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### Controlled Document

Quest CCS Project

# Quest Operating Reliability Data Start-up to 2016 Year End

<b>Project</b>	Quest CCS Project
<b>Document Title</b>	Quest Operating Reliability Data Start-up to 2016 Year End
<b>Document Number</b>	
<b>Document Revision</b>	0
<b>Document Status</b>	
<b>Document Type</b>	
<b>Control ID</b>	
<b>Owner / Authors</b>	Josip Vaci
<b>Issue Date</b>	Feb 17, 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	Feb 17, 2017	Issued	Josip Vaci	Scott Cornelius Patrick Allen	
<ul style="list-style-type: none"> <li>All signed originals will be retained by the UA Document Control Center and an electronic copy will be stored in Livelink</li> </ul>					

## Signatures for this revision

Date	Role	Name	Signature or electronic reference (email)
Feb 17, 2017	Reliability Engineer	Josip Vaci	Feb 17, 2017 email

## Summary

The unplanned downtime from start-up Aug 23, 2015 to Dec 31, 2016 was 1.1%. There was planned downtime only in 2015, giving a total of 0.1% Planned Downtime as of 2016 year-end, and an overall operational availability of 98.8%. Component failure rate for pumps averaged 9.5 years Mean-Time-Between-Failures <sup>[2]</sup>, while CO2 Compressor availability was 100% during the same operating period.

## Keywords

Reliability, Unplanned Downtime, Planned Downtime, Availability, Unexpected, Expected, Component Failure Rate, MTTF, MTBF

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## Detailed Report - Actual Operating Data

This report seeks to document actual Quest Carbon Capture operating unit availability and component failure rate data from start-up on Aug 23, 2015 to Dec 31, 2016.

The unplanned downtime (unexpected down-time) for the said operating period was 1.1%. The two unplanned shutdown events of 2016 are as follows: loss of amine circulation due to amine charge pump trip on low pressure and trapped pig in the pipeline during pigging activities, resulting in loss of flow to well.

There was no planned downtime (expected down-time) in 2016, yielding an overall planned downtime of 0.1% for the stated operating period.

An overall operational availability of 98.8% was achieved from start-up to 2016 year-end.

The Mean-Time-Between-Failures (MTBF) for process pumps<sup>[2]</sup> was 9.5 years for the operating period, and due to spared operation did not lead to unit unplanned downtime. C-24701 compressor availability<sup>[3]</sup> was 100% for the same period, while Flue Gas Recycle machines in HMU1,2,3 (C-24103, C-24203, C-44105) achieved 99.9, 99.9, 100.0% availability, respectively.

Table 1 summarizes the above unit availability and component failure rate data, along with 2016 operating year data separately.

A listing of components and their respective failure rates can be seen in Table 2. Significant components are listed, basis the modeling study<sup>[1]</sup> along with some additional components including non-critical auxiliary pumps.

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**Table 1** – Quest Operating Reliability Data Summary

	Aug 23, 2015 to Dec 31, 2016	Jan 1, 2016 to Dec 31, 2016
Unplanned Downtime	1.1%	1.2%
Planned Downtime	0.1%	0.0%
Operational Availability	98.8%	98.8%
C-24701 Compressor Availability <sup>[3]</sup>	100.0%	100.0%
Pump MTBF <sup>[2]</sup>	9.5 yrs	28.0 yrs
C-24103 Flue Gas Recycle Fan	99.9%	100.0%
C-24203 Flue Gas Recycle Fan	99.9%	100.0%
C-44105 Flue Gas Recycle Fan	100.0%	100.0%

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**Table 2** – Quest Carbon Capture Component<sup>[5]</sup> Failure Data for operating period Aug 23, 2015 to Dec 31, 2016.

CO2 Capture Unit Equipment	Tag ID	MTBF <sup>[2,3,4]</sup>	Failure Rate <sup>[6]</sup>	Comments (year of failure)
Amine Absorber #1	V-24118	no failures	0	
Absorber #1 Water Wash Vessel	V-24119	no failures	0	
Absorber #1 Circulating Water Pump	P-24108A	1.4 yrs	0.7 per year	(2015) Bearing isolator misalignment, causing noise and vibration. Repaired isolator.
Absorber #1 Circulating Water Pump	P-24108B	no failures	0	
Absorber #1 Circulating Water Cooler	E-24129	no failures	0	
Amine Absorber #2	V-24218	no failures	0	
Absorber #2 Water Wash Vessel	V-24219	no failures	0	
Absorber #2 Circulating Water Pump	P-24208A	no failures	0	
Absorber #2 Circulating Water Pump	P-24208B	no failures	0	
Absorber #2 Circulating Water Cooler	E-24229	no failures	0	
Amine Absorber #3	V-44118	no failures	0	
Absorber #3 Water Wash Vessel	V-44119	no failures	0	
Absorber #3 Circulating Water Pump	P-44108A	1.4 yrs	0.7 per year	(2015) Bearing isolator misalignment, causing noise and vibration. Repaired isolator.
Absorber #3 Circulating Water Pump	P-44108B	no failures	0	
Absorber #3 Circulating Water Cooler	E-44129	no failures	0	
Lean/Rich Amine Exchangers	E-24602A	no failures	0	
Lean/Rich Amine Exchangers	E-24602B	no failures	0	
Amine Stripper	V-24601	no failures	0	
Stripper Reboiler	E-24603A	no failures	0	
Stripper Reboiler Condensate Pot	V-24603A	no failures	0	
Stripper Reboiler	E-24603B	no failures	0	
Stripper Reboiler Condensate Pot	V-24603B	no failures	0	
Lean Amine Pump	P-24601A	no failures	0	
Lean Amine Pump	P-24601B	no failures	0	
Lean Amine Pump	P-24601C	no failures	0	
Stripper Overhead Condenser	E-24601A	no failures	0	
Stripper Overhead Condenser	E-24601B	no failures	0	
Stripper Reflux Drum	V-24602	no failures	0	
Stripper Reflux Pump	P-24603A	no failures	0	
Stripper Reflux Pump	P-24603B	no failures	0	
Lean Amine Cooler	E-24604A	no failures	0	
Lean Amine Cooler	E-24604B	no failures	0	
Lean Amine Trim Cooler	E-24605A	no failures	0	
Lean Amine Trim Cooler	E-24605B	1.4 yrs	0.7 per year	(2016) Leaking plate pack on E-24605B (plate and frame style exchanger), requiring slowdown to repair
Lean Amine Charge Pump	P-24602A	1.4 yrs	0.7 per year	(2016) Loss of amine circulation due to both P-24602A/B amine charge pumps tripping on low pressure. Process Control logic was modified to avoid pressure drop during amine filter isolation activity.
Lean Amine Charge Pump	P-24602B	0.7 yrs	1.5 per year	(2016) Loss of amine circulation due to both P-24602A/B amine charge pumps tripping on low pressure. Process Control logic was modified to avoid pressure drop during amine filter isolation activity. (2016) Leaking Outboard Mechanical seal, requiring repair.
Lean Amine Charge Pump	P-24602C	no failures	0	

<b>CO2 Capture Unit Equipment – cont'd</b>	<b>Tag ID</b>	<b>MTBF<sup>[2,3,4]</sup></b>	<b>Failure Rate<sup>[6]</sup></b>	<b>Comments (year of failure)</b>
Stripper Inlet Valve 1		no failures	0	
Stripper Inlet Valve 2		no failures	0	
AMINE RE-INVENTORY PUMP	P-24604	no failures	0	
AMINE MAKE-UP PUMP	P-24605	no failures	0	
AMINE DRAIN PUMP	P-24607	no failures	0	
P-24608A REC CLEAN COND PUMP	P-24608A	1.4 yrs	0.7 per year	(2015) Bearing isolator misalignment, causing noise and vibration. Replaced isolator.
P-24608B REC CLEAN COND PUMP	P-24608B	no failures	0	
P-24609A WATER MKUP PUMP	P-24609A	no failures	0	
P-24609B WATER MKUP PUMP	P-24609B	no failures	0	
P24610A DEMIN PUMP	P-24610A	no failures	0	
P24610B DEMIN PUMP	P-24610B	no failures	0	
P-24611A COOLING WATER BOOSTER PUMP	P-24611A	no failures	0	
P-24611B COOLING WATER BOOSTER PUMP	P-24611B	no failures	0	
<b>CO2 Compression &amp; Dehydration System Equipment</b>				
6th Stage Cooler Fan/Motor	E-24706-1	no failures	0	
6th Stage Cooler Fan/Motor	E-24706-2	no failures	0	
6th Stage Cooler Fan/Motor	E-24706-3	no failures	0	
CO2 8-Stage Compressor Driver	C-24701	no failures	0	(2015) Multiple trips of pipeline caused by UV-24701 [C-24701] anti-surge valve opening, with compressor running on recycle. Slowdown did not exceed 25%. <sup>[3]</sup>
Compression 1st Stage Cooler	E-24701	no failures	0	
Compression 2nd Stage Cooler	E-24702	no failures	0	
Compression 3rd Stage Cooler	E-24703	no failures	0	
Compression 4th Stage Cooler	E-24704	no failures	0	
Compression 5th Stage Cooler	E-24705	no failures	0	
Compression Aftercooler Fan/Motor	E-24707A-1	no failures	0	
Compression Aftercooler Fan/Motor	E-24707A-2	no failures	0	
Compression Aftercooler Fan/Motor	E-24707A-3	no failures	0	
Compression Aftercooler Fan/Motor	E-24707B-1	no failures	0	
Compression Aftercooler Fan/Motor	E-24707B-2	no failures	0	
Compression Aftercooler Fan/Motor	E-24707B-3	no failures	0	
Compressor	C-24701	no failures	0	
Compressor 2nd Stage KO Drum	V-24702	no failures	0	
Compressor 3rd Stage KO Drum	V-24703	no failures	0	
Compressor 4th Stage KO Drum	V-24704	no failures	0	
Compressor 5th Stage KO Drum	V-24705	no failures	0	
Compressor 6th Stage KO Drum	V-24706	no failures	0	
Compressor 7th Stage KO Drum	V-24707	no failures	0	
Compressor 8th Stage KO Drum	V-24708	no failures	0	
Compressor Suction KO Drum	V-24701	no failures	0	
Lean TEG Cooler	E-24804A	no failures	0	
Lean TEG Cooler	E-24804B	no failures	0	
Lean TEG Cooler	E-24804C	no failures	0	
Lean TEG Cooler	E-24804D	no failures	0	



<b>CO2 Compression &amp; Dehydration System Equipment – cont'd</b>	<b>Tag ID</b>	<b>MTBF<sup>[2,3,4]</sup></b>	<b>Failure Rate<sup>[6]</sup></b>	<b>Comments (year of failure)</b>
Lean TEG Cooler	E-24804E	no failures	0	
Lean TEG Filter	V-24804A	no failures	0	
Lean TEG Filter	V-24804B	no failures	0	
Lean/Rich TEG Exchanger	E-24803	no failures	0	
TEG Absorber	V-24801	no failures	0	
TEG Flash Drum	V-24803	no failures	0	
TEG Inlet Scrubber	V-24707	no failures	0	
TEG Lean Pump	P-24801A	no failures	0	
TEG Lean Pump	P-24801B	no failures	0	
TEG Stripper	V-24802	no failures	0	
TEG Stripper Condenser	E-24801	no failures	0	
TEG Stripper Reboiler	E-24802	no failures	0	
TEG Stripper Reboiler Condensate Pot	V-24805	no failures	0	
TEG Surge Drum	V-24806	no failures	0	
<b>Pipeline Injection Equipment</b>				
Pipeline		0.7 yrs	1.5 per year	(2016) While working on Analyzer AI-247001, Analyzer AI-247002 Hydrogen content spiked false-high and shut valve to pipeline XV-247001, causing slowdown minutes in duration.  (2016) Trapped pig in the pipeline during pigging activities, resulting in loss of flow to well.
Line Block Valve 1	LBV1	no failures	0	
Line Block Valve 2	LBV2	no failures	0	
Line Block Valve 3	LBV3	1.4 yrs	0.7 per year	(2015) Fail closed due to low battery voltage. Solar charger and battery bank inadequately sized in terms of accounting for environmental conditions, system energy loss, accurate solar radiance data, and battery de-rating factors.
Line Block Valve 4	LBV4	no failures	0	
Line Block Valve 5	LBV5	no failures	0	
Line Block Valve 6	LBV6	no failures	0	
CO2 Particle Filter	S-70201	no failures	0	
CO2 Particle Filter	S-70202	no failures	0	
CO2 Particle Filter	S-70203	no failures	0	
Well Site #1		no failures	0	
Well Site #2		no failures	0	
Well Site #3		no failures	0	
<b>Non-Critical and Auxiliary Pumps</b>				
P-24606 ANTI FOAM INJECTION PUMP	P-24606	no failures	0	
SP-246026 SAFETY SHOWER	P-246101	no failures	0	
STORM WATER PUMP	P-24612	no failures	0	
LUBE OIL PUMP MOUNTED ON COMPRESSOR	P-24701	no failures	0	
SCE-AUXILIARY OIL PUMP FOR LUBE OIL SKID	P-24702	no failures	0	
HYDRAULIC PUMP	P-24703	no failures	0	
MANUAL HYDRAULIC PUMP	P-24704	no failures	0	

## References and Notes

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[1] Reliability, Availability and Maintainability Report addressing

sparing, RRM and turndown – Doc No. 07-0-NA-8239-0002 – Aaron Balaban - Issued 2014-08-22

[2] Following Shell methodology, auxiliary pump failure data is not utilized when calculating overall pump MTBF (Mean Time Between Failures), but is presented in this report for additional information. Overall pump MTBF figure also excludes any repairs to driver, auxiliary lube oil skid, process control systems, and process and utility piping. Functional failures of the pump component (outside MTBF definition above), that impacted Operational Availability (unplanned shutdown) or incurred a unit slowdown greater than 25% of unit capacity are reported adjacent to the component, and included in the pump's individual MTBF (and Failure rate) in Table 2.

[3] Following Shell methodology, compressor (C-24701) availability excludes any repairs to driver, process control systems, process and utility piping. Failures of excluded components that translated into shutdown or slowdown greater than 25% of unit capacity are reported in Table 2 in the adjacent 'Comments' section, and are included in MTBF for component C-24701. (none in 2015 or 2016)

[4] For remaining equipment (vessels, exchangers, etc.), MTBF is taken to mean functional failure of equipment, necessitating shutdown or a slowdown greater than 25% of unit capacity in order to repair.

[5] Component taken to mean equipment plus typical instrumentation (level alarms, pressure control, high temperature, etc.), in order to represent overall reliability figure.

[6] Failure rate expressed as failures per year, (1 divided by MTBF).

[7] Quest Operating Reliability Data Start-up to 2015 Year End – Rev 2 – Detailed Report Section 1.6, 2015 Submission – Josip Vaci

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