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Pipeline Investigation Report: PIR-22/01

Enbridge Inc. Natural Gas Pipeline Rupture

Hillsboro, Kentucky
May 4, 2020

1. Factual Information



Figure 1. Ruptured pipeline.
(Source: BGC Engineering USA, Inc.)

1.1 Accident Summary

On May 4, 2020, about 4:36 p.m. local time, a 30-inch diameter interstate natural gas transmission pipeline owned and operated by Enbridge Inc. (Enbridge) ruptured about 3 miles east-northeast of Hillsboro, Kentucky, resulting in a fire.¹ (See figure 1.) The rupture occurred on Line 10 at a hillside location that was previously identified by Enbridge for geotechnical monitoring because of an active landslide.²

Line 10 was the northernmost of three parallel pipelines—Lines 10, 15, and 25—along the same right-of-way. At the time of the rupture, Line 10's operating pressure was about 674 pounds per square inch, gauge.³ The rupture occurred

¹ (a) For more detailed information about this investigation, see the [public docket](#) and search for number PLD20LR001. Use the [CAROL Query](#) to search safety recommendations and investigations. (b) All times in this report are local time unless otherwise noted.

² The rupture occurred on a Texas Eastern Transmission, Limited Partnership, pipeline. Texas Eastern Transmission is an indirect, 100-percent-owned subsidiary of Enbridge Inc.

³ The maximum allowable operating pressure of the pipeline was 936 pounds per square inch, gauge.

at a girth weld at an elevation of about 923 feet.⁴ There were no fatalities or injuries, and Enbridge estimated the cost of property damage and emergency response at \$11.7 million.

1.2 Integrity Management

In the years before the rupture, several indications were available to Enbridge that Line 10 was exposed to external loads (loads transmitted to a pipeline from an external source):

- Results of an April 17, 2018, in-line inspection (ILI) indicated pipeline movement of about 4.2 feet.⁵
- On October 9, 2018, Enbridge identified the rupture location as a potential geohazard.
- On April 16, 2019, an aerial patrol observed erosion on the right-of-way near the rupture location.
- Results of a June 7, 2019, ILI indicated pipeline movement of about 5.2 feet.
- A July 8, 2019, ground inspection identified scarps.⁶

In 2019 and 2020, Enbridge evaluated Line 10 for geohazard threats. After a site assessment in October 2019 and analysis comparing the strain exerted on the pipeline (tensile strain demand) to the strain capacity of the pipeline (tensile strain capacity), Enbridge determined that urgent action was not required but recommended monitoring and mitigation of the identified threats.⁷

In February 2020, Enbridge held a multidisciplinary review meeting to determine the monitoring and mitigation plan for this location. Based on estimated tensile strain demand and other geotechnical considerations, Enbridge planned to install strain gauges and improve drainage. According to Enbridge, they also planned to complete

⁴ A *girth weld* is used to join two pipes along their circumference. The girth weld that ruptured had been hydrostatically tested before the pipeline's initial service in 1952 and retested in 1986; a hydrostatic test involves filling the pipeline with water at a predetermined pressure to test the pipeline's integrity.

⁵ *In-line inspection* is an internal pipeline inspection technique that uses magnetic flux leakage, ultrasound, eddy current, or other sensing technology to locate and characterize indications of defects, such as metal loss or deformation in the pipeline.

⁶ A *scarp* is a steep surface of exposed material produced by differential, or non-uniform, ground surface movement.

⁷ (a) The *tensile strain demand* is the amount of strain that is being exerted on the system or material, whereas the *tensile strain capacity* is the amount of strain that the system or material can withstand; strain can be expressed as a ratio or percentage. (b) Enbridge estimated a tensile strain demand of 0.6 percent by adding the maximum bending strain at a girth weld to the estimated axial strain. (c) The tensile strain capacity analysis assumed a flaw 2 inches in length and 0.0394 inches in depth. (d) After applying a safety factor, Enbridge determined that the tensile strain capacity threshold was 1 percent for the girth welds.

additional monitoring, mitigation, and stress relief in summer 2020. The rupture occurred before the monitoring and mitigation activities were completed.

1.3 Postaccident

1.3.1 Postaccident Geotechnical Assessment

Following the rupture, a contractor directed by the National Transportation Safety Board (NTSB) found that the area around the incident site was highly susceptible to landslides and determined that Line 10 was situated in past landslide deposits at the rupture location. The contractor concluded that Line 10 was installed within a landslide feature that was accelerating, causing a rapid increase in strain on the pipeline before the rupture. The contractor indicated that landslide acceleration in the 6 months before the rupture was likely driven by high levels of precipitation, pre-existing cracks in the soil, ground water movement along the pipeline trenches, and loading from grading activities.

1.3.2 Postaccident Metallurgical Testing and Tensile Strain Analysis

Other contractors directed by the NTSB evaluated the ruptured girth weld, removed and evaluated exemplar girth welds, and estimated the tensile strain demand and capacity. Two incomplete penetration and lack of root fusion defects were identified on the fracture face of the ruptured girth weld.⁸ One defect was about 7 inches long and 0.13 inches deep. The other defect was about 4.9 inches long and 0.10 inches deep.

The objective of the tensile strain demand analysis was to estimate the strain on the pipeline caused by land movement at the failure location. The results of the pre- and post-rupture tensile strain demand analyses are shown in Table 1. The analyses assessed overall performance and did not account for known defects.

Table 1. Estimated tensile strain demand

Pipeline Configuration	Pre-Rupture Analyses (Enbridge)	Post-Rupture Analyses (NTSB Investigation)
April 2018	N/A	1.8%
July 2019	0.6%	N/A
May 2020	N/A	3.0%

⁸ (a) *Incomplete penetration defects* occur when the weld root is not completely filled. (b) *Lack of root fusion defects* occur when the weld fails to fuse one side of the joint in the root. (c) The *root* is the point at which the weld metal intersects the base metal and extends furthest into the weld joint.

Further, tensile strain capacity analysis was performed to determine the amount of strain that a pipe section with a representative girth weld could withstand. The tensile strain capacity was estimated by evaluating exemplar girth welds, fabricating and testing material property samples, and developing a finite element model. The model used to estimate tensile strain capacity explicitly included flaws found in the exemplar girth welds that were up to 4 inches in length. The estimated tensile strain capacity was between 1.3 percent and 2 percent.

1.3.3 Postaccident Actions

1.3.3.1 Enbridge

Enbridge issued several new procedures for managing geohazards, including for estimating tensile strain capacity, conducting multidisciplinary reviews, and determining appropriate response actions. Enbridge reported that the new procedures would result in a reduced tensile strain capacity threshold (0.5 percent) on Line 10 in the area where the rupture occurred, which, given the information available before the incident, would trigger a high-priority response action.⁹ Additionally, Enbridge acknowledged that the pre-rupture strain demand methodology may have underestimated the actual strain demand. Enbridge indicated that it would continue to work with its contractors to determine whether a different method with an appropriate level of conservatism should be applied.

1.3.3.2 Pipeline and Hazardous Materials Safety Administration

On June 1, 2020, the Pipeline and Hazardous Materials Safety Administration (PHMSA) issued an amended Corrective Action Order to Enbridge that required corrective actions be taken with respect to Lines 10, 15, and 25 for failures on August 1, 2019, near Danville, Kentucky, and May 4, 2020, near Hillsboro, Kentucky.¹⁰ The order required Enbridge to reduce the operating pressure of the affected segment, review prior ILI results, and review and assess its emergency response plans, operations, and public awareness program. Further, on December 21, 2021, PHMSA issued a Notice of Probable Violation, Proposed Civil Penalty, and Proposed Compliance Order to Enbridge alleging probable violations related to the Hillsboro accident.

On May 26, 2022, PHMSA issued an advisory bulletin, citing the Hillsboro accident among others, that reminds owners and operators of gas and hazardous liquid

⁹ The *high-priority response action* requires a site visit within 48 hours, site-specific monitoring plan within 30 days, immediate pressure reduction or shutdown, and drainage installation, if appropriate, for site-specific conditions.

¹⁰ The August 1, 2019, rupture that occurred near Danville, Kentucky, is currently under investigation by the NTSB. Additional information can be found in the public docket for NTSB investigations (number PLD19FR002) by accessing the NTSB [Dockets Link](#) at www.nts.gov.

pipelines of the potential for damage to pipeline facilities caused by earth movement in variable, steep, and rugged terrain and for varied, changing subsurface geological conditions. The bulletin states that changing weather patterns, including increased rainfall and higher temperatures, can result in flooding, soil saturation, and erosion impacting soil stability surrounding pipeline facilities. PHMSA's advisory bulletin further lists pipeline safety actions operators should consider to ensure pipeline safety.¹¹

2. Analysis

In 2018, Enbridge identified the rupture location as a potential geohazard. They took action to analyze the active landslide and started taking steps to mitigate the hazard before the rupture. However, Enbridge's pre-rupture analysis estimated a girth weld tensile strain demand that was at least three times lower than post-rupture analysis later indicated. The post-rupture analysis demonstrated that in April 2018 or earlier Enbridge could have foreseen the likelihood that the tensile strain demand would exceed the strain capacity due to documented land movement at the site.

Like all analyses, tensile strain demand and capacity calculations include certain modeling assumptions and associated uncertainties that must be considered in any decision-making that relies on the results. Notably, Enbridge's pre-rupture analyses did not appropriately consider uncertainties such as weld defects, changes in the slope and direction of the landslide that could increase the susceptibility of the girth welds to fracture, acceleration of the landslide, or the response of the pipeline to these factors. As a result, Enbridge determined that no immediate action was needed to mitigate the identified geohazard threat and therefore did not take necessary actions before the rupture.

As a result of this accident, Enbridge issued new procedures for estimating tensile strain capacity, conducting multidisciplinary reviews, and determining appropriate response actions reporting the new procedures would result in a reduced tensile strain capacity threshold. Further, PHMSA took enforcement action against Enbridge. PHMSA also issued an advisory bulletin on damage to pipeline facilities from earth movement in rugged, steep terrain, citing the Hillsboro accident among recent land movement events.

¹¹ The suggested actions include, but are not limited to, monitoring geological and environmental conditions near facilities, including changing weather patterns; identifying areas surrounding pipelines that may be prone to large earth movement; developing design, construction, and monitoring plans and procedures and developing mitigation measures to remediate identified locations; and tracking changes in ground conditions. For more information, see *PHMSA Advisory Bulletin: Potential for Damage to Pipeline Facilities Caused by Earth Movement and Other Geological Hazards*, <https://www.phmsa.dot.gov/news/phmsa-advisory-bulletin-potential-damage-pipeline-facilities-caused-earth-movement-and-other>.

3. Probable Cause

The National Transportation Safety Board determines that the probable cause of the pipeline rupture was Enbridge Inc.'s analysis of an active landslide that did not fully address uncertainties associated with pipeline defects, landslide movement, and corresponding pipeline response.

The National Transportation Safety Board (NTSB) is an independent federal agency dedicated to promoting aviation, railroad, highway, marine, and pipeline safety. Established in 1967, the agency is mandated by Congress through the Independent Safety Board Act of 1974, to investigate transportation accidents, determine the probable causes of the accidents, issue safety recommendations, study transportation safety issues, and evaluate the safety effectiveness of government agencies involved in transportation. The NTSB makes public its actions and decisions through accident reports, safety studies, special investigation reports, safety recommendations, and statistical reviews.

The NTSB does not assign fault or blame for an accident or incident; rather, as specified by NTSB regulation, "accident/incident investigations are fact-finding proceedings with no formal issues and no adverse parties ... and are not conducted for the purpose of determining the rights or liabilities of any person" (Title 49 *Code of Federal Regulations* section 831.4). Assignment of fault or legal liability is not relevant to the NTSB's statutory mission to improve transportation safety by investigating accidents and incidents and issuing safety recommendations. In addition, statutory language prohibits the admission into evidence or use of any part of an NTSB report related to an accident in a civil action for damages resulting from a matter mentioned in the report (Title 49 *United States Code* section 1154(b)).

For more detailed background information on this report, visit the NTSB investigations website and search for NTSB accident ID **PLD20LR001**. Recent publications are available in their entirety on the NTSB website. Other information about available publications also may be obtained from the website or by contacting—

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