Utility Unit Descriptions

CO_2 Capture Facility

Kårstø, Norway

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Contents

1.0 UTILITY UNIT DESCRIPTIONS

The utilities associated with the Karsto CO_2 Capture and Compression (CCC) Project Front End Engineering Design (FEED) Study are noted below:

- Low pressure steam
- High pressure steam
- Low pressure condensate
- Sea water cooling
- Potable water
- Fuel gas
- Compressed air
- Nitrogen gas
- Fire water
- Raw (softened) water
- Demineralized water

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 spray water 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.

A description of each utility for the Karsto CCC Plant is provided below:

1.1 LOW PRESSURE STEAM

Low pressure (LP) steam is supplied by Gassnova from the CCPP LP steam turbine cross-over piping to an interface at the CCC Plant battery limit (B/L). The interface connection size is 36". A carbon steel, Class 150, weld neck, raised face, flange with blind and counter flange are provided by the Contractor. The interface point is the welded connection to the counter flange.

The LP steam conditions at the B/L are 2.2 barg and 270°C and the maximum quantity of steam available from the CCPP is 165 tonnes/hr. The LP steam piping

that is routed from the interface point contains a pressure reducing and desuperheating station to reduce the LP steam temperature to approximately 135°C.

During certain plant operating scenarios, the quantity of LP steam required exceeds the 165 tonnes/hr available from the CCPP. During these operating scenarios, the CCC Plant auxiliary boiler is used to supplement the LP steam demands to the stripper reboilers. The auxiliary boiler is sized for approximately 20 tonnes/hr of saturated steam to meet the LP steam conditions. This auxiliary boiler steam is piped to the common LP steam supply line downstream of the desuperheating station. Downstream of this station, the LP steam line branches to supply steam to the stripper reboilers and to each of the seven utility stations located in the CCC Plant. LP steam flow control valves are provided on the inlet piping to each reboiler. Steam line drains are provided throughout the system as required and routed to the LP condensate blowdown tank.

1.2 HIGH PRESSURE STEAM

High pressure (HP) steam is supplied by Gassnova from the CCPP auxiliary boiler to an interface at the CCC Plant B/L. The interface connection size is 6". A carbon steel, Class 150, weld neck, raised face, flange with blind and counter flange are provided by the Contractor. The interface point is the welded connection to the counter flange.

The HP steam conditions at the B/L are 7 barg at approximately 165°C (saturated). The quantity of HP steam available from the CCPP auxiliary boiler is approximately 12 tonnes/hr and is only available when not required by Naturkraft's internal use. HP steam is used for amine reclaimation at the CCC Plant in the thermal reclaimer. The CCC Plant amine reclaimation is not a continuous process. It is anticipated that mutually agreed upon schedules can easily be developed for the use of the CCPP auxiliary boiler An HP steam flow control valve is provided on the inlet piping to the reclaimer. Steam line drains are provided throughout the system as required and routed to the LP condensate blowdown tank. In addition, a manual globe valve is provided in the HP steam line near the reclaimer to facilitate cleaning or aid in reclaimer waste removal.

1.3 LOW PRESSURE CONDENSATE

Low pressure condensate is produced in the stripper reboilers. This LP condensate is piped from the reboilers to an LP condensate blowdown tank. HP condensate is produced from the amine reclaimer and piped to the LP blowdown tank. In addition, small quantities of blowdown from the CO_2 compressor 1st, 2nd, and 3rd stage steam generators are routed to the LP blowdown tank. Some of the LP and HP condensate flashes in the blowdown tank which is vented to the stripper column. The remaining condensate in the LP blowdown tank is used as follows:

- Spray water for the LP steam desuperheater
- LP condensate supply to the three CO_2 compressor steam generators

- LP condensate return to the CCC Plant B/L (return to CCPP condenser)
- Supply to the CCC Plant auxiliary boiler
- Reject to the process water surge tank, as required

The LP condensate system includes the blowdown tank and 2x100% LP condensate pumps. Continuous sampling of the LP condensate is performed before it is returned to the CCPP. In the event the return condensate doesn't meet the CCPP requirements, the condensate is discharged to the CCC Plant surge water tank.

1.4 SEA WATER COOLING

Sea water cooling water is used as the cooling medium for all of the heat exchangers in the CCC Plant via a once-through direct cooling water system. Gassnova is supplying the intake tunnel and structure and the discharge pit and outfall tunnel. The intake and discharge pit are located outside the CCC Plant B/L. The Contractor will supply and install 2x100% sea water cooling pumps in the Gassnova intake structure and the piping from the intake structure to the CCC Plant B/L. All of the other intake structure equipment (i.e., traveling water screens, screen wash pumps, etc.) required are provided by Gassnova. The sea water return piping from the CCC Plant to the Gassnova discharge pit is also provided by the Contractor. A back pressure control valve located in the common return line ensures the various heat exchangers remain full during operation. Also, this control valve is located in a dry pit within the CCC Plant boundary at the required elevation to preclude cavitation of the valve.

Sea water cooling booster pumps (2x100%) are provided to increase the system pressure to the stripper overhead condensers that are located at a higher elevation than all of the other system heat exchangers. The flow rate to these condensers is only approximately 30% of the total sea water cooling flow rate. The addition of these booster pumps precludes the need to add approximately 8m more to the main sea water cooling pumps, therefore, reducing overall pumping power.

The sea water cooling system design is based on the traveling screens filtering the debris in the sea water down to 2.5mm in diameter to preclude plugging of the various CCC Plant plate and frame heat exchangers. The design is also based on a sea water supply and return temperatures of 11°C and 21°C, respectively. The CCC Plant permit limit for cooling water return temperature to the sea is 25°C.

1.5 POTABLE WATER

The potable water is supplied by Gassnova at an interface at CCC Plant B/L. The interface connection size is 3". A carbon steel, Class 150, weld neck, raised face, flange with blind and counter flange are provided by the Contractor. The interface point is the welded connection to the counter flange.

The potable water is supplied in accordance with the Norwegian potable water quality standard and at 5.0 barg pressure and ambient temperature at the B/L. Potable water is used for sanitary needs, emergency safety showers (ES), utility

stations, and raw (softening) water and demineralized water systems to meet additional water needs. A hose connection for potable water is provided at each of the seven utility stations. There are eight temperature controlled ES located in the following areas:

- Amine Storage Tank Area
- CO_2 Compressor area
- Absorber-1 Area
- Absorber-2 Area
- Stripper Area
- Reboiler/Reclaimer Area (Upper Level)
- Reboiler/Reclaimer Area (Lower Level)
- Electrical Building Area

As per Gassnova's requirement, heated emergency eyewash stations (EW) are supplied by bottle water. There are nine EW Stations with eight located adjacent to each ES and one in analyzer building area. Total potable water demand is based on the raw water (softening) system needs, simultaneous use of all sanitary water users, and assuming two ES operating simultaneously.

1.6 FUEL GAS

Fuel (natural) gas is supplied by Gassnova to an interface at the CCC Plant B/L. The interface connection size is (Later). A carbon steel, Class 150, weld neck, raised face, flange with blind and counter flange are provided by the Contractor. The interface point is the welded connection to the counter flange.

The fuel gas conditions at the B/L are 4.9 barA and 20°C. This system is designed to convey fuel gas to the CCC Plant auxiliary boiler. The fuel gas piping that is routed from the interface point to the auxiliary boiler contains an emergency shutdown valve that closes on a burner trip.

1.7 COMPRESSED AIR

The Karsto CCC Plant will be self sufficient for its compressed air needs. The compressed air system (PA) will supply instrument air (IA) and service air (SA) for all consumers within CCC plant. An air receiver is provided to knock out any water droplets and will be of sufficient size to provide instrument air (IA) for ten minutes at specified pressure in the event of a feed failure.

The PA system consists of 2x100% air-cooled compressors, 2x100% air dryers and a single air receiver. Compressed air system will supply dry, oil free air at 8.62 barg and at a dew point of -40°C and can operate at 100% humidity and maximum ambient temperature. Both IA and SA are supplied dry air. SA connections are provided in each of the seven utility stations located within the CCC Plant. A hose connection for SA is provided at each utility station. As required by Gassnova, a connection for an Owner supplied temporary portable compressor is also provided. The maximum allowable discharge pressure from this portable compressor is 13.8

barg. Low priority users (e.g. SA) will be automatically shutoff in case of low IA system pressure. Both air compressors will be connected to emergency power, however only one will run on emergency power at the same time. The continuous IA requirement is based on the modulating control valves in service and the on/off valves not stroking. For the intermittent IA demand, the flow rate is based on typical sizing flow rate assuming time averaged stroking activity for the control valves, including dryer purge air, plus a 10% allowance. For plant air, the demand is based on an estimate of using a few pneumatic tools during maintenance.

1.8 NITROGEN GAS

The Karsto CCC Plant will be self sufficient for its nitrogen gas needs with the gas bottles supplied by Gassnova. The nitrogen will be used for system and equipment lay-up as needed. The amine (concentrated) storage tank and the 35% MEA storage tank will have nitrogen blanketing. A nitrogen connection is provided in each of the seven utility stations located in the CCC Plant. The nitrogen gas system supply header pressure to the utility stations is controlled to approximately 5 barg. The nitrogen gas system supply header pressure to the storage tanks is controlled to approximately 2 barg.

1.9 FIRE WATER

The fire water is supplied by Gassnova at two separate interfaces at the CCC Plant B/L. The Gassnova interface pipe size is a 14" and the pipe material is glass reinforced plastic (GRP). A 14" GRP, Class 150, weld neck, raised face, flange with blind and counter flange are provided by the Contractor. The interface point is the glued connection to the counter flange.

Fire water supplied by Gassnova will be at 11.7 barg and at ambient temperature. The two Gassnova fire water supply lines feed the CCC Plant underground fire loop that includes service branch lines to the CO_2 compressor area automatic wet pipe sprinkler system and the yard hydrants. Fire hydrants will be spaced at approximately 250-foot intervals around the fire loop. The hydrants will be located in accordance with NFPA 24 and local fire codes. Hose houses are provided for each hydrant. The system will supply the design maximum water demand for any automatic suppression system plus 114 m^3/hr of flow for fire hydrants based on the National Fire Protection Association (NFPA) requirements.

Augmenting the fire protection system, portable fire extinguishers will be located throughout the CCC Plant.

A fire alarm system will be provided for the plant, with local fire alarms, automatic fire and gas detectors, and fire and gas detection programmable logic controller (PLC) as required by design codes. The PLC will interface with the CCC Plant DCS.

1.10 RAW (SOFTENED) WATER

Raw (softened) water is required to produce 35% MEA for the amine system and provide additional makeup water to the amine system, as needed, if the system is slightly out of water balance. This water is also supplied to the LP condensate blowdown tank for initial fill/startup and as the feed to the demineralized water system. Potable water is the supply source for the raw water system. The potable water system pressure is sufficient to push the water through the raw water softened water vessel (sodium cation bed) and into the softened water storage tank.

The raw water system includes the softened water skid, storage tank, 2x100% softened water pumps, and a brine regeneration skid. The design capacity of the raw water system is approximately 9 m^3/hr. Manual loading of salt into the brine solution tank dissolving basket is required, however, the softener backwash cycle is automatic. The regeneration waste is discharged into the waste water drain system.

1.11 DEMINERALIZED WATER

Demineralized water is required for makeup to the CCC Plant auxiliary boiler. Raw (softened) water is the supply source for the demineralized water system.

The demineralized water system includes the 2x100% demineralizer feed pumps, 1x100% cation bed, 1x100% anion bed, and 1x100% mixed bed units, a bed regenerative chemical feed skid, demineralized water storage tank, and 2x100% demineralized water pumps. The design capacity of the demineralized water system is 1.0 m^3/hr which is sufficient to cover the CCC Plant auxiliary boiler blowdown losses.