



CRUDE MOVE

Crude Oil Movement in the Great Lakes-St. Lawrence River Region

Inspection and Maintenance of Crude Oil Transmission Pipelines in the Great Lakes-St. Lawrence River Region

Yorick-Oden-Plants,
Doris Duke Conservation Scholars Program Intern

September 2017

Introduction

The Great Lakes-St. Lawrence River (GLSLR) region is a major hub for the transportation of crude oil. Pipelines are the traditionally preferred mode of transportation for oil; more oil is transported through the region by this mode than by any other. Growing production from the Bakken shale oil fracked from the Midwestern United States and Alberta oil sands extracted from Canada has brought an increasing amount of product to the GLSLR, increasing the use of pipelines in this region exponentially.¹

Within the GLSLR region, crude oil pipelines extend over 9,122 miles.^{2,3} 46 percent of the crude oil pipelines in Great Lakes states were installed prior to 1970⁴. In the Canadian provinces, 48 percent of crude pipelines were installed prior to 1985.⁵ Increased crude oil traffic in the GLSLR region presents risks, specifically from pipeline accidents, leaks, and failures. In general, pipelines have been shown to have the fewest spills per billion ton-miles of oil transported when compared to other transportation methods such as rail and vessels. However, pipeline failure incidents have a significant effect on the local economy, environment, and population.⁶ Therefore, proper maintenance and inspection protocols, and the regulations of such, are critical to the protection of the natural resources and inhabitants of the Great Lakes states and provinces.⁷ The sheer number of pipelines transiting the Great Lakes basin, which holds 20 percent of Earth's fresh surface water, makes understanding potential hazards and measures to minimize risk particularly valuable to policy-makers, industries, communities and the basin's residents.

How are oil pipelines inspected and maintained?

Typical Pipeline Vulnerabilities

Pipeline failures are often the result of corrosion, equipment failure, manufacturing error, environmental incidents, and human interference.⁸ To detect and prevent these failures, operators and regulators conduct regular inspections. Inspections generally target typical pipeline vulnerabilities in three categories: corrosion, deformations, and cracking.

Corrosion may be the most consistent integrity challenge facing operators of cast iron and steel pipelines. While other concerns can be considered incidental and only affect certain sections of pipeline, corrosion constantly affects every inch of pipeline. Corrosion is a natural phenomenon that occurs whenever a metal is exposed to the surrounding environment. This electrochemical process pulls ions from the surface of the steel pipe to dissimilar metals (i.e. more passive metals) in the soil, water, or air. As ions are pulled from the steel pipelines by these dissimilar metals, oxygen can bond and create rust.⁹ Left unchecked it can eventually degrade the structural integrity of a pipeline.¹⁰ Although pure oil does not present a corrosion risk to the pipeline, sediment and water carried by crude can cause internal corrosion.¹¹ Corrosion generally results in minor leaks from small holes in the steel pipeline.

Steel is generally a strong and malleable metal. However, improper installation and/or maintenance of steel pipelines can lead to stress induced separation of the metal or cracking.¹² Stress is a physical quantity measured in pascals that describes the force per unit area acting on a material. Stress generally leads to cracks in oil pipelines in three ways: cyclic fatigue, stress corrosion, or manufacturing error. Cyclic fatigue is the structural damage that occurs when the steel pipeline is subjected to fluctuating internal pressures.¹³ Stress-corrosion cracking occurs where pipe is under tension and exposed to corrosive elements. Cracks that are built into the pipe tend to be too small to cause pipe failure but are usually detected nevertheless.¹⁴ Cracks generally cause leaking but severe cracks can lead to a burst pipe.¹⁵

The most common causes of deformations in steel pipelines are environmental incidents and human interference; human interference is the most common of the two. When heavy equipment or rocks strike the steel pipe, they can make dents or gouges that change the internal geometry of the line. Changes in the internal geometry alter the distribution of internal pressure by focusing it on certain sections of pipeline. Overtime these deformations may result in pipeline failure. Deformations are often accompanied by a loss of coating, which increases the risk of corrosion.¹⁶

Preventative Measures

Pipeline operators and regulators carefully consider the integrity management of transmission pipelines. Integrity management plans include emergency protocols but most importantly include maintenance and preventative measures. Operators take measures to defend pipelines against specific risks. Considering the potential for costly public and environmental damages given a pipeline failure, these measures are generally mandated by the federal government. Through proper maintenance and inspection, operators can manage the integrity of their pipelines and mitigate the risk of failure.

A variety of preventative measures can be taken to reduce corrosion including implementing cathodic protection, regular cleanings, pipe coatings, and pipeline inspections.¹⁷ The simplest and most effective way to prevent a pipeline from corroding is to keep it out of contact with the environment. Any pipeline that is buried or submerged is required by law to have an external coating for external corrosion control.¹⁸ Many pipeline operators use an epoxy coating to seal off the surface of the pipe. While epoxy coatings are the most popular, the diverse terrain through which pipelines operate sometimes require specialized coatings. For example, a pipeline operator might use a cement coating for a pipeline crossing a river to help weigh it down and keep it in place.¹⁹

Regular cleaning is an industry standard for oil pipeline operators. These cleanings ensure that the pipeline is operating at peak efficiency and that corrosive buildup is removed. Pipelines can be cleaned mechanically, with a tool known as a pig, or chemically. Mechanical cleanings are the most commonly accepted practice to remove deposits within the pipeline. The pig is passed through the pipeline, scraping away at deposits until it is retrieved in a relatively clean condition. Because operators usually cannot see the inside of the pipeline while cleaning, the cleanliness of the pig was historically used as a proxy for the cleanliness of the pipe. However, assuming the

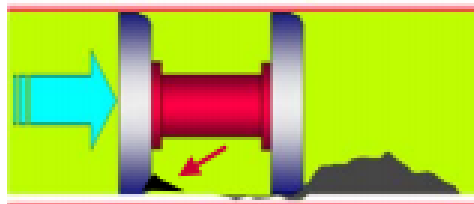


Figure 1 Deposits are not cleaned perfectly by mechanical pigs. van der Werff, Andre. The Importance of Pipeline Cleaning: Risks, Gains, Benefits, Peace of Mind. Pipeline Technology 2006 Conference, 2006

pipeline is clean when the pig is clean can be inaccurate because the mechanical pig is not capable of perfectly removing deposits. As it passes through the pipe, it smears a small amount of debris along the surface, creating a thin coating (Fig. 1). This thin layer is compacted over multiple cleanings. It is possible for water and other corrosive elements to be trapped underneath this layer, which increases the risk of internal corrosion. The interior coating can also interfere with in-line inspection tools. The historical failures of mechanical pigging have led to the quick adoption of chemical cleaning. Used in conjunction with a mechanical pig, liquid chemicals can remove more debris in fewer runs.²⁰ While mechanical cleaning can be performed on both active and inactive pipelines, chemical cleaning requires the pipeline to be temporarily deactivated. The section to be cleaned must be closed off, after which it is be filled with liquid chemicals. The flow rate and the pH of the chemicals are monitored as the pipeline is cleaned – both values increase. Once the flow rate and pH level off, the pipeline is flushed and reactivated.²¹ The

chemical blends used are proprietary but all follow a few key parameters. Ideal cleaning products have the following properties: wetting, to reduce surface tension of deposits; emulsification, to prevent hydrocarbons from redepositing down the line; detergency, to mobilize hydrocarbon deposits; and dispersion, to keep the deposits in suspension by preventing aggregation of particles.²²

Cathodic protection is another industry standard for protecting steel pipelines from corrosion. In older, simpler galvanic systems this involved coating the pipeline in an anode, such as zinc, to prevent the steel from reacting to environmental conditions. The anode corrodes in place of the steel. Because the zinc eventually corrodes and leaves the steel bare, galvanic systems have a limited lifetime. Newer pipelines are required to make use of an impressed current protection system (Fig. 2).²³ In this system, the steel pipeline is connected to an anode made of a metal that is more reactive than steel (e.g., magnesium, aluminum, zinc). Because the anode is more reactive, it needs to lose all its ions before the steel begins to corrode. The anode is then connected to a power source called a rectifier. As the anode loses electrons to corrosion in place of the steel, the electrons are replenished by the power source. This system is limited only by the rectifier and therefore has a much longer lifespan.²⁴ There is no legal requirement for the spacing or number of rectifiers and anodes. However, operators, where a standard is not incorporated by reference, strive to maintain certain electrical standards set by the National Association of Corrosion Engineers.²⁵

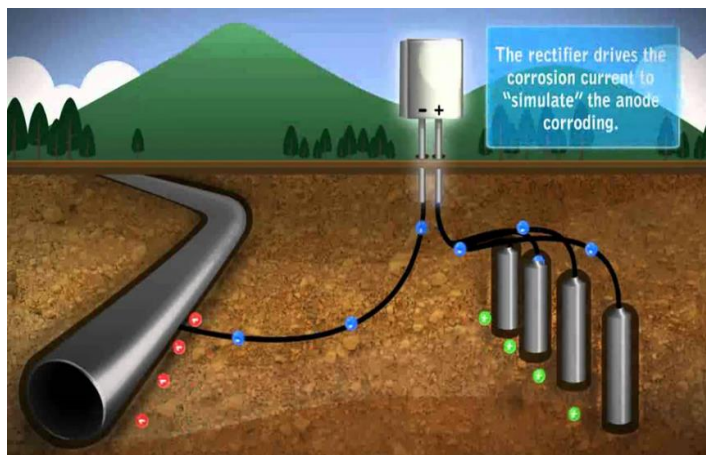


Figure 2 Impressed current cathodic protection systems use electricity to drive the corrosion of the sacrificial anode and protect the steel pipeline. Impressed Current Cathodic Protection. CorrConnect, GSG Systems.

Because human interference is the main cause of deformations, preventative measures predominantly target public awareness. Pipeline operators participate in federal, state, and provincial programs in both the United States and Canada that provide toll-free hotlines for property owners planning any excavation projects.^{26,27} Property owners are required by law to check with these programs before they begin a project. To increase the general visibility of submerged and buried pipelines, land based pipelines are often clearly marked and no-anchor zones are established along aquatic pipelines in the Great Lakes.²⁸ Federal law requires that markers be located "at each public road crossing, at each railroad crossing, and in sufficient number along the remainder of each buried line so that its location is accurately known."²⁹

Cracking requires active management near bends and at girth welds where the pipes are welded together. Thicker pipe is less susceptible to cracking. Pipelines that are under water require bracing so that currents and the weight of the water do not stress and fatigue the steel.³⁰ There is no standard set by the federal government for bracing, but agreements with local governments often stipulate certain bracing regimes. The only transmission pipeline in the Great Lakes, Line 5, is required by Michigan to brace the line such that there is no span greater than 75 meters.³¹ Federal laws also require that pipelines not operate above 80 percent of the first pressure test conducted. Maintaining stable and safe pressures reduces the cyclic fatigue on pipelines and reduces cracking.

In-line Inspection Tools

Once a pipeline has been installed, the best way for an operator or regulator to inspect it is to use a smart pig. Smart pigs get their name from the cleaning pigs that are pushed along the inside of pipeline by the force of the product. These devices travel in the same way but are much more sophisticated. These specialized tools “record irregularities that may represent corrosion, cracks, laminations, deformations (dents, gouges, etc.), or other defects.”³²

In-line inspections can detect and corrosion using a device known as a Magnetic Flux Leakage tool (Fig. 3). This tool induces a magnetic field within the pipeline and measures changes in the field as it is pushed through by the product. Corrosion pits distort the magnetic field, alerting inspectors to imperfections and defects. With GPS equipped, the tool can accurately relay the location of any abnormalities.³³ A Transverse Flux Inspection tool works in the same way except that the magnetic field is oriented circumferentially. This orientation allows the tool to assess longitudinally-oriented corrosion that may be present around the seams of a pipe.³⁴



Figure 3 Magnetic flux leakage tool “Results Metal Loss Corrosion.” Results Metal Loss Corrosion - Enbridge Inc.



Figure 4 Caliper in-line tool “Results Deformations.” Results Deformations - Enbridge Inc.

Caliper in-line tools are used during in-line inspections to detect deformations in a pipeline (Fig. 4). The tool uses highly sensitive spring loaded arms to detect variance in the internal diameter of a pipeline. The tool can relay the position of any deformations (e.g. on top of the pipe, underneath the pipe, on the side of the pipe) and provide inspectors with the GPS location of deformations. The tool also collects data on the size and shape of any deformations.³⁵

Circumferential crack inspection tools are used to assess the integrity of a pipeline. “Free swimming” circumferential crack inspection tools are pushed along the pipeline by the force of the product; whereas, tethered circumferential crack inspection tools stop at each gird weld to examine the condition of the connection (Fig. 5).³⁶ Crack inspection tools use ultrasonic waves to measure wall thickness and detect imperfections. Using a pulse-echo system, a transducer produces ultrasonic blasts that travel through the oil and reflect off the interior pipeline walls. By analyzing the transmission times of the echoes and the sound velocity, technicians can accurately measure wall thickness to detect cracks.³⁷



Figure 5 Crack inspection tool “Results Cracking.” Results Cracking - Enbridge Inc.

Monitoring Techniques

Inspections can uncover abnormalities that could lead to future failures, so operators maintain procedures for monitoring pipelines between regular in-line inspections to detect a failure quick enough

to prevent serious damage to the public and the environment. Pipeline operators have an arsenal of tools commonly used for monitoring purposes. Aerial and ground patrols, controller surveillance, and 24/7 monitoring by trained controllers in a control room allows companies to detect failures as soon as possible, reducing potential damage to surrounding urban areas or environmental zones.

It is common for pipeline operators to keep pilots on retainer for regular aerial inspections of a pipeline right of way (ROW). These pilots operate small one or two passenger planes. In some situations, the pilot is responsible for flying and inspecting the ROW. In others, the pilot is accompanied by a passenger whose sole responsibility is monitoring the ROW. Aerial inspections look out for signs of a leak, unauthorized construction, or other potentially dangerous situations. In one instance, an aerial inspector spotted an elephant on a ROW.³⁸ A nearby circus used a three-foot stake to tether the animal, but the pipeline was not damaged. This stands out as an anomaly, however, as pipeline operators are generally aware of any activity in their respective ROWs.³⁹ Along with these aerial inspections, it is common for pipeline operators to have regular ground patrols for the same purpose. These measures are in accordance with federal law, which requires that each operator shall, at intervals not exceeding three weeks but at least 26 times each calendar year, inspect the surface conditions on or adjacent to each pipeline right-of-way."⁴⁰ To facilitate efficient inspections and repairs, operators are also required to maintain ROWs to a set standard. The goal of these standards is to prevent extensive landscaping or other obstructions from impeding an operator's access to the pipeline.

Regular on-site monitoring is important for ensuring safe procedures along ROWs. However, these above ground inspections do not provide enough information to safely monitor the length of pipeline every hour of every day. Furthermore, it is infeasible for operators to provide constant on-site monitoring along the thousands of miles of pipeline they maintain. For this reason, operators are required by PHMSA to manage off-site control rooms.⁴¹ These control rooms are operated by controllers that have been trained by operators. Operators are required to have a written plan for "normal, abnormal, and emergency operating conditions."⁴² The written plan includes a controller's authority to make decisions in emergency situations, a controller's role when abnormal operating conditions are detected, and a shift-change method for controllers. The federal government also regulates the fatigue mitigation of controllers. Shift lengths are required to provide controllers with enough time for eight hours of sleep, and each controller must have a maximum limit on hours of service.⁴³ These regulations are designed to ensure that controllers can act swiftly in the face of an emergency.

Controllers monitor and operate supervisory control and data acquisition computer systems (SCADAs). SCADA systems continuously relay information about the pressures, flow rates, etc., of the product in real time. Flow meters capture data on the pressure and temperatures at specific, strategic locations along the pipeline. With all this data, operators can detect leaks using scheduled computations.⁴⁴ When a leak is detected, an operator can shut down a system within minutes. Unique emergency response protocols, which include procedures to contain leaks, clean spills, and restart pipelines, are maintained by operators for each facility. These emergency response plans (ERPs) are audited and approved by the federal governments in both Canada and the United States.⁴⁵

Recently, advances in fiber optics have given operators the potential to provide an even greater level of security. Despite the deployment of all the monitoring techniques detailed above, a large percentage of leaks originate from external causes like excavators or slope movements and can occur between inspections. Fiber optics offer technology that allows for the earliest detection of leaks. Traditionally used for data transmission and communication around pipelines, fiber optic sensors may also be used to detect

leaks, ground movement, structural health, fire, and third party activities around oil pipelines.⁴⁶ Because of their capability to identify very small leaks, fiber optic sensors are ideal for monitoring pipelines. Operators in the United States are working to validate fiber optic sensors as a monitoring technique in scientific studies.^{47,48}

Repair Methods

When monitoring or inspection activities detect issues with oil pipelines, it is important that they are repaired properly. There are several repair methods available to operators to address a variety of pipeline defects. When deciding how to repair a pipeline defect, operators consider the severity of the defect, the cost of repair, and the risk to people and the environment.

In some circumstances, the most cost-effective and/or safest way to repair a pipeline defect is to remove the affected segment of pipe and replace it. Removal requires that the pipeline be shut down, or that the affected segment be isolated and depressurized. When the pipeline is shut down, it is cleaned and flushed with an inert gas to remove crude oil and reduce any explosive conditions. To isolate the affected segment without removing the product, operators can shut valves on either end of the defective segment. Operators sometimes use a freeze plug for the same purpose. A freeze plug is a procedure that uses liquid nitrogen to freeze the product before and after the segment that is to be replaced. Once the product has been removed or isolated, the pipeline is cut out as a cylinder and replaced by an already hydrostatically tested pipe to ensure it can withstand the operating pressure. After the tie in welds are inspected, the product flow may resume. Operators may elect to remove a pipeline while product is still in the line using a method known as a hot tie-in. By maintaining a low positive pressure in the pipeline, specially trained personnel can weld and cut the pipeline without explosions while igniting the escaping product. Removal repair is one of the costlier repair options; however, it is considered a permanent fix for any pipeline defect.⁴⁹

Grinding is a common method used to repair gouges and cracks in pipelines, but it is only effective under specific circumstances. When all the damaged metal can be removed and the pressure carrying capacity is not reduced, grinding can be considered a permanent repair. Federal law in Canada and the United States limits the amount of pipeline that be ground out to 40 percent of nominal wall thickness. In situations where repairing a gouge or crack would require grinding more than 40 percent of nominal wall thickness away, operators can combine grinding with a steel reinforcement sleeve or composite.⁵⁰

Full-encirclement steel sleeves are historically a widely-used method for general repairs to onshore pipelines. Because they require welding, steel sleeves are less popular for offshore pipelines. Underwater welding is a risky proposition as there is a greater chance for insufficient welding resulting in a leak or injury to personnel during the work, such as electric shock, explosions, and decompression sickness.⁵¹ Steel sleeves are two halves of a cylinder of pipe that are placed around the defective segment of pipe. There are two types of steel sleeves: type A and type B. Type A sleeves reinforce pipe segments without being welded to the pipe itself. They are favored for their very simple construction; however, they cannot be used to repair circumferentially oriented or leaking defects because they do not reduce longitudinal stress or contain pressure. More recently, composite reinforcement sleeves have been used in a similar way to type A steel sleeves. Composite reinforcement sleeves are proprietary products and are most commonly made of fiberglass. They are approved for specific applications, such as blunt corrosion defects and blunt wall-loss. Type B sleeves are welded to the carrier pipe at each end, so they can be used to repair leaks and strengthen circumferentially oriented defects. Because they are expected to contain leaks, type B sleeves must be designed to carry the full pressure of the carrier pipe.⁵²

Mechanical clamps include bolt-on clamps and leak clamps. Bolt-on clamps are designed with elastomeric seals that can contain the full pipeline pressure. Operators may elect to weld bolt-on clamps to the pipeline to protect against failing seals. Bolt-on clamps can also be made with circumferential clamping mechanisms at each end of the sleeve. These designs make bolt-on clamps a permanent solution for leaking defects and circumferential cracks. Leak clamps are used to repair leaking external corrosion pits. These clamps have a sealing plug on the inside that can be screwed into a defect. These clamps can be made into a permanent repair if they are encapsulated by a domed fitting.⁵³

Who conducts pipeline inspections?

United States Inspection Regime

In the United States, the regulation of pipelines transporting oil is the responsibility of the Department of Transportation (DOT). The Pipeline & Hazardous Materials Safety Administration (PHMSA) is the branch of the DOT that conducts inspections and enforces regulations.⁵⁴ United States law does not require that PHMSA test each pipeline at regular intervals. Instead, federal inspections are scheduled on a case by case basis. The frequency of these inspections is determined after considering factors related to the pipeline facility itself such as its location, type, age, size, operator, and general condition. The properties of the product are also considered. For example, pipelines with denser crude oil at higher pressures that is harder to clean may be inspected more often than those that carry light crude at lower pressures. Features of the surrounding area are also considered, including climatic, geologic, and seismic characteristics. Proximity to densely populated areas that are unusually sensitive to environmental damage is an especially prescient concern when determining the inspection frequency, and so is the infraction history of the operator.⁵⁵ In short, PHMSA tends to prioritize pipelines that have a history of leakage, are near urban centers, and/or present excessive risk to the environment.

The regulation of all interstate oil pipelines is the responsibility of PHMSA; however, through certification, individual states can be granted the power to regulate intrastate pipelines.⁵⁶ If a state does not participate in the pipeline safety program, the intrastate pipelines are PHMSA's responsibility to inspect and enforce. To become certified, states must adopt the minimum pipeline safety regulations, but they may choose to adopt additional more stringent standards. PHMSA reimburses certified states up to 80 percent of the total cost through grants to support pipeline safety programming.⁵⁷ All the states, except Alaska and Hawaii, have been certified for natural gas pipelines; Minnesota, Indiana, and New York are the only states in the GLSLR region that have been certified to regulate, inspect, and enforce intrastate hazardous liquids pipelines.

Companies operating pipelines in the United States are required to carry out written plans for inspection and maintenance that have been submitted to and approved by the PHMSA. The adequacy of each operator's plan is determined by: "relevant available pipeline safety information; the appropriateness of the plan for the particular kind of pipeline transportation or facility; the reasonableness of the plan; and the extent to which the plan will contribute to public safety and the protection of the environment."⁵⁸ These plans are reviewed within every 15 months and at least once a year. These plans must include procedures for numerous specific maintenance, operational, and emergency situations.⁵⁹ United States law requires that operators establish inspection intervals not to exceed five years for any pipeline that could affect a 'high-consequence area'.⁶⁰ High consequence areas (HCAs) are those that have a large population; are commercially navigable waterways; or contain sensitive habitats.⁶¹ 44 percent of

hazardous liquid pipelines are in HCAs.⁶² The remaining 56 percent are inspected as often as their PHMSA approved plans dictate.

Canadian Inspection Regime

In Canada, the regulation of oil pipelines is the responsibility of the National Energy Board (NEB).⁶³ Canadian law does not require that the NEB inspect pipelines at specific intervals.⁶⁴ Rather, they use a risk-informed model to prioritize the inspection of pipelines on a case-by-case basis. The model is most concerned with the potential for and the severity of consequences to people and the environment in the event of a pipeline failure. It also considers factors related to the facility itself such as a pipeline's location, type, age, and operating history. Aside from a pipeline's individual history, the operator's overall compliance history is also considered. For example, the more inspection, audits, and incident reports an operator compiles, the more often they may expect a federal inspection.⁶⁵ The scope of NEB inspections is also variable. Officers inspect based on their own areas of expertise and competencies, and their scope is generally determined by the potential risks at a specific facility and an operator's history.⁶⁶ The NEB's inspection jurisdiction covers all international and inter-provincial pipelines. Provinces are responsible for the regulation of intra-province pipelines, but these pipelines are largely used for natural gas distribution, and not crude oil transmission.

Operators in Canada are also responsible for inspecting their pipelines. Unlike the United States, Canada does not have a set frequency for pipeline inspection. Instead, Canadian pipeline operators are required to submit inspection and maintenance plans to the NEB for approval. These plans must be audited by the operators at least every three years. Canadian operators must also submit an annual report to the NEB detailing the status of their maintenance plans and any corrective measures they have taken.⁶⁷

How are pipeline operators regulated?

United States Integrity Standards

In the United States, pipelines must meet certain standards for integrity. Immediate repair is required by law when inspections show a metal loss greater than 80 percent of nominal wall thickness; a calculated burst pressure less than maximum operating pressure at an anomaly; a top dent with any indication of metal loss, cracking, or stress, or any other anomaly judged to require immediate attention. Operators have 60 days to repair a top dent greater than 3 percent of nominal pipe diameter or a bottom dent with any indication of metal loss, cracking, or stress. PHMSA gives operators 180 days to fix less serious errors and anomalies.⁶⁸ Outside of these regulations, repairs are up to the operator's discretion. When operators conduct in-house inspections, they are required to provide any relevant data on their actions to PHMSA.

United States Enforcement Capabilities

PHMSA has a toolbox of enforcement mechanisms to employ when operators are non-compliant. These include measures to correct violations and to preclude future non-compliant operations. The enforcement program issues different actions dependent on the significance of the hazards, violations, or inadequacies encountered.⁶⁹

The swiftest enforcement action available to PHMSA is the Corrective Action Order (CAO). CAOs are issued when PHMSA finds that a pipeline presents an imminent hazard to life, property, or the environment. These are generally issued in urgent situations such as an accident, spill, or other immediate safety

concern. The CAO includes “a finding that the pipeline facility is or would be hazardous to life, property, or the environment; relevant facts supporting the finding; the legal basis for the CAO; a description of specific corrective actions the operator must take; the date by which corrective actions must be completed; and the opportunity for an operator to request a hearing.”⁷⁰ Operators have 10 days to respond to a CAO (i.e. request a hearing). When conditions for a CAO exist, but the CAO does not require expeditious processing, a Notice of Proposed Corrective Action Order (NOPCAO) may be dealt. A NOPCAO gives the operator a chance for a hearing prior to the issuing of a CAO. CAOs often require an operator to reduce operating pressure in a line or shut it down all together. Pipeline tests such as in-line inspections and hydrostatic pressure testing are often required as well.

When PHMSA identifies conditions that pose a risk to public safety, property, or the environment, it may issue a Notice of Proposed Safety Order (NOPSO). NOPSOs may require operator action to correct the pipeline integrity risk. They notify the pipeline operator that a condition that poses an integrity risk has been identified and relay the data regarding the infraction. NOPSOs also require that the operator take specific actions to correct non-compliance by a certain time and provide a legal basis for the mandate.⁷¹ Operators are given 30 days to respond to a NOPSO. Similar action may be taken, a Notice of Amendment (NOA), when PHMSA identifies that an operator’s plans or procedures, which are required by the federal government, are inadequate. The NOA contains the alleged inadequacies and proposed provisions. Operators have 30 days to submit revisions, comments, or request a hearing.⁷²

To initiate an enforcement proceeding against an operator found to be in violation of pipeline safety regulations, PHMSA may issue a Notice of Probable Violation (NOPV). A NOPV lists the laws, regulations or orders that the operator has broken and provides any evidence to back the claim.⁷³ A NOPV also includes an operator’s response options. A NOPV may propose a civil penalty and/or a Compliance Order. When a civil penalty is proposed, the NOPV will include the amount of the proposed penalty. The Pipeline Safety, Regulatory Certainty, and Job Creation Act of 2011 set the maximum civil penalty to \$200,000 per violation per day. The cap for a related series of violations is \$2,000,000. When a Compliance Order is proposed, the NOPV specifies the actions to correct the alleged violation. These proposed corrections are designed to modify procedures by changing operation and maintenance practices; conducting pipeline surveillance; or repairing/replacing inoperable or ineffective equipment.⁷⁴ In certain circumstances, PHMSA may elect to issue a written warning in place of a NOPV. The written warning notifies the operator of the probable violation and possible enforcement actions. No response is required for a written warning.

In some situations, criminal penalties may be pursued for violations of pipeline safety regulations. Willfully violating any provision can result in a fine; up to five years’ imprisonment; or both for each offense. Willfully injuring or destroying an interstate pipeline facility, or attempting to do so, can result in a fine; up to 20 years’ imprisonment; or both for each offense. Intentionally damaging or removing ROW markers of any kind may result in a fine; up to 12 months’ imprisonment; or both for each offense. Finally, anyone that begins an excavation project before using the 811 call before you dig program is subject to a fine; up to five years’ imprisonment; or both for each offense.⁷⁵

United States Adjudication Process

Once an enforcement action has been issued (i.e. CAO, NOPSO, NOA, NOPV), operators usually have an opportunity to respond. Responses include providing additional information for consideration; contesting the alleged violations in writing; or requesting a hearing. Operators may also elect to waive their right to respond. Responses may result in a variety of final decisions.

One of the options sometimes available to operators is the Consent Order. Prior to any final decisions, the operator and PHMSA may agree to resolve the case to avoid the adjudication and enforcement process. In these cases, the Consent Order is considered a Final Order.⁷⁶ When consent orders are not issued, operators have 10 days to request a hearing for a CAO and 30 days to request a hearing for NOPSOs, NOAs and NOPVs. These hearings are informal and provide the operator and PHMSA the opportunity to present their case and respond to any presented information. In some cases, the operator may petition to submit information after the hearing is conducted.⁷⁷

After the operator has responded or waived their right to respond, PHMSA issues a final order. The final order includes a statement concerning PHMSA's findings and determinations on the violation issues, including a determination as to whether each alleged violation was substantiated. If a civil penalty was proposed, a final order will include the amount of the penalty and the procedures for payment of the penalty. When a compliance order is issued, the final order states actions required of operators and a deadline by which remedial actions must be completed.⁷⁸ Once the operator has paid the civil penalty and/or completed the required actions, the case is closed.⁷⁹

Typically, final orders conclude enforcement cases. However, in situations where new evidence is found after a final order is issued, operators can submit a petition for reconsideration. A petition for reconsideration must be submitted within 20 days of the issuing of a final order. The petition must include the reasons why any additional facts were not presented prior to issuing the final order. PHMSA may grant or deny any petition without any further hearings.⁸⁰

Canadian Integrity Standards

In Canada, the standards for pipeline integrity are set by the NEB Onshore Pipeline Regulations (OPR).⁸¹ The integrity standards are set in the OPR as provided by the Canadian Standards Association (CSA). The 2015 CSA Z662 is the most recent and comprehensive document concerning oil and gas pipeline systems published by the CSA. The document outlines the inspection and maintenance standards that must be followed by operators in Canada. If an operator detects defects more serious than those permitted by the CSA Z662, they are required to document the non-compliance and the corrective action taken.

Canadian Enforcement Capabilities

The NEB has several enforcement tools it can use when an operator is found to be in non-compliance. These include measures to correct violations and measures to preclude future non-compliant operations. These tools are used to incentivize compliance with pipeline integrity regulations to protect both people and the environment.⁸²

A Corrected Non-Compliance (CNC) is recorded when a company can correct a non-compliance in the field with the inspector on site. Typically, a CNC is used when there is a relatively low risk of environmental or personal harm. The actions taken to correct the non-compliance are recorded in the CNC. The NEB issues a Notice of Non-Compliance (NNC) when a non-compliance with low severity that cannot be immediately addressed is observed by an inspector. NNCs are designed to bring pipeline safety issues to the attention of operators. Inspections officers include the necessary corrective actions after consulting with the operator and propose a timeline for actions to be taken. The NNC factors into inspection planning for future visits but it does not constitute civil liability or a finding of guilt. The most severe infractions illicit an Inspection Officer Order (IO order), which suspends all work at a site. NEB officers use IO orders when a hazard presents an immediate danger to the security of the public or the environment. An IO may also include the remedial actions necessary to correct the violation.

When operators are found to be in non-compliance or have a series of non-compliances, the NEB has the authority to take additional actions, including issuing large fines called Administrative Monetary Penalties (AMP). NEB also has the authority to revoke an operator's authorization, which would disable the company's operation within Canada. These punishments can be enacted in concert with other corrective actions. They may also be issued regardless of an operator's corrective actions to deter future non-compliance.

Are there inspection registries available to stakeholders?

United States Registry

PHMSA keeps online records of inspection and enforcement reports. PHMSA's enforcement records include data from 2002, including the number of cases initiated and closed each year.⁸³ For every initiated case, PHMSA includes the date the case opened; the operator involved; the PHMSA region with jurisdiction; the case status; the date closed; and the case number.⁸⁴ Each case number serves as a link to a detailed report of each case, which includes links to any documents related to the case and a description of any proposed penalties.⁸⁵ For every case closed, PHMSA includes the same information in a separate list. Both lists are organized by year.

Separate from its enforcement database, PHMSA keeps a registry of inspection information organized by operator. Each operator is assigned an operator ID that can be used to find their registry. PHMSA has data on inspections from 2006.⁸⁶ The numbers of site-specific inspections, system-wide program inspections, and targeted inspection/investigations per year are included for each operator. Site-specific field inspections include inspections conducted at specific pipeline facilities. PHMSA verifies an operator's submitted protocols, pipeline inspections, ROW marking, participation in One-Call systems, repairs, and other pipeline safety and compliance tasks with site-specific field inspections. System-wide program inspections include inspections that verify pipeline safety programs that apply to an entire pipeline system such as operating, maintenance, integrity, and emergency procedures. Targeted inspections/investigations include inspections related to a specific pipeline safety issue. These inspections are generally included in failure investigations or follow-up activities for non-compliance issues. The operator page also includes the number of cases initiated and resolved, penalties proposed, and corrective action orders issued per year.⁸⁷

Canadian Registry

Since 2011, the NEB has compiled information on their compliance and enforcement activities online. The NEB organizes their records in five databases related to specific enforcement and inspection activities. These include Compliance Verification Activity (CVA), Audit, Inspection Officer Order (IOO), Incident Investigation, and Administrative Monetary Penalty (AMP) databases.⁸⁸

The NEB's CVA data base includes the date, the regulated company, the province, the facility, and a description of the activity. This database includes field inspections for specific issues such as damage prevention, environmental protection, safety management, emergency management, and integrity management.⁸⁹ When these plans are audited, the NEB records it in the Audit registry. This registry includes the audit number, themes, related documents, date published, recipient, and the region/facility.⁹⁰ Anytime an inspection officer order is issued, it is recorded in IOO registry. The registry includes the IOO number, the resume work order, the recipient, the region/facility, and the reasoning for the IOO.⁹¹ The Incident Investigation registry records the incident number, related documents, the date

of the last update, the operator, the region, and a reasoning for the investigation. Currently this registry has only one entry.⁹² When the NEB wants to correct a non-compliance or create a disincentive for future violations, it may issue an administrative monetary penalty (AMP). The AMP registry includes the reference number; any related documents; the date of the last update; the operator; the region; the reason for the AMP; and the dollar amount for the AMP.⁹³

Conclusion

Given the international nature of many crude oil transmission pipelines, the ways in which Canada and the United States approach safety are relatively similar. Cross-border coordination is mutually beneficial as it reduces energy congestion between the two countries. In fact, to increase the effectiveness of their cooperation, the NEB and PHMSA signed an agreement in 2005.⁹⁴ The agreement put in place provisions that allowed for staff exchanges, joint training initiatives, and sharing of compliance data and reports. They also opened the possibility of joint research ventures and audits/inspections. While the agreement stops short of creating an international regulatory agency, it increased transparency and cooperation between the two federal agencies.

Although there are many similarities between PHMSA's and NEB's approach to safety, some differences do exist. The United States has been publicly recording inspection and enforcement data longer than Canada. PHMSA has records of inspection and enforcement dating back to 2006 but Canada only started publicly releasing data late in 2015. There are, however, some differences between Canada and the United States in how regulations are created. This is especially clear when comparing the two nations' integrity management regulations. The United States requirements enforce a strict timeline on pipeline operators. For example, the US regulates how often pipeline operators must conduct in-line and ROW inspections. These regulations are flexible about the techniques used, though. In-line inspections can be conducted based on the operators' risk-based assessment and appropriate method. Canadian regulations are more goal-oriented. Rather than require that operators adhere to a set schedule, the NEB requires operators to draw up integrity management plans, which it audits. This approach gives the pipeline operators more autonomy and might allow them to be more innovative with their pipeline management programming. Pipeline operators that cross the border are required to follow regulations from both approaches. To compensate for discrepancies, special permits are sometimes issued.

As the demand for crude oil increases in both countries, it becomes more and more important that PHMSA and NEB work together to regulate international pipelines.⁹⁵ Oil production is important to both nations as a source of energy, employment, and revenue. Increased domestic product has diminished reliance on foreign entities for energy, bolstering the national security of the United States and Canada. The Great Lakes themselves are a significant resource to both nations as well. More than 43 million people, living in the GLSLR region, benefit from industries reliant on the Great Lakes, such as tourism, fishing, and manufacturing.⁹⁶ Given the risks associated with moving crude oil, balancing the objectives of energy movement and protection of the Great Lakes requires careful integrity management of pipelines.

-
- ¹ Welch, Lyman et al., *Oil and Water: Tar Sands Crude Shipping Meets the Great Lakes?* Alliance for the Great Lakes. 2013. 1-3.
- ² EIA GIS database. Accessed July 20, 2014. <http://www.eia.gov/state/notes-sources.cfm>
- ³ Data and Statistics for each individual U.S. states can be found at Pipeline and Hazard Materials Safety Administration. Accessed July 21, 2014. http://primis.phmsa.dot.gov/comm/reports/safety/WI_detail1.html?nocache=2566#_OuterPanel_tab_5
- ⁴ Data on age of pipelines for U.S. states can be found at Pipeline and Hazard Materials Safety Administration database. Accessed August 16, 2017. http://opsweb.phmsa.dot.gov/pipeline_replacement/by_decade_installation.asp
- ⁵ 2011 December Report of the Commissioner and the Environment and Sustainable Development. Officer of Auditor General of Canada. 2011. Accessed August 16, 2017. http://www.oag-bvg.gc.ca/internet/English/parl_cesd_201112_01_e_36029.html#ex5
- ⁶ Furchtgott-Roth, Diana and Green, Kenneth. *Intermodal Safety in the Transport of Oil*. Studies In Energy Transportation. 2013. Fraser Institute.
- ⁷ Frittelli, John et al. *US Rail Transportation of Crude Oil: Background and Issues for Congress*. 2014. Congressional Research Service.
- ⁸ "Frequently Asked Questions (FAQs) Concerning Federally-Regulated Petroleum P in Canada". *Natural Resources Canada*. Accessed August 16, 2017. www.nrcan.gc.ca/energy/infrastructure/5893.
- ⁹ "What Is Cathodic Protection and How Does It Work?". EonCoat, LLC. Accessed July 14, 2017. eoncoat.com/what-is-cathodic-protection-and-how-does-it-work/.
- ¹⁰ "How Do Pipeline Operators Prevent Corrosion?" Corrosion Factsheet. CEPA. Accessed June 27, 2017. www.aboutpipelines.com/wp-content/uploads/2012/09/CEPA-Factsheet_Corrosion_web1.pdf.
- ¹¹ *Managing Corrosion Of Pipelines That Transport Crude Oils*. Pipeline & Gas Journal. Vol. 240. No. 3. Mar. 2013. pgjonline.com/2013/03/04/managing-corrosion-of-pipelines-that-transport-crude-oils/.
- ¹² *Pipeline Safety Stakeholder Communications*. PHMSA: Stakeholder Communications - Pipe Defects, PHMSA. December 1, 2011. Accessed July 13, 2017. primis.phmsa.dot.gov/comm/FactSheets/FSPipeDefects.htm.
- ¹³ Silva, Jorge. *Fatigue Crack Growth in Steel used in Oil and Gas Pipelines*. 2011. Electronic Theses and Dissertations. Paper 5391.
- ¹⁴ Silva, Jorge. *Fatigue Crack Growth in Steel used in Oil and Gas Pipelines*. 2011. Electronic Theses and Dissertations. Paper 5391.
- ¹⁵ Silva, Jorge. *Fatigue Crack Growth in Steel used in Oil and Gas Pipelines*. 2011. Electronic Theses and Dissertations. Paper 5391.
- ¹⁶ *Pipeline Safety Stakeholder Communications*. PHMSA: Stakeholder Communications - Pipe Defects, PHMSA. December 1, 2011. Accessed July 13, 2017. primis.phmsa.dot.gov/comm/FactSheets/FSPipeDefects.htm.
- ¹⁷ *Pipeline Safety Stakeholder Communications*. PHMSA: Stakeholder Communications - Pipe Defects, PHMSA. December 1, 2011. Accessed July 13, 2017. primis.phmsa.dot.gov/comm/FactSheets/FSPipeDefects.htm. "Pipeline Safety Stakeholder Communications." PHMSA: Stakeholder Communications - Pipe Defects, PHMSA, December 1, 2011, accessed July 13, 2017, primis.phmsa.dot.gov/comm/FactSheets/FSPipeDefects.htm.
- ¹⁸ 49 CFR 195.557
- ¹⁹ *How Do Pipeline Operators Prevent Corrosion?* Corrosion Factsheet, CEPA. Accessed June 27, 2017. www.aboutpipelines.com/wp-content/uploads/2012/09/CEPA-Factsheet_Corrosion_web1.pdf.
- ²⁰ van der Werff, Andre. *The Importance of Pipeline Cleaning: Risks, Gains, Benefits, Peace of Mind*. Pipeline Technology 2006 Conference. 2006. www.pipeline-conference.com/sites/default/files/papers/224%20van%20der%20Werff.pdf.

-
- ²¹ Ellison, Dan. *Investigation of Pipe Cleaning Methods*. Denver, CO, AWWA Research Foundation and American Water Works Association, 2003.
- ²² Wylde, Jonathan J. *Chemically Assisted Pipeline Cleaning for Pigging Operations*. Pipeline & Gas Journal, vol. 238, no. 8, Aug. 2011. pgjonline.com/2011/08/15/chemically-assisted-pipeline-cleaning-for-pigging-operations/.
- ²³ 49 CFR 195.563
- ²⁴ *What Is Cathodic Protection and How Does It Work?*. EonCoat, LLC, accessed July 14, 2017, eoncoat.com/what-is-cathodic-protection-and-how-does-it-work/.
- ²⁵ *Standard Practice*. SP01690, NACE, accessed July 13, 2017. www.nace.org/uploadedFiles/Corrosion_Central/Industries/SP016907PHMSA.pdf.
- ²⁶ call811.com
- ²⁷ www.clickbeforeyoudig.com
- ²⁸ *"Results Deformations."* Results Deformations - Enbridge Inc., accessed July 6, 2017. www.enbridge.com/Projects-and-Infrastructure/Public-Awareness/Line-5-Michigan/Safeguarding-the-Great-Lakes/Inspections/Inline-inspection-results/Results-deformations.aspx.
- ²⁹ 49 CFR 195.410
- ³⁰ *"Results Cracking."* Results Cracking - Enbridge Inc., Enbridge, accessed July 6, 2017. www.enbridge.com/Projects-and-Infrastructure/Public-Awareness/Line-5-Michigan/Safeguarding-the-Great-Lakes/Inspections/Inline-inspection-results/Results-cracking.aspx.
- ³¹ *"Results Cracking."* Results Cracking - Enbridge Inc., Enbridge, accessed July 6, 2017, www.enbridge.com/Projects-and-Infrastructure/Public-Awareness/Line-5-Michigan/Safeguarding-the-Great-Lakes/Inspections/Inline-inspection-results/Results-cracking.aspx.
- ³² *"Pipeline Safety Stakeholder Communications."* PHMSA: Stakeholder Communications - Smart Pig Fact Sheet, PHMSA. Accessed July 6, 2017. primis.phmsa.dot.gov/comm/FactSheets/FSSmartPig.htm.
- ³³ *"Results Metal Loss Corrosion."* Results Metal Loss Corrosion - Enbridge Inc. Accessed July 6, 2017. www.enbridge.com/Projects-and-Infrastructure/Public-Awareness/Line-5-Michigan/Safeguarding-the-Great-Lakes/Inspections/Inline-inspection-results/Results-metal-loss-corrosion.aspx.
- ³⁴ *"Pipeline Safety Stakeholder Communications."* PHMSA: Stakeholder Communications - Smart Pig Fact Sheet. PHMSA. Accessed July 6, 2017. primis.phmsa.dot.gov/comm/FactSheets/FSSmartPig.htm.
- ³⁵ *"Results Deformations."* Results Deformations - Enbridge Inc. Accessed July 6, 2017. www.enbridge.com/Projects-and-Infrastructure/Public-Awareness/Line-5-Michigan/Safeguarding-the-Great-Lakes/Inspections/Inline-inspection-results/Results-deformations.aspx.
- ³⁶ *"Results Cracking."* Results Cracking - Enbridge Inc. Accessed July 6, 2017, www.enbridge.com/Projects-and-Infrastructure/Public-Awareness/Line-5-Michigan/Safeguarding-the-Great-Lakes/Inspections/Inline-inspection-results/Results-cracking.aspx.
- ³⁷ de la Camp, Hans-Joachim. *High Precision With Ultrasonic Pigging*. Pipeline & Gas Journal. August 2010. pgjonline.com/2010/08/04/high-precision-with-ultrasonic-pigging/.
- ³⁸ "Eagle-Eyed Pilots Scour Pipeline Routes for Safety Concerns." TransCanada Corporation Blog. TransCanada. 25 September 2014. Accessed July 5, 2017. blog.transcanada.com/eagle-eyed-pilots-scour-pipeline-routes-for-safety-concerns/.
- ³⁹ *"ROW Patrol and Clearing."* Right of Way Patrols & Clearing, Marathon Pipe Line. accessed July 6, 2017. www.marathonpipeline.com/What_We_Do/Pipelines/Right_of_Way_PatrolClearing/.
- ⁴⁰ 49 CFR 195.412
- ⁴¹ 49 U.S. Code § 60108
- ⁴² 49 CFR 195.446

⁴³ 49 CFR 195.446

⁴⁴ "Topics of Importance Maintaining the Fitness of Our Systems and Leak Detection." Csr.enbridge.com, Enbridge. Accessed July 6, 2017. csr.enbridge.com/report-highlights/material-topics/maintaining-the-fitness-of-our-systems-and-leak-detection/management-approach/.

⁴⁵ "Getting It Right." TransCanada CSR Report. TransCanada. Accessed July 5, 2017. www.transcanada.com/globalassets/pdfs/commitment/safety/transcanada-csr-report-2015-safety.pdf.

⁴⁶ Frings, Jochen. *Enhanced Pipeline Monitoring with Fiber Optic Sensors*. Proceedings of the 6th Pipeline Technology Conference. 2011. Hannover, Germany. Vol. 45.

⁴⁷ "Piping Up For Technology Part 7 Fiber Optics." Piping Up For Technology Part 7 Fiber Optics - Enbridge Inc. 7 Jan. 2016. www.enbridge.com/Stories/Piping-Up-For-Technology-Part-7-fiber-optics.aspx.

⁴⁸ "TransCanada Uses Latest Proven Technology for Detecting Leaks." TransCanada Corporation Blog. 20 June 2013. Accessed July 5, 2017. blog.transcanada.com/transcanada-uses-latest-proven-technology-for-detecting-leaks/.

⁴⁹ Jaske, Carl E, et al. Pipeline Repair Manual. Pipeline Research Council International. 8 Aug. 2006. Accessed July 13, 2017, www.ttoolbox.com/documents/free_prci/I52047.pdf?cm_mmc.

⁵⁰ Jaske, Carl E, et al. Pipeline Repair Manual. Pipeline Research Council International. 8 Aug. 2006. accessed July 13, 2017. www.ttoolbox.com/documents/free_prci/I52047.pdf?cm_mmc.

⁵¹ "Application of Underwater Welding Processes for Subsea Pipelines." CDiver. February 15, 2016. accessed July 15, 2017. cdiver.net/news/application-of-underwater-welding-processes-for-subsea-pipelines/.

⁵² Jaske, Carl E, et al. *Pipeline Repair Manual*. Pipeline Research Council International. 8 Aug. 2006. accessed July 13, 2017. www.ttoolbox.com/documents/free_prci/I52047.pdf?cm_mmc.

⁵³ Jaske, Carl E, et al. Pipeline Repair Manual. Pipeline Research Council International, 8 Aug. 2006, accessed July 13, 2017, www.ttoolbox.com/documents/free_prci/I52047.pdf?cm_mmc.

⁵⁴ "Pipeline & Hazardous Materials Safety Administration." PHMSA: Stakeholder Communications | Home. Department of Transportation, n.d. Web.

⁵⁵ 49 U.S. Code § 60108

⁵⁶ 49 U.S. Code § 60126 t

⁵⁷ "State Programs." PHMSA - Supporting Community Response. PHMSA, August 14, 2007. Accessed July 19, 2017. www.phmsa.dot.gov/pipeline/state-programs.

⁵⁸ 49 U.S. Code § 60108

⁵⁹ 49 CFR 195.402

⁶⁰ 49 CFR 195.452

⁶¹ 49 CFR 195.450

⁶² Groeger, Lena. *Pipelines Explained: How Safe Are America's 2.5 Million Miles of Pipelines?* ProPublica. 6 December 2016. Accessed July 6, 2017. www.propublica.org/article/pipelines-explained-how-safe-are-americas-2.5-million-miles-of-pipelines.

⁶³ "Pipeline Safety Regimes in Canada" Natural Resources Canada. 9 May 2017. accessed July 5, 2017, www.nrcan.gc.ca/energy/infrastructure/pipeline-safety-regime/16440

⁶⁴ R.S.C., 1985, c. N-7

⁶⁵ "Inspection Reports - Questions and Answers." Government of Canada, National Energy Board. 2 December 2016, Accessed July 5, 2017. www.neb-one.gc.ca/sftnvrnmnt/cmplnc/nspectnrprtq-eng.html.

⁶⁶ "Inspection Reports - Questions and Answers." Government of Canada, National Energy Board. 2 December 2016. Accessed July 5, 2017. www.neb-one.gc.ca/sftnvrnmnt/cmplnc/nspectnrprtq-eng.html.

⁶⁷ National Energy Board Onshore Pipeline Regulations (SOR/99-294)

-
- ⁶⁸ "*Hazardous Liquid Integrity Management: Fact Sheet.*" Hazardous Liquid Integrity Management: Fact Sheet. PHMSA. Accessed July 5, 2017. primis.phmsa.dot.gov/iim/fact.htm
- ⁶⁹ "*Pipeline Safety Stakeholder Communications.*" PHMSA: Stakeholder Communications: Enforcement Program, PHMSA. Accessed July 5, 2017. primis.phmsa.dot.gov/comm/EnforcementProgram.htm?nocache.
- ⁷⁰ Title 49 Subtitle B Chapter 1 Subchapter D Part 190.233
- ⁷¹ Title 49 Subtitle B Chapter 1 Subchapter D Part 190.239
- ⁷² Title 49 Subtitle B Chapter 1 Subchapter D Part 190.206
- ⁷³ "*Pipeline Safety Stakeholder Communications.*" PHMSA: Stakeholder Communications: Enforcement Program. PHMSA, accessed July 5, 2017. primis.phmsa.dot.gov/comm/EnforcementProgram.htm?nocache.
- ⁷⁴ Title 49 Subtitle B Chapter 1 Subchapter D Part 190.207
- ⁷⁵ Title 49 Subtitle B Chapter 1 Subchapter D Part 190.291
- ⁷⁶ "*Pipeline Safety Stakeholder Communications.*" PHMSA: Stakeholder Communications: Enforcement Program. PHMSA. Accessed July 5, 2017. primis.phmsa.dot.gov/comm/EnforcementProgram.htm?nocache.
- ⁷⁷ "*Pipeline Safety Stakeholder Communications.*" PHMSA: Stakeholder Communications: Enforcement Program. PHMSA. Accessed July 5, 2017. primis.phmsa.dot.gov/comm/EnforcementProgram.htm?nocache.
- ⁷⁸ Title 49 Subtitle B Chapter 1 Subchapter D Part 190.213
- ⁷⁹ "*Pipeline Safety Stakeholder Communications.*" PHMSA: Stakeholder Communications: Enforcement Program. PHMSA. Accessed July 5, 2017. primis.phmsa.dot.gov/comm/EnforcementProgram.htm?nocache.
- ⁸⁰ Title 49 Subtitle B Chapter 1 Subchapter D Part 190.243
- ⁸¹ "*Guidance Notes for the National Energy Board Onshore Pipeline Regulations.*" Government of Canada, National Energy Board. 6 December 2016. Accessed July 5, 2017. www.neb-one.gc.ca/bts/ctr/g/gnnb/nshrppln/gdncntnshrpplnrgltn-eng.html.
- ⁸² "*Compliance and Enforcement.*" Compliance and Enforcement. Government of Canada, National Energy Board. 26 April 2017. Accessed July 5, 2017.
- ⁸³ "*Pipeline Safety Stakeholder Communications.*" PHMSA: Stakeholder Communications - Summary of Enforcement Activity - Nationwide, PHMSA. Accessed July 5, 2017. primis.phmsa.dot.gov/Comm/reports/enforce/EnfHome.html?nocache.
- ⁸⁴ "*Pipeline Safety Stakeholder Communications.*" PHMSA: Stakeholder Communications - Listing of Cases Initiated, PHMSA. Accessed July 5, 2017. primis.phmsa.dot.gov/Comm/reports/enforce/CasesOpen_opid_0.html?nocache=1601#_TP_1_tab_16.
- ⁸⁵ "*Pipeline Safety Stakeholder Communications.*" PHMSA: Stakeholder Communications - Enforcement Action Details, PHMSA. Accessed July 5, 2017. primis.phmsa.dot.gov/Comm/reports/enforce/CaseDetail_cpf_520167001S.html?nocache=1500#_TP_1_tab_2.
- ⁸⁶ "*Pipeline Safety Stakeholder Communications.*" PHMSA: Stakeholder Communications - Operator Information. Accessed July 12, 2017. primis.phmsa.dot.gov/comm/reports/operator/Operatorlist.html.
- ⁸⁷ "*Pipeline Safety Stakeholder Communications.*" PHMSA: Stakeholder Communications - Operator Information. PHMSA, Accessed July 12, 2017. primis.phmsa.dot.gov/comm/reports/operator/OperatorIE_opid_11169.html?nocache=6043#_OuterPanel_tab_2.
- ⁸⁸ "*Compliance and Enforcement.*" Government of Canada, National Energy Board. 29 June 2017. Accessed July 6, 2017, www.neb-one.gc.ca/sftnvrnmnt/cmplnc/index-eng.html.
- ⁸⁹ "*CVA (Compliance Verification Activity) Reports.*" National Energy Board Site. Accessed July 6, 2017. apps.neb-one.gc.ca/cmplnc/Home/Index?lang=eng.
- ⁹⁰ "*Audit Reports.*" Government of Canada, National Energy Board. 23 June 2017. Accessed July 12, 2017. www.neb-one.gc.ca/sftnvrnmnt/cmplnc/rpts/dt/index-eng.html

⁹¹ “*Inspection Officer Order.*” Government of Canada, National Energy Board. 23 June 2017. Accessed July 12, 2017. www.neb-one.gc.ca/sftnvrnmnt/cmplnc/rprts/inspctnffcrdr/index-eng.html.

⁹² “*Incident Investigation.*” Government of Canada, National Energy Board. 21 June 2017. Accessed July 12, 2017. www.neb-one.gc.ca/sftnvrnmnt/cmplnc/rprts/nvstgtn/index-eng.html.

⁹³ “*Administrative Monetary Penalty (AMP).*” Government of Canada, National Energy Board. 23 June 2017. Accessed July 12, 2017. www.neb-one.gc.ca/sftnvrnmnt/cmplnc/rprts/dmnmntrypnlt/index-eng.html.

⁹⁴ “*Arrangement Between the National Energy Board and the Pipeline and Hazardous Materials Safety Administration, U.S. Department of Transportation.*” PHMSA-NEB_Arrangement. 18 Nov. 2005. Accessed July 13, 2017. www.phmsa.dot.gov/staticfiles/PHMSA/DownloadableFiles/PHMSA-NEB_Arrangement.pdf.

⁹⁵ Michael Baker Jr., Inc. “*Comparison of US and Canadian Transmission Pipeline Consensus Standards.*” FinalReport_TransborderStandards, PHMSA, May 2008, accessed July 13, 2017, primis.phmsa.dot.gov/gasimp/docs/FinalReport_TransborderStandards.pdf.

⁹⁶ “*Issues and Trends Surrounding the Movement of Crude Oil in the Great Lakes-St Lawrence River Region.*” Oil-Transportation-Full-Report-2015, Great Lakes Commission. February 2015. www.glc.org/wp-content/uploads/Oil-Transportation-Full-Report-2015.pdf