent part of life and is associated with industrial activities as well as nature. While the overall risk of an operating pipeline can be managed, changed, or possibly reduced, it cannot be reduced to zero. The process or result of changing risks of one source or type can affect risks of another source or type. Risk is generally defined as the product of the likelihood of an event and the consequence of that event. Each of these events results in the loss of pipeline integrity. Understanding risk factors is an important part of an IMP, because it is used to identify mitigation strategies. The total risk for a particular pipeline segment is the summation of the risks from the various threats to that segment.

G. Establish Integrity Programs for Pipeline Segments

Pipeline segment integrity programs are developed within the IMP framework. At this stage, operators identify the threats to which a specific pipeline segment is exposed. Approaches used by operators for assessing and prioritizing a pipeline segment for the development of a mitigation strategy covers the spectrum from the use of operational knowledge through use of probabilistic based models. Regardless of the approach used for assessing and prioritizing segment integrity concerns, the operator's local knowledge, skill, and judgment play an important role in establishing pipe segment integrity programs.

H. Mitigation Strategy

After establishing integrity programs for pipeline segments, operators develop a mitigation strategy. This involves examining individual pipeline segments within the broader scope of system-wide integrity. Mitigation is the action of reducing a pipeline's integrity-related concerns by addressing factors affecting either the likelihood of failure or the consequence expected from a loss of pipeline integrity. Mitigation actions generally fall into one of the following four categories: monitoring, inspection, remediation, or education. Selecting the appropriate mitigation action(s) is based on effective use of resources for improving a pipeline's integrity. Mitigation may also lead to improvements in the way a pipeline is designed, constructed, tested, and operated.

A combination of mitigation actions may be employed along a segment of pipeline to ensure or improve its integrity. These actions may require immediate implementation or may be scheduled over a short- or long-term.

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The final result is a comprehensive strategy of specific mitigation actions that reduce integrity concerns for the natural gas transmission pipeline.

I. Assess Plan Effectiveness

The effectiveness of an IMP is assessed by collecting performance information and conducting audits to evaluate the success of integrity assessment methods, pipeline repair activities, and other prevention and mitigation activities. The techniques employed to collect performance information may include internal benchmarking, external benchmarking, integrity management process audits, and feedback from operating personnel. One or more of these techniques can be employed to assess the effectiveness of systems, processes, and results that support integrity management decisions.

J. Improvement

Pipeline systems and the environment in which they operate are dynamic. IMPs are adapted to meet the changes to the pipeline system, its environment, new technology, and the industry challenges. The performance measurement and audit results along with operating personnel feedback are essential to the continuous improvement of the plan.

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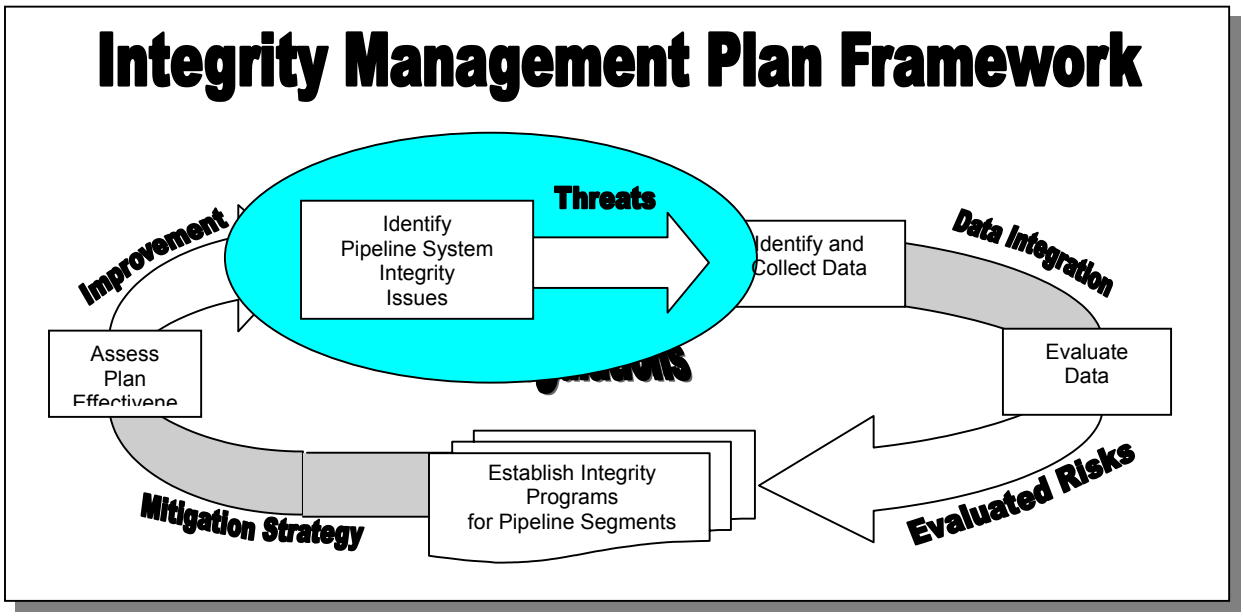
V. ISSUES AND THREATS TO PIPELINE INTEGRITY

Figure 2 highlights Integrity Management Plan (IMP) activities described in this section.

Figure 2 – Issues and Threats to Pipeline Integrity



A. Identify Pipeline System Integrity Issues

No two transmission systems are identical. Transmission systems vary in length[2], operating pressure, diameter of pipe, mechanical properties of pipe, operating environments, and other characteristics. Integrity concerns vary from one location to the next and from one section of pipe to the next. Not every section of pipe is exposed to the same risks. Therefore operators generally review integrity concerns on a segment-by-segment basis.

Typically an operator conducts reviews to identify integrity concerns using company personnel with local knowledge and technical expertise about the specific pipeline segment. Considerations that may affect both the likelihood of a pipeline integrity failure and the expected consequence from the loss of pipeline integrity are identified. Conditions that might increase the likelihood of pipeline failure are referred to as threats.

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B. Threats

The demands on the pipeline system and threats to pipeline integrity are constantly changing. The identification of threats to a pipeline and the management of those threats are integral parts of the IMP. The types of threats to a pipeline are numerous and the mechanics of failure may be time dependent, static, or random[3]. Table 1 contains a representative list of threats to pipeline integrity.

Table 1: A LIST OF THREATS TO PIPELINE INTEGRITY

Threats	Comments
Defective girth weld	Some examples include: • Lack of penetration. • Lack of fusion. • Porosity. • Welds with lower yield strength than the pipe. • Arc burn outside of the heat affected zone. • Low toughness welds (e.g., early arc or oxyacetylene welds). • Inadequate transition of wall thickness • Unusual joint designs (e.g., bell and spigot joints joined by fillet welds)
Defective pipe	Some examples include: • Blisters (raised spots on the surface of the pipe that result from the expansion of gas in cavities in the wall of the pipe). • Ovality (oval or egg shaped pipe). • Laminations (internal metal separation creating layers parallel to the pipe surface). • Inclusions (impurities within the pipe wall). • Burnt pipe (a sporadic lap-welded pipe problem that occurs when the edges of the skelp are heated too high and austenite grain-boundary sulfides form, making the pipe brittle and susceptible to cracks). • Hard spots (high hardness areas in the pipe caused by localized quenching during hot rolling of the skelp).
Earth movement	Landslides, earthquakes, or mining (e.g., long wall) may remove lateral support from the pipeline, buckle the pipeline, or collapse the pipeline. Earth movement may also expose the pipeline to greater threats, such as excavation damage or increased overburden stresses.

[2]Some transmission systems have less than a mile of pipe and others have tens of thousands of miles of pipe.
[3] See Hartford Steam Boiler Inspection and Insurance Company Report

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