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Controlled Document

Quest CCS Project

Quest CO_2 Pipeline Operations Report 2017

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Signatures for this revision

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Summary

This document summarizes the operation of the Quest CO2 pipeline in 2017 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)

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1. PIPELINE COMMISSIONING SUMMARY

The CO_2 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_2 and pressure up prior to injection occurred August 19th through 22nd, 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_2. In total, roughly 600 pigs were run through each pipeline section, until the penetration of debris into the foam pigs met the ¼" 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_2.

The initial fill of the pipeline was achieved by:

1) The low pressure N_2 pad was displaced with low pressure CO_2 from the compressor (pipeline pressure ~0.2 MPag during N_2 displacement). The N_2 was vented from the line until the composition changed to predominantly CO_2, as measured by a portable gas detector.
2) The line pressure was increased to 4 MPag (gas phase CO_2) 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_2) 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 2017.

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 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. Major impacts to the pipeline flow rates in 2017 are listed below.

Feb 23-24 – A Power surge in the Cogeneration unit lead to a trip of the Amine charge pumps in the Quest capture unit.

May 7-16 – Quest spring turnaround to complete a compressor inspection and exchanger cleaning followed by Quest compressor trip testing after implementing MOC to re-rate the C-24701 compressor from 12MPa to 13.58MPa.

June 4-14: HMU3 trip resulting in reducing hydrogen production. Prolonged start up activities at reduced capture was required to prove unit reliability which resulted in reduced capture ratio's.

July 3-23: HMU3 unplanned shutdown resulting in reduced hydrogen production.

August 25 – Follow up Quest C-24701 compressor pinion inspection and lube oil nozzle replacement.

September 27 – October 13th – A&V1 furnace de-coke resulting in reduced hydrogen demand

October 23 to November 1 - A&V2 furnace de-coke resulting in reduced hydrogen demand.

November 16 – 25 – RHC3/4 valve packing leak resulting in reduced hydrogen demand.

December 29-31 – Low hydrogen production resulting in reduced capture to maintain fuel gas volumes and heating values.

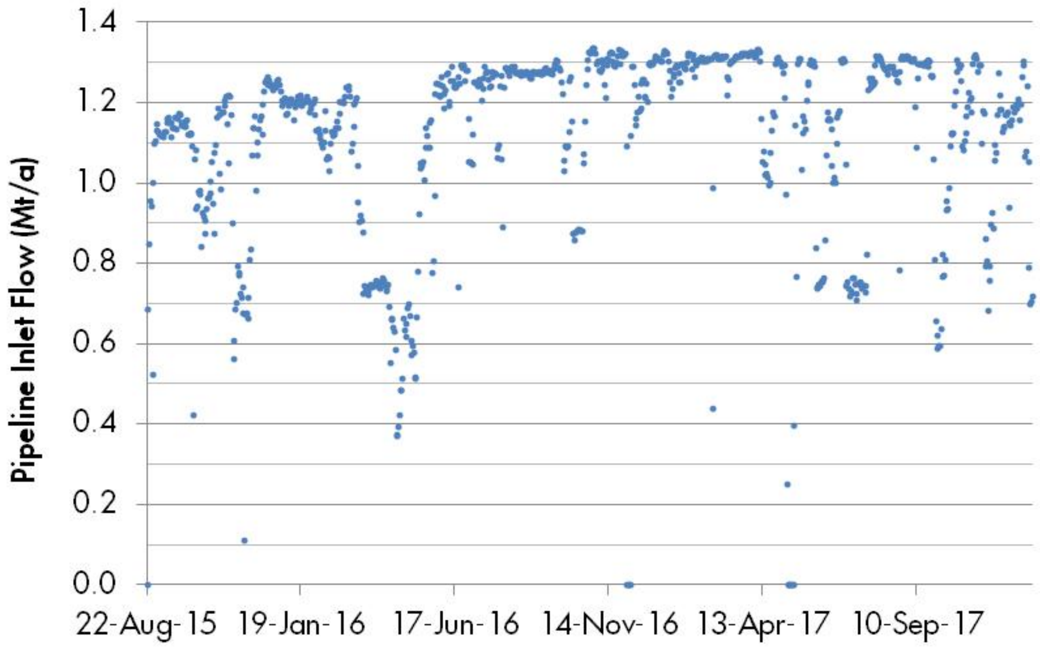

Figure 1: Pipeline Inlet Flow Rate (Mt/a)

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%)	Actual Operating 2017 (vol%)
CO_2	99.45	99.38	99.46
H_2	0.48	0.51	0.47
CH_4	0.06	0.06	0.06
CO	0.02	0.02	0.01
N_2	0	0	0
H2O	0.0046	0.0055	0.0046

Table 2: Monthly average pipeline composition

MONTHLY DATA	Injection Stream Content (Volume %)				
	CO_2	H_2	CH_4	CO	H_2O
Jan-17	99.59	0.42	0.05	0.008	0.004
Feb-17	99.50	0.46	0.06	0.001	0.004
Mar-17	99.44	0.48	0.06	0.008	0.005
Apr-17	99.41	0.47	0.06	0.006	0.005
May-17	99.53	0.48	0.06	0.008	0.005
Jun-17	99.49	0.51	0.06	0.005	0.004
Jul-17	99.40	0.50	0.06	0.007	0.004
Aug-17	99.45	0.47	0.06	0.004	0.004
Sep-17	99.43	0.48	0.06	0.004	0.005
Oct-17	99.43	0.48	0.06	0.006	0.005
Nov-17	99.45	0.48	0.06	0.010	0.005
Dec-17	99.46	0.46	0.06	0.010	0.005

The pipeline water content was maintained on spec easily. Refer to the document "Quest CO_2 Dehydration Performance" for more information on water content over the reporting period. The average content on volume basis was 46 ppm for 2015, 55 ppm in 2016 and 46 ppm for 2017. This equates to 19 ppm for 2015, 23 ppm for 2016 and 19 ppm for 2017 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 approximately 0.6 MPa to 8-19. Figure 2 below shows the daily average inlet pressure to the pipeline, and the average pressure drop from inlet to each wellsite in service.

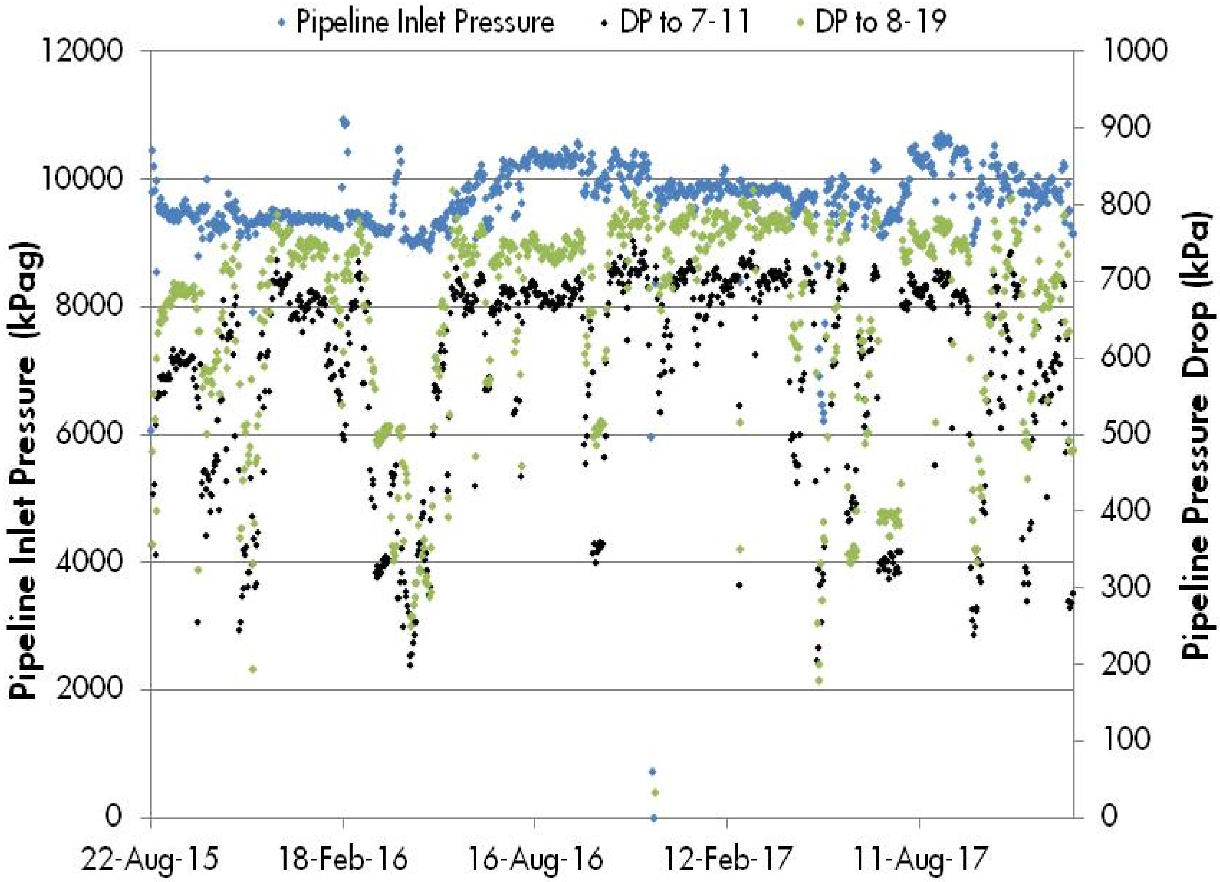

Figure 2: Pipeline Inlet Pressure and Pressure Drop to Each Wellsite

The temperature profile has been included in Figure 3. The pipeline inlet temperature averaged 40.5°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.

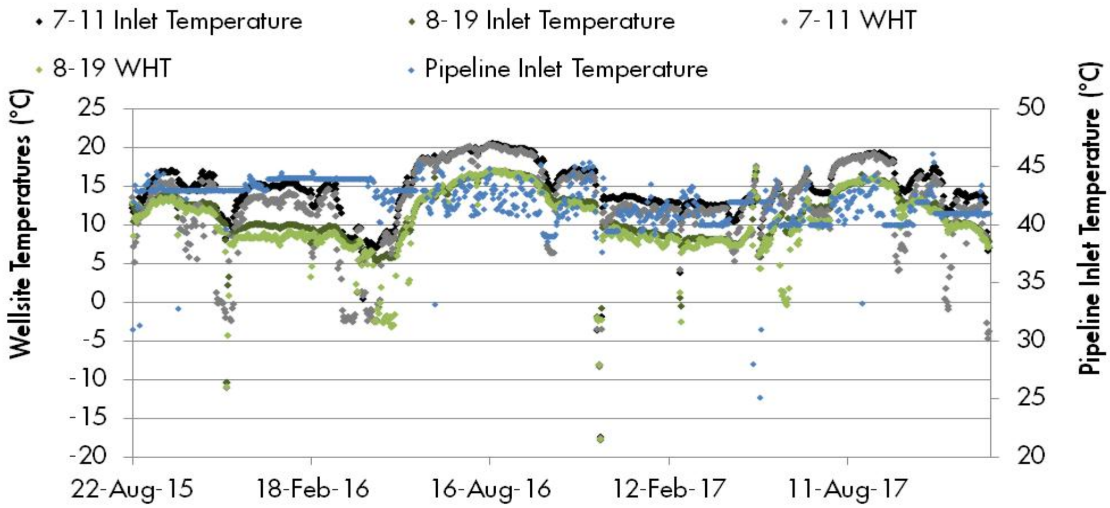

Figure 3: Pipeline Inlet Temperature and Temperatures at each Wellsite

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_2 leaving the Scotford site is in the supercritical phase (dense phase), and arriving at the wellsites the CO_2 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 between 2015 - 2017, with the exception of the initial pressure up activities prior to August 23rd.

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_2. This was assessed to be due to venting dry CO_2 (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_2 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. In 2017, the fuel cell methanol

consumption was optimized, using performance data collected from winter months, by modifying fuel cell switch-on voltage, absorption time, and maximum charge time. Solar charging during daytime hours was also optimized by connecting the solar charge sense lines to the batteries and compensating for the voltage drop losses.

- In 2017, the LBV sites had experienced a high number of intermittent communication issues during peak sun hours. Power quality measurements identified poor voltage quality at the radio transmitter power terminals due to solar charger pulse-width modulated output at peak sun hours. The power quality issues were resolved by redirecting stable power directly from the batteries to the radio transmitters.
- 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.
- LBV valves are maintained open with a hydraulic actuator unit. The unit on LBV3 has had periods of time where it was unable to maintain internal pressure and required intervention by operations to increase the pressure manually. Multiple attempts have been made to repair this unit but due to the complexity of the hydraulic skid; specialized maintenance personal are needed. Alternative options are currently being pursued to repair or replace the unit.

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, 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 with the AER to perform an in-line inspection within the first year of operation. Results from the inspection indicate no active internal CO2 corrosion in the pipeline however they did note a few external anomalies which were analyzed and determined not to be an integrity threat. These results were entered into Shell's proprietary software for risk based inspection, more specifically Shell's pipeline integrity management system (P-IMS), which assesses the inspection data, along with the risk and likelihood. Therefore, the P-IMS database provides the next inspection date and the local areas that require digging to further investigate. Based on the 2016 inspection findings, P-IMS has determined that the next smart pig should take place in 2021. Since the pipeline is relatively new, no areas have been identified that require a dig to further inspect. Regular ultrasonic testing inspections are completed for above ground launching and receiving stations, laterals, and block valve stations, along with corrosion probes that are inspected regularly at each well site to monitor for potential corrosion. Completing these routine inspections could alter the P-IMS results, possibly changing the next inline inspection date. In agreement with the AER, regularly scheduled fly overs (currently bi-weekly) are completed to check for any changes to the landscape and grade covering the pipeline.

4. CO_2 PIPELINE INSTALLED DEVIATIONS FROM DETAILED DESIGN

There were no significant deviations taken from the CO_2 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_2 stream via the triethylene glycol (TEG) dehydration unit below the winter water content specification described above.

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.