Fahn, Patrick J.

From: Ken Crowl [ken_crowl@transcanada.com]
Sent: Thursday, June 02, 2011 2:32 PM
To: Fahn, Patrick J.; Jeffcoat-Sacco, Illona
Cc: Vern Meier; Jim Krause
Subject: Keystone Ludden Pump Station Release
Attachments: 0 Ludden Operations Data Summary 2011 05 11.pdf; Ludden Swage Nipple Failure Investigation.pdf; Ludden Corrective Action and Restart Plan.pdf

Mr. Fahn and Ms. Jeffcoat-Sacco,

Attached are the three documents that were submitted to the Pipeline and Hazardous Materials Safety Administration Central Region regarding the release at the Keystone Ludden Pump Station that was requested.

We are in the process of trying to locate any applicable environmental submittals also. If any are found they will be forwarded also.

If you have any questions please contact me directly.

Regards,

Ken Crowl Ken Crowl
Manager, US Regulatory Compliance
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734 PU-06-421 Filed: 6/2/2011 Pages: 34
Ludden Pump Station failure - documents provided by PHMSA

TransCanada Keystone Pipeline, LP

Ken Crowl

TransCanada
In business to deliver

Operations Data Summary for Ludden Pump Station

Prepared for the Pipeline and Hazardous Materials Safety Administration

Prepared by: Oil Pipelines Commercial Operations
Revision: 0.0
Issue Date: May 11, 2011

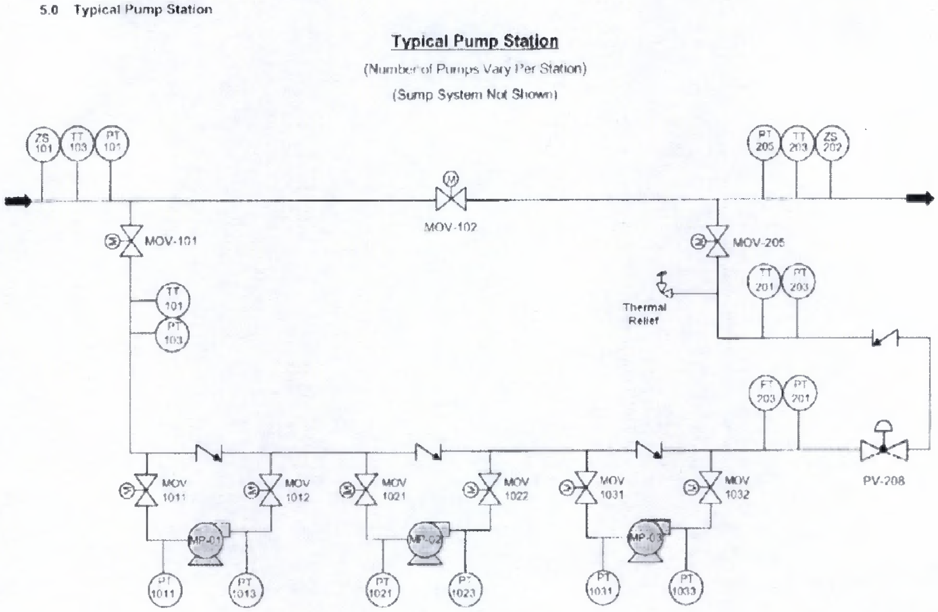
1 Background

PHMSA has requested the following data from TransCanada with regard to the May 7th, 2011 incident at Ludden, ND pump station.

1. Mainline Suction Pressure (PT-0101)
2. Station Suction Pressure (PT-0103)
3. Mainline Discharge Pressure (PT-0205)
4. Station Discharge Pressure (PT-0203)
5. Flow (FT-0203)
6. Ludden Station SCADA and HMI alarms

A schematic of a typical TransCanada pump station is provided below which illustrates the relative location of the station pressure transmitters and flow meter.

5.0 Typical Pump Station



This report contains the above data in spreadsheet format as requested by PHMSA. Specifically, the data is provided for a period of 5 minutes prior to the incident and 6 minutes following the incident. In addition, TransCanada has provided a summary interpretation of the data provided.

2 Data Sources

The data provided in this report has been made available from the following sources.

Data Description	Instrument Name	Data Sources	Description
Mainline Suction Pressure	PT-0101	Station DataLogger, SCADA	Mainline Suction Pressure upstream of station suction valve, MOV-101
Station Suction Pressure	PT-0103	SCADA	Station Suction Pressure downstream of station suction valve, MOV-101
Mainline Discharge Pressure	PT-0205	Station DataLogger, SCADA	Mainline Discharge Pressure downstream of station discharge valve, MOV-105
Station Discharge Pressure	PT-0203	SCADA	Station Discharge Pressure downstream of PCV-208
Flow Rate	FT-0203	SCADA	Flow rate at station ultrasonic flow meter

Station DataLogger

The above instruments (PT-0101, PT-0205) report data to a chartless DataLogger on a time interval of 0.1 seconds. These instruments have been installed specifically for the purpose of accurately recording transient pressure excursions in order to continuously improve TransCanada's modeling and predictive capabilities.

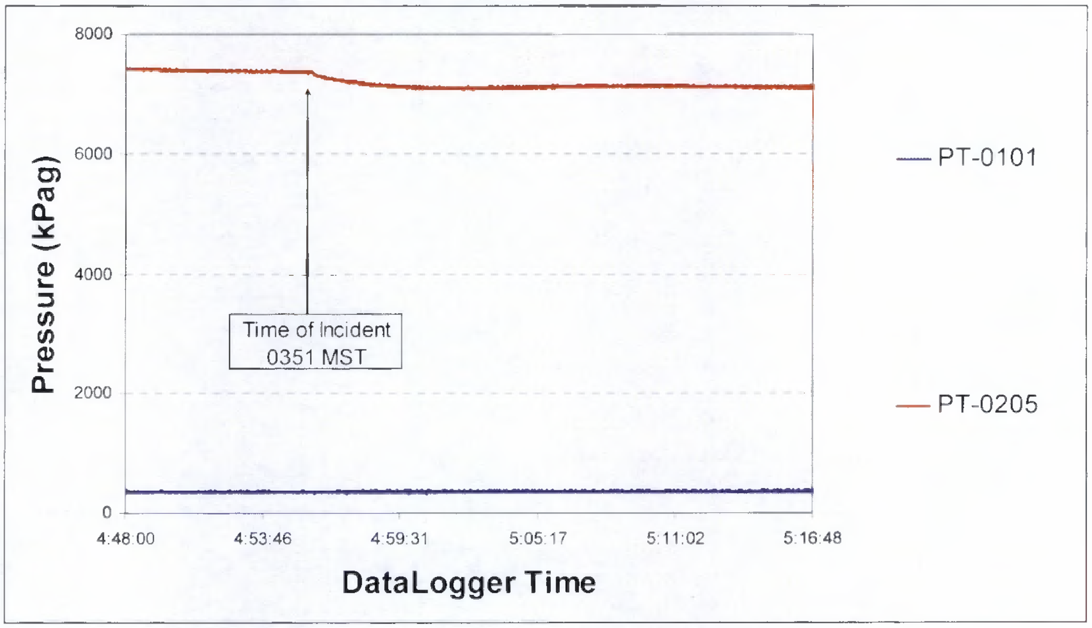
SCADA

The above instruments (PT-0101, PT-0103, PT-0205, PT-0203, FT-0203) also report data to the central Supervisory Control and Data Acquisition (SCADA) system and are available on 1 minute intervals.

3 Data from Station DataLogger

Appendix A provides the raw pressure data for PT-0101 and PT-0205. This data is furnished on a time interval of one second commencing at 04:50:00 to 05:30:00 Mountain Daylight Time (MDT) May 7, 2011.

The data from Appendix A is shown graphically below. The Ludden Mainline Suction Pressure (PT-0101) is constant at 350 kPag throughout the time period shown. The Ludden Mainline Discharge Pressure (PT-0205) shows a trending decrease in pressure from approximately 7360 kPag commencing at approximately 0456 MDT May 7, 2011.



The pressures shown above from the Ludden Station DataLogger are confirmed to be accurate. When the DataLogger is configured to a time step interval of less than 2 seconds, a time synchronization error between the DataLogger and the Station HMI results.

Based on the screen data from the Ludden Station HMI provided in Appendix C, the time synchronization error between the Station DataLogger and HMI is approximately + 65 minutes. This difference includes a 60 minute offset to reflect the time difference between Mountain Standard Time (MST) and Mountain Daylight Time (MDT).

Based on the above data, the actual decrease in Mainline Discharge Pressure (PT-0205) commenced at approximately 0351 MST May 7, 2011. Analysis of this data confirms this time to be commencement of the Ludden incident.

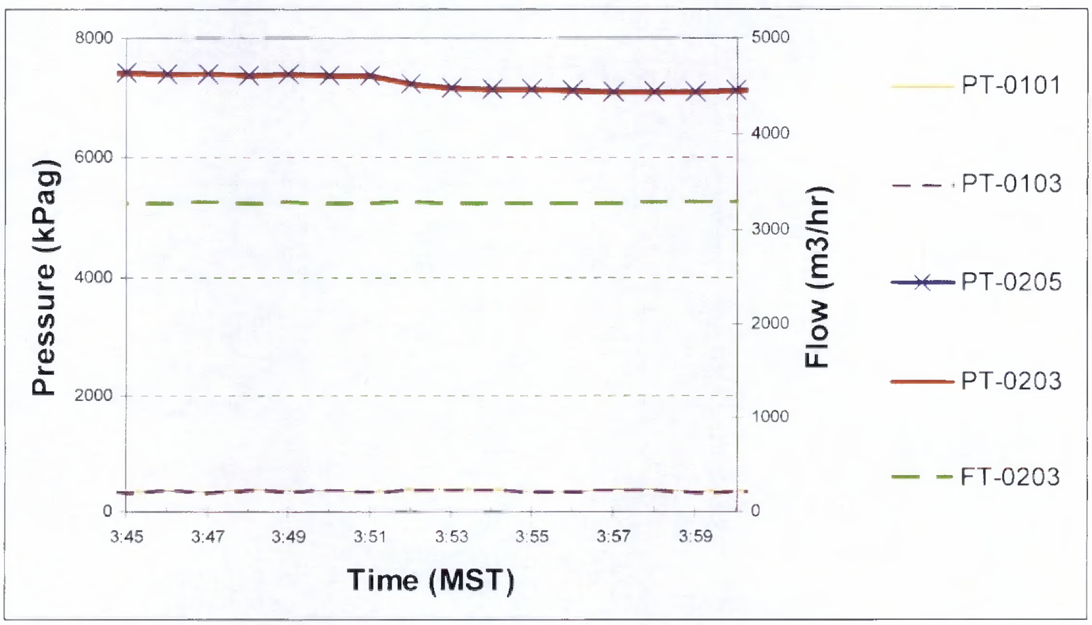
While the minor pressure drop in the discharge pressure shown would not initiate an alarm in SCADA, it was observed as anomalous by the Controllers. Based on the pressure drop as validated through a review of all other operating parameters, the controller escalated the issue in preparation for initiating a system shutdown. Just prior to shutting down the line based on the controller's assessment, a leak at the Ludden station was reported by a landowner.

4 Historical SCADA Data

Appendix B provides the data for PT-0101, PT-0205, PT-0203 and FT-0203. This historical data is furnished on a time interval of one minute commencing at 03:45:00 to 04:00:00 Mountain Standard Time (MST) May 7, 2011.

The historical data from Appendix B is also shown graphically below. As shown with the data from the station DataLogger, the Ludden Mainline Suction Pressure (PT-0101) from the historical SCADA data is constant at 350 kPag throughout the time period shown. The Ludden Station and Mainline Discharge Pressure (PT-0203 and PT-0205) show a trending decrease in pressure from approximately 7360 kPag to 7160 kPa commencing at approximately 0351 MST May 7, 2011. The historical SCADA data correlates to the station DataLogger data provided in Section 3 to confirm the commencement of the Ludden incident to be 0351 MST May 7, 2011.

The Ludden Flow Rate provided by Flow transmitter (FT-0203) is constant at approximately 3270 m^3/hr throughout the time period shown.



Throughout the incident period, all SCADA communication between Ludden Station and the Oil Control Center system has been confirmed to be functioning normally.

5 Ludden Station SCADA and HMI Alarms

Appendix D provides the data from the Ludden Station HMI event log as per the screen shots provided in Appendix C.

Appendix E provides screen shots and Excel data files of the SCADA events centered on the Ludden Station incident and SCADA confirmation of ESD and isolation of the Ludden pump station facility. Highlights of this data include:

- No significant events were reported from the Ludden pump station to SCADA in the 11 minute interval surrounding the incident.
- A sectionalize command was issued to Ludden pump station at 04:28:55 MST May 7, 2011.
- An ESD command was issued to Ludden pump station at 04:36:37 MST May 7, 2011.
- Confirmation of closed status for the Ludden pump station suction and discharge valves was received at 04:38:49 MST and 04:39:33 MST on May 7, 2011 respectively.

6 Conclusion

A review of the pressure data provided establishes the Ludden Station incident event occurred at 0351 MST May 7, 2011 and that the incident was not associated with a pressure excursion. This data further validates the SCADA communication and hardware design as providing sufficient accuracy and sensitivity to support industry leading leak detection.

The results of this incident demonstrate that all system operations associated with the Ludden incident were operating as designed. These systems include: Ludden pump station operation and data measurement, SCADA communications and control, Oil Control Center operating systems and procedures and landowner awareness and response.

APPENDIX A: RAW PRESSURE DATA FROM LUDDEN STATION DATALOGGER

Separate Excel File:

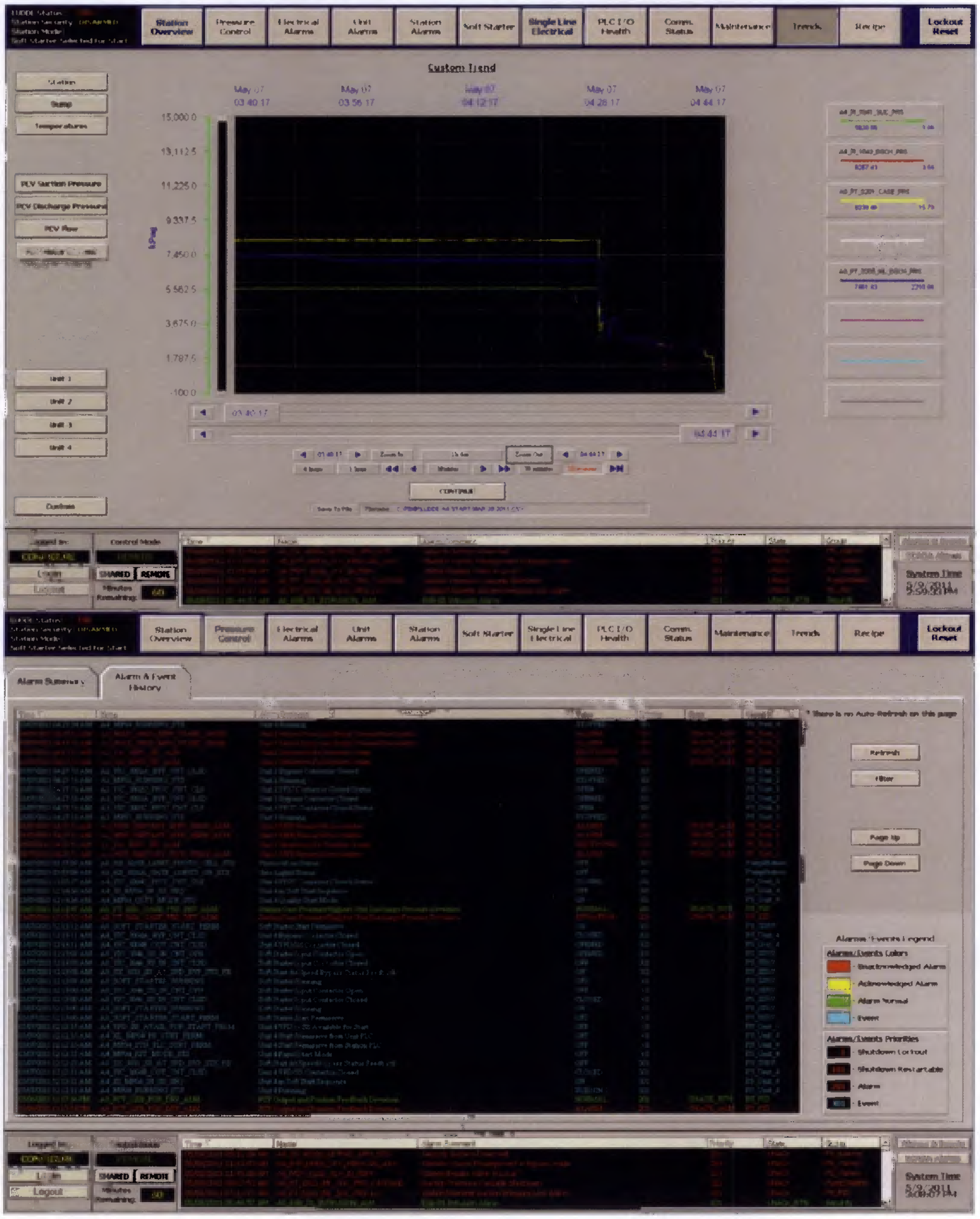
1 Ludden DataLogger 2011 05 07.xls

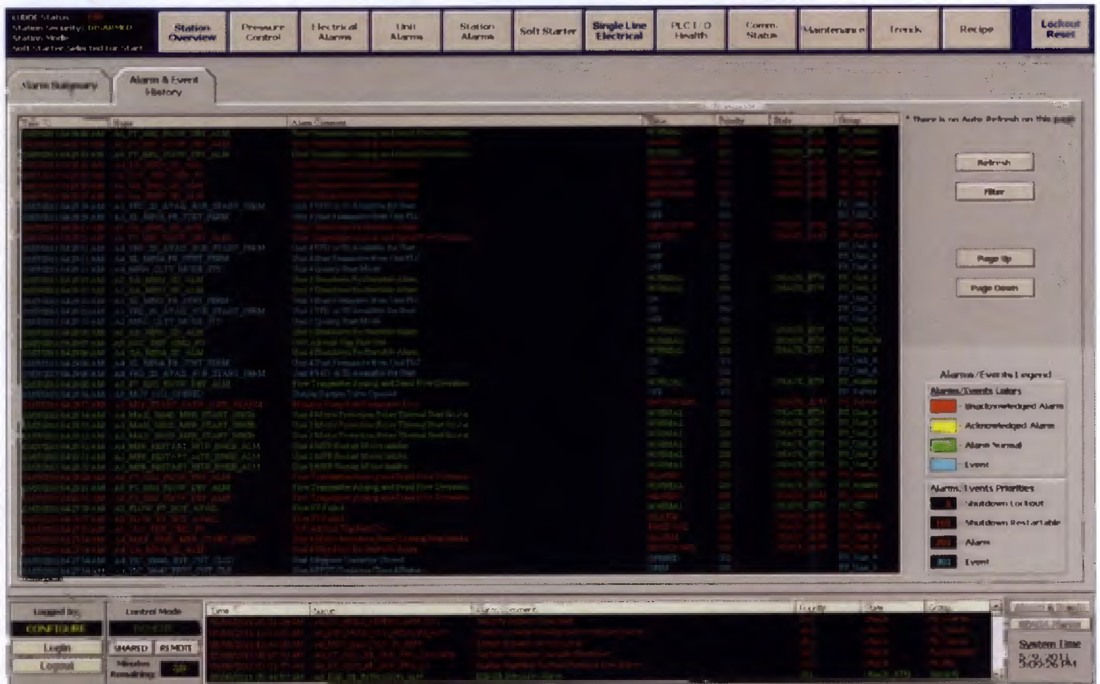
APPENDIX B: HISTORICAL SCADA DATA

Separate Excel File:

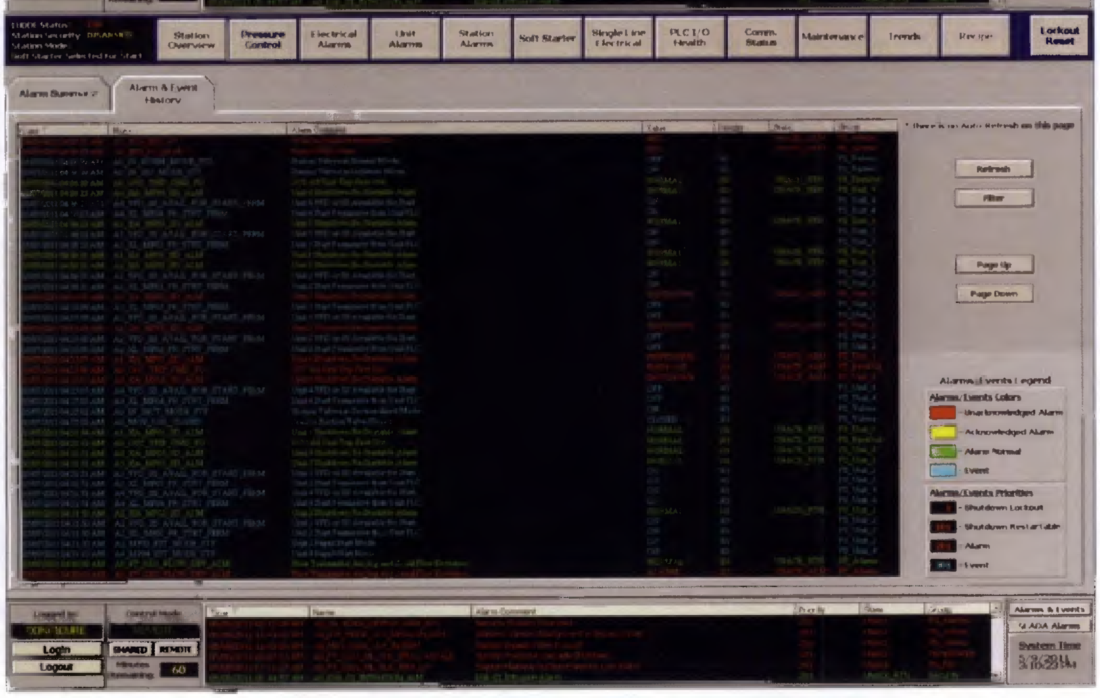
2 Ludden Historical SCADA Data 2011 05 07.xls

APPENDIX C: HMI SCREEN SHOT – PROVIDED TO PHMSA MAY 9, 2011





Station Overview
Pressure Control
Electrical Alarms
Unit Alarms
Station Alarms
Soft Starter
Single Line Electrical
PLC I/O Health
Comm. Status
Maintenance
Trends
Recipe
Lockout Reset
Alarm Summary
Alarm & Event History
Refresh
Filter
Page Up
Page Down
Alarms/Events Legend
Unacknowledged Alarm
Acknowledged Alarm
Alarm Normal
Event
Login
Logout
System Time



Station Overview
Pressure Control
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Page Down
Alarms/Events Legend
Unacknowledged Alarm
Acknowledged Alarm
Alarm Normal
Event
Login
Logout
System Time

APPENDIX D: LUDDEN HMI ALARMS

Separate Excel File:

3 Ludden HMI Event Log 2011 05 06.xls

APPENDIX E: SCADA ALARMS – LUDDEN INCIDENT

Separate Files:

4 Ludden Pump Station ESD Event and Valve Closure Confirmation 2011 05 07.jpg

5 Ludden Pump Station Shutdown 2011 05 07.xls

6 Ludden Pump Station SCADA Events Centered on Incident 2011 05 07.xls

7 Ludden Pump Station SCADA Events Centered on Incident 2011 05 07.jpg

LUDDEN SWAGE NIPPLE FAILURE INVESTIGATION

12 May 2011

TCPL Investigation Team: Cindy Guan, Materials Engineering
Bruce Dupuis, Keystone Pipe Integrity
Robert Lazor, Materials Engineering

Blade Investigation Team: Ming Gao, Materials Engineering
Uday Arumugam, Materials Engineering

1 DESCRIPTION OF FAILED COMPONENT

The configuration of the piping assembly containing the failed fitting as found at the field site is depicted in Figure 2. The vertical leg of the piping includes the following: NPS 1 weldolet on run pipe, NPS 1 nipple, NPS valve, NPS 1 nipple, NPS 1tee, NPS 1 x ¾ swage nipple, NPS ¾ union, and finally PSV.

The piping assembly containing the failed fitting was shipped to Blade Energy Partners in Houston, who coordinated the testing with the primary laboratory being Anderson & Associates, Inc. The assembly as received by Blade on May 10th is depicted in Figure 4.

The swage nipple had separated at the last thread exposed against the connected union as shown in Figure 5.

Figure 2 Failed Assembly as Found

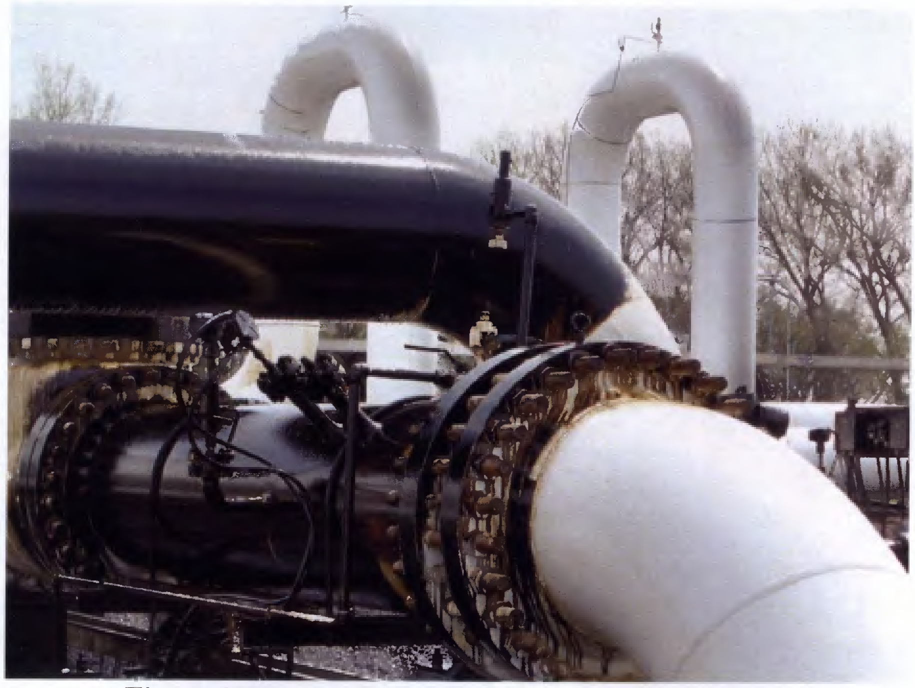

Figure 3: View of Failed Piping Assembly Location

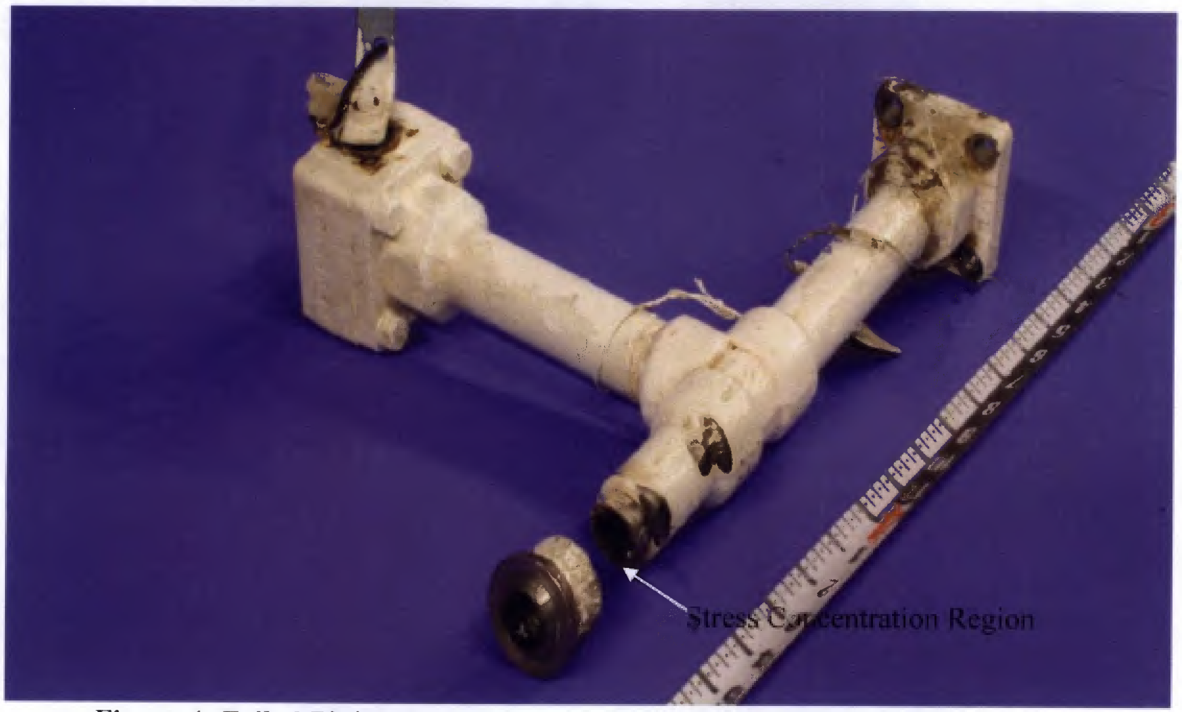

Figure 4: Failed Piping Assembly sent to Lab for Analysis, As-received

Figure 5: Matching Fracture Surfaces, As-received

2 FAILURE ANALYSIS INVESTIGATION

Blade Energy Partners and Anderson & Associates are engaged for this failure analysis investigation.

The scope of work included:

- Chemical analysis to validate that the material composition meets the specification
- Stress-strain curve test to confirm the fitting meets specified mechanical properties
- Visual examination and macro-photography on the fracture surface to identify the characteristic of the fracture, the nature of failure, and the failure initiation points
- Scanning Electron Microscopy (SEM) examination of the fracture surfaces to characterize the fracture propagation
- Microstructure examination of cross-sections to determine microstructure of the material and identify deformations.

Figure 6 shows the swage nipple marking information, indicating that the nipple had been produced using ASTM A420 WPL6. ASTM A420, Specification of Piping Fittings for Wrought Carbon Steel and Alloy Steel for Low-Temperature Service, [1] This material specification is correct for this application.

Figure 6: Stamped Markings on Swage Fittings

---

[1] The drawings for this piping shows A333 Gr 6, Specification for Seamless and Welded Steel Pipe for Low Temperature Service as the intended material. It would appear that the ASTM A420 was properly substituted for the swage nipple.

2.1 Chemical Analysis

The chemical analysis of the swage nipple was compared against ASTM A420 WPL6, and the results confirm that the nipple met the chemistry requirements of ASTM A420 WPL6.

Table 1: Swage Nipple Chemical Analysis Results in Comparison with Specified ASTM A 420 WPL6 Requirements

Element Composition, %	Swage Nipple	ASTM A420 WPL6, Max %
Carbon	0.20	0.30
Manganese	1.02	0.15-1.35
Phosphorus	0.010	0.035
Sulfur	0.016	0.040
Silicon	0.23	0.15-0.40
Nickel	0.09	0.40
Molybdenum	0.04	0.12
Chromium	0.16	0.30
Copper	0.11	0.40
Aluminum	0.024	
Vanadium	0.004	0.08
Titanium	<0.002	
Niobium	<0.002	0.02
Cobalt	0.007	
Boron	<0.0005	
Iron	Balance	

2.2 Mechanical Properties

The tensile and yield strength properties of swage nipple was measured using meet the requirements of the specified ASTM A420 WPL6, minimum yield strength of 35 ksi and tensile strength between 60 and 95 ksi. The average of five measurements using SSM (stress-strain microprobe) indicate a yield strength of 41 ksi and tensile strength of 74 ksi, confirming that the nipple meets the requirements of ASTM A420 WPL6.

Test Location	Engineering YS		Engineering UTS	
	MPa	ksi	MPa	ksi
1	270	39.2	495	72
2	279	40.5	506	73
3	277	40.2	508	74
4	287	41.6	524	76
5	279	40.5	511	74
6	283	41.0	512	74
Average	279.3	**40.5**	509.2	**73.9**
Stdev	5.5	**0.8**	9.4	**1.4**

2.3 Visual Examination and Macro-photography

Preliminary examination using a stereo microscope indicated that there were three distinct zones on the fracture surface (see Figure 7), and will be identified as Zones 1, 2, and 3.

Zone 1 represents an area of crack initiation is located around the entire circumference of the first thread visible on the surface with numerous crack initiation sites. Zone 2 extends approximately 150 degrees around the circumference, with crack propagation from the OD towards the ID, characterized with coarse ratchet (radial ridge) marks. The ratchet marks are indicative of fatigue. The remainder of the fracture surface, Zone 3 exhibits a slanted dull gray featureless surface that is typically associated with ductile shear failure.

The observations suggest that fracture had radiated from one side of the threaded connection, thus indicating that bending stresses had contributed to the failure.

Figure 7: Close-up View of the Failure Surface Defined by Zones 1, 2 &3, As-received

The ID surface of the swage nipple (Figure 8) shows some secondary cracking below the fracture surface and indicates that this side of the fitting would have been subjected to high tensile bending stresses.

The as-received parts were cleaned before further examination.

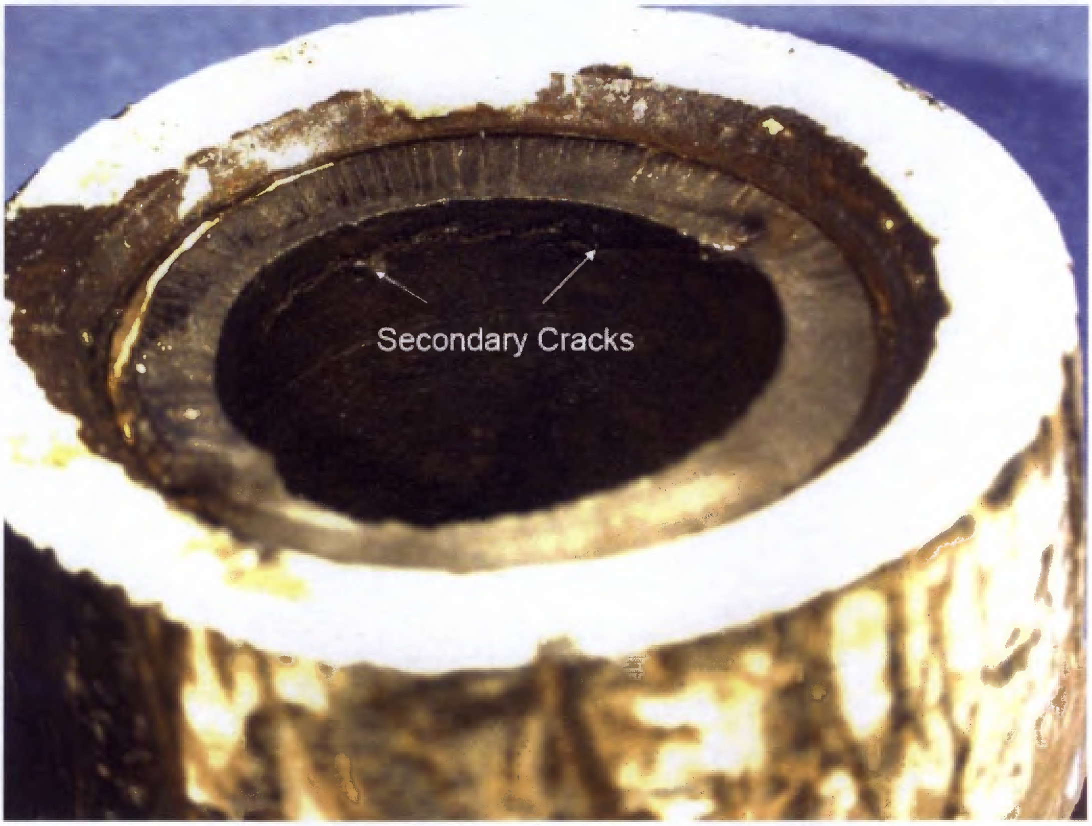

Figure 8: Secondary Cracks on the ID Surface of the Swage Nipple, As-received

2.4 Scanning Electron Microscope (SEM) Examination

Scanning electron microscopy was used to examine the fracture surfaces, focusing on determining the cause for crack initiation and propagation. Figure 9 shows the plastic deformation on the root of the first thread, which may be due to over torque during installation. At the edge of the 'smeared' root there are numerous shallow cracks that extend towards the ID of the nipple.

Figure 10 shows multiple parallel striations typical of fatigue fracture and commonly associated with cyclic bending stress fatigue. This finding is consistent with the macro examination indicative of fatigue by the ratchet marks.

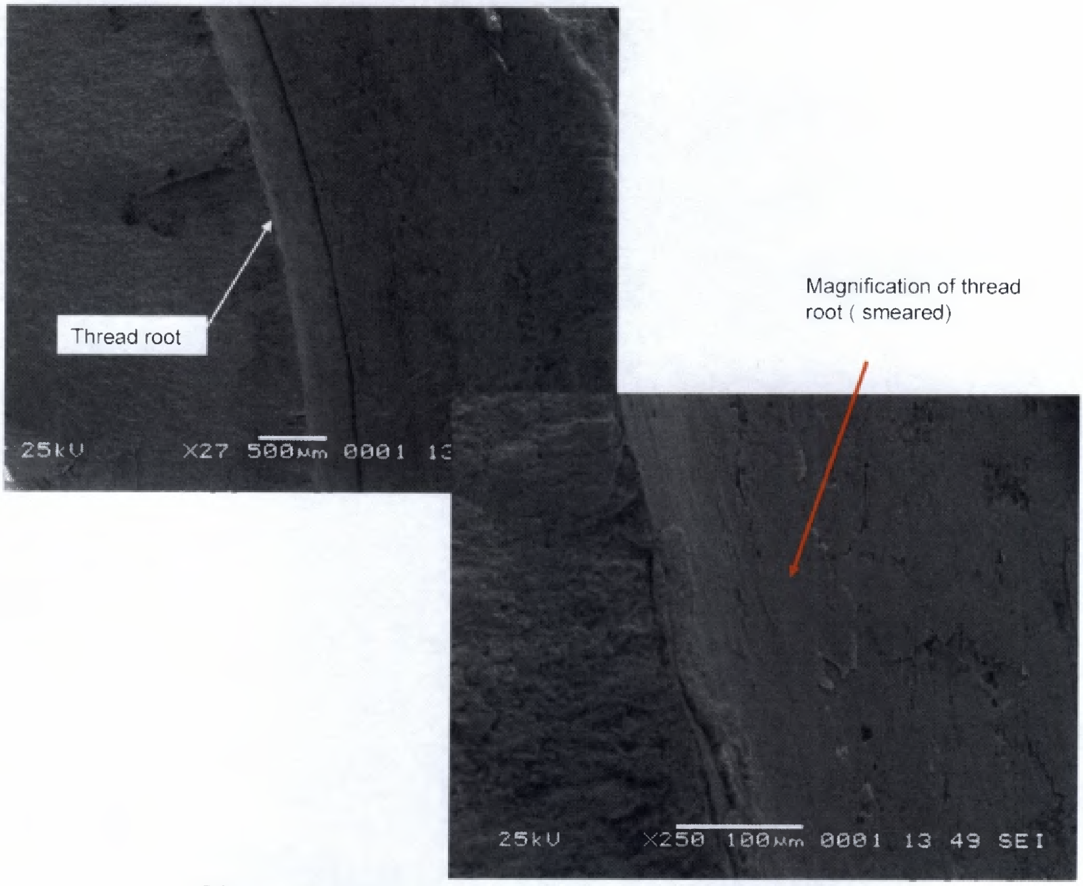

Figure 9: Appearance on the Root of the First Thread

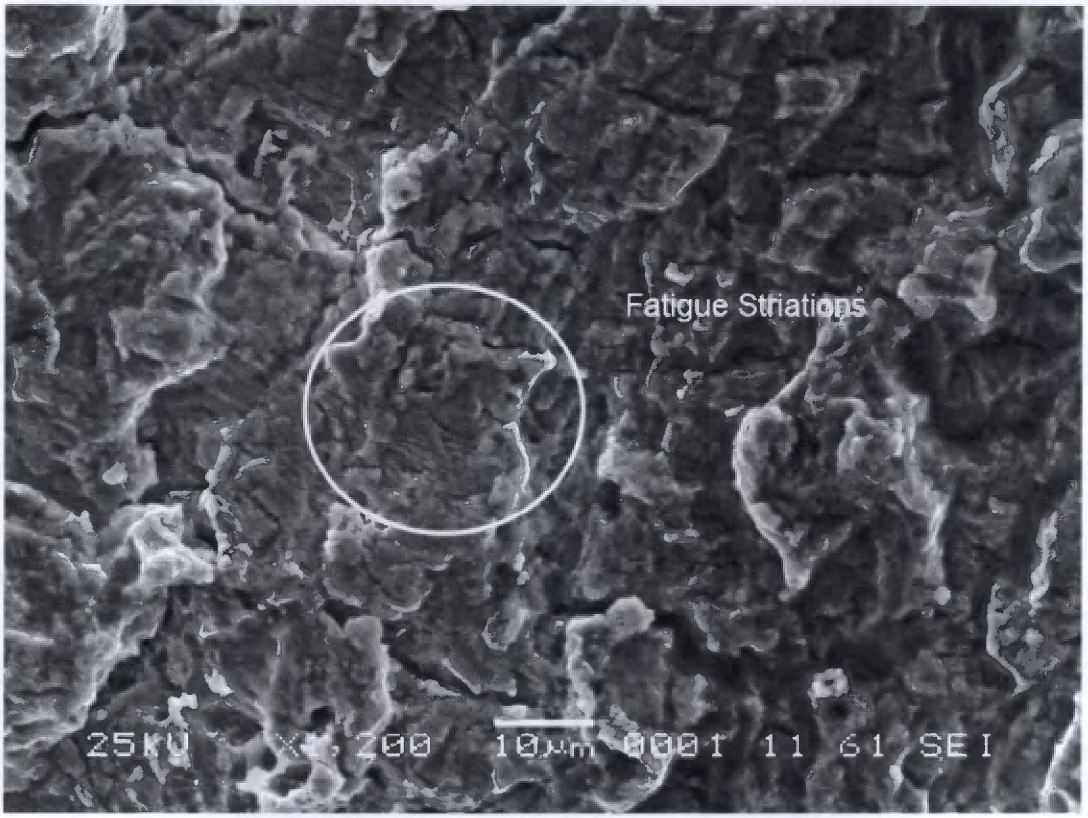

Figure 10: Typical Fatigue Fracture Defined by Striations

2.5 Microstructure Examination

Cross-sections of the swage/union were prepared from both parts for microstructural examination, and specifically to confirm the expected microstructures, to examine for evidence of material defects, and to determine if there are any regions of plastic deformation, the latter being indicative of overstressing at the threaded connection. Figure 11 shows the swage union section cracks and engaged threads. Figure 12 shows straight secondary cracks that had initiated at the root of the third thread. Figure 13 is the close-up view of Fig. 12 with an etched sample. The secondary crack is straight and transgranular, which is consistent with cyclic stress fatigue. The root of the thread was heavily deformed, which is consistent with the observation of the smeared surface apparent in Figure 9.

The general microstructure shows typical ferrite and pearite carbon steel features, a fine distribution of inclusions, and no evidence of gross microstructural defects.

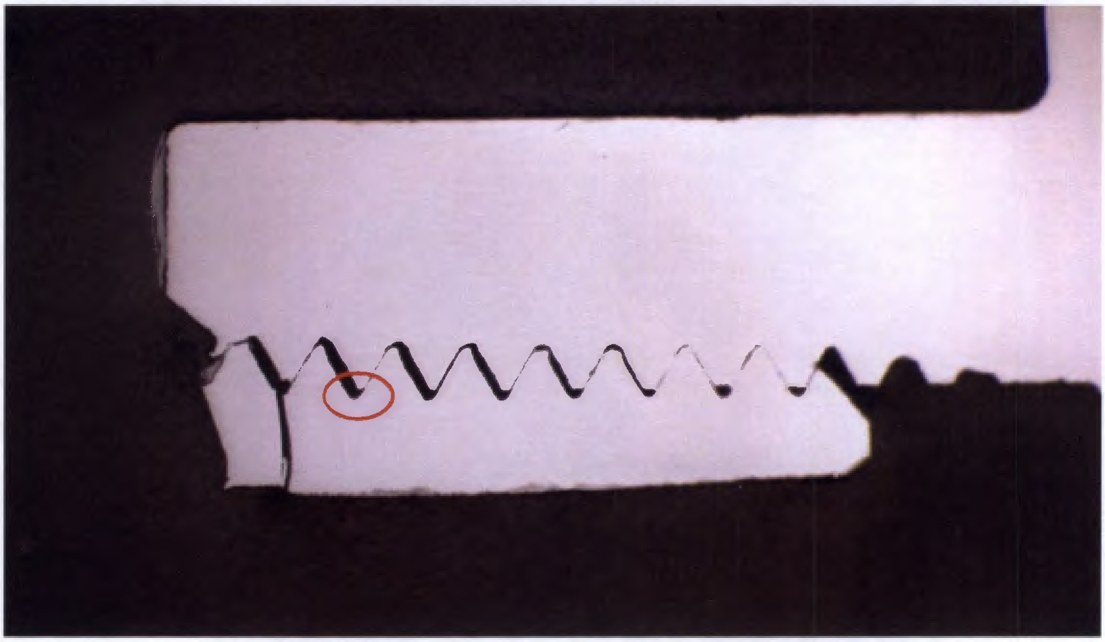

Figure 11: Location and Orientation of Microstructure Sample Highlighting the Root of the Third Thread

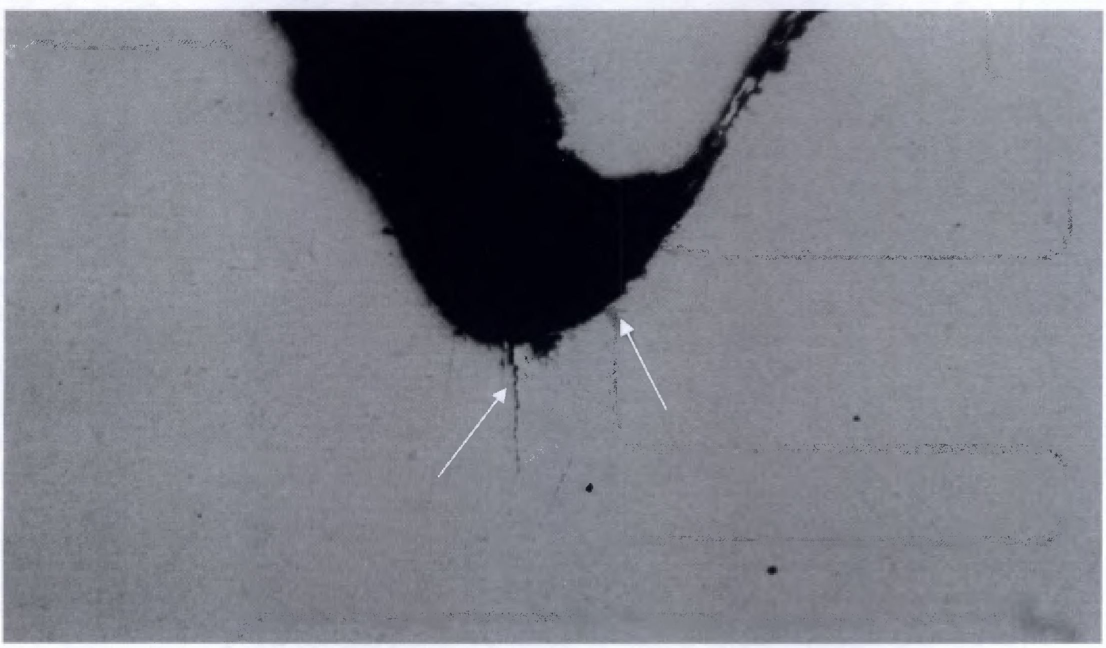

Figure 12: Secondary Cracks (White Arrows) on the Root of the Third Thread, Unetched, 50X

Figure 13: Secondary Crack on the Root of the Third Thread, Etched, 400X (Note that this view is inverted to the one shown in Figure 12.)

2.6 Summary and Conclusions

The piping associated with the failure at Ludden Station on the Keystone Pipeline was examined to determine the cause of failure. The investigation focused on the material of construction, observations of the fracture surfaces, mechanical testing, and metallographic examination of the fracture and microstructure of the failed component, a swage nipple.

The failure is not due to the material itself The ASTM A420 WPL6 is the correct material for the swage nipples, and the results of the examinations confirmed that this material was used. The chemical compositions, mechanical properties and microstructure meet the requirements for ASTM A420 WPL6.

The swage nipple failure had initiated from shallow cracks associated with plastic deformation at the root of the thread, likely as a result of over-torque during installation. The cyclic bending stress fatigue due to the vibration propagated the cracks to failure.

The observations consistent with this conclusion are:

- The fracture had initiated from the root of the first thread at several locations, and there were multiple secondary cracks found on the root of the second and third threads. The roots of the threads exhibited smeared surfaces,which acted as stress raisers and led to crack initiation.
- The fracture surfaces have multiple ratchet marks, the fracture surfaces exhibited parallel striations, and corresponding cross-sections across these features indicated straight transgranular cracks, all of which are indicative of fatigue crack growth.
- Fractures radiated from one side of threads, which is consistent with failure due to bending stress due to the vibration of the piping assembly.

LUDDEN SWAGE NIPPLE
CORRECTIVE ACTION and RE-START PLAN

12 May 2011

TCPL Investigation Team:

Cindy Guan, Materials Engineering
Bruce Dupuis, Keystone Pipe Integrity
Robert Lazor, Materials Engineering
Mark Kuczynski, Major Equipment

1 INTRODUCTION

The following are objectives of this report:

- Identify the primary failure mode and contributing elements for the failure of the 1" x ¾"swage fitting located on the thermal relief valve piping tied into the discharge line of the Ludden, ND pump station.
- Identify the corrective actions required to ensure non-recurrence of these failure modes in preparation for system restart

2 BACKGROUND INFORMATION

2.1 Failure Event and Corresponding Operations

The Ludden pump station is located in Sargent County, North Dakota along TransCanada's Keystone Oil Pipeline. Land use is agricultural and is sparsely populated.

The Ludden station is not within a High Consequence Area nor could a release at Ludden flow into a High Consequence Area. Also of note is that the station piping is not associated with Keystone's special permit, as defined within the permit.

On May 7 at approximately 03:51 MST the Keystone Leak Detection System started to report an increasing 2 minute flow imbalance in the Ludden, ND to Ferney, SD section. By 04:05 MST the flow imbalance increased to 471 barrels per hour, or approximately 2.3% of the pipeline flow rate at the time. Keystone Oil Control Centre (OCC) personnel immediately started analysis of the flow imbalance trends. The 15 minutes trends showed a similar flow imbalance and the OCC personnel started preparations for Ludden station shutdown and isolation. At 04:26 MST, while the OCC personnel were in the process of completing the validation procedures associated with the pipeline shutdown, a call was received by TransCanada's call center (PDL) from a local farmer reporting a release at the Ludden pump station. Keystone system shutdown was initiated immediately and it was completed at 04:35 MST. TransCanada Emergency Response Procedures were initiated and a TransCanada Field Operations Technician was dispatched to Ludden to verify an oil release had occurred and to begin containment and control procedures as necessary. Verification of the release occurred upon arrival at site at 07:00 MST.

At the time of the failure at Ludden, Keystone oil flow was 494,140 BPD and Ludden pump discharge pressure was 1029 psig. A review of the station pressure data and the Leak Detection System trends confirmed that the commencement of the incident occurred at 03:51 MST May 7, 2011. Additional information surrounding the system operating conditions and events leading up to and after the incident are contained in the report titled Operations Data Summary for Ludden Pump Station submitted to PHMSA on May 11, 2011.

TransCanada Compliance notified the National Response Center (reference number 975573) at or about 07:55 MST upon confirming a product release had occurred. The release occurred due to a fracture of a 1" x ¾" swage nipple at the inlet to a thermal relief valve located on the station discharge piping. As a result of the fracture approximately 500 barrels of oil released, the majority of which was contained within the station property.

2.2 Pipeline Design

Keystone Pipeline System, including Ludden pump station started commercial operations in July 2010. The system consists of 30" and 34" pipeline and 50 pump stations in Canada and the US. Keystone transports diluted bitumen and synthetic crude oil from oil sands in Alberta to delivery terminals in Wood River and Patoka in Illinois, and Cushing in Oklahoma.

Each pump station has a thermal relief valve installed in the discharge piping. The purpose of the valve is to prevent overpressure of the station piping due to thermal expansion of crude oil within the piping, in the event of a station shut down and isolation from the mainline for a significant period of time. The thermal relief valves have ¾" male national pipe thread (MNPT) inlets and 1" female national pipe thread (FNPT) outlets.

The Ludden station utilizes fixed speed pumps and a pressure control valve (PCV) on the discharge line to control the station flow and pressure. The PCV is located approximately 30 feet upstream of the thermal relief valve pipe assembly that failed. This fixed speed pump configuration is utilized at 21 of the 50 pump stations along the Keystone system.

2.3 Operational History

The discharge piping portion of the Ludden station piping was pressure tested on September 13, 2009 and the entire station was released for commissioning on April 8, 2010. This station commenced commercial operations on July 1, 2010.

On April 26, 2011, an operator observed a minor oil leak at the swage nipple that failed. The operator isolated and inspected the component. No thread sealer was observed on the swage fitting threads. The operator applied thread sealer and reassembled the threaded connection. The corrective actions were completed and logged according to TransCanada Operating Procedures that same day.

A Facilities Engineering review was completed on this leak and a recommendation directing the installation of supports for the thermal relief valves at all Keystone pump stations was issued. No supports however could be installed before the Ludden incident on May 7.

3 SWAGE NIPPLE FAILURE INVESTIGATION

The failure investigation report titled Ludden Swage Nipple Investigation has been sent to PHMSA on May 12, 2011 and the summary section is copied below.

The piping associated with the failure at Ludden Station on the Keystone Pipeline was examined to determine the cause of failure. The investigation focused on the material of construction, observations of the fracture surfaces, mechanical testing, and metallographic examination of the fracture and microstructure of the failed component, a swage nipple.

The failure is not due to the material itself. The ASTM A420 WPL6 is the correct material for the swage nipples, and the results of the examinations confirmed that this material was used. The chemical compositions, mechanical properties and microstructure meet the requirements for ASTM A420 WPL6.

The swage nipple failure had initiated from shallow cracks associated with plastic deformation at the root of the thread, likely as a result of over-torque during installation. The cyclic bending stress fatigue due to the vibration propagated the cracks to failure. The observations consistent with this conclusion are:

- *The fracture had initiated from the root of the first thread at several locations, and there were multiple secondary cracks found on the root of the second and third threads. The roots of the threads exhibited smeared surfaces, which acted as stress raisers and led to crack initiation.*
- *The fracture surfaces have multiple ratchet marks, the fracture surfaces exhibited parallel striations, and corresponding cross-sections across these features indicated straight transgranular cracks, all of which are indicative of fatigue crack growth.*
- *Fractures radiated from one side of threads, which is consistent with failure due to bending stress due to the vibration of the piping assembly.*

4 CORRECTIVE ACTION and RE-START PLAN

Based on the findings in the failure investigation the work required to prevent similar failures has been focused on two areas:

- increasing mechanical strength of the swage nipple by replacing it with Schedule 160 nipple (the failed swage nipple was Schedule 80)
- elimination of the thermal relief valve piping vibration by installing proper pipe supports.

The above work will be completed at each pump station prior to returning that station to service. Although not required by any code, use of Schedule 160 nipples for all small diameter threaded connections is a best practice being adopted by TransCanada for Keystone. The thicker walls of the Schedule 160 materials will increase the fatigue strength of these fittings. Installation of Schedule 160 nipples will also significantly reduce the potential risk for over torquing the threaded end of the nipple during installation.

The return of the Keystone system to service will take place in stages as replacements and modifications are completed on a pump station system priority basis.

Stage 1

The failed swage nipple on the thermal relief piping at Ludden and similarly situated nipples at all Keystone pump stations will be replaced with Schedule 160 nipples to increase mechanical and fatigue strength. In addition, the thermal relief valve piping will be supported to eliminate strain due to vibration. An engineering analysis of the proposed support structure has been completed and has confirmed that this solution will reduce the low frequency vibration believed to have led to the failure. The above replacements and modifications will allow for Keystone system re-start and ramping up of flows over a period of days.

Stage 2

As the system is being returned to full service, vibration surveys will be completed at selected stations to verify the effectiveness of the new piping supports. Arrangement of the thermal relief valve piping at all Keystone pump stations will be further analyzed and modified where required with an objective to further optimize the configuration of the piping to improve the long term strength of the assembly. Piping supports installed in stage 1 will be further modified and additional supports added if required to match the new piping arrangements. In addition to the review and any improvements to the pressure relief piping a complete audit of the pump station piping design, including vibration surveys, will be completed. Particular attention will be paid to all small bore piping and all threaded connections.

Further Considerations

- TransCanada will propose to API that construction and maintenance of thread fitting assemblies should become a covered Operator Qualified task.
- investigate the opportunity to modify TransCanada's procedures for escalating field identified threaded joint issues related to high pressure, oil pipeline service
- investigate opportunities to improve TransCanada's installation and maintenance procedures relating to threaded fittings