

## **Disclaimer**

This Report, including the data and information contained in this Report, is provided to you on an “as is” and “as available” basis at the sole discretion of the Government of Alberta and subject to the terms and conditions of use below (the “Terms and Conditions”). The Government of Alberta has not verified this Report for accuracy and does not warrant the accuracy of, or make any other warranties or representations regarding, this Report. Furthermore, updates to this Report may not be made available. Your use of any of this Report is at your sole and absolute risk.

This Report is provided to the Government of Alberta, and the Government of Alberta has obtained a license or other authorization for use of the Reports, from:

Shell Canada Energy, Chevron Canada Limited. and Marathon Oil Canada Corporation, for the Quest Project

(collectively the “Project”)

Each member of the Project expressly disclaims any representation or warranty, express or implied, as to the accuracy or completeness of the material and information contained herein, and none of them shall have any liability, regardless of any negligence or fault, for any statements contained in, or for any omissions from, this Report. Under no circumstances shall the Government of Alberta or the Project be liable for any damages, claims, causes of action, losses, legal fees or expenses, or any other cost whatsoever arising out of the use of this Report or any part thereof or the use of any other data or information on this website.

## **Terms and Conditions of Use**

Except as indicated in these Terms and Conditions, this Report and any part thereof shall not be copied, reproduced, distributed, republished, downloaded, displayed, posted or transmitted in any form or by any means, without the prior written consent of the Government of Alberta and the Project.

The Government of Alberta’s intent in posting this Report is to make them available to the public for personal and non-commercial (educational) use. You may not use this Report for any other purpose. You may reproduce data and information in this Report subject to the following conditions:

- any disclaimers that appear in this Report shall be retained in their original form and applied to the data and information reproduced from this Report
- the data and information shall not be modified from its original form
- the Project shall be identified as the original source of the data and information, while this website shall be identified as the reference source, and
- the reproduction shall not be represented as an official version of the materials reproduced, nor as having been made in affiliation with or with the endorsement of the Government of Alberta or the Project

By accessing and using this Report, you agree to indemnify and hold the Government of Alberta and the Project, and their respective employees and agents, harmless from and against any and all claims, demands, actions and costs (including legal costs on a solicitor-client basis) arising out of any breach by you of these Terms and Conditions or otherwise arising out of your use or reproduction of the data and information in this Report.

Your access to and use of this Report is subject exclusively to these Terms and Conditions and any terms and conditions contained within the Report itself, all of which you shall comply with. You will not use this Report for any purpose that is unlawful or prohibited by these Terms and Conditions. You agree that any other use of this Report means you agree to be bound by these Terms and Conditions. These Terms and Conditions are subject to modification, and you agree to review them periodically for changes. If you do not accept these Terms and Conditions you agree to immediately stop accessing this Report and destroy all copies in your possession or control.

These Terms and Conditions may change at any time, and your continued use and reproduction of this Report following any changes shall be deemed to be your acceptance of such change.

If any of these Terms and Conditions should be determined to be invalid, illegal or unenforceable for any reason by any court of competent jurisdiction then the applicable provision shall be severed and the remaining provisions of these Terms and Conditions shall survive and remain in full force and effect and continue to be binding and enforceable.

These Terms and Conditions shall: (i) be governed by and construed in accordance with the laws of the province of Alberta and you hereby submit to the exclusive jurisdiction of the Alberta courts, and (ii) ensure to the benefit of, and be binding upon, the Government of Alberta and your respective successors and assigns.



## Heavy Oil

### Controlled Document

Quest CCS Project

# Quest CO<sub>2</sub> Pipeline Operations Report 2016

<b>Project</b>	Quest CCS Project
<b>Document Title</b>	Quest CO <sub>2</sub> Pipeline Operations Report 2016
<b>Document Number</b>	
<b>Document Revision</b>	2
<b>Document Status</b>	
<b>Document Type</b>	
<b>Control ID</b>	New
<b>Owner / Authors</b>	Adella Domm/Jordan Houtstra
<b>Issue Date</b>	July 24, 2017
<b>Expiry Date</b>	None
<b>ECCN</b>	None
<b>Security Classification</b>	
<b>Disclosure</b>	None

*Revision History shown on next page*

## Revision History

REVISION STATUS			APPROVAL		
Rev.	Date	Description	Originator	Reviewer	Approver
0	February 24, 2016	Issued for Annual Report	Stephen Tessarolo	Sofia Karmali	
1	February 24, 2017	Issued for Annual Report	Adella Domm	Wim Guijt	
2	July 24, 2017	Updated to address deficiencies from GoA	Jordan Houtstra	Sarah Kassam	

## Signatures for this revision

Date	Role	Name	Signature or electronic reference (email)

## Summary

This document summarizes the operation of the Quest CO2 pipeline in 2016 to satisfy the post-startup requirements of sections 2.1, 2.2, and 2.3 of the annual report.

## Keywords

Quest, CCS, CO2, pipeline

## DCAF Authorities

Date	Role	Name	Signature or electronic reference (email)

CO2 Pipeline Operations Report		01
Heavy Oil		

**TABLE OF CONTENTS**

- 1. PIPELINE COMMISSIONING SUMMARY.....4
  - 1.1. Cleaning, Dewatering, Dry-out.....4
  - 1.2. First Fill and Startup.....4
- 2. OPERATING SUMMARY .....4
  - 2.1. Capacity.....4
  - 2.2. Composition, Operating Conditions, Phase Behavior.....5
  - 2.3. Operating Issues and Lessons Learned .....8
- 3. PIPELINE INSPECTION AND MAINTENANCE .....9
- 4. CO<sub>2</sub> PIPELINE INSTALLED DEVIATIONS FROM DETAILED DESIGN .....9
- APPENDIX A: QUEST PIPELINE FIRST FILL PROCEDURE .....10

## 1. PIPELINE COMMISSIONING SUMMARY

The CO<sub>2</sub> pipeline was cleaned, dewatered and dried in 2014. Prior to first fill, the pipeline was being preserved by a low pressure nitrogen pad. The pipeline first fill with CO<sub>2</sub> and pressure up prior to injection occurred August 19<sup>th</sup> through 22<sup>nd</sup>, 2015.

### 1.1. Cleaning, Dewatering, Dry-out

Cleaning, dewatering and drying activities were undertaken by first running brush pigs through the line followed by foam pigs. Multiple pig trains were first pushed by dry air, followed by N<sub>2</sub>. In total, roughly 600 pigs were run through each pipeline section, until the penetration of debris into the foam pigs met the 1/4" spec. The final water dew point achieved was -48°C (target -45°C) in October 2014.

### 1.2. First Fill and Startup

Filling activities for the pipeline were only conducted during the day to minimize the impact to residents living near the pipeline at night due to noise concerns with venting CO<sub>2</sub>.

The initial fill of the pipeline was achieved by:

- 1) The low pressure N<sub>2</sub> pad was displaced with low pressure CO<sub>2</sub> from the compressor (pipeline pressure ~0.2 MPag during N<sub>2</sub> displacement). The N<sub>2</sub> was vented from the line until the composition changed to predominantly CO<sub>2</sub>, as measured by a portable gas detector.
- 2) The line pressure was increased to 4 MPag (gas phase CO<sub>2</sub>) and left to stabilize for roughly 24 hours to equalize temperatures and pressure across the line, as well as provide an opportunity for leak checking of the system. Wellhead pressure was equalized with the main line at this pressure level to minimize the pressure drop across the wellsite choke (flow valve) during initial injection.
- 3) Line pressure was then increased to 10 MPag (dense phase CO<sub>2</sub>) prior to commencing with injection.

A copy of the operations procedure has been included in Appendix A.

## 2. OPERATING SUMMARY

The following sections summarize the operating data obtained from 2016.

### 2.1. Capacity

The pipeline, as designed, was provided with significantly more capacity than required for day to day operation of the Quest asset (2.2 Mt/a installed vs 1.2 Mt/a required on a

CO <sub>2</sub> Pipeline Operations Report		01
Heavy Oil		

regular basis). Figure 1 below shows the daily averaged throughput in the line since commissioning in August 2015. The pipeline has demonstrated sufficient performance at or above the 1.2 Mt/a nameplate. Flow reduction in March/April 2016 was a result of reduced CO<sub>2</sub> capture due to low hydrogen demand at the Upgrader/Refinery.

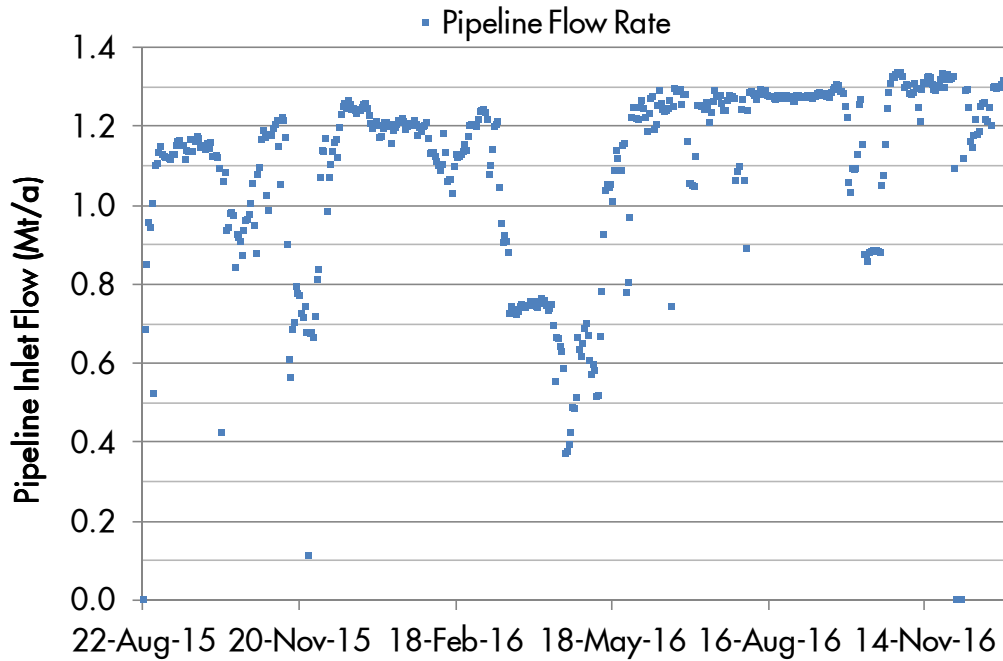


Figure 1: Pipeline Inlet Flow Rate (Mt/a)

## 2.2. Composition, Operating Conditions, Phase Behavior

The pipeline composition was fairly consistent during the operating period. The average annual composition has been indicated in Table 1 below. The composition compares well to the estimated composition from the design phase.

Table 1: Annual average pipeline composition

Component	Actual Operating 2015 (vol%)	Actual Operating 2016 (vol%)
CO <sub>2</sub>	99.45	99.38
H <sub>2</sub>	0.48	0.51
CH <sub>4</sub>	0.06	0.06
CO	0.02	0.02
N <sub>2</sub>	0	0
H <sub>2</sub> O	0.0046	0.0055

Table 2: Monthly average pipeline composition

MONTHLY DATA	Injection Stream Content (Volume %)				
	CO <sub>2</sub>	H <sub>2</sub>	CH <sub>4</sub>	CO	H <sub>2</sub> O
Jan-16	99.44	0.48	0.05	0.02	0.006
Feb-16	99.46	0.48	0.06	0.02	0.006
Mar-16	99.38	0.51	0.06	0.02	0.006
Apr-16	99.28	0.56	0.06	0.02	0.006
May-16	99.31	0.55	0.06	0.02	0.006
Jun-16	99.52	0.46	0.06	0.02	0.006
Jul-16	99.31	0.55	0.06	0.02	0.006
Aug-16	99.41	0.51	0.06	0.02	0.006
Sep-16	99.41	0.49	0.05	0.02	0.006
Oct-16	99.45	0.48	0.05	0.02	0.005
Nov-16	99.41	0.44	0.05	0.02	0.005
Dec-16	99.17	0.62	0.06	0.02	0.004

The pipeline water content was maintained on spec easily. Refer to the document "Quest CO<sub>2</sub> Dehydration Performance" for more information on water content over the reporting period. The average content on volume basis was 46 ppm for 2015 and 55 ppm in 2016 and 19 ppm for 2015 and 23 ppm for 2016 on a mass basis. This was well within the winter specification of 4 lb / MMScf (84 ppmv, 35 ppmw).

Since commissioning, the pipeline inlet pressure has been on average 9.7 MPag (9700 kPag) with an average pressure drop of around 0.6 MPa. Figure 2 below shows the daily average inlet pressure to the pipeline, and the average pressure drop from inlet to each wellsite in service.



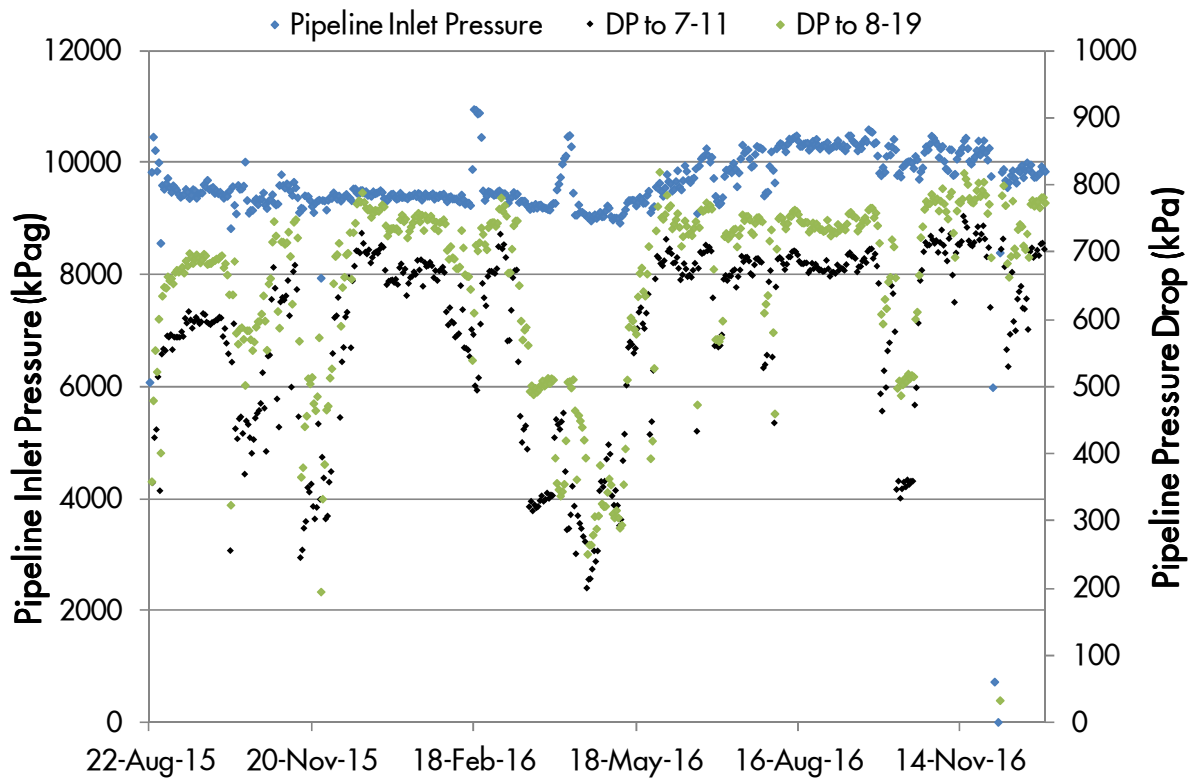


Figure 2: Pipeline Inlet Pressure and Pressure Drop to Each Wellsite

The temperature profile has been included in Figure 3. The inlet temperature for most of the year was maintained around 43°C, while the outlet temperature, depending on the wellsite, rate, and ambient conditions, was typically in the 8-20°C range. The further wellsite, 8-19, was on average 3-5°C cooler than 7-11 due to additional ambient heat loss over the extra line length.

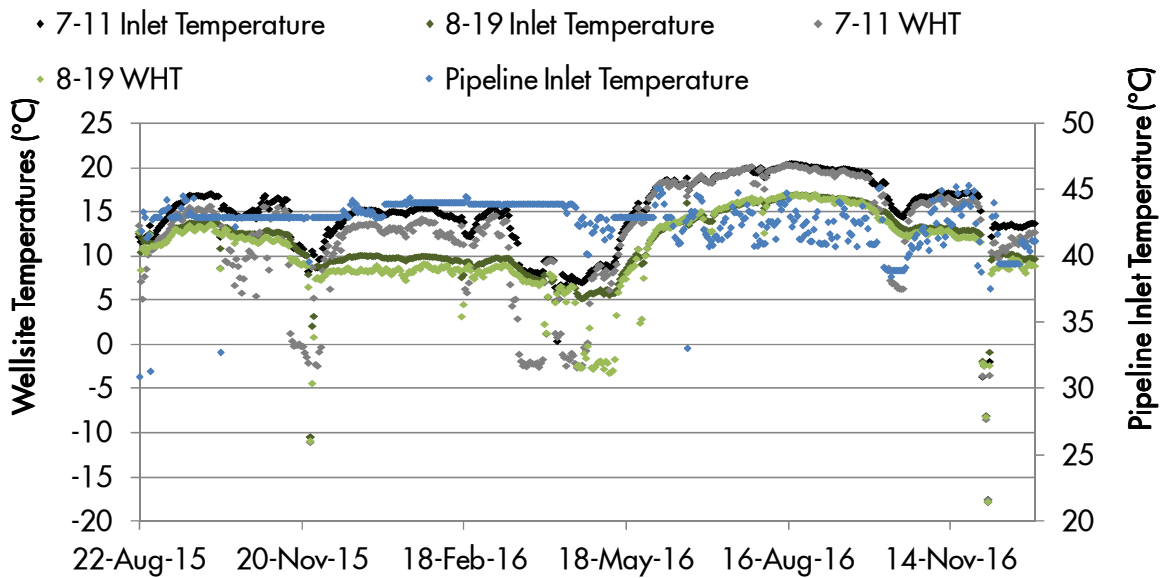


Figure 3: Pipeline Inlet Temperature and Temperatures at each Wellsite

Based on the process data in Figures 2 and 3, and the composition in Table 1, it can be concluded that the phase of the CO<sub>2</sub> leaving the Scotford site is in the supercritical phase (dense phase), and arriving at the wellsites the CO<sub>2</sub> is in the liquid phase (also referred to as dense phase typically in industry) since the pressure is above the critical pressure, but the temperature is below the critical temperature. This phase behavior held true for all operating periods in 2015, with the exception of the initial pressure up activities prior to August 23<sup>rd</sup>.

### 2.3. Operating Issues and Lessons Learned

- During the first fill, there was no acoustic or visual changes noticed when the vented stream changed from nitrogen to CO<sub>2</sub>. This was assessed to be due to venting dry CO<sub>2</sub> (no moisture) while the fluid was in the vapour phase in the line, so there was not a significant Joule Thompson cooling effect of the CO<sub>2</sub> causing condensation of water vapour in the air. A portable gas detector was used instead to check for the completion of the nitrogen displacement.
- The most significant reliability issue on the pipeline has been the power supply to the LBVs (line break valves). At LBV3 in particular, the solar panel/battery bank setup has had issues maintaining a decent charge on the batteries to manage nighttime operation in the winter during extended periods with overcast conditions. The problems were worst at LBV3 due to solar panel shading, and under-cycling the battery voltage leading to poor battery performance. This resulted in several near-loss of power events, and one actual pipeline trip due to closure of LBV3 because the power to the solenoid had dropped off. In 2016, methanol fuel cells were

installed at each LBV. These fuel cells provide supplemental charge to the LBV battery bank so that there is sufficient power during nighttime and overcast conditions.

- Actuation of the flow valve at each wellsite was done using a supply of compressed nitrogen. The style of valve in use was found to consume significant amounts of nitrogen when making moves to control tightly to a flow setpoint. This resulted in frequent deliveries of nitrogen bottles to the wellsites to mitigate the issue (not typically a problem when the valve is located at a large site, being fed off the common instrument air system). A change was made to the valve control scheme to adjust position when the flow measured was deviating from the setpoint by greater than ~2.5 tonnes/hr. The control scheme change along with some tuning of the valve itself, reduced nitrogen consumption to manageable levels.
- The control philosophy of the pipeline was to have the ability to run each wellsite flow valve (choke) in either pressure or flow control. Flow control has worked sufficiently, but controlling pipeline pressure directly off one of the wellsite flow valves proved difficult due to the large, pressurized volume of the 64 km line. Instead, the pipeline pressure was monitored by the panel operator, and flow setpoint adjustments were made to the wells when the pressure moved outside of the desired range.

### 3. PIPELINE INSPECTION AND MAINTENANCE

In 2015, no post startup inspection activities took place (with the exception of verifying that the cathodic protection was functioning properly), and no significant maintenance activities have occurred. No wellsite particulate filter replacements were required due to the extensive cleaning campaign taken in 2014. Only a few minor issues were addressed, such as the flow valve nitrogen consumption issues, and replacement of batteries/removal of the anti-climb device on the communications tower shading the solar panels at LBV3 and installation of methanol fuel cells at each LBV. During 2016, a pipeline smart pig was run through the line to satisfy the commitment made to perform an in-line inspection within the first year of operation. Results from the inspection indicate no active internal CO<sub>2</sub> corrosion in the pipeline.

### 4. CO<sub>2</sub> PIPELINE INSTALLED DEVIATIONS FROM DETAILED DESIGN

There were no significant deviations taken from the CO<sub>2</sub> pipeline detailed design phase. The only clarification required from the BDEP was that no chemical injection facilities (e.g. methanol) were ever installed, as the risk of hydrate formation/corrosion was managed completely by adequate drying of the CO<sub>2</sub> stream via the triethylene glycol (TEG) dehydration unit below the winter water content specification described above.

CO2 Pipeline Operations Report		01
Heavy Oil		

**APPENDIX A: QUEST PIPELINE FIRST FILL PROCEDURE**

Refer to the document "Quest Pipeline First Fill Procedure.pdf" for the operations steps required to fill, and pressure up the pipeline.

CO2 Pipeline Operations Report		01
Heavy Oil		