



Pipeline Leak Detection Testing using hifi Engineering Fiber Optics

**C-CORE Report Number
R-16-067-1331**

**Prepared for:
LOOKNorth**

**Revision 1.0
January, 2016**

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REVISION HISTORY

VERSION	NAME	DATE OF CHANGES	COMMENTS
1.0	Rodney McAfee	26/01/2017	Final Report

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hifi Engineering	John Hull	PDF
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Executive Summary

The objective of the program was to determine if Distributed Acoustic Sensing (DAS) systems, for this program specifically a system supplied by hifi Engineering, could reliably detect leaks given the conditions present in these tests. The leak detection tests detailed in this report took place in the C-CORE testing facility from November 28 to December 2, 2016. The test week activities included “announced” leaks for calibrating the monitoring equipment, “blind” tests using both water and nitrogen with leaks initiated at different pressures and durations in a damp sand test bed and tests in a submerged condition with one of the test boxes completely filled with water. hifi Engineering monitored for leaks from a remote location in the building while C-CORE staff generated leaks in the laboratory. This report details the test conditions, operations and results from the testing program.

The hifi Engineering system successfully detected all leaks generated during this testing program, with no false positives. This included pressures between 5 and 195 psi for nitrogen and water leaks in a damp soil condition, between 5 and 44 psi for water leaks, and between 3 and 65 psi for nitrogen leaks in submerged conditions. These pressures are considered to be lower than expected in most pipeline leaks. Higher pressures would be easier to detect due to the higher energy levels of the leaked fluid or gas.

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1 Test Program Setup

1.1 Introduction

The leak detection testing program detailed in this report took place in the C-CORE testing facility from November 28 to December 2, 2016. The test week activities included:

- 28th of November - setup and “announced” leaks for calibrating the monitoring equipment;
- 29th of November through the 1st of December - blind tests using both water and nitrogen with leaks initiated at different pressures and durations in a damp sand test bed; and
- 1st and 2nd of December - tests in a submerged condition with one of the test boxes completely filled with water.

During the “blind” tests, C-CORE personnel initiated either water or nitrogen leaks of different intensities and durations at random times through the day. Personnel from hifi Engineering were located in a remote location of the building during the testing. At the end of each day or after a set of tests, hifi Engineering was required to show what they believed happened during the day and it was determined if their system could accurately detect the leaks. The objective of the tests was to validate Distributed Acoustic Sensing (DAS) technology as a viable method to monitor for leaks in pipelines and to also understand any limitations. Can they observe low pressure leaks, can fiber optic cable placed in protective conduit still work, how close does the cable have to be to the pipeline to reliably detect the leak, etc.?

1.2 The Test Beds

Testing took place in two large test boxes, measuring 7 m long, 2.5 m wide, and 1.2 m deep in the C-CORE geotechnical lab. The cross-sectional dimensions were selected based on boundary conditions determined in a previous project that evaluated DAS technologies. The boxes (labeled as Box A and Box B in this report) were identical in their construction, though the cable and conduit configuration (discussed later) differed. Figure 1 shows photographs of Box A and Box B as they were half filled with soil and the pipeline and the conduits were placed in the test bed. Figure 2 shows the test tank completely filled with soil. Figure 3 shows one of the boxes after being submerged with water for part of the testing.

Crushed concrete sand, with a total depth of 1 m was used as the base material for the test bed. The majority of the tests were run with a damp soil condition in which the pore space between solid soil particles consisted of air and water. As the leaked fluid pushed some of the nearby soil away from the leak nozzle, some resets of the soil were performed to mechanically reposition the soil to its initial state between tests. These resets were performed at the end of each test day at each nozzle location.



Figure 1. Box A and Box B Pipe Setup

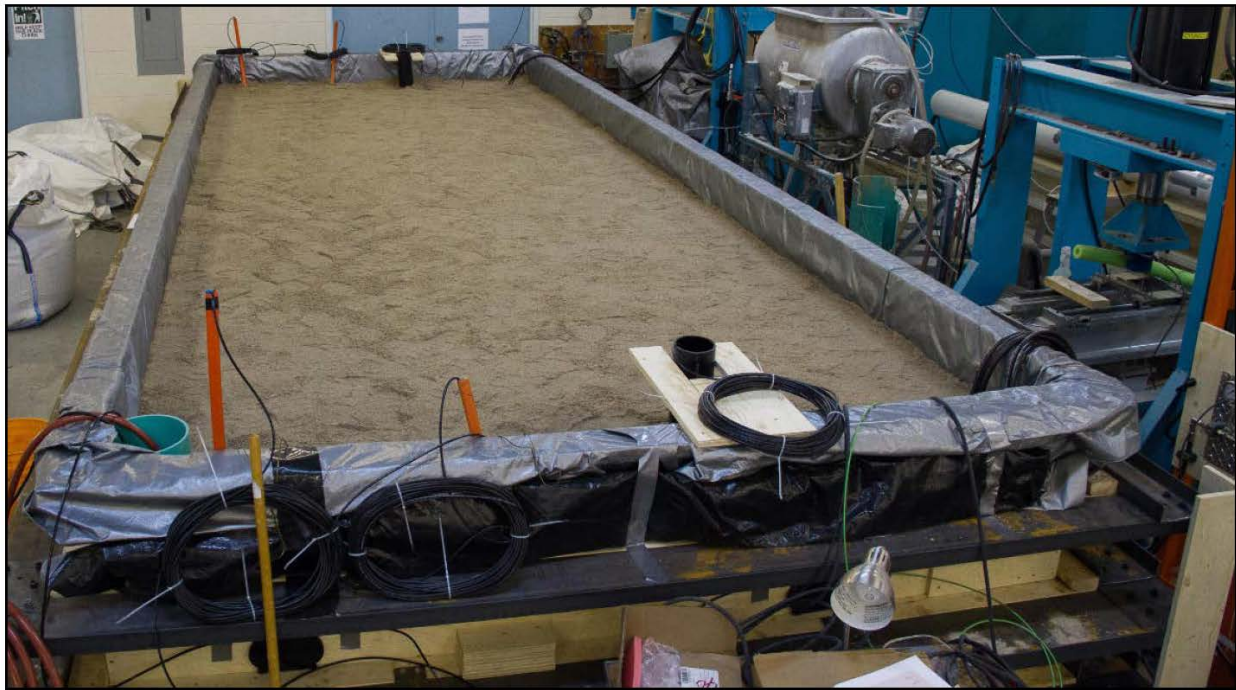


Figure 2. Soil Box Filled

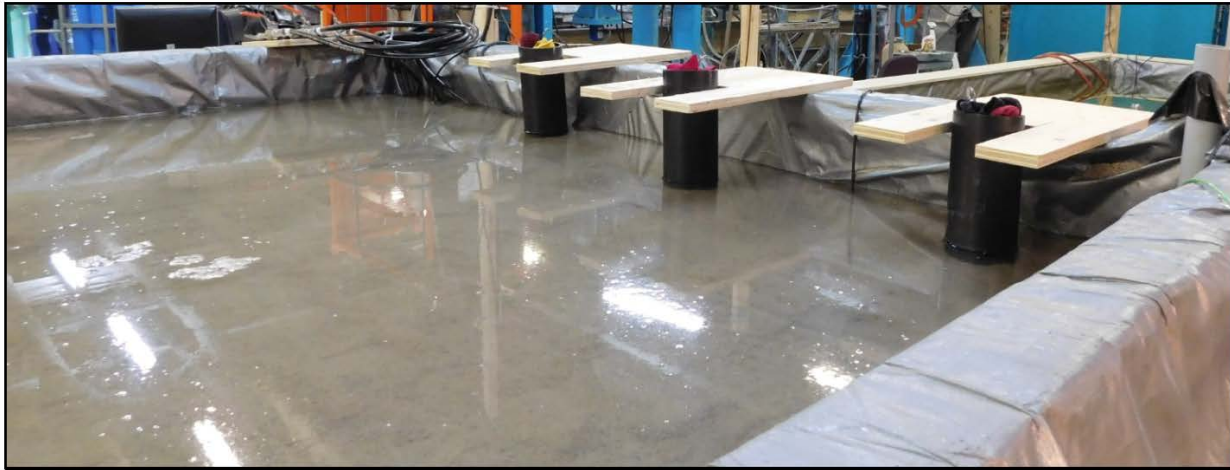


Figure 3. Submerged Soil Box

1.3 Test Pipe and Cable Routing

A 200 mm diameter pipe with three 3.2 mm (1/8-inch) nozzles centered in the pipe one meter from each other, was utilized as the leak points. Leak tests were performed with both nitrogen and water as the leaked fluids. Analysis and testing during previous projects has demonstrated that these fluids are appropriate substitutes for methane and oil (i.e., with similar acoustic energy signals). Furthermore, testing with nitrogen and water offers significant logistical, health, safety, and environmental advantages over conducting tests with methane and oil. Varying pressures and durations of leaks were investigated throughout the testing program. The line pressure was maintained such that the leak rate does not significantly diminish over the test interval in order to replicate the in-situ application in which the pressure of a voluminous pipe is not significantly impacted by a small leak. Leaks were generated from an accumulator rig, Figure 4, pre-charged with nitrogen or water. For water tests, hand activated valves were used to generate the leak, while for nitrogen tests, pneumatically activated valves inside the test pipe were used to generate the leaks.

Within each box, there were multiple passes of the fiber optic cable at varying distances from the “pipeline” where the leaks were initiated. Some of the fiber optic cables were placed in protective conduits and some were simply placed in the soil. Figure 5 and Figure 6 show the fiber optic cable arrangements, the cables indicated by the red dot, inside the soil boxes, where cable was looped along the length of the box either inside a conduit, alongside a conduit or alongside the test pipe. At the end of each cable run a quantity of cable was looped at the end of the box before the next cable run was placed. All fiber optic cable was provided by hifi Engineering and placement was completed by hifi Engineering staff, with assistance from C-CORE as required.

Two different conduits were used for this testing to evaluate the impact of placing the sensing cable inside a protective conduit. One conduit was a 4-inch HDPE conduit with Silicore lining that was selected based on a guidance document generated for a previous project. The other conduit was a dual-core micro-conduit supplied by Duraline. The former was used in all positions in Box A and at the 0.3 m offset location

of Box B, while the smaller conduit was utilized at the 0.9 m and 1.5 m offset positions of Box B, as shown in Figure 1. An image of the smaller conduit is shown in Figure 7.



Figure 4. Accumulator Rig

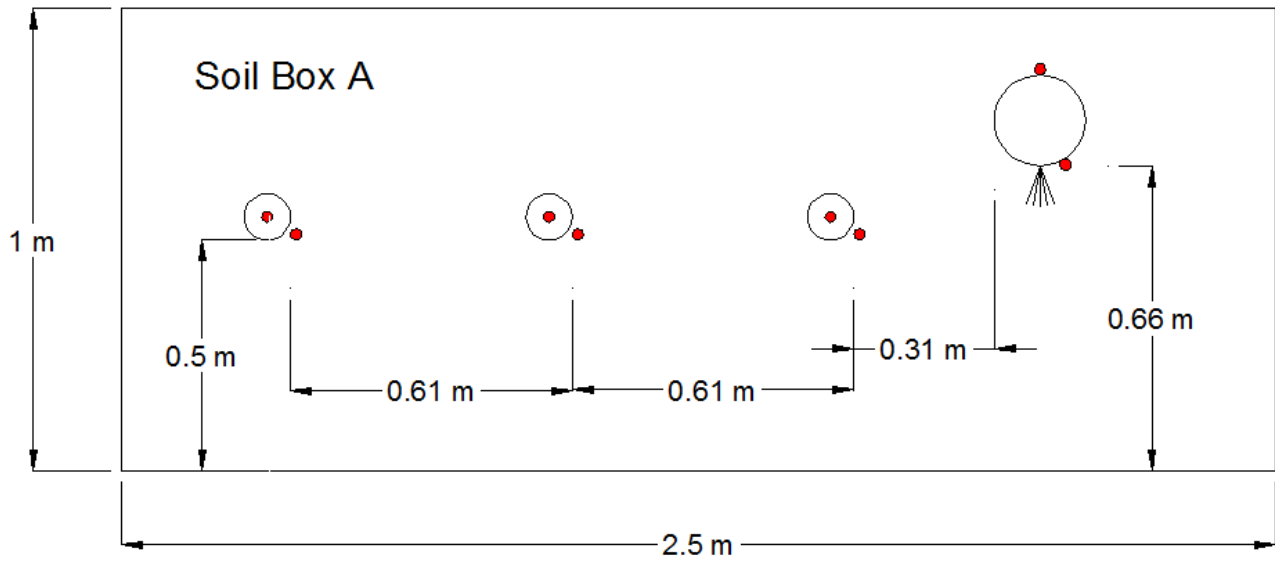


Figure 5. Soil Box A, Conduit and Pipe Arrangement

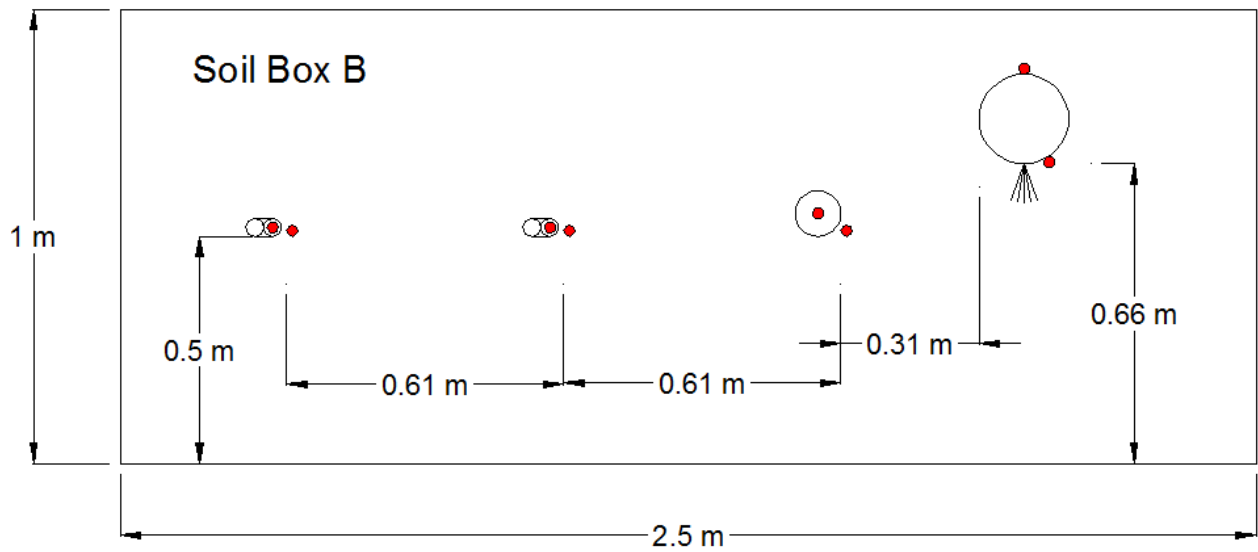


Figure 6. Soil Box B, Conduit and Pipe Arrangement



Figure 7. Micro-conduit supplied by Duraline

2 Test Execution and Results

The tests were performed by initiating a fluid discharge for a prescribed duration (typically on the order of 30 to 60 seconds) and maintaining the constant leak rate during this duration. Care was taken to not have a pressure spike at initiation that might be picked up by the DAS systems instead of direct detection of the leak. A total of approximately 86 test points were run over a range of conditions. All test points were taken through 3.2 mm (1/8-inch) nozzles in the test pipe. Pressures ranged from 5 to 210 psi at the pressure transducer downstream of the nozzle.

The data were collected using an HBM 840B data acquisition and control box with CATMAN software. Data was also collected from Bruel & Kjaer 8104 hydrophones buried in the soil beds. These sensors were installed to serve as a reference if there were signals detected by the fiber optic system that could not be explained by audible observations made in the lab. Review of these hydrophone records could be used to reconcile any uncertainty that maybe have come about. However, there were no such instances of unexplained signals on the fiber optic system so use of the hydrophone data was not necessary. In addition to the hydrophone measurements, pressure data was collected from transducers in the accumulator rig and in a line downstream from the nozzles.

Table 1 through Table 6, are details of the tests including the date executed, test tank used, leak fluid, soil condition, test number, test time and the average nozzle pressure through the test duration. Each day these data were compared to hifi Engineering's observations and they detected each of the leaks noted and did not detect any false alarms. Additional noise including forklift operating, bleeding of water and pneumatic systems in other parts of the lab and other laboratory background noises were present during the test week without any false alarms reported.

Table 1. Tank A, Water Leaks

Date:	29-Nov-16	Average Nozzle Pressure (psi)
Tank:	Tank A (damp)	
Leak Fluid:	Water	
Test #	Time	
1	9:50	80
2	9:57	70
3	10:18	90
4	10:34	120
5	10:55	80
6	11:05	80
7	11:24	100
8	11:35	130
9	2:02	7
10	2:22	7

Date:	29-Nov-16	Average Nozzle Pressure (psi)
Tank:	Tank A (damp)	
Leak Fluid:	Water	
Test #	Time	
11	2:40	10
12	2:52	18
13	3:03	22
14	3:13	30
15	3:25	32
16	4:05	25

Table 2. Tank A, Nitrogen Leaks

Date:	30-Nov-16	Average Nozzle Pressure (psi)
Tank:	Tank A (damp)	
Leak Fluid:	Nitrogen	
Test #	Time	
17	9:01	5
18	9:13	15
19	9:25	12
20	9:35	25
21	10:01	38
22	10:26	48
23	10:35	68
24	11:00	105
25	11:10	135
26	11:21	195

Table 3. Tank B, Nitrogen Leaks

Date:	30-Nov-16	Average Nozzle Pressure (psi)
Tank:	Tank B (damp)	
Leak Fluid:	Nitrogen	
Test #	Time	
27	2:45	8
28	2:53	5
29	3:04	15
30	3:22	13
31	3:33	12
32	3:41	8
33	3:50	23
34	4:02	35
35	4:13	55
36	4:20	85

Table 4. Tank B, Water Leaks

Date:	01-Dec-16	Average Nozzle Pressure (psi)
Tank:	Tank B (damp)	
Leak Fluid:	Water	
Test #	Time	
37	9:18	6
38	9:32	7
39	9:51	5
40	10:00	8
41	10:05	7
42	10:30	10
43	10:41	13
44	10:55	9
45	10:59	8
46	11:04	7
47	11:10	15
48	11:20	32

Table 5. Tank A, Water Leaks (Submerged)

Date:	01-Dec-16		Average Nozzle Pressure (psi)
Tank:	Tank A (Submerged)		
Leak Fluid:	Water		
Test #	Time		
49	1:30	5	
50	1:40	7	
51	1:56	22	
52	2:09	25	
53	2:13	9	
54	2:36	9	
55	2:48	10	
56	2:58	12	
57	3:13	8	
58	3:25	44	
59	3:30	16	
60	3:42	35	

Table 6. Tank A, Nitrogen Leaks (Submerged)

Date:	02-Dec-16		Average Nozzle Pressure (psi)
Tank:	Tank A (Submerged)		
Leak Fluid:	Nitrogen		
Test #	Time		
61	9:44	6	
62	9:51	6	
63	10:01	11	
64	10:04	9	
65	10:07	9	
66	10:13	7	
67	10:16	7	
68	10:22	16	
69	10:24	15	
70	10:32	26	

Date:	02-Dec-16	Average Nozzle Pressure (psi)
Tank:	Tank A (Submerged)	
Leak Fluid:	Nitrogen	
Test #	Time	
71	10:36	23
72	10:41	15
73	10:45	39
74	10:50	34
75	10:54	27
76	10:57	25
77	11:03	24
78	11:05	24
79	12:57	13
80	1:02	7
81	1:08	4
82	1:14	3
83	1:23	40
84	1:30	65
85	1:36	10
86	1:43	3

3 Conclusion

The objecting of the testing program was to determine if DAS systems, for this program specifically a system supplied by hifi Engineering, could reliably detect leaks given the conditions present in these tests. The hifi Engineering system successfully detected all leaks generated during this testing program, with no false positives. This included pressures between 5 and 195 psi for nitrogen and water leaks in a damp soil condition, between 5 and 44 psi for water leaks, and between 3 and 65 psi for nitrogen leaks in submerged conditions. These pressures are considered to be lower than expected in most pipeline leaks. Higher pressures would be easier to detect due to the higher energy levels of the leaked fluids.



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