Rupture Detection System Test Report

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United States v. Enbridge Energy et al Case 1:16 –cv-914

Consent Decree	VII. Injunctive Measures, G. Leak Detection And Control Room Operations, Paragraph 102, Rupture Dectection System Alarm		
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ENBRIDGE

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Introduction

Paragraph 102 of the Consent Decree entered in Case 1:16-cv-00914 (ECF No. 14, 05/23/17) requires the Enbridge defendants (collectively referred to as “Enbridge”) to continuously operate a new Rupture Detection Alarm System, which is integrated with Enbridge’s SCADA system and MBS Leak Detection System.

Per Paragraph 102(c) of the Consent Decree, Enbridge is required to complete testing of the Rupture Detection Alarm System for at least two separate MBS segments, to document compliance with the requirements of the Consent Decree, and to submit the results of such testing to EPA within 90 Days of the Effective Date of the Consent Decree. Enbridge has prepared this Rupture Detection Alarm System (“RDS”) Test Report in satisfaction the latter requirement.

Background

Enbridge initiated a Rupture Recognition Program (“RRP”) in 2013 with the intent to explore and develop innovative ways of detecting ruptures on its pipeline system, as well as to identify improvements to enhance Enbridge’s existing (SCADA and MBS) leak detection systems. For the purpose of Enbridge’s RRP, a rupture was defined as that size of a leak that can be detected with a very high degree of reliability – i.e., a rupture detection system that results in, at most, one false alarm per year.

Based on the thorough study conducted as part of the RRP, Enbridge developed and implemented a *SCADA-based Rupture Detection System* (“RDS”). The main objective of the RDS is to: (1) exploit the signatures or patterns of abnormal operating conditions, such as abnormally low pressure, and abnormal pressure drop that may be indicative of a rupture; and (2) use the available SCADA telemetry to systematically identify those patterns and generate reliable alarms. The RDS is then intended to alert the Control Room operator and all members of the Alarm Response Team of each generated alarm, and to also initiate the automatic emergency shutdown of the affected pipeline.

RDS Algorithm

The primary algorithm used in SCADA-based rupture detection is called “Single Station Algorithm (SSA).” This algorithm uses measurements from each pump station independently. Inputs to the SSA are:

1. Station discharge pressure;
2. Station Suction pressure; and,
3. Pump unit(s) status.

SSA processes these inputs independent from any other station. Based on these inputs, different features or attributes are calculated and extracted from the pressures. These attributes are categorized and explained in the following chart:

Attribute	Notes
Accumulated discharge pressure change	Accumulation based on recursive least squares algorithm.
Instant discharge pressure change in 5 seconds	Change between two scans.
Equalization Pressure	Value to describe if the discharge pressure crosses the suction pressure.
Difference between suction and discharge pressures	Value to evaluate if the suction and discharge pressures converge.

These attributes are used to form the complex decision tree of the algorithm. This decision tree consists of five (5) leafs, each of which has its own conditions for determining the presence of a rupture. For example, the most straightforward decision is the monitoring for a significant drop in discharge pressure between scans while still maintaining a normal suction pressure. The individual thresholds for these attributes in the decision tree were tuned through many iterations of testing historical data to ensure the key historical and simulated ruptures were detected quickly (< 1 minute), with a minimum of false alarms (see “Rupture Detection System Testing” Section for more details).

RDS Continuous Operations

As an integrated component of Enbridge’s comprehensive Leak Detection program, the RDS is designed to continuously monitor real-time data from the SCADA system for the purpose of detecting a rupture. To ensure continuous operations, a hot failover backup system has been implemented within the RDS and is ready to take over in the event of a primary system failure. The hot backup is continually processing field data but does not generate/annunciate alarms unless the primary system is not functioning as designed. The backup system receives messages from the primary source, and if no suitable message is received for 60 seconds the primary source is determined to be non-functioning at which time the hot backup will take control and generate any alarms. If the primary RDS server experiences a failure, failover to the hot backup is completed automatically and a message is sent out to IT on-call for immediate response. If both the primary and backup servers experience failures, a system fail alarm will be generated to the Leak Detection Analyst and the Control Room Operator.

The Leak Detection Analysts provide 24/7 support of RDS alarms and are equipped with appropriate training and procedures. Routine checks of RDS on each line are also conducted as part of the MBS Routine Maintenance Tracking by each Line Custodian. These checks occur weekly, quarterly, and annually. Some of the key RDS checks include but are not limited to:

- RDS configuration of station(s);
- RDS tags;
- RDS data quality; and,
- Active RDS-related issues.

An RDS dashboard is utilized by the Line Custodians to help complete these checks. An example of part of this dashboard illustrating an Enbridge Lakehead System pipeline (Line 2) is shown below in **Error! Reference source not found.**. In this example, there are two data states shown *No_Data* and *Good_Data*. The *No_Data* state indicates that the system is waiting to receive the next data point (following the last calculation). Both these states are normal, however, it is important to note that this is a snapshot in time.

Figure 1 – RDS Dashboard Example

Current Station Calculation Status - Last 15 Minutes only

	line	station	algorithm	latest_log_time	latest_rds_state	latest_calc_state	latest_data_state
41	2	LB	DecisionTree_SSA_V7	07/19/2017 17:25:55.787	Enabled	Normal_Calculation	Good_Data
42	2	LP	DecisionTree_SSA_V7	07/19/2017 17:25:55.703	Enabled	Normal_Calculation	Good_Data
43	2	ME	DecisionTree_SSA_V7	07/19/2017 17:25:55.686	Enabled	No_Pump_Running_for_a_While	Good_Data
44	2	MI	DecisionTree_SSA_V7	07/19/2017 17:25:55.736	Enabled	Normal_Calculation	Good_Data
45	2	NC	DecisionTree_SSA_V7	07/19/2017 17:25:50.696	Enabled	Waiting_for_Data	No_Data
46	2	OD	DecisionTree_SSA_V7	07/19/2017 17:25:50.784	Enabled	Normal_Calculation	Good_Data
47	2	PL	DecisionTree_SSA_V7	07/19/2017 17:25:55.730	Enabled	Normal_Calculation	Good_Data
48	2	QU	DecisionTree_SSA_V7	07/19/2017 17:25:45.722	Enabled	Normal_Calculation	Good_Data
49	2	SP	DecisionTree_SSA_V7	07/19/2017 17:25:55.702	Enabled	Normal_Calculation	Good_Data
50	2	ST	DecisionTree_SSA_V7	07/19/2017 17:25:50.840	Enabled	Waiting_for_Data	No_Data
	8614						

Rupture Detection System Testing

Prior to production implementation, comprehensive testing was completed by running the RDS through a diverse set of rupture scenarios at various operating conditions. A data set consisting of operational information from actual historic ruptures and more than two hundred simulated leaks and ruptures was compiled for testing. In addition, a large amount of historical operational data was used to verify the system reliability. This data includes the following:

- 26 lines (2 years data for 22 lines, 1.5 years for 1 line, 1 year for 3 lines): 48.5 years of normal pipeline operational data;
- 256 Stations; and,
- Thousands of operational events (e.g., transient conditions, start-up, shutdown, etc.) compared against rupture signatures.

From this data (which encompasses multiple years of pipeline operations), a total of 3 true false alarms were generated. Combined with its ongoing performance, the testing demonstrates that the RDS's reliability exceeds the performance specifications by producing less than one false alarm per year per pipeline.

The simulated leaks were created covering a range of different parameters such as:

- Rupture equivalent hole size
- Location between pump stations
- Fluid type
- Station discharge and suction pressures
- Pipe diameters
- Operating conditions (e.g. steady state, transient conditions, line startup and shutdown)

One set of such simulated data is shown in the following table:

Attribute	Detail
Length	60 miles
Diameter	30”
Discharge Pressure	400/600/800 PSI (Three stations)
Rupture Location	10%/20%/33% of the distance between stations (6 miles/12 miles/20 miles)
Liquid Type	Heavy/Medium

A custom-built testing environment was created to allow for algorithm testing and tuning. Enbridge used the outcomes from the testing to ensure an effective RDS implementation on all Lakehead pipeline systems, in compliance with the requirements of the Consent Decree.

Further, in accordance with Paragraph 102(c) of the Consent Decree requirement, historical rupture tests for two Lakehead MBS segments were selected for testing of the RDS. Tests of the RDS were specifically performed on the two following separate MBS segments: (1) Line 14 Adam station (AM); and (2) Line 6B Marshall station (MR). The historical data used for these tests are from the 2010 Line 6B Marshall release and the 2012 Line 14 release. These two releases represent real-case scenarios that would be expected to generate RDS alarms.

MBS Segment Rupture Test Results

The graphs of the historical suction and discharge pressures for the Line 14 and Line 6B ruptures are shown below.

Figure 2 – Line 14 Rupture Trend

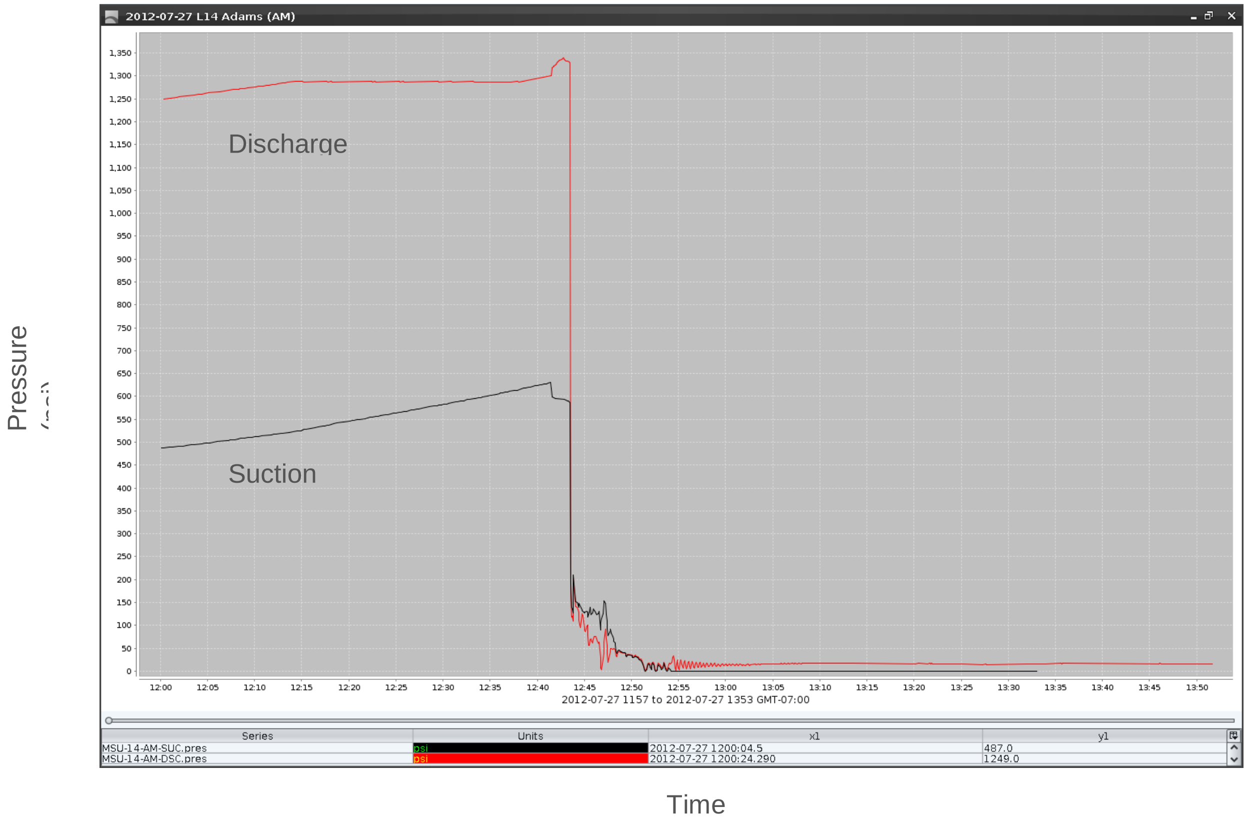
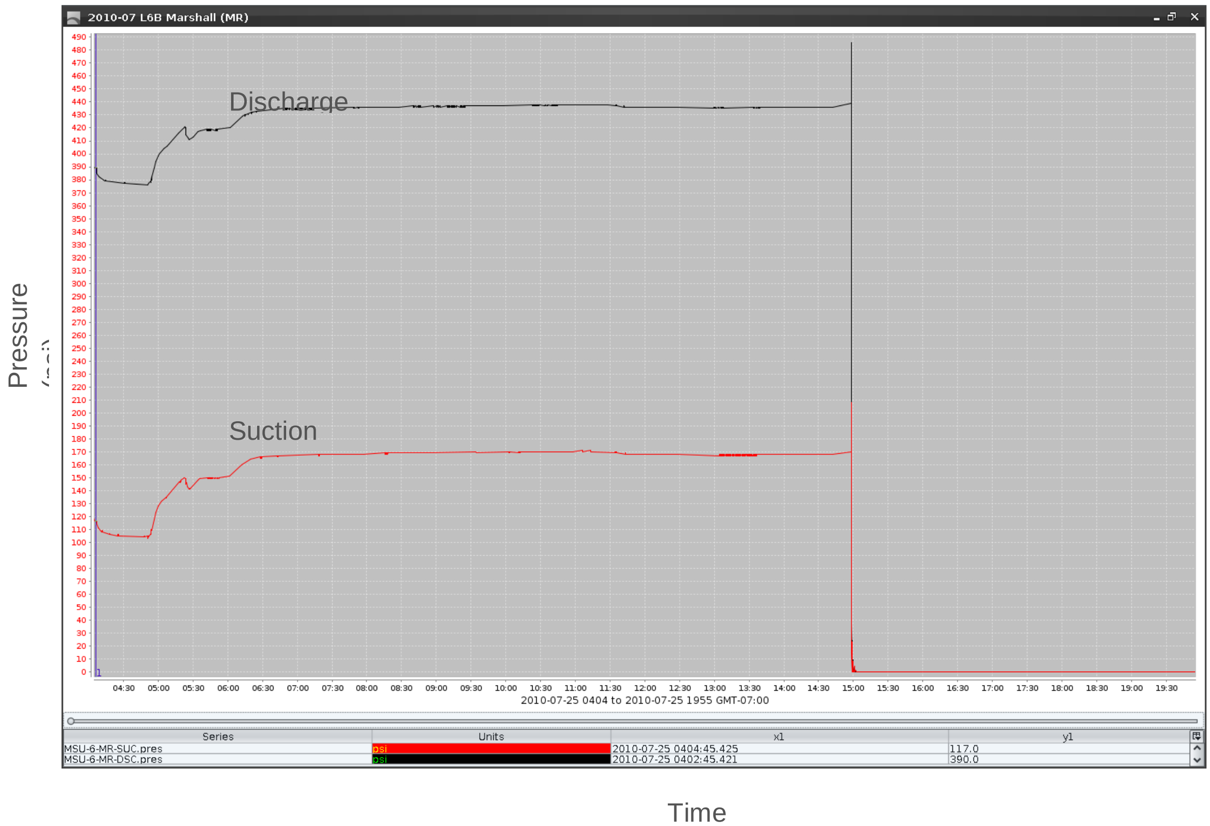


Figure 3 – Line 6 Rupture Trend



Testing of the RDS based on the Line 14 and Line 6B events demonstrates that the RDS would alarm in the event of a sudden pressure drop on both sides of a pump station. The following table illustrates the key details pertaining to the RDS's accurate generation of an alarm in response to the two events:

Line #	Station	Time	Steady Discharge (psi) and Suction (psi) BEFORE rupture	Discharge and Suction pressures (psi) AFTER rupture (1 minute later)	Discharge and Suction pressure changes (psi) in 5 seconds	Time to detect rupture*
14	AM	2012-07-27	Discharge: ~1330 Suction: ~590	Discharge: ~100 Suction: ~130	Discharge: -787 psi Suction: -267 psi	**10 seconds**
6	MR	2010-07-25	Discharge: ~480 Suction: ~200	Discharge: ~1 Suction: ~3	Discharge: -250 psi Suction: -108 psi	**10 seconds**

For Line 14, the key attribute to the RDS accurately generating an alarm was due to the extreme sudden discharge pressure change (large rate of change), which is indicative of a rupture based on the tuned threshold.

For Line 6B, the RDS accurately generated an alarm due to a number of attributes, and not only based on the discharge pressure change. Specifically, the rate of change of the discharge pressure is not nearly as large as the change occurring with the Line 14 rupture and the tuned threshold. Thus, the rate of change of discharge pressure alone did not determine the discharge pressure change on Line 6B to be a rupture. However, a combination of the calculated rate of change, along with the low equalization (calculated to be -149 at the time of rupture), suction and discharge pressures (relative to the tuned thresholds for each factor) resulted in the RDS algorithm correctly categorizing the Line 6B event as a rupture. Thus, the RDS would be expected to continuously monitor abnormal operating conditions on all Lakehead system pipelines and similarly generate an alarm in the event of a sudden pressure drop on both sides of a pump station of any MBS segment, during both steady state and transient state operations.

Summary

Enbridge has implemented the RDS on the Lakehead system prior to the effective date of the Consent Decree as required. The RDS is continuously operational and is integrated with existing Enbridge Leak Detection systems, including the SCADA and MBS systems. In accordance with Paragraph 102 of the Consent Decree, the RDS continuously reads and analyzes real-time operational data and generates an alarm if abnormal conditions are identified during both steady state and transient state operations. The RDS-generated alarm alerts the Control Room operator and all members of Enbridge's Alarm Response Team of a rupture, and proceeds to automatically initiate a shutdown of the affected pipeline. In accordance with Paragraph 102(c), Enbridge has successfully tested two separate MBS Segments (on Lines 6B and 14) to confirm that the RDS operates as required under Paragraph 102 to continuously monitor Enbridge pipelines during transient and steady-state conditions, and reliably detect a rupture based on one or more of the following: abnormally low pressure, and/or abnormal pressure drop. The successful and reliable alarms generated as a result of the testing those two MBS Segments, as well as testing based on the Enbridge historical data set, demonstrate that the RDS is able to detect a rupture and generate an alarm within 10 seconds of the rupture event while resulting in minimal false alarms. Thus, targets of high reliability have been exceeded and Enbridge has confirmed that the RDS will successfully detect and generate an alarm in the event of a sudden pressure drop on both sides of a pump station of any MBS segment on a Lakehead system pipeline.