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Heavy Oil

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Quest CCS Project

Quest Power Efficiency and Parasitic Loss Summary

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Summary

This document provides a high level overview of Quest compressor efficiency and a discussion around parasitic losses in Quest.

Keywords

Quest, CCS, CO2, parasitic, power, compressor

DCAF Authorities

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1. POWER EFFICIENCY AND PARASITIC LOSS SUMMARY

This report presents a summary of the parasitic power losses associated with electrically driven equipment in Quest, and presents an efficiency overview of the CO_2 compressor, C-24701 for the first 15 months of operation (August 2015 – November 2016).

1.1. Quest Power Consumption – Normal Operating

Power to the Quest unit is primarily provided via two sources – high voltage power to the CO_2 compressor, and a low voltage system to drive pumps, fans and auxiliary equipment on the Quest plot. Power to the Quest pipeline is provided by solar panels, and power to the wellsites is source from the local electrical grid, but is insignificant in terms of magnitude.

The primary power consumer in the Quest CCS process is the CO_2 compressor driver. The compressor is equipped with a 16.5 MW electric driver, with typical operation in the 12-15 MW range. The Quest plot itself, for other electrical loads such as pumps, fans, etc. consumes on the order of 4 MW at rated load. The following figure displays the power consumption of the Quest compressor and non-compressor electrical loads over time alongside CO_2 capture rates, in millions of tonnes/annum (Mt/a), over the first 15 months of operation.

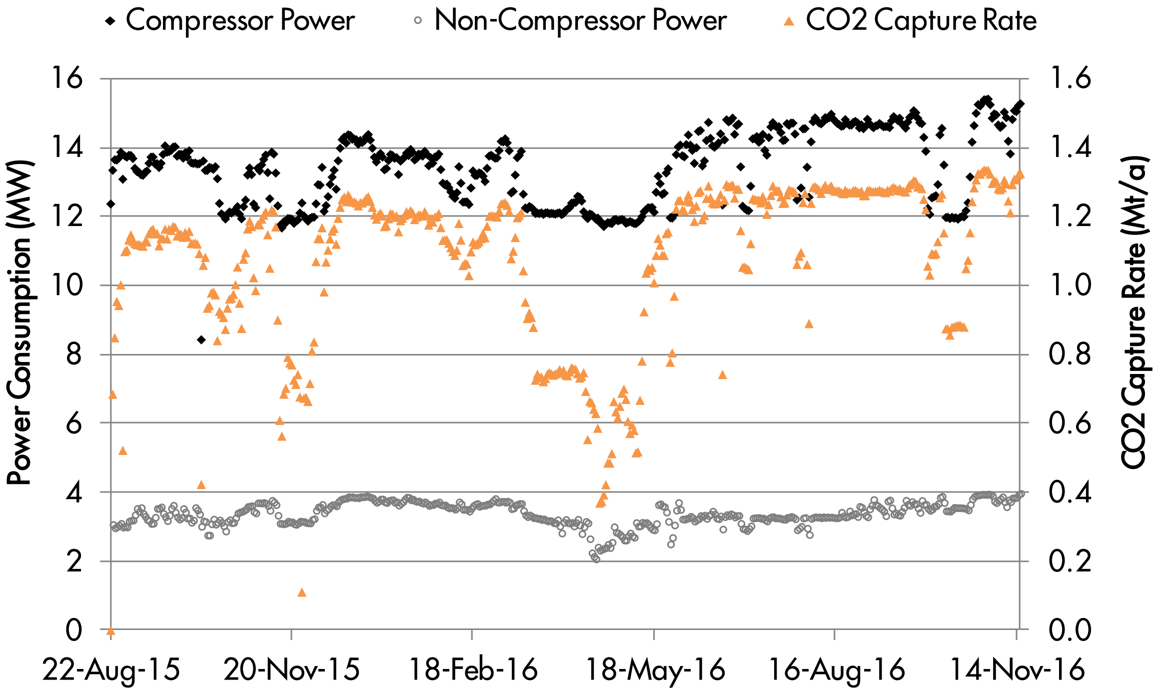

Figure 1: Quest Power Consumption

The consumption rates are heavily dependent on throughput. For production rates greater than 1.05 Mt/a the compressor power consumption is proportional to throughput within the control range. Several of the non-compressor loads are also throughput dependent (pump/fan VFDs, etc.). For production rates less than1.05 Mt/a the fixed speed compressor motor draws ~12 MW at turndown, and is equipped with inlet guide vanes to provide better efficiency when operating below full capacity on the machine. This base-load power consumption is a result of operating the compressor with the anti-surge (recycle) valve open to protect the machine from operating in a surge condition at low flow rates.

With the unit's design objective to run at higher capacities the lower efficiency on a per ton CO2 basis at lower capacities is a result due to the nature of re-compressing gas that circulates through the machine to provide min flow/surge protection, but never enters the pipeline for transport to the injection wells for storage. Operation with the anti-surge valve open is an infrequent operating mode, and typically occurs only during low hydrogen demand periods at the Upgrader. Total electrical draw on the integrated Quest system has been as high as 19 MW during peak production periods, while turndown periods draw as little as 14 MW.

1.2. Non-Compressor Driver Primary Loads vs Parasitic Loads

As described in the previous section, non-CO_2 compressor electrical loads are a significant consumer of electricity in the Quest CCS unit, on the order of 4 MW at rated Quest capture unit capacity.

In the ADIP-x amine unit and TEG dehydration unit, electrical loads directly contributing to the capture/dehydration of CO_2 are loads such as those driving the amine circulation/charge pumps, water/condensate handling systems, chemical injection pumps, glycol circulation pumps, etc. These loads can be considered as primary electrical loads as their contribution directly results in the removal of CO_2 from the raw hydrogen streams in the HMUs, and dehydration of the CO_2 prior to transport to the wells. Table 1 provides a summarized breakdown of the electrical loads in the Quest capture unit.

Table 1: Non-Compressor Driver Electrical Load Summary

Electrical Load Type	**MW**
Amine/Glycol Circulation Pumps	2.3
Cooling Water Circulation Pumps	0.6
Condensate/Water Handling Pumps	0.1
Compressor Interstage Aerial Cooling, Lube oil heaters	0.2
Auxiliary Loads (EHT, HVAC, Lights, UPS/Instrumentation/Controls, transformer/MCC components)	0.8
Total Load @ Nameplate Capacity	~4.0

Chemical circulation (amine/glycol) is the largest normal power consumer around 2.3 MW, with power for the cooling water booster pumps in Quest as the next largest load around 0.6 MW. The lumped auxiliary loads at 0.8 MW above are effectively the parasitic loads in the context of the Quest capture unit. These are loads that continue to consume electricity when the amine unit/compression/dehydration units are not performing the task of capturing CO_2 with the purpose of transport for final storage. These loads vary seasonally, as EHT (electric heat tracing – primarily for freeze protection) will pull significantly more load in the winter and is typically offline in the warmer summer months. HVAC loads (heating ventilation and air conditioning) also vary seasonally given ambient conditions to maintain the capture unit buildings in the desired temperature range for safe/reliable operation.

1.3. CO_2 Compressor Efficiency Summary

The primary consumer of electricity in the Quest CCS process is the 8-stage integrally geared centrifugal compressor. The compressor contains interstage cooling and knockout for water removal up to and including the 6th stage prior to TEG dehydration. The compressor was designed with the ability to compress low pressure CO_2 from near atmospheric conditions leaving the capture unit to over 12 MPa at a rate exceeding 1.3 Mt/a to the pipeline. To accomplish this, the compressor was equipped with an electrically driven motor with a rated load of 16.5 MW.

A study was conducted for the purpose of this report to compare the expected power consumption with the operational consumption and thus assess the efficiency performance of the CO_2 compressor against design. Table 2 outlines expected performance of the Quest CO_2 compressor for the rated design case, and then compares this against averaged operating performance over a 5-week steady operating period (August 13, 2016 through September 17, 2016).

For the design case, the expected compressor driver power consumption to bring the CO_2 from 0.13 MPaa to 12.4 MPaa was roughly 15.1 MW. This considered losses within the driver itself (expected efficiency of 98.4%), losses within the compressor from mechanical means (assumed 95% efficiency), and the compression power requirement of roughly 14.1 MW at a polytropic efficiency of 84.9% from the design case.

The polytropic efficiency is utilized in this situation as the standard efficiency measurement for multi-stage centrifugal compression since the dynamic nature of centrifugal compression is best represented by a polytropic process vs an isentropic/adiabatic process.

The expected parasitic loads on the system in this case are the electrical power losses that are not directly associated with bringing the pressure of the CO_2 up to pipeline transmission pressure. The following is a qualitative summary of the electrical power losses.

Driver (motor):

- Mechanical friction losses, shaft driven lube oil pump, motor space heaters, etc.

Compressor Mechanical Losses:

- Frictional losses from bearings, seals, gears, etc.

Compression Process:

- Non-ideal nature of compression, deviation from fully reversible compression, temperature rise across each stage, interstage cooling influences, anti-surge flow (not relevant in this case, but certainly during turndown operation), etc.

Table 2: Compressor operating conditions and energy performance, rated vs operating

Compressor Process Conditions and Energy Performance	**Rated Design Case**	**Aug - Sep 2016 5 Weeks of Steady Operation**
Suction Pressure	0.13 MPa	0.13 MPa
Discharge Pressure	12.4 MPa	10.6 MPa
Suction Temperature	36°C	31°C
Discharge Temperature (estimated/actual)	135°C	131°C
Flow to pipeline	1.30 Mt/a	1.27 Mt/a
Polytropic Efficiency	84.9%	~81.1%[i]
Compression Power Requirement[ii]	~14.1 MW	~13.7 MW
Mechanical Efficiency	95.0%	~93% (combined)[iii]
Driver Efficiency	98.4%	
Overall Efficiency[iv]	79.4%	~75.3%
Driver Power Consumption	15.1 MW	14.8 MW

To compare expected performance with actual, a case study of operation over a 5-week period beginning August 13, 2016 through September 17, 2016 was compared against design performance conditions. Total throughput was similar to the rated case (1.27 vs 1.3 Mt/a), discharge pressure was lower (10.6 MPa vs 12.4 MPa), and composition and interstage cooling conditions were slightly different.

The power required for compression and overall efficiency of the machine/driver/process were marginally lower than the design rated case. The combined driver/mechanical efficiency for the operating case appears to be very close to that of the design case (both in the 93% range). The polytropic efficiency for the operating case (estimated) was 81.1% vs the design 84.9% value, and is the primary reduction in overall compressor efficiency. This was not unusual since the operating pressure in the August – September 2016 dataset was significantly lower than that of the design case, and throughput was slightly lower as well. Overall efficiency of the machine was well within acceptable tolerance (79.4% design vs 75.3% operational).

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[i] Polytropic efficiency for the operating case was estimated based on actual operating conditions to match stage-compression temperature performance using a Unisim simulation model.

[ii] Compressor power requirement was derived using Unisim Design Process Simulation, specifying polytropic efficiency from design case.

[iii] For the actual operating case, driver efficiency and mechanical efficiency are lumped together as independent measurements are not readily available.

[iv] Overall efficiency in this assessment has been considered as the product of the polytropic efficiency, mechanical efficiency, and driver efficiency.