Fiber Optic Leak Detection

On December 4, 2020, Agnico Eagle Mines Limited (Agnico Eagle) met with Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC) to discuss Agnico Eagle's response to the CIRNAC's technical comments on the Waterline application. Agnico Eagle agreed to provide CIRNAC with additional information to resolve technical comment CIRNAC-TRC-08. CIRNAC asked additional clarifying questions about the operation of the fiber optic leak detection system and requested an example of its operation.

During the NIRB Technical meetings for the Water FEIS Amendment (held January 11 and 12, 2021), the Northlands Denesuline First Nation and Sayisi Dene First Nations requested clarification of a statement from the Failure Modes and Effects Analysis (FMEA):

- Fiber optic leak detection system must be calibrated, but leak detection is difficult during caribou migration (too much interference).

Agnico Eagle has structured the response as follows:

- Technical Description of Leak Detection System
- Calibration
- Example of Operation during Pilot Test at Goldex Mine, Val-d'Or, QC

Technical Description of Leak Detection System

The proposed fiber optic leak detection system uses a compact, lightweight, strong, and flexible fiber optic cable installed along the exterior surface of the pipe for the entire length of the Meliadine waterline. With this system, the fiber optic cable acts as a distributed sensor with thousands of detection points along the entire length of the waterline, capable of detecting a leak of varying size (OptaSense, n.d.). Figure 1 shows an example of a fiber optic cable used in this application. The cable houses quartz glass fibers, strengthened by reinforced plastic cores and protected by a polyethylene jacket (Corning, 2017). Figure 2 illustrates the potential method of installation of fiber optic cable to a pipe using straps.

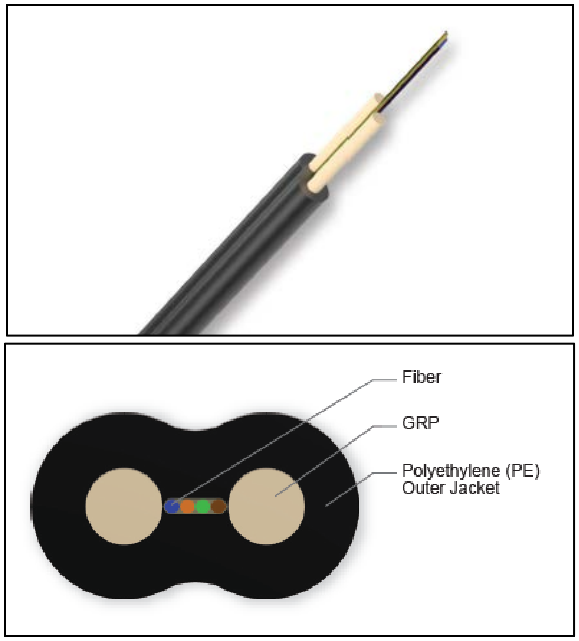

Figure 1 *Cutaway of a fiber optic cable (top) and cross-section (bottom). Retrieved from Corning, 2017.*

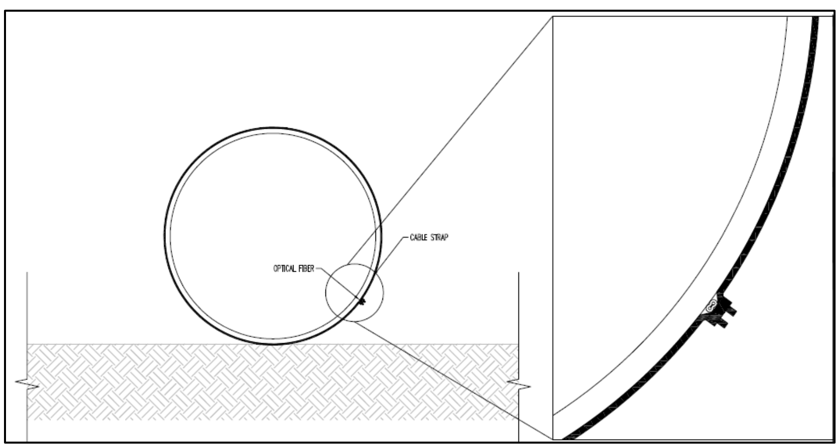

Figure 2 *Cross-section of a potential fiber optic cable installation on the outside of a pipe. Retrieved from D. Pellerin, 2020.*

Quartz glass fibers in the optical cable are extremely sensitive and respond to subtle changes in temperature and pressure resulting in an effect known as Raleigh scattering. This back scattered signal is detected, measured, and subsequently processed by software at a control station resulting in a reconstruction of the event at the source of the signal – such as a leak.

During a leak, the optical fibers may pick up a signal from the sudden pressure change in the pipe, ground movement or displacement, the noise of a leak, physical contact of leaking effluent on the cable, or a combination of these signals. This triggers an alert, notifying the operator of the time and location of the leak. Depending on the specific system provider, and actual installation conditions, sensitivity of the leak detection can be as low as 2-3 l/min with a response time of a few seconds after the leak starts.

Thus, in the event of even a small leak, the operator of the system, who is a member of the water treatment team, is able respond rapidly by shutting down the system and initiating the spill response protocol.

Calibration

In addition to leaks, the system may detect disturbances outside of the pipe such as passing vehicles, construction activity, and wildlife movement (e.g. caribou). However, the backscattered signals generated by vehicles, construction activity, and wildlife movement differ in acoustic energy and duration from those of leaks, and thus these disturbances are distinguishable from leaks. This includes the disturbances expected to occur during caribou migrations. The FMEA stated that leak detection is difficult during caribou migration (due to too much interference). This statement is only partially true; indeed caribou migrations are expected to produce interference signals, however, calibration of the processing software to differentiate the signals produced by caribou from those produced by leaks is expected to allow successful leak detection during caribou migration.

Calibration will strategically be applied to differentiate the signature of vehicles, construction activity, and wildlife movement (including the caribou migration) from that of leaks. This calibration is expected to allow the signal processing software to effectively differentiate these events, reducing the potential for a leak false-alert. The calibration strategy is expected to follow the following general framework:

- Characterization of individual disturbance (i.e., signal backscatter) signatures including those from vehicles and caribou movement. Application of calibration and site experience data from Agnico Eagle’s Goldex Mine, Val-d’Or, QC will also be applied where possible.
- Careful observation and verification to validate signal classification. Regarding the caribou migration, this will involve frequent communication between the waterline operators and mine site personnel responsible for caribou monitoring in order to validate signal interpretation during this period of increased signal interference.

Details of the calibration strategy will be determined once the specific equipment is selected and prior to commissioning.

Following successful calibration, the signal processing software is expected to effectively differentiate between leaks and interference; including that produced by the caribou migration. However, operator field visits will still be required after calibration if false-alerts do occur.

Example of Operation during Pilot Test at Goldex Mine, Val-d'Or, QC

A visual example of a leak detected through a detected pressure change can be seen in Figure 3.

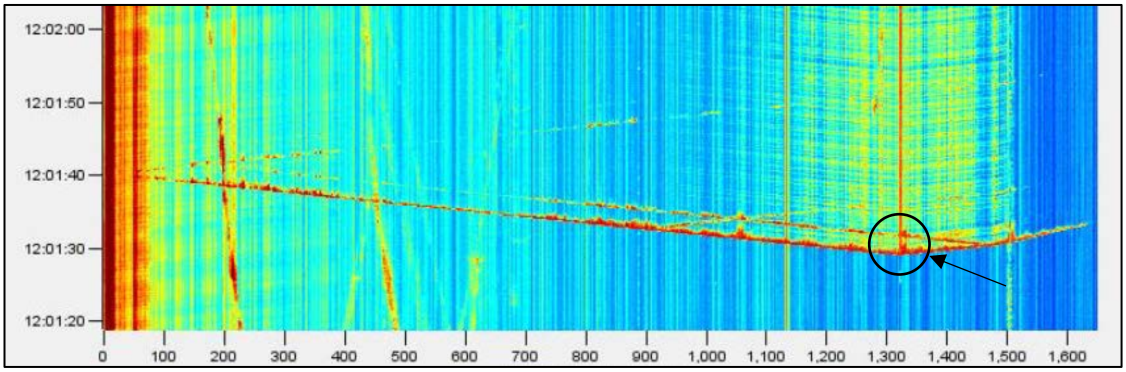

Figure 3 *Leak detection signal on a waterfall chart, due to a negative pressure pulse in a pressurized pipe. The horizontal axis represents position along the pipe. The vertical axis represents the time.*

In this case, Agnico Eagle conducted a pilot test in which a leak resulted in a negative pressure pulse which propagated along the optical fiber in both directions, away from the leaking point source. The bottom point of the "V" shape coincides with the location of the leak (horizontal axis) along the fiber optic cable, with each arm coinciding with the pressure signal as it travels away from the source through time (vertical axis). This is an example of raw data output from the processed signal, with more intuitive alerts and signals available to an operator once they have been filtered by the leak detection software. Figure 4 shows the corresponding alert generated during this test, indicating the leak detection time and the location of the leak.

Start Date/Time	End Date/Time	Alert Red Time	Classification	Channel	Start C...	Duration(HH...	Latitude	Longitude
06/11/19 11:08:36	06/11/19 12:21:50	06/11/19 11:08:36	Leak	1319	1318	01:13:13	48.07237° N	77.70789° W
06/11/19 12:02:09	06/11/19 12:04:55	Unset	OFN Leak	1322	1322	00:02:45	48.07239° N	77.70752° W
06/11/19 12:02:43	06/11/19 12:02:43	06/11/19 12:02:43	NPP Leak	1320	1320	00:00:00	48.07237° N	77.70777° W
06/11/19 12:02:40	06/11/19 12:02:40	06/11/19 12:02:40	NPP Leak	1320	1320	00:00:00	48.07237° N	77.70777° W
06/11/19 12:02:37	06/11/19 12:02:37	06/11/19 12:02:37	NPP Leak	1320	1320	00:00:00	48.07237° N	77.70777° W
06/11/19 12:02:34	06/11/19 12:02:34	06/11/19 12:02:34	NPP Leak	1320	1320	00:00:00	48.07237° N	77.70777° W
06/11/19 12:02:31	06/11/19 12:02:31	06/11/19 12:02:31	NPP Leak	1320	1320	00:00:00	48.07237° N	77.70777° W
06/11/19 12:02:28	06/11/19 12:02:28	06/11/19 12:02:28	NPP Leak	1320	1320	00:00:00	48.07237° N	77.70777° W
06/11/19 12:02:25	06/11/19 12:02:25	06/11/19 12:02:25	NPP Leak	1320	1320	00:00:00	48.07237° N	77.70777° W

Figure 4 *Leak detection software alerting the operator of a leak detected via the pressure loss (referred to as NPP) and sound of the leak (referred to as OFN), and its position along the pipe.*

As explained in the technical description above, and as exemplified during the pilot test performed at the Goldex Mine, the use of a fiber optic leak detection system will enable Agnico Eagle to detect the presence of even a small leak and its specific location along the waterline only moments after it occurs. This enables the dedicated operator of the leak detection to rapidly cease discharge and minimize the impact of a spill resulting from the potential leak. The details of the complete leak detection system (including monitoring, alarms, and responding procedures) will be developed once the specific equipment is selected and prior to installation.

Pipeline Leak Detection - OptaSense. (n.d.). Retrieved January 07, 2021, from https://optasense.com/pipeline-monitoring/leak-detection/

Corning Inc. (2017). Distributed Sensing Cables, 4 F, SMF-28® Ultra fiber, Single-mode (OS2) [Brochure]. Hickory, NC: Author.

D. Pellerin. (2020, July 23). Optical Fiber Installation Pipe Leak Detection System. (65-180-280-200). Technical Report Submitted to Agnico Eagle Mines Ltd. By SNC-Lavalin, July 2020.

Mishra, A., & Soni, A. (2011). Leakage Detection using Fibre Optics Distributed Temperature Sensing. Retrieved 2021.