Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

COMMODITY PIPELINE OCCURRENCE REPORT

TRANSCANADA PIPELINES LIMITED
NATURAL GAS PIPELINE RUPTURE
LINE 100-2, 914-MILLIMETRE (36-INCH) MAINLINE
KILOMETRE POST MAIN LINE VALVE 110-2 + 22.098 KILOMETRES
LATCHFORD, ONTARIO
23 JULY 1994

REPORT NUMBER P94H0036

Canada

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MANDATE OF THE TSB

The Canadian Transportation Accident Investigation and Safety Board Act provides the legal framework governing the TSB's activities. Basically, the TSB has a mandate to advance safety in the marine, pipeline, rail, and aviation modes of transportation by:

- conducting independent investigations and, if necessary, public inquiries into transportation occurrences in order to make findings as to their causes and contributing factors;
- reporting publicly on its investigations and public inquiries and on the related findings;
- identifying safety deficiencies as evidenced by transportation occurrences;
- making recommendations designed to eliminate or reduce any such safety deficiencies; and
- conducting special studies and special investigations on transportation safety matters.

It is not the function of the Board to assign fault or determine civil or criminal liability. However, the Board must not refrain from fully reporting on the causes and contributing factors merely because fault or liability might be inferred from the Board's findings.

INDEPENDENCE

To enable the public to have confidence in the transportation accident investigation process, it is essential that the investigating agency be, and be seen to be, independent and free from any conflicts of interest when it investigates accidents, identifies safety deficiencies, and makes safety recommendations. Independence is a key feature of the TSB. The Board reports to Parliament through the President of the Queen's Privy Council for Canada and is separate from other government agencies and departments. Its independence enables it to be fully objective in arriving at its conclusions and recommendations.

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The Transportation Safety Board of Canada (TSB) investigated this occurrence for the purpose of advancing transportation safety. It is not the function of the Board to assign fault or determine civil or criminal liability.

Commodity Pipeline Occurrence Report

TransCanada PipeLines Limited
Natural Gas Pipeline Rupture
Line 100-2, 914-millimetre (36-inch) Mainline
Kilometre Post Main Line Valve 110-2
+ 22.098 kilometres
Latchford, Ontario
23 July 1994

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Synopsis

At approximately 0713 eastern daylight time, on 23 July 1994, a rupture and a fire occurred on the TransCanada PipeLines Limited 914-millimetre (36-inch) natural gas pipeline at Kilometre Post Main Line Valve 110-2 + 22.098 kilometres near Latchford, Ontario.

The Board determined that the rupture was caused by a ductile overload fracture as a result of extensive thinning of the pipe wall from external corrosion.

Ce rapport est également disponible en français.

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1.0 Factual Information

1.1 The Accident

On 23 July 1994, at approximately 0713 eastern daylight time (EDT), the TransCanada PipeLines Limited (TCPL) 914-millimetre (mm) outside diameter (nominal pipe size (NPS) 36 inches) main natural gas pipeline, designated as Line 100-2, suddenly experienced a simultaneous loss of operating pressure and increase in natural gas flow rates downstream of Station 4110 near Haileybury, Ontario, at Main Line Valve (MLV) 110-2. The Control Centre Operator (CCO), located at Station 4116 near North Bay, Ontario, approximately 139.2 kilometres (km) (86.5 miles) away, remotely operates Station 4110. Station 4116 is staffed 24 hours per day.

At approximately 0725 EDT, an Ontario Provincial Police (OPP) officer noticed a fire on the system and identified the location to the OPP dispatcher in North Bay as being on the TCPL system, which is approximately 8 km south of the town of Latchford, Ontario, and approximately 350 metres (m) (1,148.3 feet) to the east of Highway No. 11. The OPP officer noted that rocks and debris from an explosion had landed on the highway. The OPP dispatcher immediately advised the CCO at Station 105, located at Ramore, Ontario, at MLV 105, who in turn advised the CCO at Station 4116.

Between 0729 and 0738 EDT, TCPL personnel provided confirmation of the location of the occurrence as being between Stations 4110 and 4112. Based on instructions from the TCPL Calgary Gas Controller (CGC), the CCO at Station 4116 initiated emergency isolation procedures for Stations 4110 and 4112. These procedures were designed to isolate the section of the pipeline upstream and downstream of the reported occurrence site. The CCO at Station 4116 initiated an emergency shut-down of compressor unit 112-B1 at Station 4112.

At 0745 EDT, the CCO at Station 4116 initiated the emergency shut-down of compressor units 110-A1, 110-A2 and 110-B1 at Station 4110. At this time, the OPP dispatcher reconfirmed the general location of the explosion and also indicated that the pipeline fire had started a forest fire.

At approximately 0746 EDT, fire crews from the Ontario Provincial Ministry of Natural Resources arrived at the occurrence site and proceeded to fight the forest fire on both sides of the 62.5-m-wide (205-foot-wide) right-of-way. A check of the four unoccupied dwellings in the vicinity of the occurrence was also made. Three of these dwellings form a cluster approximately 360 m (1,181.1 feet) northeast of the occurrence site and the fourth dwelling is approximately 560 m (1,837.3 feet) to the north of the site. The single road providing access to the cluster of four dwellings was covered in numerous locations by rocks and debris from the explosion.

At 0748 EDT, TCPL personnel initiated the isolation of Lines 100-1, 100-2 and 100-3 at Station 4112 from the upstream accident site. This procedure was completed at 0749 EDT. At 0750 EDT, the CCO at Station 4116 initiated the isolation of Lines 100-1, 100-2 and 100-3 at Station 4110. This procedure was completed at 0751. At this time, the OPP advised TCPL that Highway No. 11, in the vicinity of the occurrence, had been closed due to the presence of large rocks and other debris that had landed on the highway.

At 0751 EDT, the portion of the pipeline system between MLV 110 and MLV 112 was effectively isolated by the closure of isolation valves by TCPL personnel between 0729 and 0750 EDT.

At 0825 EDT, TCPL personnel arrived at the occurrence site, confirmed that Line 100-2 had ruptured and identified the location of the rupture as Kilometre Post (KP) MLV 110-2 + 22.098 km, approximately 117 km from Station 4116. It was reported at this time that approximately 20 m (65.62 feet) of pipe had blown out of the ground, that the forest around the break site was still on fire, and that a small natural gas fire existed on the upstream side of Line 100-2.

At 0840 EDT, since all of the rocks and debris had been removed, the OPP re-opened Highway No. 11 in the vicinity of the occurrence site.

At 0910 EDT, the pipeline fire self-extinguished and TCPL personnel completed securing the occurrence site against unauthorized entry.

At 2135 EDT, on 25 July 1994, approximately 63 hours after the explosion and fire and after repairs were made, TCPL personnel returned Line 100-2 to normal pipeline operations.

1.2 Injuries

There were no injuries as a result of this occurrence.

1.3 Damage to Equipment - Product Lost

Damage to the pipeline consisted of 21.76 m (approximately 71.4 feet) of ruptured pipe which had split open in the longitudinal direction and blown out of the pipeline system. The fracture created a crater approximately 16 m wide by 36 m long and roughly 2 to 4 m deep. The fire burned an area around the pipeline system of approximately 4.77 hectares (ha) (11.79 acres) with a combined burned and heat-affected area of approximately 7.52 ha (18.58 acres).

An estimated 4,194,000 cubic metres (m3) (148,108,900 cubic feet) of natural gas was consumed by the fire. An additional 23,200 m3 (819,000 cubic feet) of natural gas was used to purge air out of this segment before returning to normal operations.

Since sections of the undamaged pipeline were removed upstream and downstream of the occurrence site, the repair was completed using pipe of a length of 48.59 m (159.42 feet).

1.4 Weather

The weather was overcast with a temperature of 16.6 degrees Celsius, wind at 150 degrees (south-southeast) at three knots (8 km/h), and a 1,066.8-m (3,500-foot) ceiling. The barometer was reading 753.36 mm (29.66 inches) of mercury.

1.5 Particulars of the Pipeline

At the occurrence site, TCPL has three parallel lines of pipe, one designated as Line 100-1 with a nominal outside diameter of 762 mm (NPS 30), a second designated as Line 100-2 with a nominal outside diameter of 914 mm (NPS 36) and a third designated as Line 100-3 with a nominal outside diameter of 1,067 mm (NPS 42). The three pipelines are buried about 0.914 m in a rocky area of the pipeline route where there is a rapid change in pipe gradient due to a steep slope.

The nominal wall thickness of Line 100-2 is 9.14 mm (0.360 inches) with a specified minimum yield strength (SMYS) of 448 megapascals (MPa) (American Petroleum Institute (API) pipe grade X-65). This section of Line 100-2 was constructed in 1972 and was externally coated at that time with a mastic primer, a hot applied asphalt enamel coating, and an asbestos and kraft paper outer wrap. While TCPL is of the opinion that the exterior coating at the accident site was damaged during the original construction, the metallurgical investigation of the ruptured pipe found no evidence of original construction damage on the pipe surface. TCPL has known from the results of the Pipeline Maintenance Program begun in 1985 that the asphalt coating on Lines 100-1 and 100-2 had undergone degradation because of low adhesion to the pipe steel, the lack of mechanical strength and the high degree of water permeation compared to newer coatings. As a result, TCPL has found that the cathodic protection (CP) requirements on the asphalt-coated sections of the system have increased as the asphalt coating has aged.

This section of Line 100-2 was hydrostatically tested in January 1973 to a minimum test pressure of 9,198 kilopascals (kPa). The National Energy Board (NEB) issued a Leave to Open to TCPL in January 1973, at a maximum allowable operating pressure (MAOP) of 6,895 kPa. In 1986, the entire MLV section containing the accident site successfully passed a hydrostatic strength test. Until 1977, TCPL operated Line 100-2 at a reduced MAOP of 6,454 kPa due to interconnections with Line 100-1, which had an approved MAOP of 6,454 kPa. With the re-rating of Line 100-1 to a higher MAOP after 1977, TCPL operated Line 100-2 at the approved MAOP of 6,895 kPa.

Prior repairs in this section of Line 100-2 from MLV 110 to MLV 116 have involved construction-initiated or rock-induced dents in the pipe wall. These locations were identified by an in-line dent inspection survey and repairs were made in 1980. During 1986 and later in 1987, the entire section was electronically inspected for dents and other surface deformations using an in-line dent inspection device. This work was part of a more extensive inspection of six consecutive MLV sections: MLV 110 to MLV 116. A series of five dents was identified from this work and these sections were replaced; one of which was immediately downstream of the occurrence site. In 1991, repair of Line 100-2 was necessitated in the immediate area of the occurrence site because of outside force damage.

This portion of Line 100-2 had never been inspected for corrosion using an in-line metal loss inspection device. TCPL based this decision on the following points:

(i) the operating history of the system to that point did not include corrosion-related occurrences;
(ii) prior results of in-line metal loss inspections elsewhere on Line 100-2;
(iii) the results of 22 excavations on Line 100-2 during 1986 in this particular valve section that revealed no significant corrosion; and
(iv) the successful hydrostatic retesting of this particular valve section in 1986.

The failure of Line 100-2 did not cause any damage to Lines 100-1 and 100-3. The last aerial patrol conducted over this portion of the pipeline system before the occurrence was on 21 July 1994, at approximately 1630 EDT, with no concerns being reported.

As part of its ongoing operational activities, TCPL personnel performs annual natural gas leak surveys of its pipeline system by walking the right-of-way with hand-held gas detectors.

The last leak survey of this portion of the pipeline system was completed on 13 July 1994 and no natural gas leaks were detected in the area of the occurrence.

1.6 Commodity Pipeline Operations

The TCPL Gas Control Centre (GCC), located in Calgary, Alberta, relies on selected telemetric data from compressor and meter stations coming from the TCPL Supervisory Control and Data Acquisition (SCADA) telemetry network to determine the optimum operating scenarios for moving contracted quantities of natural gas. The TCPL pipeline system is subdivided in operating sectors, each under the direct command of a CCO with direct remote control over a series of compressor stations.

A review of the telemetry data for the day in question shows that TCPL had been flowing natural gas at approximately 4.183 billion cubic feet per day through the three lines in Northern Ontario. All functions had been normal for the previous 24 hours and no abnormalities in operations were identified from this review.

1.7 Cathodic Protection on Line 100-2

When the section of Line 100-2 which contained the break was installed in 1972, TCPL piggybacked the CP requirements of Line 100-2 upon those of Line 100-1. Based on information at that time, there was no perceived need for the provision of

additional CP for this section of Line 100-2. However, in 1976, TCPL did provide a direct electrical connection between this section of Line 100-2 and the Line 100-1 rectifier at R100 + 17.85 km.

The occurrence site was situated in a high electrical resistance rock environment with measured values of soil resistivity in 1989 of approximately 1,250,000 ohm- centimetres, at a 3-m depth. An underground stream observed at the site after the rupture was generally known by TCPL personnel to exist in the vicinity of the occurrence site and would have provided a constant stream of oxygen to this area of the pipeline.

In order to determine the effectiveness of the CP system and to ensure that the existing minimum industrial norm of 850 millivolts (mV) is met, TCPL field staff perform pipe-to-soil surveys at various times during the life of the system. These surveys consist of either a close pipe-to-soil potential survey (close survey), a test lead pipe-to-soil potential survey (test lead survey), or both. The test lead surveys during 1974 and 1975 and a close survey during 1975 over this section of Line 100-2 showed areas of sub-criterion potentials, that is, below the minimum industrial norm. Two impressed current systems were installed in 1976 at R110

+ 24.75 km and R110 + 30.27 km. At this time, Line 100-2 was also electrically connected by a cable to R110 + 17.85 km on Line 100-1.

From 1976 to 1980, as part of the company's Corrosion Remedial Survey Program (CRSP), close and test lead surveys identified further areas of sub-criterion potentials, resulting in the installation in this segment of an additional 102 magnesium anodes.

From 1982 until the present, TCPL field staff have performed numerous close and test lead surveys. While the results of the surveys were initially favourable, in 1991, deficiencies were identified and additional CP was proposed for this section of the system to increase the impressed potential above the minimum industrial criterion. However, this work, referred to as remedial repair work on the CP system, was postponed due to the construction of a new section of pipeline in this general area, which was designated as Line 100-3. These mainline construction activities prevented access to remedial repair sites by TCPL field staff, and no pre-remedial survey, which would have aided in identifying the optimum location for a new rectifier, could be conducted because existing rectifiers had been turned off for safety reasons during this time period. Similar postponements occurred during 1992 and 1993 due to construction activities. In 1994, the CRSP proposed a rectifier and associated current distribution system at R110 + 27.16 km to provide additional CP protection for this segment.

TCPL records also indicate that the rectifiers providing protection to this segment have had outages totalling approximately 13 months since 1976. During this period of time, the rectifiers were turned off for construction and survey purposes as well as suffering outages because of electrical faults or lightning damage.

1.8 Cathodic Protection on the TCPL Pipeline System

TCPL records also indicate a backlog of remedial CP repair work to correct sub-criterion CP potentials at other locations on the pipeline system. One of these locations is in the region of Toronto, Ontario, which will be completed during 1995.

1.9 Metallurgical Testing

A metallurgical analysis of the fracture area determined that the pipe failed in shear-by-ductile overload mode as a result of extensive wall thinning from external corrosion. This defect occurred during the operational life of the pipeline and was not the result of a pre-installation manufacturing defect in the pipe wall. The defect that initiated the rupture was a patch of external surface corrosion which measured approximately 1,440 mm in length and 1,210 mm in width. There was no evidence of damage from the original construction. The area of the fracture initiation had experienced up to 70 per cent loss of material from the pipe wall. The location of the rupture initiation through this corrosion patch was located between the five and six o'clock position on the outer surface of the pipe when looking in the direction of gas flow. Visual examination of the other removed joints of pipe immediately adjacent to the rupture-initiation site identified further evidence of corrosion pitting, however, less severe

2.0 Analysis

2.1 Introduction

The metallurgical examination identified general external corrosion as the source of the pipeline weakness that led to the ductile overload fracture of the pipe wall. The pipeline rupture and loss of internal operating pressure were immediately acted upon, triggering a series of timely emergency procedures by TCPL field staff.

The analysis will focus on the coating and environmental conditions which led to the pipe deterioration and the policies and procedures employed by TCPL when implementing and verifying the effectiveness of its CP system.

2.2 Consideration of the Facts

2.2.1 Asphalt Coating System

The asphalt coating, which was one of the prevailing standard at the time of construction of Line 100-1 and this section of Line 100-2, had experienced extensive degradation over time. This fact was evident from the increase in CP requirements from initial installation in 1976 to the present. Since being initially used on pipeline systems, hot applied asphalt coatings have been discontinued by the pipeline industry in general. A number of important technical factors contributed to this decision. Over time, asphalt coatings were found to have low adhesion characteristics, to lack mechanical strength and to have a high degree of water permeation when compared to newer coatings.

Considering the amount of surface corrosion found at the fracture-initiation site and on the adjacent areas of pipe, coating degradation was a direct factor. The lack of mechanical strength of this type of coating, the normal operating oscillations of the pipeline, the rapid change in pipe gradient because of the steep slope of the right-of-way, and the high external stress due to the interaction of the pipe and the soil (rock and granular materials) were sufficient to continuously deteriorate the coating and to permit a corrosion cell to begin and progress to the point of rupture. A second direct contributor to the progression of the corrosion cell was the wet environment around the pipe. The underground stream in the immediate area of the occurrence site provided a continual source of oxygen, which accelerated the corrosion cell and contributed to the coating degradation.

2.2.2 Cathodic Protection System

While TCPL diligently performed various corrosion surveys of its CP system and continually upgraded the system to ensure that the pipeline was protected by an adequate level of CP, the actual corrosion protection provided to this section of the pipeline system may have been inadequate for up to a period of 10 years.

From its original construction in 1972 until 1976, Line 100-2 may not have been adequately protected against corrosion by piggybacking the CP requirements of Line 100-2 to the single rectifier installed in 1960 for Line 100-1. While there did not appear to be any unusual CP problems in this section between 1976 and 1990, TCPL did install additional rectifiers and a large number of sacrificial anodes. On the basis of pipe-to-soil surveys, TCPL field personnel has recommended the installation of an additional rectifier in this section of the pipeline system since 1991 as part of remedial CP work to ensure that industrial standards are met. However, the installation of the additional rectifier was delayed due to construction-related activities. If this remedial work had been carried out, the pipeline would have had proper CP.

The situation in this section was further complicated by the fact that the rectifiers protecting this section were shut off during periods of construction and were out of service for various reasons for a total period of approximately 13 months. During these periods of outages and inadequate corrosion protection, the presence of the underground stream provided a constant source of oxygen which contributed to and accelerated the corrosion process.

Because of construction-related delays in implementing corrective remedial measures to ensure a minimum impressed voltage and the failure to ensure that the CP system was operational, up to 70 per cent of the pipe wall corroded at the fracture site. TCPL is aware of similar locations on its system where remedial repair programs to correct areas of sub-criterion potentials on the pipeline system have been recommended but not acted upon. The most pressing of these locations is in the region of Metropolitan Toronto.

2.2.3 In-Line Metal Loss Inspection for Corroded Areas

From the time that TCPL built this section of Line 100-2, there have been concerns with its structural integrity because of the potential for damage to the pipeline since this section was built in rock. TCPL has run in-line dent inspection surveys to identify structural damage caused by construction and other outside forces such as rock damage. However, these in-line dent inspection surveys did not identify zones of metal loss. A mandatory requirement to carry out in-line metal loss inspection surveys of pipeline systems on a regular basis was not in place for TCPL and other pipeline companies under the jurisdiction of the NEB. Since first being developed in the mid-1970s, the in-line metal loss inspection survey equipment has gone through several stages of development which have enhanced it, and its level of sophistication is now such that it can always identify zones of corrosion similar to the one responsible for this occurrence.

3.0 Conclusions

3.1 Findings

1. The pipeline rupture initiated at a point on the surface of the pipe wall which had extensively thinned from external corrosion.

2. There were other areas of extensive thinning of the pipe wall due to external corrosion in the adjacent joints of pipe.

3. From the time of initial installation of this section of Line 100-2 in 1972 until 1976, little or no cathodic protection (CP) was provided by piggybacking the CP system from Line 100-1 onto Line 100-2.

4. From 1990 until 1994, the proposed remedial repair plans for the CP system in this section of Line 100-2 were delayed because of new pipeline construction activities, in spite of the fact that the level of CP was below the minimum industrial standard of 850 millivolts (mV).

5. From 1976 until the present, the rectifiers providing protection of this section of the pipeline were out of service for approximately 13 months.

6. When this section was installed in 1972, it was located in an area with high soil resistivity, with an underground stream acting as a continual source of oxygen, and in a rocky, steep-graded slope. These all acted to deteriorate the coating and initiate a corrosion cell.

7. Asphalt coatings have been found to deteriorate over time, leading to the need to provide greater protection, as evidenced by the increase in the number of rectifiers in this section to satisfy the increases in CP requirements to meet the minimum industrial standard of 850 mV.

3.2 Cause

The rupture was caused by a ductile overload fracture as a result of extensive thinning of the pipe wall from external corrosion.

4.0 *Safety Action*

4.1 *Action Taken*

4.1.1 *Pipeline Maintenance and Cathodic Protection (CP)*

In September 1994, TCPL performed an in-line high-resolution metal loss survey in a section of Line 100-2. Seven significant corrosion features were detected in the 140 km of pipe inspected.

Also, TCPL reviewed its CP records to identify areas where there was a backlog of CP work or low impressed CP current.

Information gained from this survey and review has formed the basis of an ongoing effort to develop a statistical model and database which will predict corrosion susceptibility. TCPL intends to use the prioritized list of corrosion susceptibilities developed by the model and database as the basis for scheduling in-line metal loss inspection surveys.

TCPL's 1995 Pipeline Maintenance Program (PMP) contains the requirement that the two most populated mainline valve sections identified in this survey and review will be inspected using an in-line high-resolution metal loss device.

4.1.2 *Cathodic Protection Rectifiers*

TCPL has implemented a remote monitoring system for some rectifiers to immediately identify malfunctions and reduce rectifier down time. The system is being developed in conjunction with scheduled upgrading work on the Supervisory Control and Data Acquisition System (SCADA).

4.1.3 *Gradient Survey Technique*

As a means of detecting anomalies or deficiencies in the external coating of its pipeline system, TCPL has experimented with a new gradient survey technique as part of its normal maintenance program. This technique has been used in areas where the pipeline is buried in rock, coated with an asphalt exterior coating, and an in-line metal loss survey has identified zones of corrosion. Unless technological advances are made in this technique, TCPL does not intend to use it in similar environments.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson, John W. Stants, and members Zita Brunet and Hugh MacNeil, authorized the release of this report on 17 July 1995.

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Appendix A - Glossary

API	American Petroleum Institute
CCO	Control Centre Operator
CGC	Calgary Gas Controller
close survey	close pipe-to-soil potential survey
CP	cathodic protection
CRSP	Corrosion Remedial Survey Program
EDT	eastern daylight time
GCC	Gas Control Centre
ha	hectare(s)
km	kilometre(s)
km/h	kilometre(s) per hour
KP	Kilometre Post
kPa	kilopascal(s)
m	metre(s)
m3	cubic metre(s)
MAOP	maximum allowable operating pressure
MLV	Main Line Valve
mm	millimetre(s)
MPa	megapascal(s)
mV	millivolt(s)
NEB	National Energy Board
NPS	nominal pipe size
OPP	Ontario Provincial Police
SCADA	Supervisory Control and Data Acquisition
SMYS	specified minimum yield strength
TCPL	TransCanada PipeLines Limited
test lead survey	test lead pipe-to-soil potential survey
TSB	Transportation Safety Board of Canada