LCC Pipe Design

CO_2 Capture Facility

Kårstø, Norway

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1.0 INTRODUCTION

This report outlines the Life Cycle Cost (LCC) evaluation used in the system piping design for the Karsto CO_2 Capture and Compression (CCC) Project Front End Engineering Design (FEED) Study.

The Karsto CCC Project is located adjacent to the Karsto gas terminal and the combined cycle power plant (CCPP) owned and operated by Naturkraft AS. The CCC plant is owned by Gassnova SF. The CCC project's technology is based on the use of amine for the bulk removal of CO_2 from a flue gas stream by liquid chemical absorbents. The amine plant mainly consists of flue gas ducting and blowers, direct contact coolers, absorption columns, a stripper column, reboilers, reclaimer, and CO_2 compression and drying, along with other equipment such as pumps, filters, and heat exchangers.

Flue gas from the adjacent CCPP is cooled by water spray cooling and discharged into the absorber columns for processing. Off gas from the absorbers leaves the absorber stacks and is released to the atmosphere after processing. The CO_2 gas product is dried and compressed into liquid and pumped to the CCC plant battery limit (B/L). Gassnova is responsible for the compressed CO2 pipeline and use outside the CCC plant B/L.

The report evaluates the major systems noted below that have the most impact the overall plant design, capital costs, and operating costs:

- Lean amine system
- Rich amine system
- Liquid CO_2 product system
- Sea water cooling system

2.0 LCC PIPE DESIGN

The material selection for the CCC Plant amine and CO_2 system piping is described in document 25474-000-G65-GEN-00001, Corrosion Evaluation for Main System". The material selection for the amine and liquid CO_2 systems is stainless steel and for the sea water cooling system is glass reinforced plastic (GRP).

The piping sizes and wall thicknesses are based on the system design pressure and temperatures. The Contractor's standard recommended velocities were used in determining the pipe sizes. These velocities are based on industry experience that includes potential erosion, pressure transient, and in accordance with good engineering practices. For the amine, sea water cooling, and liquid CO2 systems these maximum values are 4.57 m/s, 3.04 m/s, and 3.66 m/s, respectively. The current pipe sizes selected for these systems are below these maximum recommended values.

The piping sizes and pipe class designations for each system are shown on their respective piping and instrument diagrams (P&ID). The information for the system pipe materials, including sizes and schedules, is provided in document 25474-000-3DS-P72G-00001, Pipe Class Selection.

2.1 AMINE AND LIQUID CO2 SYSTEM DESIGNS

With the stainless steel material selected for the rich and lean amine systems and liquid CO_2 product system in the document noted in Section 2.0 above, these systems are further evaluated for the following:

- Review of larger diameter piping and pumping power impacts
- Review of smaller diameter piping and pumping power impacts
- Costs of the stainless steel piping associated with the pipe size changes.

The systems evaluations are shown in Table 1.

2.2 SEA WATER COOLING DESIGN

For the sea water cooling system, the use of GRP and prestressed concrete cylinder pipe (PCCP) was specifically evaluated for the underground (UG) piping. The majority of the sea water cooling system piping is U/G. The piping, valves and instrumentation near each heat exchanger and cooler are located aboveground. In addition to the material selection, this system evaluation included review of the piping characteristics, such as absolute roughness factors, and various pipe sizes and pumping power.

The system evaluation is shown in Table 1.

3.0 CONCLUSION

The following summarizes the evaluations for these four systems based on the information in Table 1:

- Rich amine system - The existing system pipe material selection and sizes are considered a cost effective viable design. The evaluation shows that using larger or smaller size piping does not provide a more economical LCC design in all cases.

- Lean amine system - The existing system pipe material selection and sizes are considered a cost effective viable design. The evaluation shows that using larger or smaller size piping does not provide a more economical LCC design.

- Liquid CO2 product - The existing system pipe material selection and size are considered a cost effective viable design. The evaluation shows that using larger or smaller size piping does not provide a more economical LCC design.

- Sea water cooling system - The existing system pipe GRP material selection and sizes are considered a cost effective viable design. The evaluation shows that using larger or smaller size piping does not provide a more economical LCC design.

This study is based on the information available during the short duration and preliminary design of the FEED phase. We appreciate that the piping design, especially for these systems, is a critical aspect of the Karsto overall project design and impacts capital costs, operating costs, the environmental impact and the project risk profile. During the EPCI phase, these systems will be revisited to ensure that all aspects of the design, costs, and environmental impact and risks are assessed in detail.

TABLE 1

System	**Difference in Pumping Head**	**Difference in Pumping Power**	**Pipe Size/Velocity (in. & m/s)**	**Remarks**
Rich amine	2.6 m (lower)	31 kW (lower)	Current sizes 20"/3.9 18"/3.8 14"/4 8"/2.2 1 size larger 24"/2.64 20"/ 3.1 16"/3.1 10"/1.4	Next <u>larger</u> pipe sizes: • As shown, the pipe velocities are below the recommended 4.67m/s. • The estimated additional OOM cost for the larger pipe sizes is approx. $250K. • With the rich amine pumps operating at a lower pressure, the pumping power savings associated in terms of the net present value of LCC of energy is approx. $200K. • Based on the above, the use of larger rich amine pipe sizes is not warranted.
Rich amine	4.5 m (higher)	53 kW (higher)	Current sizes 20",18",14", & 8" 1 size smaller 18"/4.8 16"/ 4.9 12"/4.8 6"/3.7	Next <u>smaller</u> pipe sizes: • As shown, the pipe velocities are greater than the recommended 4.67m/s, except for the 6" pipe. • The estimated OOM cost savings for the smaller pipe sizes is approx. $150K. • With the rich amine pump operating at a higher pressure, the pumping power additional cost in terms of the net present value of LCC of energy is approx. $350K. • Based on the above, the use of smaller rich amine pipe sizes is more over the 25 year period and there maybe concerns with the higher velocities; therefore the changes are not considered warranted.

Lean amine	4 m (lower)	38 kW (Lower)	**Current sizes** 20”’/3.1 18”/4 14”/3.4 8”/1.1 **1 size larger** 24”/2.1 20”/ 3.2 16”/2.5 10”/1.0	Next <u>larger</u> pipe sizes • As shown, the pipe velocities are below the recommended 3.66m/s. • The estimated additional OOM cost for the larger pipe sizes is approx. $415K • With the lean amine pump operating at a lower pressure, the pumping power savings associated in terms of the net present value of LCC of energy is approx. $250K. • Based on the above, the use of larger lean amine pipe sizes is not warranted.
Lean amine	6 m (higher)	57 kW (higher)	**Current sizes** 20”,18”,14”, & 8” **1 size smaller** 18”/3.8 16”/ 5.1 12”/4.0 6”/1.8	Next <u>smaller</u> pipe sizes: • As shown, the pipe velocities are greater than the recommended 3.66m/s, except for the 6”. • The estimated OOM cost savings for the smaller pipe sizes is approx. $285K. • With the lean amine pump operating at a higher pressure, the pumping power additional cost in terms of the net present value of LCC of energy is approx. $375K. • Based on the above, the use of smaller lean amine pipe sizes is not warranted.

Liquid CO2 product	3.3 m (lower)	21 kW (lower)	**Current size** 8"/2.3 **1 size larger** 10"/1.5	Next larger pipe size: • As shown, the pipe velocity is significantly lower that the recommended 3.66m/s. • The estimated additional OOM cost for the 10" pipe is approx. $400K. • With the liquid CO2 sendout pump operating at a lower pressure, the pumping power savings associated in terms of the net present value of LCC of energy is approx. $140K. • Based on the above, the use of the larger liquid CO2 sendout pipe size is not warranted.
Liquid CO2 product	13.5 m (higher)	86 kW (higher)	**Current size** 8" **1 size smaller** 6"/3.9	Next smaller pipe sizes: • As shown, the pipe velocity is slight higher than the recommended 3.66m/s. • The estimated OOM cost savings for the 6" pipe is approx. $295K. • With the CO2 sendout pump operating at a higher pressure, the pumping power additional cost in terms of the net present value of LCC of energy is approx. $560K. • Based on the above, the use of the smaller liquid CO2 sendout pipe size is not warranted.

Sea water cooling	1.6 m (lower)	93 kW (lower)	**Current sizes** 60"/2.7 48"/2.5 36"/2.1	The current system designed pipe sizes: • As shown, the pipe velocities are below the recommended 3.04m/s. • The GRP pipe material versus PCCP pipe material was evaluated for the main U/G lines. Based on the difference in pipe absolute roughness factors, the estimated additional OOM cost for the GRP pipe only is approx. $100K. • With the sea water cooling pump operating at a lower pressure, the pumping power savings in terms of the net present value of LCC of energy is approx. $600K. • Based on the above, the GRP material selection is considered the more economical design of the two piping materials.
Sea water cooling	2.1 m (higher)	118 kW (higher)	**Current sizes** 60",48", & 36" **1 size smaller** 54"/3.3 42"/3.3 30"/3.1	Next <u>smaller</u> pipe sizes: • As shown, the pipe velocities are above the recommended 3.04m/s. With these types of large flow systems (similar to circulating water systems), there is always concerns with system pressures during hydraulic transients that would need to be evaluated. • The estimated OOM cost savings for the smaller pipe sizes is approx. $100K (pipe only). • With the sea water cooling pump operating at a higher pressure, the pumping power additional cost in terms of the net present value of LCC of energy is approx. $775K. • Based on the above, the use of the smaller sea water cooling pipe sizes is not warranted.
Sea water cooling	1 m (lower)	58 kW (lower)	**Current sizes** 60",48", & 36" **1 size larger** 66"/2.2 54"/1.96 42"/1.6	Next <u>larger</u> pipe sizes: • As shown, the pipe velocities are below the recommended 3.04m/s. • The estimated additional OOM cost for the larger pipe sizes is approx. $150K (pipe only), and $200,000 for excavation. • With the sea water cooling pump operating at a lower pressure, the pumping power savings associated in terms of the net present value of LCC of energy is approx. $380K.

				- Based on the above, the use of larger sea water cooling pipe sizes is about the same cost over the 25 year period; therefore the changes are not considered warranted. There is the added -potential for sedimentation to accumulate in the piping if the velocities are less than approx. 1.4m/s. The sea water cooling system is provided with temperature control valves on the heat exchangers that will modulate and throttle the system flow. If the pipe sizes were to be increased, there is the potential for the velocities to fall below the 1.4m/s value. Further evaluation and attention to this issue will be included in the EPCI phase for the sea water cooling system final design.