Paper #2-19

NATURAL GAS PIPELINES CHALLENGES

Prepared by the Technology Subgroup

of the

Operations & Environment Task Group

On September 15, 2011, The National Petroleum Council (NPC) in approving its report, *Prudent Development: Realizing the Potential of North America's Abundant Natural Gas and Oil Resources*, also approved the making available of certain materials used in the study process, including detailed, specific subject matter papers prepared or used by the study's Task Groups and/or Subgroups. These Topic and White Papers were working documents that were part of the analyses that led to development of the summary results presented in the report's Executive Summary and Chapters.

These Topic and White Papers represent the views and conclusions of the authors. The National Petroleum Council has not endorsed or approved the statements and conclusions contained in these documents, but approved the publication of these materials as part of the study process.

The NPC believes that these papers will be of interest to the readers of the report and will help them better understand the results. These materials are being made available in the interest of transparency.

The attached paper is one of 57 such working documents used in the study analyses. Also included is a roster of the Subgroup that developed or submitted this paper. Appendix C of the final NPC report provides a complete list of the 57 Topic and White Papers and an abstract for each. The full papers can be viewed and downloaded from the report section of the NPC website (www.npc.org).

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ABSTRACT

Expanding the utilization of natural gas in the United States will require development of additional pipeline systems and increased use of existing pipeline infrastructure. In order to achieve this augmented natural gas utilization while avoiding a proportionate rise in adverse pipeline incidents, it will be necessary for pipeline operators to reduce the overall rate of adverse natural gas pipeline incidents.

The two leading causes of significant pipeline incidents, excavation damage and corrosion, have been addressed through improved technologies although industry emphasis historically has focused on detection as a higher priority that prevention. Detection evolved as the focus of efforts, in part, because the complementary regulatory components needed for prevention have been uneven and not consistently enforced. Prevention requires clear, robust and diligently enforced regulations for all pipelines. But historically different rules and authorities (federal and state) have existed for different types of pipelines including production (flow) lines, gathering lines, transmission lines and distribution lines.

Although the Pipeline and Hazardous Materials Safety Administration (within the US Department of Transportation) commonly is regarded as the nexus for pipeline safety standards, other federal agencies with various degrees of authority over pipelines include the Federal Energy Regulatory Commission (FERC), National Transportation Safety Board (NTSB), Environmental Protection Agency (EPA), Bureau of Land Management (BLM) and the Fish and Wildlife Service (FWS). In addition, intrastate pipelines are subject to regulation by individual state commissions. All federal and state regulations either directly or indirectly reference federal statutes under 49 CFR Part 192 (updated 2010).

Excavation damage has been addressed using One-Call Centers ("call before you dig" clearinghouse phone banks), pipeline marking, public education and rights-of-way patrols by pipeline operators. In addition, special industry-government collaborative programs have been established to track incidents, analyze trends and develop better preventive measures. Notable special programs include the Common Ground Alliance (CGA) and the Pipelines and Informed Planning Alliance (PIPA). In fact, the CGA Information Reporting Tool (DIRT) is regarded as the best consolidated pipeline-incident database in the US.

Progress in control of excavation damage must be proactively led by the pipeline industry but with substantial involvement by regulators, excavation contractors, municipal planners and other stakeholders. Solutions must include not only improved encroachment-detection technologies but also establishment and enforcement of regulations to prevent and document incidents of excavation-related damage.

Progress in corrosion control must be led by a pipeline industry commitment to develop and deploy improved technologies for prevention of corrosion as well as for earlier and more reliable detection of corrosion. Solutions must include continuous improvements and adoption of pipeline materials, coatings and cathodic protection methodologies as well as retrofitted inline inspections for "un-piggable" pipelines in addition to ongoing use of smart pigs.

INTRODUCTION

Increasing the utilization of natural gas in the United States will require development of additional pipeline systems and increased use of existing pipeline infrastructure. Maintaining a safe and environmentally-sound natural gas pipeline network in the face of this growing utilization will represent a major challenge facing the pipeline industry. This paper analyzes some of the major causes of adverse pipeline incidents and provides an overview of the safety measures currently used to prevent and mitigate these types of incidents. This paper also recommends measures for improving existing pipeline safety measures so that increased natural gas utilization can be achieved while avoiding a proportionate rise in adverse pipeline incidents.

TYPES OF NATURAL GAS PIPELINES

Figure 1 illustrates the interconnections and interactions among the multiple parts of a natural gas pipeline system. The system provides for collection of gas produced at the wellhead to facilities that process the gas into pipeline-compatible and marketable conditions and finally to end users of the processed gas. Essential to the system are different types of pipelines that are designed and operated to accomplish specific parts of the overall enterprise that collects, transports and delivers the gas.

There are essentially four types of natural gas pipelines:

- <u>Production or Flow Lines</u> typically transport natural gas and produced fluids at or near the wellhead or within the production facility.

- <u>Gathering Lines</u> transport natural gas from a production facility to a gas processing plant.

- <u>Transmission Lines</u> transport natural gas from a natural gas processing plant to a distribution line.

- <u>Distribution Lines</u> transport natural gas from a transmission pipeline and distribute it to commercial and residential end-users (distribution pipelines are generally smaller in diameter and operate at reduced pressures relative to transmission pipelines).

There are approximately 321,000 miles of gas transmission and gathering pipelines and 2,066,000 miles of gas distribution lines in the US (PHMSA, 2010b).

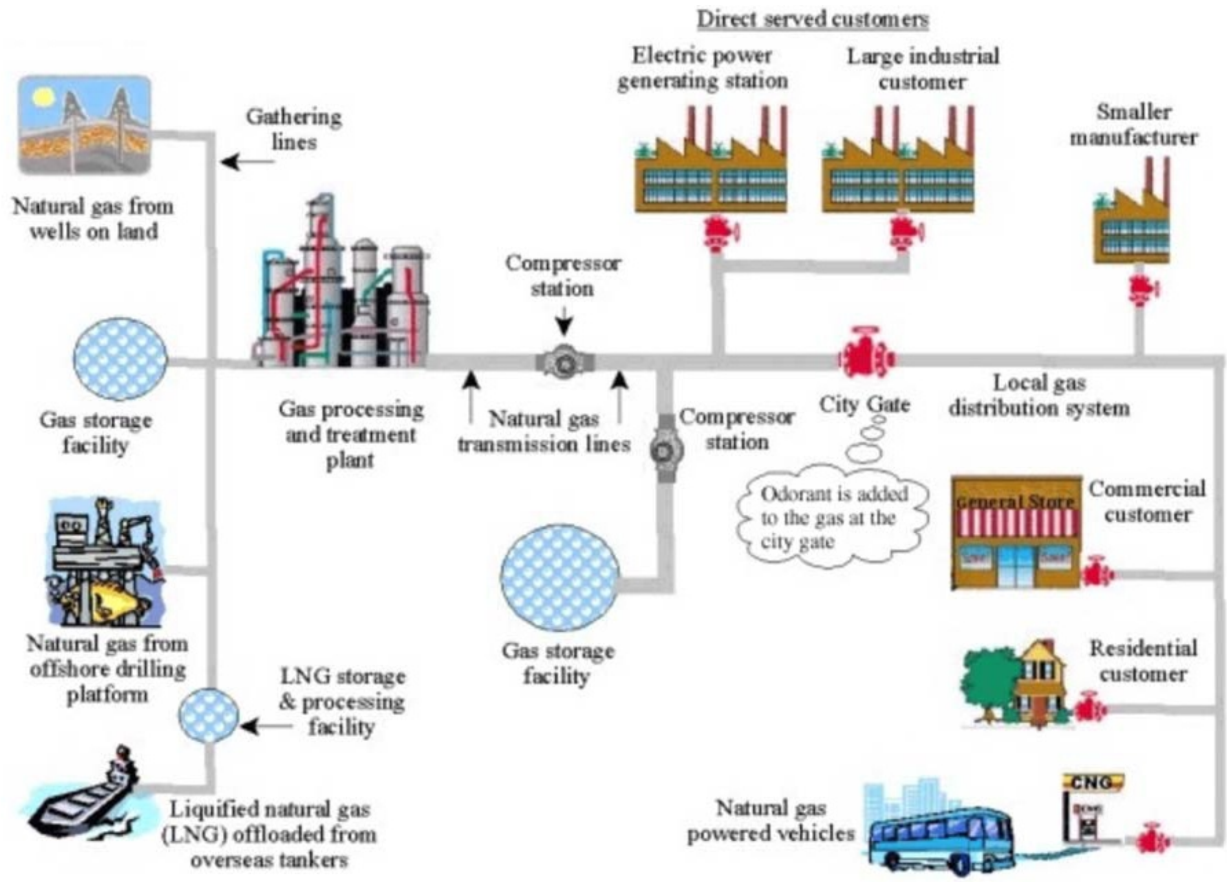

Figure 1. Schematic of a Typical Natural Gas Pipeline System (PHMSA, 2010a)

PIPELINE REGULATION

A. Overview of Regulatory Agencies and Authorities

Regulatory agencies providing industry oversight for pipeline operators in the US include the following:

- Department of Transportation (DOT) – Pipeline and Hazardous Material Safety Administration (PHMSA) - Office of Pipeline Safety (OPS)

The PHMSA OPS is the federal organization primarily responsible for ensuring the integrity of pipelines from both environmental and public safety perspectives. It is responsible for promulgating and enforcing the federal pipeline safety regulations for natural gas, petroleum, and other hazardous materials. Such regulations address safety issues relating to pipeline facilities and encompass areas including design, construction, testing, operation & maintenance, and emergency response. The regulations pertaining to the transportation of natural gas can be found at 49 CFR 192 (2010).

- State Agencies

State agencies, through certification by OPS, enforce the federal pipeline safety regulations for intrastate pipeline facilities. Certified state agencies may develop regulations for intrastate pipelines that are more stringent than the federal regulations. The types of agencies certified by OPS vary by state. Examples, however, include utilities, public service, and corporation commissions. If a state has no certified agencies, then OPS retains jurisdiction over the intrastate pipelines within that state.

- Federal Energy Regulatory Commission (FERC)

FERC, an independent federal agency, regulates many aspects of interstate transmission pipelines, including approval, permitting, siting, and abandonment. The pipeline approval process primarily entails an evaluation weighing the public need for a project against associated adverse consequences (e.g., negative impacts on landowners or the environment). FERC often specifies the conditions under which a pipeline can be constructed, including the route used, and oversees the process to ensure compliance.

- National Transportation Safety Board (NTSB)

The NTSB is an independent federal agency that investigates significant pipeline accidents (e.g., those involving a fatality or substantial property damage). The NTSB determines the probable cause of a pipeline accident and issues safety recommendations designed to avert similar types of accidents in the future. Depending on the nature of the recommendations, they may be directed to various entities, for example, OPS, other government agencies, industry associations, or pipeline operators.

- Environmental Protection Agency (EPA)

The EPA is responsible for promulgating and enforcing a wide variety of environmental regulations, some of which impact pipeline systems. Pipeline operators must comply with extensive requirements established under various EPA regulatory programs, including storm water management, air quality, waste management, toxic releases inventory, and spill prevention, control, and countermeasure (SPCC).

- Bureau of Land Management (BLM)

The BLM is an agency within the Department of the Interior that is responsible for management of certain onshore federal lands. With respect to pipelines, BLM is responsible for issuing right-of-way grants and permits for pipelines constructed in areas managed by BLM.

- Fish and Wildlife Service (FWS)

The FWS is an agency within the Department of the Interior. Under the Endangered Species Act of 1973 and the Migratory Bird Treaty Act, federal agencies with permit authority over pipeline construction and repair are required to consult with FWS on projects that could affect fish, wildlife, plants or their habitats.

B. Regulation of Pipeline Safety

The discussion below outlines how the four types of natural gas pipelines are regulated from the standpoint of pipeline safety.

- Production or Flow Lines

Currently, production or flow lines are not addressed by federal pipeline safety regulation. These types of lines are, however, typically regulated to at least some extent at the state level (this regulatory task is commonly performed by the oil & gas commission of the applicable state). In Texas, for example, production or flow lines located in populated areas are regulated under 49 CFR 192 (2010) by the Texas Railroad Commission.

- Gathering Lines

The OPS regulates gathering lines that are situated in populated locations (i.e., in areas where there are more than 10 buildings within 220 yards on either side of the pipeline in a continuous sliding mile along the pipeline). Pipelines in those locations are collectively referenced as "regulated onshore gathering lines". Regulated onshore gathering lines are further classified as either "Type A" or "Type B" gathering lines.

Type A gathering lines include those gathering lines that operate at relatively higher pressures (i.e., above 20% specified minimum yield strength for metallic piping or above 125 psig for non-metallic piping). Type A gathering lines are regulated to the full scope of 49 CFR 192 (2010) with the exception of:

1) Requirements concerning passage of internal inspection devices; and

2) Subpart O (Pipeline Integrity Management).

Type B gathering lines are those regulated onshore gathering lines that operate at a relatively lower pressures (i.e., below 20% specified minimum yield strength). Type B gathering lines need only comply with the following provisions of 49 CFR 192 (2010):

1) Maximum Allowable Operating Pressure

2) Public Awareness

3) Damage Prevention

4) Line Markers

5) Internal & External Corrosion

6) Design, Construction & Repair

- Transmission Lines

The OPS regulates all transmission lines.

- Distribution Lines

The OPS regulates all distribution lines.

PIPELINE INCIDENTS

Figure 2 shows that excavation damage and corrosion are the two leading causes of significant pipeline incidents in all pipeline systems, including hazardous liquid, gas transmission, gas gathering, and gas distribution systems. OPS estimate that, over the last twenty years, excavation damage and corrosion, together, have caused over 1 billion dollars in property damage.

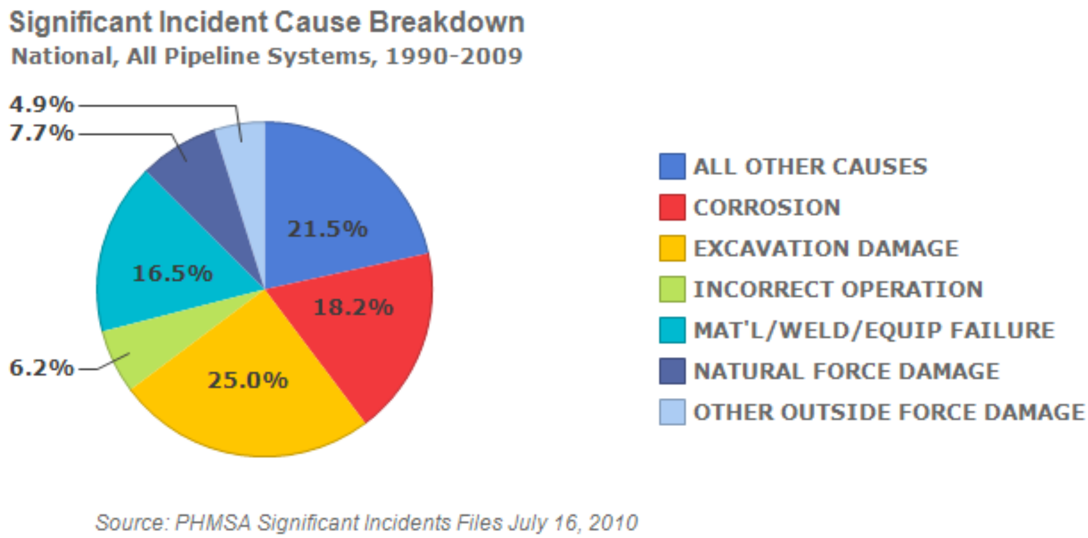

Figure 2. Significant Pipeline Incidents Categorized by Cause.

Significant Incidents are those incidents reported by pipeline operators in which any of the following conditions occur: 1) A fatality or personal injury requiring in-patient hospitalization; 2) $50,000 or more in total costs; 3) Highly volatile liquid release of 5 barrels or more or other liquid releases of 50 barrels or more; 4) Liquid releases resulting in an unintentional fire or explosion (PHMSA, 2010a).

Increasing the utilization of natural gas in the United States will require development of additional pipeline systems and increased use of existing pipeline infrastructure. In order to achieve the increased natural gas utilization while avoiding a proportionate rise in adverse pipeline incidents, it will be necessary for pipeline operators to reduce the overall rate of adverse natural gas pipeline incidents. With that goal in mind, the two leading causes of significant pipeline incidents (i.e., excavation damage, and corrosion) must be strictly managed.

A. Excavation Damage

(1) Causes of Excavation Damage

In general terms, excavation damage can be defined as localized mechanical damage to a pipeline resulting from contact with an object. Although excavation damage can occur during any phase of pipeline activity (e.g., construction, operation, or maintenance), it is most often caused by third-party activity over or near an operating pipeline. Excavation damage includes damage to the external coating of a pipeline and also dents, scrapes, cuts, or punctures directly into the pipeline.

Excavation damage can cause pipeline failures in two ways:

- Excavation damage can result in immediate catastrophic failure of a pipeline when excavation equipment punctures or tears the material forming the wall of the pipeline.
- Excavation damage can cause latent damage that can lead to catastrophic failure of the pipeline at some point in the future. Examples of latent damage include damage caused to pipeline coatings or dents or scrapes made in the pipeline material itself. Damage to a pipeline's coating material, for example, can lead to localized corrosion of the pipeline material in the damaged area with subsequent weakening of the pipeline material over time and, accordingly, eventual catastrophic failure. Dents or scrapes inflicted by excavation damage can reduce the physical strength of the pipeline material, particularly when combined with localized corrosion issues.

(2) Cost and Frequency of Excavation Damage

Excavation damage can result in both public safety and environmental hazards due to the release of natural gas and natural gas products. Personal injuries and fatalities result from excavation damage -- in fact, of all pipeline failure causes, personal injuries and fatalities are most likely to occur with pipeline failure caused by excavation damage (NTSB, 1997).

Excavation damage is the leading cause of significant pipeline incidents in all pipeline systems (i.e., hazardous liquid, gas transmission, gas gathering, and gas distribution systems) today. From 1990-2009, OPS estimates that excavation damage has resulted in 151 fatalities and 570 injuries and has cost the pipeline industry over 500 million dollars in property damage (PHMSA, 2010c).

(3) Common Practices to Prevent Excavation Damage

One-Call Centers. Pipeline operators, along with other underground facility operators (e.g., electricity providers, telecommunications companies, water and sewer companies) are required to join state "One-Call" systems or centers. Each pipeline operator must provide to the One-Call system, the locations of all of the operator's pipelines in the state.

While laws vary by state, excavators in all jurisdictions are required to contact the appropriate One-Call center before beginning any excavation. Once contacted by an excavator, the One-Call center will inform each affected underground facility operator of the planned timing and location of the proposed excavation. Each facility operator is then responsible for locating and visibly marking any of its underground facilities located at or near the proposed excavation site.

Prior to the advent of the One-Call system, an excavator typically was required to place multiple calls – one to each of the affected underground facility operators – in order to achieve complete notification of a proposed excavation. With the One-Call center system in place, however, a single telephone call from an excavator is all that is necessary to provide notification to all affected underground facility operators. The convenience offered by the One-Call center system has resulted in higher rates of excavator compliance with operator notification requirements.

As of May 1, 2007, the telephone number "811" was adopted as the new national "Call Before You Dig" number. The "811" system functions by automatically routing an excavator's call to the appropriate local One-Call center, thus, eliminating the confusion caused by the existence of multiple "Call Before You Dig" numbers across the country.

Pipeline Marking. Pipeline operators are required to mark underground pipelines with line markers. Line markers are signs or other markers installed above the pipeline to indicate the existence of an underground pipeline and the approximate pipeline route. Markers also typically include emergency contact telephone numbers that can be used to reach the operator.

Public Education. OPS requires pipeline operators to develop and maintain public awareness programs. The primary purpose of those programs is to educate the following four target audiences regarding damage prevention and emergency response practices:

- The affected public.
- Emergency officials.
- Local public officials.
- Excavators.

Rights-of-Way Patrols. Pipeline operators regularly inspect their pipeline rights-of-way (ROW) for indications of impending or existing excavation activities and/or actual excavation damage. ROW patrols, including surveillance by ground, airplane or helicopter, are performed by operators on a routine basis to identify areas where construction or excavation activity may adversely impact underground pipelines. Operators may assign onsite personnel to observe such activities, if detected near a ROW.

(4) Special Programs to Prevent Excavation Damage

Common Ground Alliance (CGA). In 1999, OPS sponsored a study entitled, *Common Ground: Study of One-Call Systems and Damage Prevention Best Practices* (CGA, 1999) which established, for all stakeholders, "best practice" procedures for preventing excavation damage. Thereafter, the CGA was established as a nonprofit organization dedicated to the reduction of damage in underground infrastructure. Today the CGA includes almost 1,400 volunteer members representing federal and state regulators, utility and pipeline companies, construction contractors, one-call centers, and equipment manufacturers who work together to identify and promote best practices aimed at keeping communities and the environment safe from the undesired consequences of damage to buried utilities.

The CGA continually updates the best practices originally set forth in the 1999 study. The most current update is *Common Ground Alliance Best Practices Version 7.0* which includes:

- Planning and Design Practices
- One-Call Center Practices
- Locating and Marking Practices
- Excavation Practices
- Mapping Practices
- Compliance Practices
- Public Education Practices
- Reporting and Evaluation Practices
- Miscellaneous Best Practices

The CGA also maintains a Damage Information Reporting Tool (DIRT) which is a national web-based database for reporting and collecting data on underground utility damage (CGA, 2010a). There are currently no federal reporting requirements for reporting excavation damage to utilities so the voluntary DIRT database is the main source of such information (CGA, 2010b). The primary purpose of the DIRT database is to identify root causes of damage, perform trend analysis, and help educate all stakeholders so that damages can be reduced through effective practices and procedures.

Grants to States. OPS offers grants to states for improving state damage prevention programs. To qualify for an OPS grant, a state must incorporate the nine elements of effective damage prevention programs identified in the Pipeline Inspection, Protection, Enforcement, and Safety (PIPES) Act of 2006 into the state programs. A guide to evaluating and incorporating the nine elements into a state damage prevention program is provided by PHMSA (2008).

Pipelines and Informed Planning Alliance (PIPA). Understanding that land use and zoning laws have a considerable positive effect on pipeline safety, OPS has partnered with local government planners, home builders, property developers, transmission pipeline operators, and local, state, and federal officials to enhance pipeline safety in communities through the Pipelines and Informed Planning Alliance (PIPA). PIPA has developed guidance and recommended practices for local governments, property developers, pipeline operators, and real estate commissions to enhance awareness and develop risk-informed guidance for property development in the vicinity of pipelines (PIPA, 2010a, 2010b).

(5) Emerging Technologies to Prevent Excavation Damage

Electronic White Lining - Phase 1 of the Virginia Pilot Project. In a process known as “white lining,” an excavator will normally mark, with white paint, the specific outline of a proposed excavation. When notifying the appropriate One-Call center, the excavator typically communicates the location of the proposed excavation by referencing, for example, the nearest major street intersection. The One-Call center then uses this general location information to identify a corresponding map “grid” within their system (see Figure 2, below) and notifies every operator having facilities within that grid. Each notified operator is then responsible for dispatching personnel to the proposed site to determine whether their underground facilities are located within the actual white lined area and, if so, provide appropriate markings for the excavator. Thus, in many cases, operators are required to dispatch personnel simply to determine that their underground facilities do not lie within the actual proposed excavation area.

In Phase 1 of the Virginia Pilot Project, cellular phones enabled with global positioning satellite (GPS) technologies and pocket PC smart phones were used to electronically “white line” excavation areas and transmit to the One-Call center coordinates corresponding to the actual outline or “polygon” of the specific proposed excavation site (Fig. 3). Each GPS-defined polygon can be transformed into a “shapefile” compatible with geographic information system (GIS) software that commonly is used to build and maintain pipeline maps. The Virginia Project concluded that by precisely identifying the excavation area with GPS coordinates, the required number of operator notifications can be significantly reduced. This, in turn, helps to streamline operation of the overall one-call process and, thus, enhance compliance, efficiency and reliability.

Figure 3: Polygon notification area versus grids (Virginia SCC, 2007).

Phase 1 of the Virginia Pilot Project, which was initiated and funded by OPS along with several other stakeholders, was completed in November 2007 (Virginia SCC, 2007). Two additional phases are also planned. Phase 2 involves integrating GPS technology into locating instruments to acquire GPS coordinates of underground facilities and create an electronic manifest of the locator's activity. That technology will allow the utility to update their mapping and give the excavator a "bird's-eye" view of the excavation area with all marked facilities overlaid with ortho-photography of the site. Phase 3 involves the development of a GPS monitor which will be attached to excavation equipment that will periodically send information to a fileserver where it will be cross-referenced with existing One-Call location tickets. If the excavation equipment is operating outside a valid One-Call ticket notification polygon, the excavating company and facility operator will be notified so they can contact the equipment operator directly and/or send an investigator to the site.

Encroachment Technologies. Pipeline operators regularly inspect their pipeline rights-of-way (ROW) for indications of impending or existing excavation activities and/or actual excavation damage (Chastain, 2009). Surveillance effectiveness depends heavily on patrol frequency. If the interval between patrols exceeds the time required for a potential excavation contractor to mobilize and commence digging, surveillance may be ineffective. New technology, such as encroachment monitoring devices, is currently being developed that can detect proximity of excavation equipment to a pipeline and/or sense actual excavation activity. While this technology may not necessarily prevent actual excavation damage from occurring in all cases, it nevertheless could serve to alert a pipeline operator that encroachment has occurred. Knowledge of such potential encroachment, in turn, would allow the operator to inspect the relevant area of the line for damage (this technology might be particularly useful for warding off latent defect failures).

None of the individual encroachment technologies is likely to find success in all applications. Rather, it is probable that different approaches will be required depending upon the specific circumstance or environment encountered. Some of the promising technologies are described below.

- Acoustic Monitoring utilizes acoustical sensors to detect third-party encroachment. The acoustical sensors, which each require a power source and a remote transmitter, are placed at predetermined intervals along the pipeline right of way (ROW). The sensors are programmed to monitor sound waves and compare them with sound signatures associated with known threats (e.g., excavation equipment). If a potential threat is detected, the sensor can then transmit an alarm to a receiver, ultimately notifying the operator.

- Seismic Monitoring (currently under various stages of development) utilizes the detection of identified acoustical characteristics of potential equipment threats (e.g., excavators of any known type). If a sound is identified as a threat, an alarm can be transmitted to a remote receiver to alert the operator. This detection technique can cover relatively large areas, may be installed above or below ground and have proven to be extremely accurate.

- Fiber-Optic Monitoring uses a fiber-optic cable buried near the pipeline to monitor various properties of light transmitted through the cable, which is sensitive to vibrations and pressures transmitted through the ground. Furthermore, if the fiber-optic cable is severed, its loss becomes an immediate indicator of possible encroachment. This technology does require some sophisticated system monitoring and processing equipment but it is viewed as a reliable, low operating cost method of providing real-time encroachment monitoring.

- Cathodic Protection Monitoring utilizes the existing external corrosion protection equipment already associated with a pipeline. This monitoring method operates by measuring changes in the existing cathodic protection current flow that may be caused by external equipment (e.g., excavation equipment) making contact with the pipeline. By monitoring and trending the normal flow of electrical current through the pipeline over time, it is relatively easy to detect abrupt changes in current flow that may be caused by contact with excavating equipment.

- Satellite Monitoring of pipeline rights of way (ROW) for encroachment is now available. One example of this technology is known as "RADARSAT". This sophisticated satellite-based radar technology can be programmed to detect and recognize specific types of equipment such as excavators or other identified threats associated with encroachment.

The technology can also be programmed to focus on narrow areas, such as a pipeline ROW which reduces the potential for nuisance alarms.

- Remote-Controlled Aerial Patrols by Drones represents new technology currently being tested to facilitate aerial survey of pipeline ROWs. The remotely controlled drones are equipped with GPS technology and digital video options. The drones can be launched frequently and from remote locations. The primary advantage of this technology is the low cost and relative convenience provided when conducting aerial surveys of established pipeline ROWs.

- Ground-Based Laser Technology is a new technology that may be installed along the pipeline ROW. Interruption of a laser beam, e.g., by excavating equipment entering the pipeline ROW, will trigger an alarm, alerting the operator to a potential problem.

Contact Prevention Technologies. Excavation damage also can be combated by equipping excavation equipment with contact-avoidance capabilities. Onboard excavator technology, which is in the testing phases, comprises sensing equipment mounted on excavators that will detect metal objects near the bucket of the excavator and provide audio and/or visual alarms, as appropriate. Proximity-based avoidance measures include GPS technology to establish the location of excavation equipment relative to a buried utility (for example, the Virginia Pilot, proposed Phase 3). If the location of the excavation equipment relative to the buried utility is deemed critical, an alarm is initiated, warning the operator of the excavation equipment. Other technologies being tested include sensing equipment mounted in the bit of a horizontal boring machine to detect both metallic and non-metallic objects in or near the path of the boring bit.

Although new contact-avoidance technologies have the potential for vastly improving the safety of excavation operations, the reliability of those new technologies has yet to be determined. Furthermore, the eventual deployment of contact-avoidance technologies may require extensive retrofitting of equipment and training for equipment operators.

Pipeline Location Technologies. Chances for avoiding excavation damage become incrementally less as precise locations of buried pipelines become incrementally better. Magnetic Gradiometer (utilizing military technology) shows some promise of improving the accuracy of line locating accuracy. As of 2009, this technology was still in the testing phase.

Electronic markers have been utilized successfully to mark non-metallic pipelines. The electronic marker, which is encased in a waterproof, chemically resistant case, does not require an internal energy source. It does, however, require the utilization of a special locator detection device, specifically designed for this application.

“Daylighting”, also referred to as “potholing”, is an extremely reliable method of positively identifying buried assets. The technology utilizes vacuum technology and water to remove soil overlying the pipeline to directly affirm the pipeline’s location and depth. This method of removing soil is easily controlled, cost effective and provides positive identification, with minimal impact on the surrounding environment.

(6) Work to Reduce Incidents of Excavation Damage

Address Root Causes. Based on the voluntary reporting to Common Ground Alliance DIRT database for 2007-2009, the primary root causes of excavation damages are (CGA, 2010b):

- Excavation Practices Not Sufficient (e.g., clearance not maintained, hand tools not used, marks not maintained, etc.).
- Notification Not Made By Excavator to One-Call.
- Locating Practices Not Sufficient (e.g., not accurately identifying and marking underground utilities, etc.).

One common recommendation for reducing the number of incidents caused by all three root causes is to improve communication practices among all stakeholders (e.g., excavator, One-Call center, facility operator, contract locater). Free exchange of accurate and timely information is critical for a successful damage-prevention process. It is recommended that pipeline operators work with all stakeholders to identify where communication deficiencies exist and initiate action where improvement is needed.

Another common recommendation addressing all three root causes is to improve training for all stakeholders involved. All stakeholders must be properly trained in their roles if the damage-prevention program is to be effective. It is important that stakeholders work together to identify, discuss and evaluate training needs based on review of incident and industry trends. It is recommended that the pipeline industry take an active stance in leading the stakeholders on improving stakeholder training.

Another important recommendation for all three root causes is to have effective state damage prevention laws in place which include enforcement provisions for violators. That legal element is particularly important for excavators who fail to notify the One-Call system. It is recommended that the pipeline industry focus on state damage prevention laws to ensure that the laws are adequate and effective and that they are being enforced.

Lower Probability and Risk of Excavation Damage Through Better Siting and Land Use. Increasing utilization of natural gas in the US will require expansion of the domestic pipeline network. This expansion, in turn, will result in more people living and working in closer proximity to pipelines, and will necessitate the construction of pipelines in more densely populated areas. Thus, it will be necessary for pipeline operators to carefully assess and plan the routes for new pipelines to reduce risk both to the public and the environment (TRB, 2004). In addition, pipeline operators must carefully consider the issue of expanding population centers encroaching upon existing pipeline systems.

The FERC has jurisdiction over the siting of interstate natural gas pipelines. Neither FERC nor DOT, however, has siting jurisdiction over intrastate natural gas pipelines (49 CFR 192 (2010), for example, does not specifically address the siting of pipelines). The siting of intrastate natural gas pipelines is typically left to state legislatures. Many states, in turn, empower local governments to protect the public through zoning and ordinance regulations. There is no single governmental agency that functions to strategically route pipelines to minimize risk to the public or the environment.

Pipeline operators will additionally be challenged by issues associated with increased utilization of existing pipelines. Again, the federal government does not regulate land use near pipelines and most states leave to local governments the decisions regarding what is appropriate in their communities. Pipeline operators, on the other hand, can generally only enforce provisions that are included in right-of-way agreements and typically have no control over development or encroachment outside of the pipeline ROW.

As discussed above, OPS has partnered with local government planners, home builders, property developers, transmission pipeline operators, and local, state, and federal officials to enhance pipeline safety in communities through the Pipelines and Informed Planning Alliance (PIPA). PIPA has developed guidance and recommended practices for local governments, property developers, pipeline operators, and real estate commissions to enhance awareness and develop risk-informed guidance for property development in the vicinity of pipelines. In order to maintain a safe pipeline infrastructure, it is recommended that pipeline operators take aggressive action to help local governments implement PIPA's recommended practices on land use around pipelines (PIPA, 2010b).

Support, Test, and Implement New Technologies. Improved technology is needed to enable increased natural gas utilization while avoiding a proportionate rise in adverse pipeline incidents. It is thus recommended that research should be continued into emerging technologies, such as those discussed above, that are likely to enhance pipeline damage prevention. It is further recommended that industry take steps to adopt and maintain an open-minded attitude toward new technologies and methods. Clearly, to meet the goal of reducing the rate of pipeline incidents, it will be necessary for industry to take an aggressive stance with respect to testing and implementing promising new technologies and practices rather than simply relying on the "status quo" of how things have been done in the past.

Measuring Performance & Damage Reporting Requirements. To assess the effectiveness of damage prevention programs and practices, accurate reporting and evaluation of excavation damage incidents will be necessary. Currently, there is no mandatory national requirement for reporting excavation damage to underground facilities. As discussed above, the Common Ground Alliance Damage Information Reporting Tool (DIRT) is the only national database established for this purpose. Since, however, use of the DIRT system is optional, the DIRT database may not accurately reflect a true indication of damage performance measures.

Although some states impose requirements for excavation damage reporting, those requirements are not consistent from state to state. At this time, the state of Texas imposes what are probably the most stringent requirements; in Texas, both the underground pipeline operator and the excavator are required to report any excavation damage.

Without a nationally mandated enforceable reporting requirement, it will remain difficult to determine accurate national trends that might point to areas where future improvement is needed. It is thus recommended that legislation be enacted that requires reporting, at the national level, of all excavation damage to underground facilities.

B. Corrosion Damage

(1) Causes of Corrosion Damage

Corrosion can result in the gradual reduction of the wall thickness of a pipe and a resulting loss in pipe strength with subsequent leakage or rupture. Pipeline corrosion creates weaknesses at points in the pipe, which can make the pipe more susceptible to third-party damage (e.g., excavation damage), overpressure events, or other stresses. Pipelines generally are vulnerable to two types of corrosion: external and internal. In both cases, stress applied to pipeline materials, either through product load or external forces, can induce "stress corrosion" by making certain components or locations more susceptible to corrosive processes.

External corrosion occurs in response to environmental conditions on the outside of the pipeline. The corrosion process itself is essentially electrochemical in nature. When an unprotected pipe is buried in moist soil, an electric current naturally flows from the metal pipe (which acts as an anode) into the soil (which acts as a cathode). That current flow causes the metal, from which the current flows, to dissolve in the surrounding moisture, thus resulting in corrosion.

Internal corrosion of pipelines occurs when chemical attack of the interior surface of the pipe is instigated by corrosive fluids flowing within the pipeline. In some cases, the corrosive fluids are contaminants, such as water or other chemicals, entrained or suspended within the product being transported by the pipeline.

(2) Cost and Frequency of Corrosion Damage

Corrosion damage is the second leading cause (18.2%) of significant pipeline incidents on all pipeline systems (i.e., hazardous liquid, gas transmission, gas gathering, and gas distribution systems). From 1990-2009, OPS estimates that corrosion damage resulted in 25 fatalities and 92 injuries and cost the pipeline industry approximately 500 million dollars in property damage (PHMSA, 2010c).

(3) Current Practices to Prevent Corrosion Damage

<u>Preventing External Corrosion</u>. There are two methods primarily used to combat external corrosion on pipelines: the application of external coatings and cathodic protection.

- <u>External coatings</u> are applied to pipelines as an external corrosion prevention measure. The external coating prevents the pipeline material (e.g., steel) from coming into contact with the surrounding environment. The coating is formed from an electrically insulating material to prevent electric current from flowing between the pipeline and the surrounding environment. External pipeline coatings are typically applied to pipeline sections at the pipe manufacturing plant. Field-applied external coating material is also added to the pipeline joint areas after completion of the welding phase, and before the pipe is lowered into the ditch.

- Cathodic protection also is used to prevent external corrosion on pipelines through measures that ensure that any electrical current will flow from the soil into the metal of the pipeline and not vice versa. In a typical cathodic protection methodology, a low-voltage DC electric current flow is induced within the pipeline in a direction opposite to that of the naturally-existing current. This prevents the metal pipe from acting as an anode and thus inhibits corrosion. Cathodic protection represents an efficient and well-proven technique for inhibiting pipeline external corrosion.

It is possible to address pipeline corrosion issues by utilizing external coating and cathodic protection methodologies separately. Those two approaches, however, are more commonly used together to form a more comprehensive corrosion prevention scheme. Although pipeline coatings generally work well to prevent corrosion, the coating material may contain small faults or gaps (sometimes in the industry called "holidays") caused, for example, by damage inflicted during construction or operation of the pipeline. Such defects in the coating material allow the pipeline material to come into electrical contact with the soil. Unless the line is cathodically protected, current can flow from the pipeline into the soil in these areas, resulting in localized occurrences of corrosion. It is therefore a common industry practice to provide cathodic protection and coating together to prevent external corrosion.

Preventing Internal Corrosion. As discussed in further detail below, some of the methods used to control internal pipeline corrosion include controlling product composition, using corrosion inhibitors, and the use of cleaning pigs.

- Product Composition. One method used to combat internal corrosion in pipelines involves controlling the composition of the product being transported through the pipeline to eliminate or limit the amount of entrained, corrosion-causing contaminant. Pipeline operators generally attempt to remove, for example, corrosive contaminants such as water, carbon dioxide, and hydrogen sulfide, where possible, to reduce the occurrence of internal corrosion.

- Corrosion Inhibitors. Operators may also introduce corrosion inhibitors into the pipeline. Corrosion inhibitors work by forming a protective film on the internal surface of the pipeline, thereby reducing corrosive interaction between the pipeline material and the product. Corrosion inhibitors are typically continuously injected into the pipeline and must be specifically selected to avoid contaminating the product.

- Cleaning Pigs. Pipeline operators also routinely run mechanical devices called "pigs" through their lines to remove accumulations of materials that can lead to internal corrosion. In-line cleaning pigs are frequently used to displace any corrosive fluids, including water, that may settle and collect at the low points of the pipeline. The recent generation of "smart pigs" are more capable by virtue of instrumentation that can make sophisticated measurements inside the pipeline.

(4) Practices to Assess Corrosion in Pipelines

By implementing the requirements of the regulations and through responsible maintenance programs, pipeline operators continuously inspect their pipelines for corrosion damage and potential susceptibility to corrosion.

The OPS has implemented pipeline integrity management regulations that require pipeline operators to inspect and assess the integrity of their pipelines in "high consequence" locations, such as population centers or environmentally sensitive areas. In such high consequence locations, operators are required to inspect and assess their pipelines for integrity issues such as corrosion, and repair or replace affected pipe.

Depending on characteristics of the pipe being examined, operators may select among several measurement methods for determining pipeline integrity, including:

- Magnetic Flux Leakage (MFL) tools
- Transverse Flux Inspection (TFI) tools
- Compression Wave Ultrasonic Inspection tools
- Shear Wave Ultrasonic Inspection tools
- Geometry (Caliper) tools
- Hydrostatic testing
- Direct Assessment, and
- Close Interval Surveys.

(5) Emerging Technologies to Help Prevent Corrosion Damage

New Technologies for "Un-Piggable" Lines. One of the major obstacles associated with older pipelines in the United States today is that such lines may be un-piggable (i.e., they that cannot accept an in-line inspection device, such as a smart pig). Although new transmission pipelines are required to be designed and constructed to accommodate the use of in-line inspection devices, many older lines cannot accommodate in-line inspection devices due to various factors, such as use of over- or under-sized valves; different sizes of pipe diameters; tight radius bends; and mitered bends.

OPS has sponsored research and development projects that may provide some solutions to the problems of un-piggable lines. Some of those projects are in the final stages of testing or are scheduled for completion within the next few years. The use of fluidized sensors and the meandering winding magnetometers in conventional cleaning pigs are two technologies that may be mounted on conventional cleaning pigs and provide an alternative to smart pigging. Smart pigging typically requires longer pig launchers and receivers and longer radius bends in the pipeline because of the overall length and rigidity of the pig. Conventional cleaning pigs are shorter and generally pass through short radius bends with fewer negative consequences. Accordingly, mounting fluidized sensors and meandering winding magnetometers on cleaning pigs enables these inspection technologies to be used in many older pipelines that cannot accept conventional smart pigs.

Better Assessment Technology. The OPS is sponsoring research in the following areas.

- Improved Magnetic Flux Leakage technology is being developed and tested to focus on improved anomaly sizing accuracy. This will greatly improve the assessment of anomalies, and thus, enhance the management of pipeline system mechanical integrity.

- Broadband Electromagnetic Technology Sensor is being developed to assess the pipe metallurgy through the coating. This research will focus on the detection and trending of metal loss, pitting and cracking. This assessment is an external measurement taken without removing the pipe coating.

- Stress Corrosion Cracking (SCC) monitoring technology is being developed to provide operators of pipelines with a tool to assist in the identification and monitoring of SCC locations.

Better Prevention Technology. The OPS is conducting research and development of pipeline coating materials to determine if there are opportunities for improving coating effectiveness and durability. The focus of the research and development is to reduce coating disbondment (the tendency of a coating to separate from its substrate) by performing better coating application, increasing coating thickness, improving coating material properties and performing multi-layering of the coating.

(6) Opportunities to Reduce Incidents Caused by Corrosion

Corrosion control is an essential tool to ensure the long-term integrity of pipeline systems. Significant improvements in corrosion prevention and assessment have been made over the years; however, challenges will continue to grow as our pipeline network ages and we see population density increasing near natural gas pipelines. Outlined below are two recommendations for reducing corrosion-related pipeline incidents.

Change Mindset on Importance of Corrosion Prevention. Both industry and regulators need to take aggressive steps to change the current mindset in which detection is considered to be the primary strategy for fighting pipeline corrosion. Although corrosion detection will always remain an important tool, focus needs to be shifted from corrosion detection to corrosion prevention. Industry must take a more proactive stance regarding corrosion prevention and should realize that, in addition to safety issues, corrosion prevention is also critical for asset preservation. Asset preservation, in turn, is necessary for long-term natural gas utilization in this country.

Corrosion prevention should be viewed not only as a maintenance function but also as a critical factor during all phases of the pipeline life cycle. During the pipeline design phase, for example, this might entail considering the use of piping material that is more corrosion resistant or the use of better pipe coating materials. In the pipeline construction phase, consideration might, for example, be given to the use of better rock shield materials, or more importantly, better inspection and supervision prior to and during the backfilling process (and possibly better training and qualification for inspectors in this regard).

Regulators also should adopt a more proactive stance regarding corrosion prevention, for example, by increasing the levels of inspection and possibly imposing stiffer penalties for non-compliance with corrosion prevention measures.

Support, Test and Implement New Technologies. Improved technology is needed in the area of corrosion prevention and assessment to decrease the number of corrosion-related pipeline incidents. As discussed above, the OPS currently conducts and supports research and development efforts in the areas of pipeline corrosion prevention and assessment. More research and development effort, however, is needed and it is recommended that the pipeline industry take an aggressive stance to support the OPS in their research and development endeavors by funding, testing, and implementing new technologies aimed at controlling pipeline corrosion.

FINDINGS

- Excavation damage and corrosion remain the main physical threats to the structural integrity and safe operation of natural gas pipelines.

- Reducing the rate of pipeline incidents will require broad and intensive efforts to improve technologies, policies and access to complete and accurate data needed to assure safe practices.

- Progress in corrosion control must be led by a pipeline industry commitment to develop and deploy improved technologies for prevention of corrosion as well as for earlier and more reliable detection of corrosion. Solutions must include continuous improvements and adoption of pipeline materials, coatings and cathodic protection methodologies as well as retrofitted inline inspections for “un-piggable” pipelines in addition to ongoing use of smart pigs.

- Progress in control of excavation damage also must be proactively led by the pipeline industry but with substantial involvement by regulators, excavation contractors, municipal planners and other stakeholders. Solutions must include not only improved encroachment-detection technologies but also establishment and enforcement of regulations to prevent and document incidents of excavation-related damage.

- Key to success in reducing pipeline integrity issues is a new commitment by the pipeline industry to emphasize prevention of incidents as a top priority not only for safety but for asset protection and stakeholder acceptance.

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