PROCESS DESCRIPTION
CO_2 RECOVERY PLANT (BOLT-ON)
19.5198 PADOVA

The following functional description is intended for use for the above mentioned project number only.

Revision No.	Change	Date	BY.
0.0	1ST Draft	1-11-2019	CvK
1.0	Project Specific Customization.	12-10-2020	JdB

1. Index

2. General plant description

2.1. Process Flow Diagram

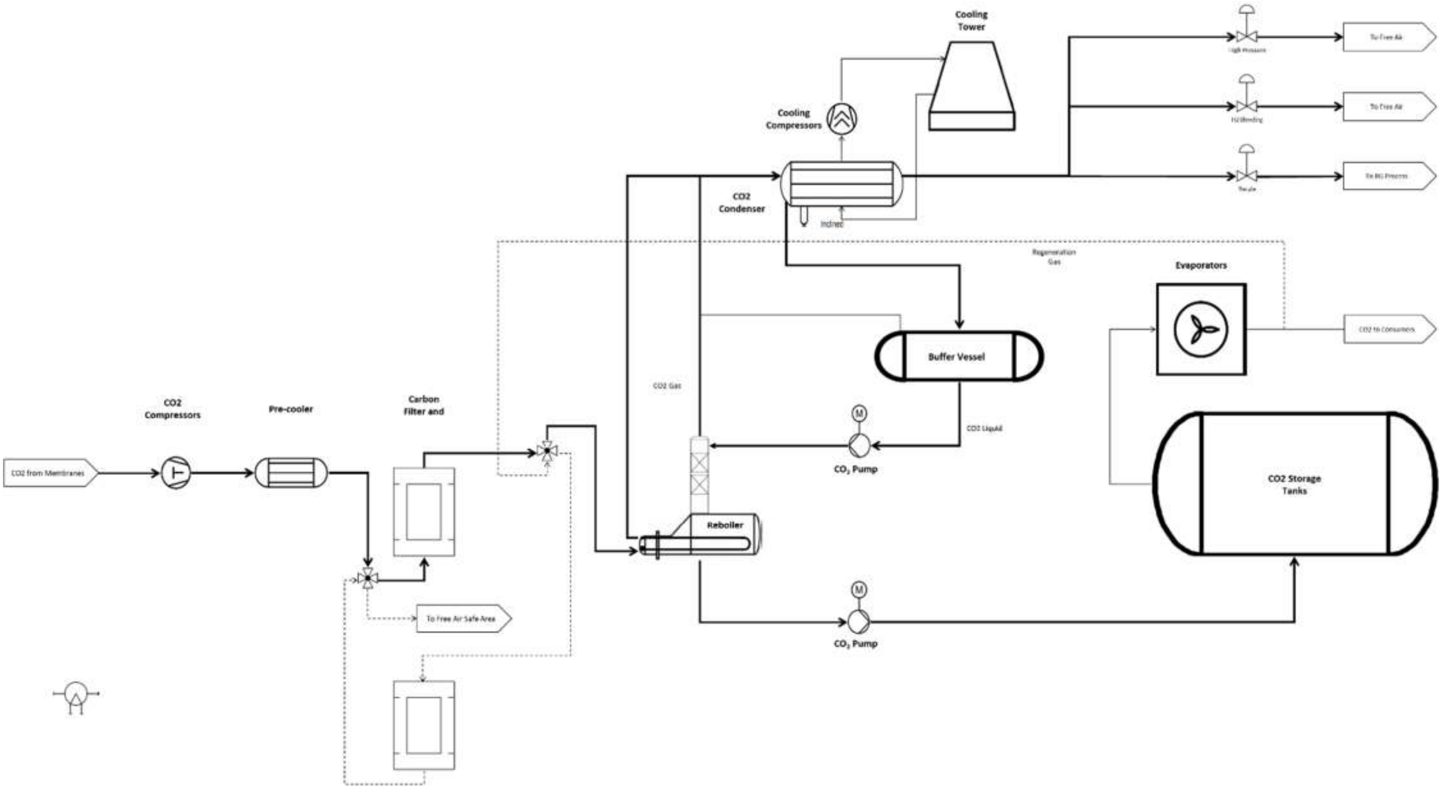


Figure 2-1.Typical Process Flow Diagram (PFD). ***Quantity of parallel installed equipment is not represented.***

2.2. General process description

The CO2 recovery installation purifies the CO2 rich gas from the Biogas Upgrade Unit (BUU) to the required purity so it can be re-used in another processes. Main installation units will be described shortly following downstream the process.

1. *CO2 Compressor*

The dry-running CO_2 compressor(s) compresses the wet CO_2 in two stages to its condensing pressure.

2. *Pre-cooler*

The CO2 pre-cooler is designed to reduce the water content in the CO2 gas through condensation. This will reduce the water load of the driers and increase the effectiveness of the carbon filters (deodorizers), lowering the chance that the CO2 condenser will freeze, therefore improving the CO2 recovery and liquefaction efficiency.

3. *Activated Carbon Filter and Drier Unit*

The Activated Carbon Filter and Drier is a fully automatic CO2 deodorizing and drying system. This system will clean the CO2 gas of undesired impurities that affect the quality of the food grade CO2 and also will remove the moisture of the CO2 gas. This system will be executed dual mode: one unit is running and the other unit will be regenerating to allow process continuity.

The Drier will dry the CO_2 to a dew point of approx. -60°C. After a production cycle of 12 hour at maximum CO2 compressor capacity, the carbon filter and drier has to be regenerated. Therefore a small flow of rinse CO_2 will be used to remove the impurities while heating the filters.

4. *CO2 purification*

The stripper/reboiler will remove the last non-condensable impurities (N2, O2 and CH4) in the liquid CO2. These non-condensable components accumulate in the CO2 condenser where they will be recycled back to the membrane unit in the BUU. By this stripping technology the Contractor is able to return all of the CH4 to the membrane unit and produce almost 100% pure liquid CO2.

This Liquid Stripping System type is designed to increase the end purity of the liquefied gas. The automatic Stripping system includes an integrated management system to optimize CO2 recovery.

5. *NH3 cooling unit + CO2 condenser*

The cooling system generates cooling capacity to liquefy the CO2 in the CO2 condenser.
The CO_2 condenser is a heat exchanger designed to liquefy CO_2 by the using of the refrigerant R717 and separate it from the remaining non-condensable. The heat of the CO_2 gas to condensing point is extracted by evaporation of the refrigerant.

6. *CO2 Tanks*

The CO2 storage tanks are used for storing the liquid CO2 from the CO2 recovery plant.

7. *CO2 Evaporator*

The CO2 evaporator is used to evaporate the liquid CO2 from the storage tanks to be used the CO2 by different consumers as ACF/dryer regeneration process.

3. CO_2 Compressor

3.1. General description

The CO_2 compressor compresses the low-pressure CO_2 gas coming from the gas washer to 18 bar (g) prior to entering the activated carbon filters and dryers. The compression is done in two stages and depending on plant capacity, one or more CO_2 compressor(s) may be installed. After each stage of compression, cooling is installed. The ‘intercooler’ and ‘after cooler’ cool gas from the first and second stages respectively.

In normal operation, CO2 compressor will either start or stop depending on the CO2 suction pressure. The capacity valves on the compressor are foreseen for unload start-up and capacity regulation in combination with a VSD.

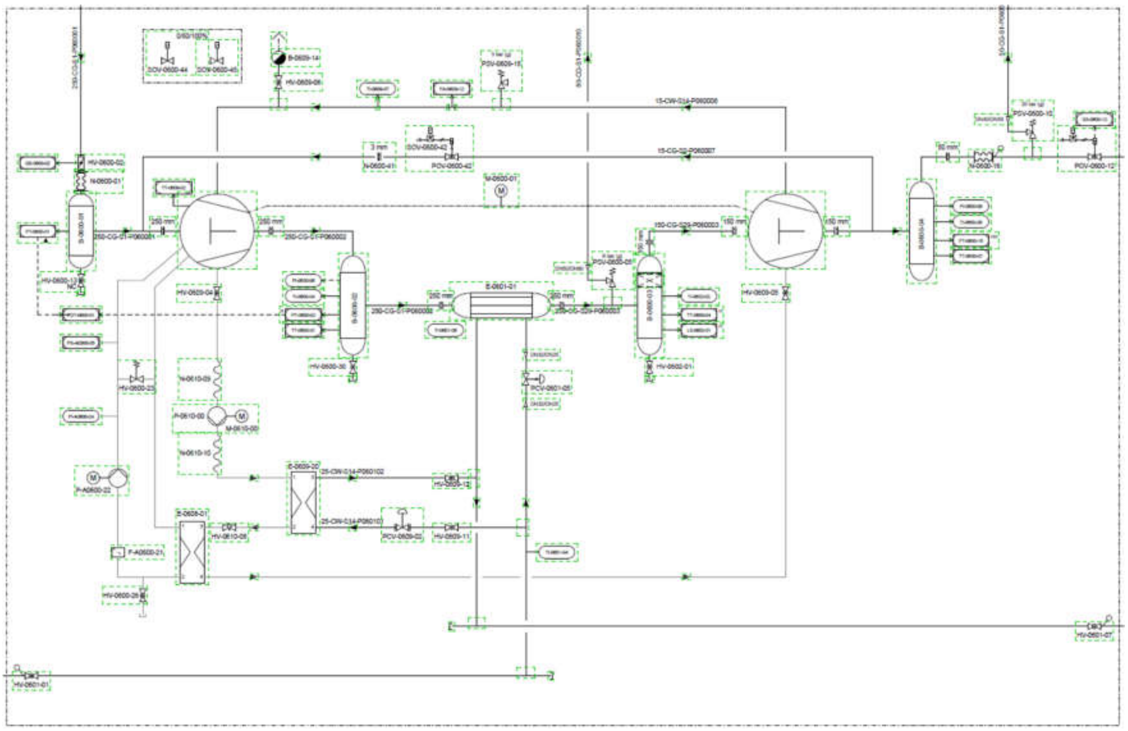


Figure 3-1. CO_2 Compressor P&ID.

3.2. Process state of the CO_2 compressor

The CO_2 compressor has 4 different process states:

1. Off
2. Standby
3. Production
4. Alarm

3.2.1. Off state

-Panel switch in off position
-Work switch off
-Inlet suction hand valve not open
-Start/Start or Stop/Start timer active
-Cat01 alarm: Stop CO_2 Compressor

3.2.2. Standby state

-Panel switch in on position
-Work switch on
-Inlet suction valve open
-Start/Start or Stop/Start timer finished
-No Cat01 alarm: Stop CO_2 Compressor 1

3.2.3. Production

-Panel switch in on position
-Work switch on
-Inlet suction hand valve open
-Start compressor command from process manager
-No Cat01 alarm: Stop CO_2 Compressor

3.2.4. Alarm

- Cat01 alarm: Stop CO_2 Compressor 1

3.3. Functional description

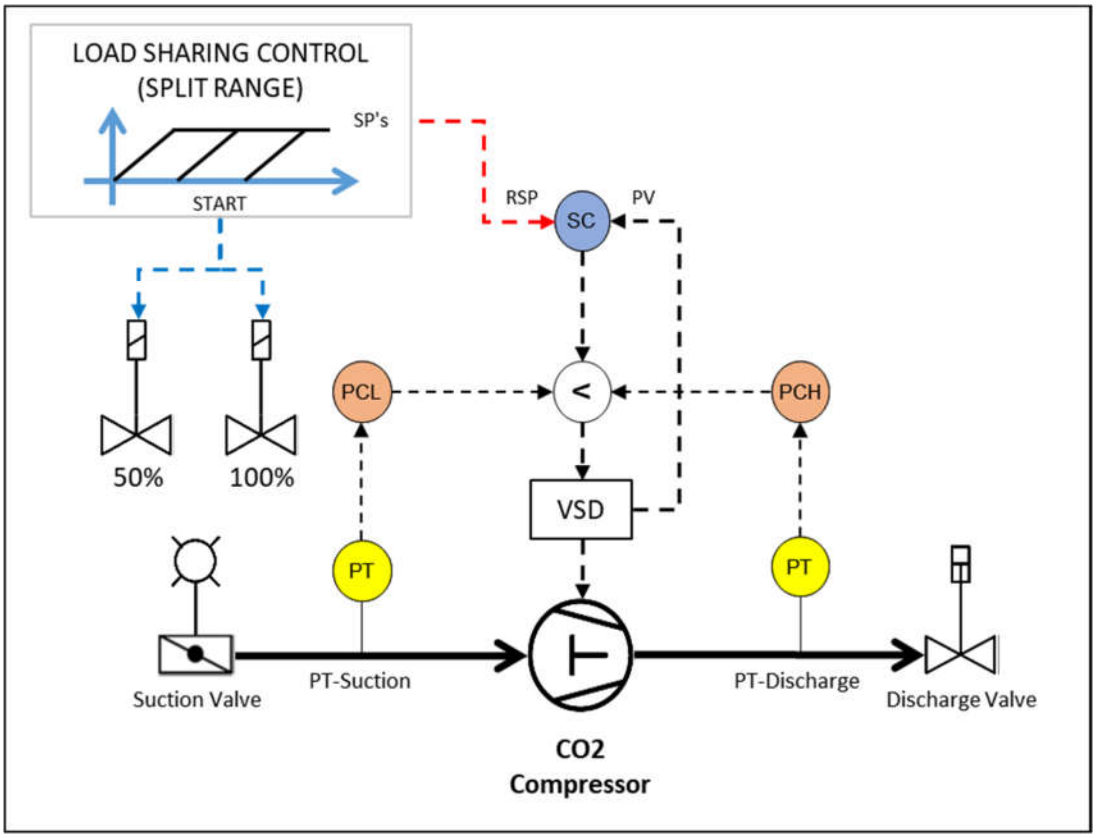


Figure 3-2. Typical CO_2 Compressor Capacity Control Loops.

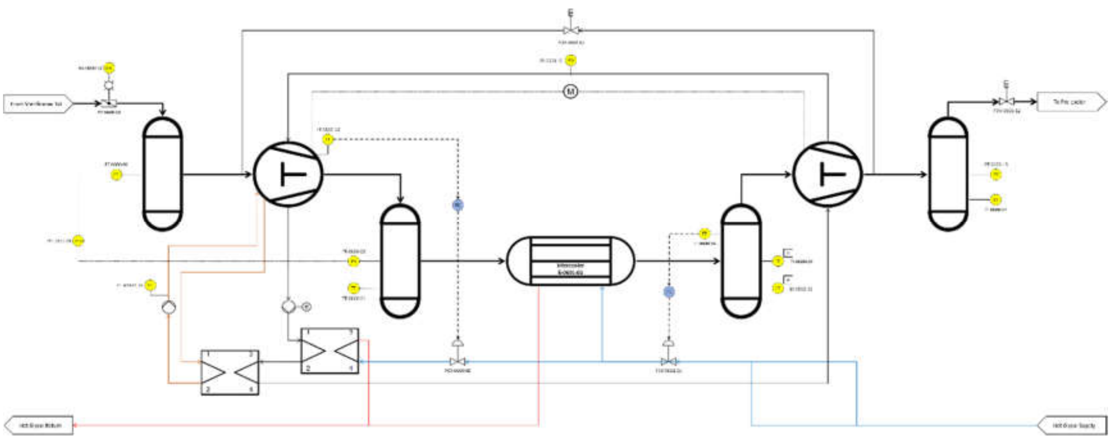


Figure 3-3. Typical Two Stages CO_2 Compressor Cooling Control Loops.

3.3.1. Starting CO_2 compressor

When there is a soft starter control on the motor the difference between start motor and run feedback is the set star-delta time. If the compressor starts the start/start timer starts counting for a second start release of the compressor. When the compressor stops the stop/start timer will be activated. When this timer is finished the compressor can start again.

3.3.1.1.Cooling pump

When the compressor is started the cooling pump is started. After the CO_2 compressor stops, the cooling pump will stop.

3.3.1.2.Head cooling pump

The cylinder head cooling pump starts on start signal from the CO_2 compressor skid and stops when there is no run feedback and the off delay of 300 seconds is finished.
The flow over the head of the CO2 compressor is checked by a flow switch. When the flow is below set point the 30 seconds the compressor will stop and an alarm “LOW FLOW HEAD COOLING” will be generated.

3.3.1.3.Unloaded start valves

In the software there is a selection for the unloaded start valve, release pressure valve and the capacity valves. This selection is depending on the compressor.

0. Two capacity valves
1. One unloaded start valve
2. One unloaded start valve and one release pressure valve
4. One unloaded start valve and one release pressure valve and two capacity valves

Selection 0:
The two capacity valves will be opened and closed on the systems requested capacity and is controlled by the process manager. For controlling the valves the capacity control must be released.

Selection 1:
The release pressure valve closes on the run feedback of the compressor and opens when the run feedback is off.

Selection 2:
The release pressure valve closes on the run feedback of the compressor and opens when the run feedback is off and the delay time of 60 seconds is finished. The unloaded start valve closes on start compressor and opens on stop compressor.

Selection 4:
The release pressure valve closes on the run feedback of the compressor and opens when the run feedback is off and the delay time of 60 seconds is finished. The unloaded start valve closes on start compressor and opens on stop compressor.

The two capacity valves will be opened and closed on the systems requested capacity and is controlled by the process manager for controlling the valves the capacity control must be released.

3.3.1.4.Release capacity control

After the run feedback of the compressor and a delay time of 5 seconds the capacity control valves of the compressor will be released. When the compressors stops, the release of the capacity control will be deactivated.

3.3.2. Condensate level control

Each water separator has a water level switch. If during the operation of the compressor one of the level sensor senses condensate for more than 60 seconds (without interruption) an alarm "HIGH CONDENSATE LEVEL" will be generated. This alarm will immediately stop the corresponding CO_2 compressor – no time delay.

3.3.3. Production phase

The CO2 compressors have a temperature protection on each stage to protect the compressor of overheating. These temperature switches will generate an alarm at a temperature of 150°C and will stop the compressor.
On the outlet of the CO2 compressor, a temperature switch (setpoint adjusted manually on the HMI) is installed to protect the installation downstream of the CO2 compressor against a too high CO2 temperature. If the temperature rises above the set point for 30 sec the compressor will stop and an alarm is "HIGH OUTLET TEMPERATURE COMPRESSOR" will be generated.

On the discharge of the 2nd stage a pressure transmitter is installed to protect the compressor from a high outlet pressure. At a pressure of 19,5 Barg (adjustable on the HMI) the compressor will stop and an alarm is "HIGH OUTLET PRESSURE COMPRESSOR" will be generated.

Other analogue sensors on the compressor are for visualization only

Oil pressure is monitored during production with a pressure switch. If oil pressure is below 0,5barg an alarm low oil pressure is generated. The low pressure alarm is muted for the first 30 seconds of operation.

4. Pre-Cooler

4.1. General introduction

The pre-cooler is intended to cool the wet CO_2 gas from the CO_2 compressor(s) in order to reduce the drying load on the Dryers and to increase the effectiveness of the carbon filters (deodorizers).

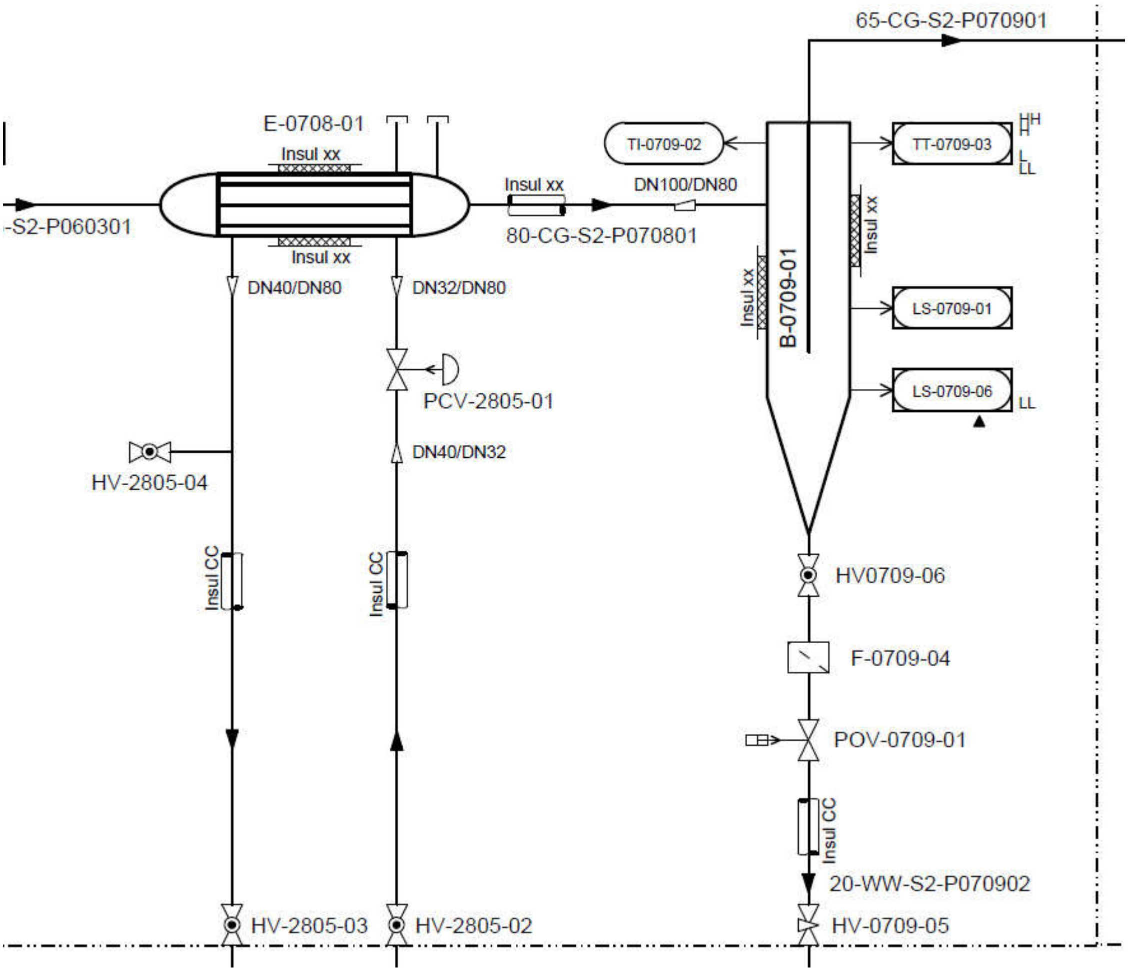


Figure 4-1. Pre-cooler P&ID.

4.2. Process state

The pre-cooler has 3 different process states:

1. Off / Alarm
2. Standby
3. Production

4.2.1. Off state

This state is active when there is no release for starting or when the panel- or work switch is switched off or when there is an alarm of the pre-cooler. In the off state all objects are switched off.

4.2.1.1. Alarms

If the high level switch of the water separator is sensing condensate for longer the 60 seconds then an alarm will be generated. This alarm will immediately stop the CO_2 compressors without any time delay.
If the Temperature sensor of the water separator measures a temperature greater than the alarm set point for more than 60 seconds, an alarm will be generated. This alarm will immediately stop the CO_2 compressors – no time delay

The water separator drain function is disable if the water level is too low (LL detection). The drain valve opens (pulse with TOFF delay) if High level is detected only if LL is not active.

4.2.2. Standby

This state is active when the panel- and work switch is switched on and there is no thermal overload alarm of the coolant pump.

4.2.3. Production

To go to production the pre-cooler must be standby, no alarm and there must be one or more CO_2 compressor running.
As the CO2 compressor stops, production phase goes over into standby or alarm (Depending on reason for stop compressor).

In production mode is the temperature control loop active. With the cold glycol control valve is the CO2 temperature controlled.

4.3. Condensate Level Control

The condensate level control loop is always active. The Level Actuator of the water separator senses the presence of condensate within the water separator.
When the sensor senses condensate for more than a set time, the pilot valve is opened (NC valve) causing the drain valve to open and thereby draining condensate from the vessel.
The drain valve will close after a period of time when the level actuator does not detect any water. When the level switch does detect water the valve stays open. When the water level is high for longer than 60sec an alarm is generated.

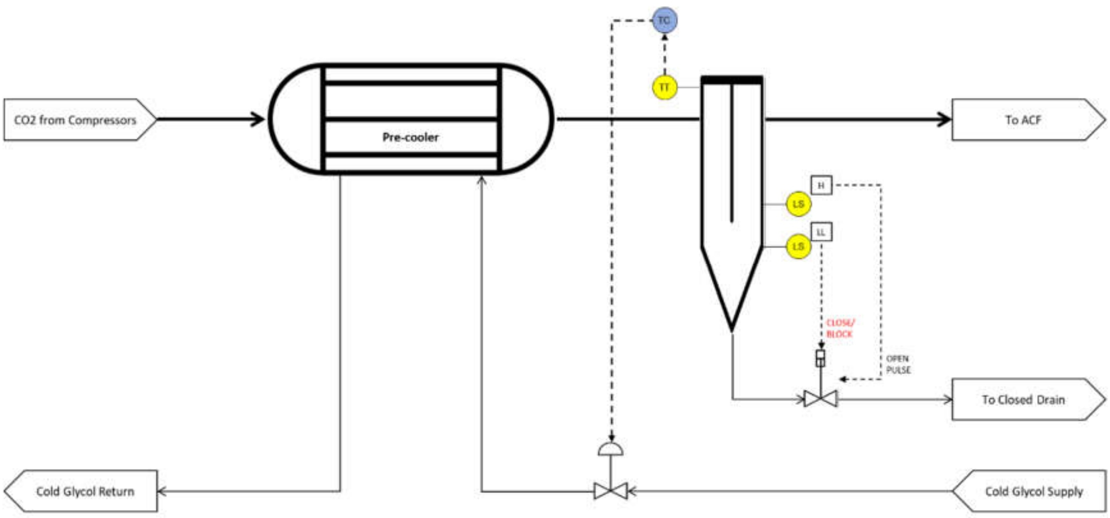


Figure 4-2. Typical Pre-cooler Control Loops.

5. ACF / Dryer

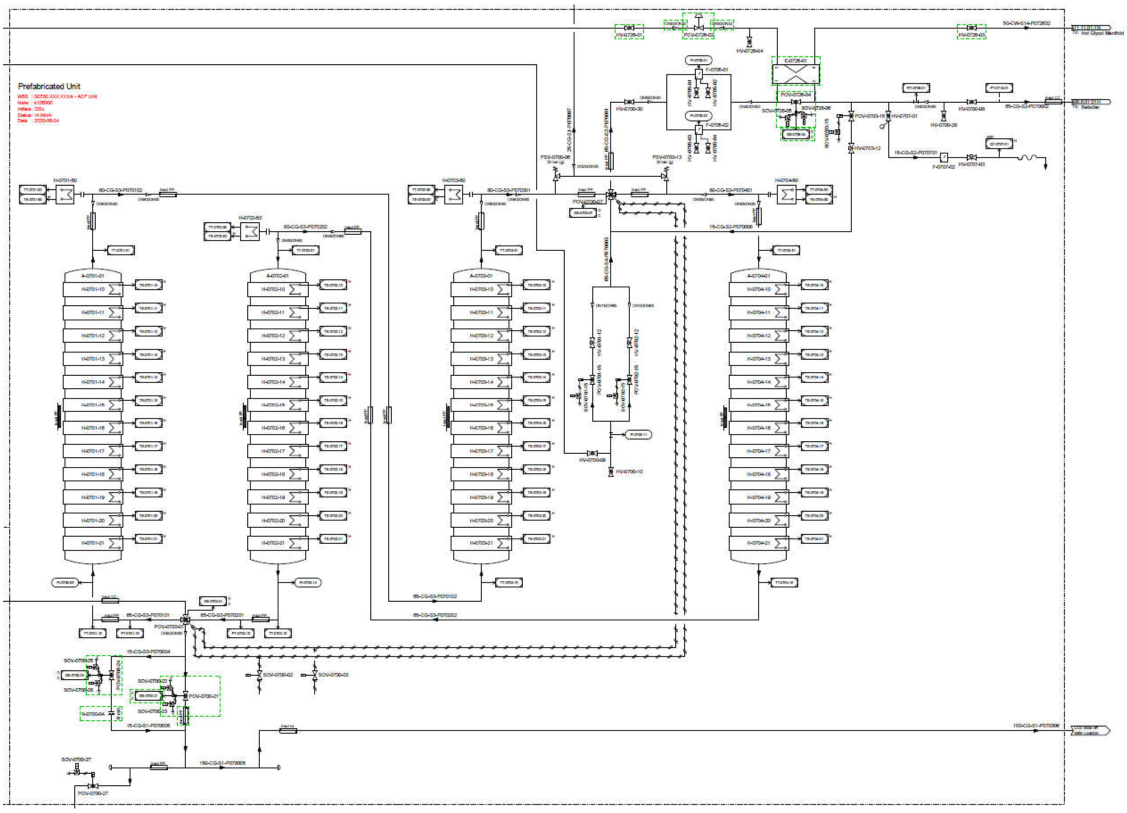


Figure 5-1. ACF/Dryer P&ID.

5.1. Working principle

De ACF/Dryer consists of a number of vessels. In these vessels the CO_2 gas is purified and the moisture is absorbed. The vessels are divided into two groups.

5.1.1. Group arrangement

2+2
Group 1 - ACF 07/1
Group 2 - ACF 07/2

5.1.2. In operation

Group 1 is in operation. The CO2 gas flows via inlet 4 way valve through the ACF/dryer 07/01 and via outlet 4 way valve to the reboiler and/or liquefaction plant. Group 1 has to be regenerated after 12 production hours at full flow of the CO2 compressor. Inlet and outlet 4 way valves switch over (only when group 2 is in stand-by mode) simultaneously.
The gas flow from the CO2 compressor now flows through group 2 of the ACF/Dryer. Group 2 is in operation and group 1 is starting to regenerate.

5.1.3. Operation time / production hours

There are 3 possibilities which can switch the vessels from production to regeneration:

1) Normal production mode (standard)
2) Continuous mode (standard selection in software)
3) Measured flow (option)

The ACF/Dryer Group capacity is designed for the maximum CO2 compressor capacity during a period of 12 hours.
When more than one CO2 compressor is connected to the ACF/Dryer unit the capacity is designed for the total CO2 compressor capacity during a period of 12 hours.

5.1.3.1.Normal production mode (production flow counter)

ACF/Dryer unit	: 1600 kg/h (12 Production hours)
2 CO_2 compressors	: 2x 800 kg/h

When one CO_2 compressor is running the production hour counter of the ACF/Dryer is raised with “1” every 10 seconds. When 2 CO_2 compressors are running the production hour counter is raised every 5 seconds with “1”.

Maximum operation time	: 12 production hours ACF/Dryer
Pulse factor	: 360 (every 10 sec 1 pulse)
Number of CO_2 compressors	: 2
Maximum counter value	: 12 x 360 x 2 = 8640 pulses

5.1.3.2.Continuous mode

In continuous mode the ACF and Dryer tower switch over after a fixed value of 12 hours. This is independent on production hours or compressors in operation.

5.1.3.3.Flow transmitter (this option is default in the HMI)

When a flow transmitter is installed at the outlet of the ACF/Drier, the inlet and outlet 4 way valves will switch over after reaching the total capacity of 12 production hours at full flow. The reached capacity is measured by the mass flow transmitter.

When one CO2 compressor is running the production flow counter of the ACF/Drier is raised by for example 10 (kg) on every high flank pulse of the mass flow meter.
The “raise” value depends on the maximum flow, the processing speed of the digital input and clock time of the PLC.
In general we advise to select a “raise” value that with a minimum pulse interval time op 2x the maximum PLC clock speed. Both the pulse setting in the flow meter and the ACF/Drier program must match.

When a group in operation reaches the full operation time (equivalent of 12 hours of full load), but the status feedback of the other group is not yet in stand-by mode, an alarm is generated (regeneration not complete) the flow through the unit is either diverted to another unit or the CO2 compressors is stopped until the other group is in stand-by mode.
When the other (regenerated) group gives the stand-by signal, the vessels are switched over and the flow control and/or CO2 compressors are automatically released.

5.2. Regeneration

5.2.1. Table: Switching of valves and heating during regeneration

	Pre-heater (optional) Controlled	Inlet regeneration (small)	Inlet regeneration (large)	Outlet regeneration (bypass)	Outlet regeneration	Drain condensate	Heating on	Approx. Time (min)
Start regeneration	Off	Close	Close	Close	Close	Close	Off	5 sec
Preheat	Off	Open	Close	Close	Close	Close	On	10
Heating / De-pres.	Off	Open	Close	Open	Close	Every 5min 10sec open	On	120
Heating after 2 hour	On when inlet regeneration valves are opened.	Close	Open	Open	Open	Every 5min 10sec open	On	300
Cooling	Off	Open	Close	Open	Open	Every 5min 10sec open	Off	240
Re-pressuring	Off	Open	Close	Close	Close	Open	Off	30
Stand-by	Off	Open	Close	Close	Close	Open	Off	

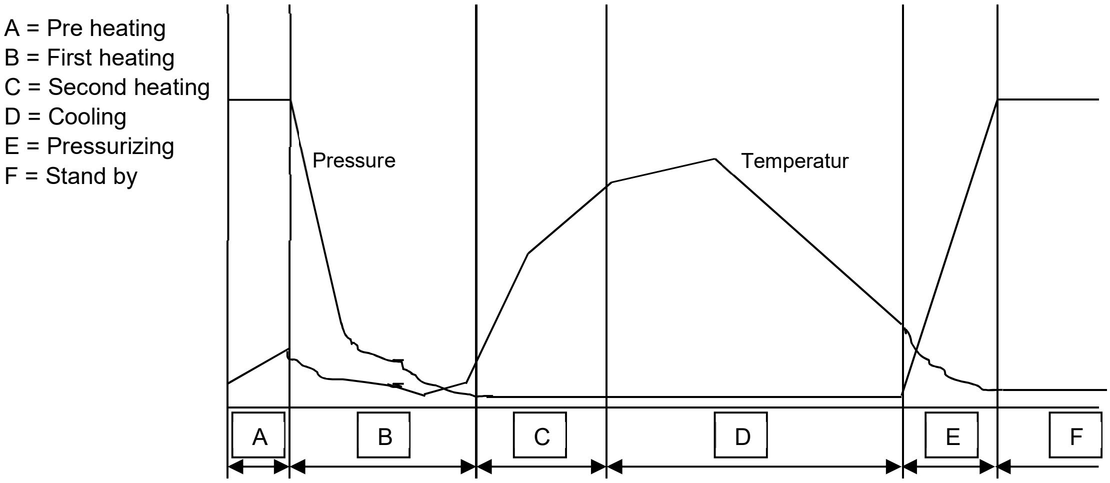


Figure 5-2. ACF/Dryer Regeneration Sequence.

5.2.2. Pre-heat

The ACF/Dryer Group 1 is pre-heated. The pre-heating is started prior the decompression of the vessel to avoid condensation.

5.2.3. Heating

The heating time of group 1 is started and the purge gas outlet valve is opened to decompress the vessels. To avoid too fast de-pressurizing of vessels with only one purge outlet valve, purge inlet small valve is opened. This purge inlet valve will supply extra CO2 form the condenser to slow the depressurizing.

5.2.4. Heating after 10 min.

After 2 hours of heating main outlet purge valve is opened to assure that the remainder of the heating process is run under “atmospheric” conditions and purge inlet valve (large) is opened to supply the sweep gas to remove the particles released during the heating from the vessels.

When the TT on the outlet of the vessels reached the maximum regeneration temperature for a certain time the heating of that tower is stopped. When the temperature is decreasing the heating will go back on heating. This continuous until both towers have reached the maximum temperature for a certain time.

5.2.4.1.Pre heater (Optional)

During the heating phase, if any regeneration inlet valve is open and we have no main alarm /failure of the unit, the pre-heater is on.

Mentioned values and set point are for example purpose only.

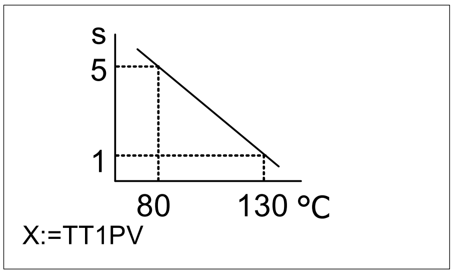
The pre heater element may only be switched on when there is a purge flow. This means one or both purge inlet valves must be open. If the ACF has a failure, the pre heater will be switched off.

The control below is for each pre-heater separated.

The control is based on the measurement of inlet and outlet temperatures of the vessel. A high-level safety thermostat generates and alarm “A07 Pre-heater overheated” which needs to be reset via the HMI.

5.2.4.1.1. Control of the pre heater by outlet gas temperature with on/off control (standard).

The TT, mounted down-stream of the pre-heater is used to control the heater based on gas outlet temperature.
The control is based on a pulse/pause control using a straight line.
The graph below visualizes the “on-time” in seconds of the solid state relais. The “off-time” is a setting in the display.

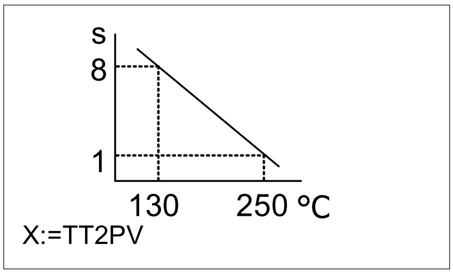


Setting 130ºC has to be 180ºC

f(x):= on-time

5.2.4.1.2. Control of the pre heater by heating element temperature with on/off control (standard).

An internal TT measures the actual element temperature, and controls to avoid over temperature of the element.
The control is based on a pulse/pause control using a straight line.
The graph below visualizes the “on-time” in seconds of the solid state relays. The “off-time” is a setting in the display.



f(x):= on-time

Setting 130°C has to be 180°C

5.2.4.1.3. Continuous Control of the pre heater by heating element temperature and outlet gas temperature.

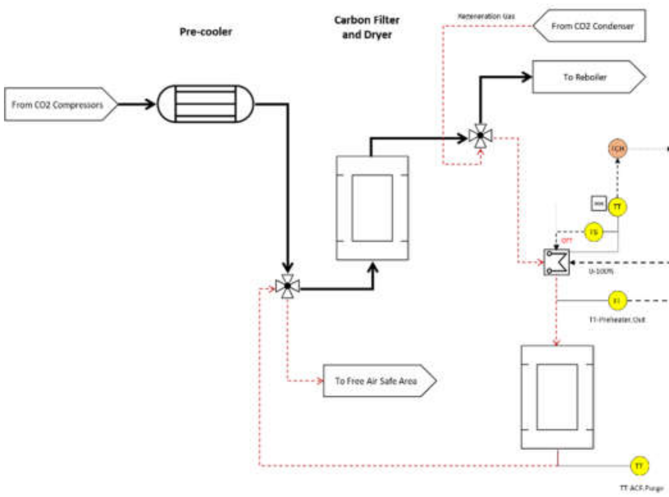


Figure 5-3. Typical Pre-heater Control Loops.

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Output to Pre-heater

The actual output to the element contactor is the smallest “on-time” (or smallest percentage) of both controllers.

5.2.4.2.Thermostat Control

Thermostat control: Heating band elements around the tower constitute a heating group. Each band element has a thermostat controlling the corresponding element.

The heating will extract the moisture and pollutions from the filling, collected there during operation. The moisture and pollutions are carried away by a small amount of CO2 purge gas. The CO2 purge gas, coming from the top of the condenser, can be adjusted with a needle valve.

The intended effect is to reach a gas temperature of ± 110°C (at 0 barg) for a given time measured at the outlet of each vessel. If this temperature is not reached there will be an alarm given.

When the switch point of a specific tower is reached, it switches off the heating. If the temperature drops again the heating is switched on again (hys 1K).

The ACF/Dryer Group 1 is heated for a maximum of 7,0 hours.

When during heating time a malfunction occurs to the circuit breakers and/or the supply voltage the heating time is stopped and an alarm is activated. The heating is restarted after the malfunction has been repaired and the button restart heating is activated.

When there is no heating (pre-heating or heating time is not active), and there is no feedback from the heating relay during 5 seconds an alarm is activated. Probably a heating relay is broken. This alarm stops the CO2 compressor and stops + resets the on that moment active regeneration time. (for example “Cooling time”). After the malfunction has been repaired, the reset time is activated.

5.2.5. Cooling

The CO2 gas from the top of the condenser keeps flowing through the ACF/Dryer Group 1 until the vessels are cooled down. The cooling process takes 4-5 hours.

5.2.6. Re-pressurizing

The outlet regeneration gas valves close after 4-5 hours cooling and inlet regeneration valve remains open.
Group 1 is re-pressurized as CO2 gas from the top of the condenser keeps on flowing until the pressure in group 1 is the same as the system pressure in the CO2 condenser.
Re-pressurizing the regenerated vessels is necessary to prevent a pressure blast during switch over. Re-pressurizing the vessels takes approximately 30-45 minutes.

5.2.7. Stand-by mode

In stand-by mode the regenerated Group 1 is “waiting” until Group 2 has operated the full operation time (equivalent of 12 hours of full load).

5.2.8. Switch over

After the full operation time (equivalent of 12 hours of full load) Group 1 switches over to Group 2 (assuming Group 1 is in stand-by mode). Group 1 is now in operation and Group 2 will regenerate.
When Group 1 is not standby the flow through the unit is either diverted to another unit or the CO_2 compressors are switched off until Group 1 is in stand-by mode.

5.3. Program run

The following is the basic run structure
Maximum operation time Group 1 reached.
Control status Group 2.
Switch over to Group 2.
Pause time. (Time delay to confirm valve position switches)
Start heating Group 1+ delayed open purge gas valve.
Start heating time Group 1.
After end of heating time/TT override, start cooling time Group 1.
After end of cooling time, start time re-pressurizing Group 1.
Group 1 in stand-by.
Maximum operation time Group 2 reached.
Control status Group 1.
Switch over to Group 1
Pause time. (Time delay to confirm valve position switches)
Start heating Group 2+ delayed open purge gas valve.
Start heating time Group 2.
After end of heating time/TT override, start cooling time Group 2.
After end of cooling time, start time re-pressurizing Group 2.
Group 2 in stand-by. See point 0

5.4. Test functions

5.4.1. Step test

The purpose of the step test is to step through program without any process control. Purpose of the step test is to test the program. In the display the next step can be forced by pushing a button. (Haffmans level only)

5.4.2. Default re-initiation of Program

When the program is reloaded or with memory loss in the PLC a so-called re-init is executed. The program will start automatically with the regeneration of Group 2 and the CO_2 compressor is blocked. After a successful regeneration cycle Group 1 and 2 is switched over and the regeneration of Group 1 is started. The CO_2 compressor is released.

The step test function may be used to step through the program to the last position in order to override the default re-initiation procedure.

5.5. Valve Position Confirmation

5.5.1. Working

The 4 applied valves of the ACF/Dryer (2 x 4-way valve + 2x purge drain valve) are all double acting. For example when one of the valve is activated a feedback has to come within 15 seconds. Is this not the case an alarm is activated. This alarm stops the CO_2 compressor and stops + resets the at that moment active regeneration time (for example “Heating”). After the malfunction has been repaired the re-set time starts again.

5.6. Regeneration Gas Temperature Control

5.6.1. Working

The temperature monitoring has three functions. The first function for safety, the second for early ending of the heating time and third for remembering the maximum regeneration temperature.

1. When a unit is equipped with purge gas temperature monitoring the maximum heating time is 7 hours. When the desired temperature is not reached after ending of the heating time, the heating time will be reset, the heating elements will be deactivated and an alarm is generated. After the malfunction has been repaired the heating has to be restarted with use of the operator panel.
2. The heating time ends when a temperature higher than the desired temperature is continuously measured for 10 minutes. The regeneration process will go on with the cooling time.
3. The highest temperature reached during regeneration per vessel is stored.

5.7. Automatic dew point tester

The dew point measurement measures the dew point of the CO2 gas at almost atmospheric pressure. This means that the water content in the CO2 gas is measured. When the water content is too high it will freeze in the CO2 condenser during the liquefaction of the CO2 gas. The dew point measurement is a continuous measurement. Therefore, you must be able to read the dew point from the display. The maximum allowable dew point temperature has to be adjustable in the display.
The automatic dew point tester will trigger an alarm if the measured atmospheric dew point (4-20mA) becomes higher than the set point normally –60˚C (delay time 60 seconds).
The alarm is disabled during the first operation hour when a particularly street is put in operation mode. Because in the beginning the CO2 gas that flows out of the freshly regenerated group is warm, the dew point measurement is inaccurate.
For service and calibration purpose the automatic dew point tester alarm (and wire break detection) can be disabled via the HMI. In case of an alarm all CO2 compressors must be deactivated.
It must be possible to deactivate he measurement, alarm and wire-break detection in the operator panel. The measured dew point temperature remains visible in the display.
Remark: As default the measurement is always active.

6. Reboiler / Stripper / CO_2 pump / CO_2 Condenser

6.1. General Description

The stripper/reboiler remove the last non-condensable impurities (N2, O2 and CH4) in the liquid CO2. These non-condensable components accumulate in the CO2 condenser where they will be recycled back to the membrane unit in the BUU. By this stripping technology the Contractor is able to return all of the CH4 to the membrane unit and produce almost 100% pure liquid CO2.

The CO_2 is fed to the CO_2 condenser into the stripping column. In the stripper N2, O2 and CH4 is removed from the liquid CO_2 by means of CO_2 strip-gas. The purified CO_2 is collected in the re-boiler. A CO_2 liquid pump transfers the CO_2 to the CO_2 storage tank. The condenser liquefies the CO_2. The purging of non-condensable is done on top of the condenser(s).

A purification system consists of the following components:

- Buffer
- Stripper
- Reboiler including heat element.
- CO_2 pump

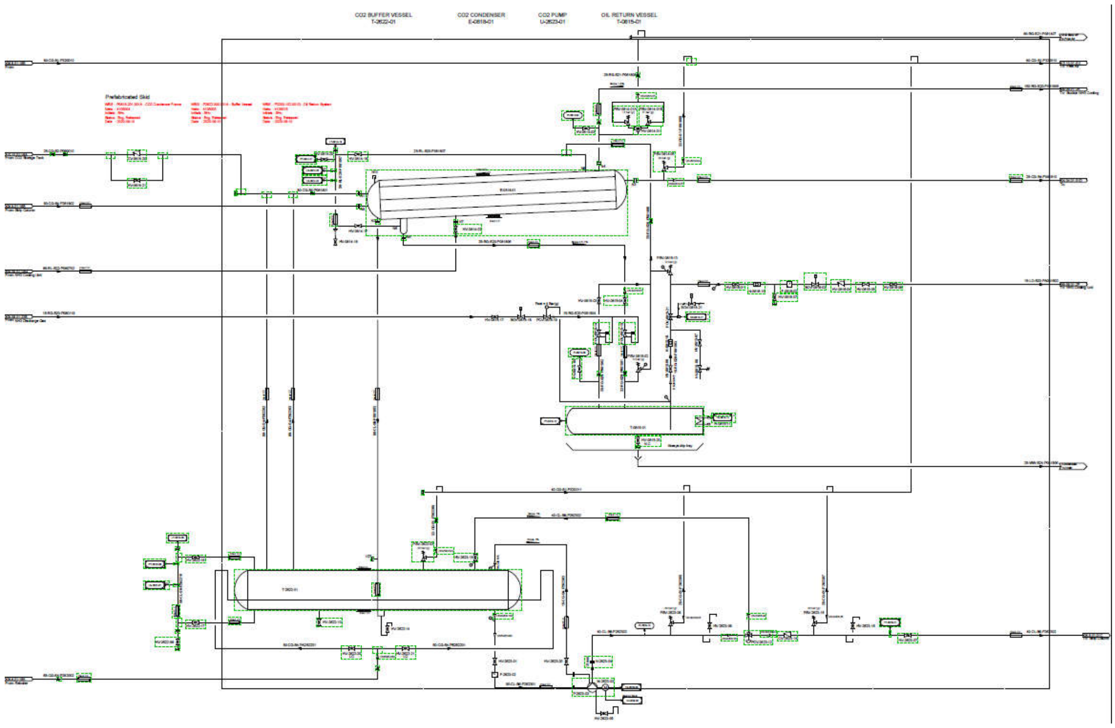

Figure 6-1. CO_2 Condenser and Buffer Vessel P&ID.

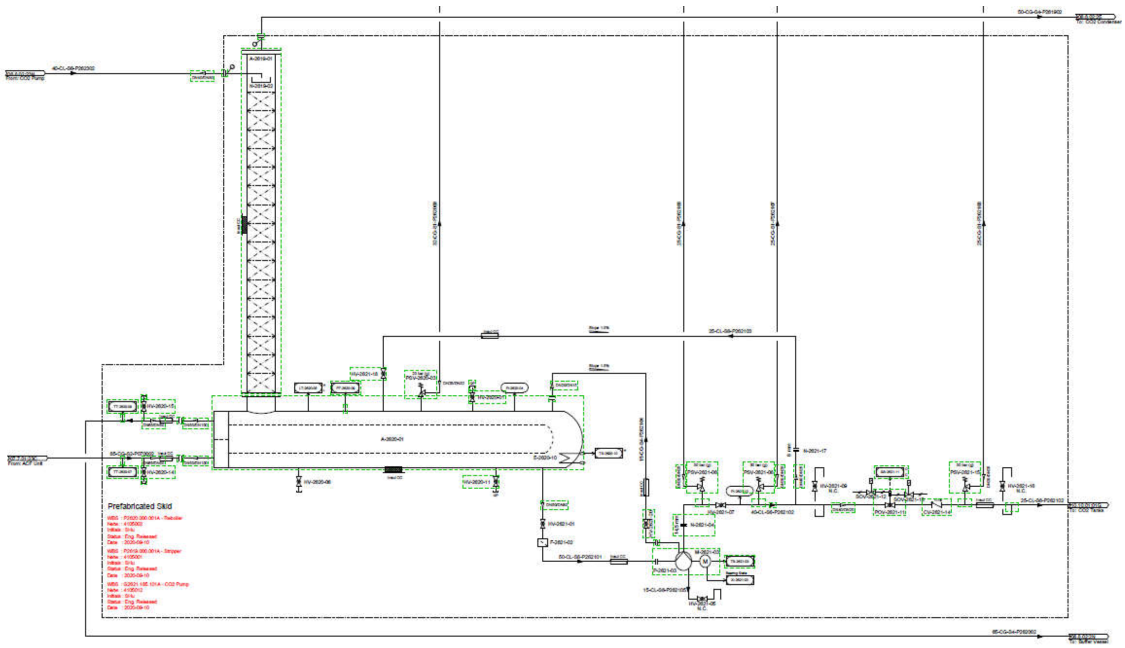

Figure 6-2. Reboiler and Stripping Column P&ID.

6.2. Process description

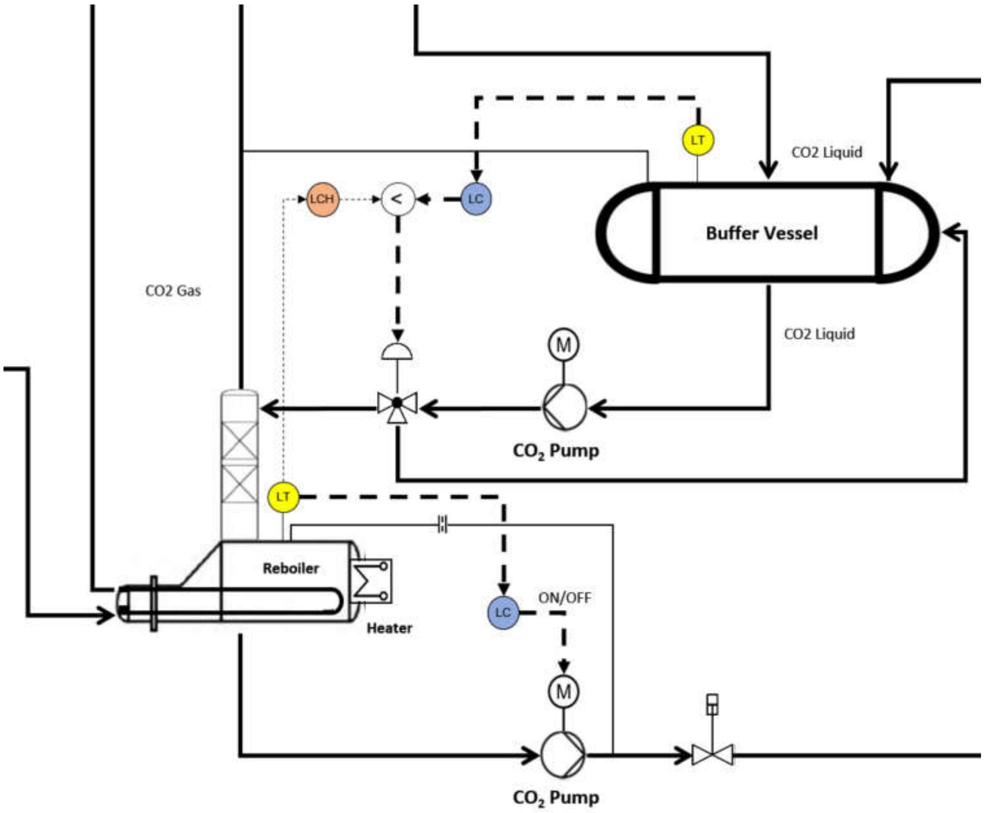

Figure 6-3. Typical reboiler/buffer Level Control Loops.

6.2.1. Buffer

This buffer is used for short-term storage of liquid CO2 and to provide a buffer volume in case of load changes. The liquid level in the vessel is maintained under “normal” operating conditions by a control loop comprising a level transmitter, level controller (executed in PLC) and level control valve. The level and valve position is displayed on the TP in (0-100%).

6.2.2. Stripper

The stripper removes non-condensable from the liquid fed via the control valve of the CO2 Buffer. The flow of liquid and required gas amount through the column depends on the system load and gas temperatures.

6.2.3. Re-boiler

The re-boiler provides two functions:

- It generates CO_2 used to strip the impure CO_2 liquid in the stripping column. The quantity of re-boiling gas is termed as discussed above.
- It provides a liquid buffer for the CO_2 re-boiler pump.

6.2.4. CO_2 re-boiler pump

The CO2 re-boiler pump is used to transport the liquid CO2 from the re-boiler to the CO2 tanks. A Level Transmitter in the re-boiler is used to control the re-boiler pump in on/off fashion. The valve behind the pump opens the pipe to the CO2 storage tank.

6.2.5. CO_2 Condenser

The CO2 condenser liquefies the CO2 and accommodates the purging of non-condensable.

6.3. Stripping Column (Stripping gas control)

The stripping gas control for heating is calculation based.

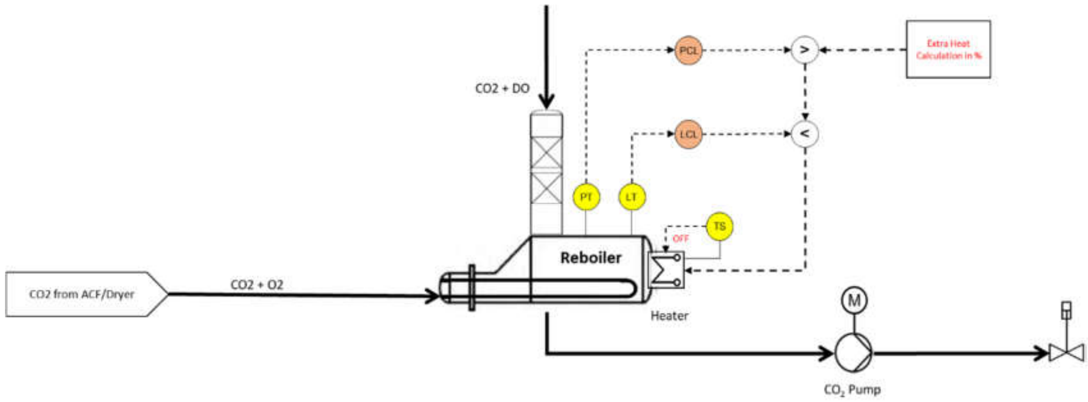

Figure 6-4. Typical Reboiler Heater Control Loops.

6.3.1. Normal mode

6.3.1.1. O2 value too high.

If active and during 10 minutes in normal mode a too high O2 value >Set point high O2 is measured in the re-boiler will switch to stopping mode.
As soon as the O2 value is < Set point high O2 the pump and heaters are switched off and the system returns to the for that moment normal operation mode.
O2 value too high, will not switch-on the recirculation mode when the level in the re-boiler and/or buffer is too high.

6.3.1.2.Start mode

In start mode, the heating elements are activated based on the calculation as described above in chapter 7.3.2.

6.3.1.3.Stopping mode

In stopping mode a fixed kilowatts of stripping gas is activated to ensure gas flow.
After the level control valve is closed the heating elements are switched off.

6.3.1.4.Production

In production mode, the amount of stripping gas is calculated according the formula.
The CO_2 re-boiler pump is controlled on re-boiler level.
In production mode the calculated heating amount can be increase/decreased with a value of extra kilowatts. These extra kilowatts are added to the calculated value.

6.3.2. Standby mode

If no compressors are running and the buffer vessel has stopped, the heating is deactivated. The CO_2-4U system is standby.

6.3.3. High Level Alarm

When the level transmitter LT77.3002.05 has reached a high level set point, (time delay 5 sec). a High reboiler Level Alarm will be generated. When this occurs the start release for the recovery plant is stopped..

- The re-boiler control goes to stopping mode.

(At this point operator intervention to solve problem is required.)

6.3.4. Safety heating elements

The heating element are switched off when the CO2 level in the re-boiler < Low re-boiler level, this is to prevent thermal overload of the elements.
Additionally a thermostat is installed that will also switch-off the heating element.

6.4. CO_2 re-boiler pump

There is a CO2 pump installed for pumping the liquid CO2 to the storage tanks.
Valve position feedback signals are checked, if the feedback is not given with-in 15 seconds an alarm is given and the pump is stopped.

6.4.1. Stand-by mode

The pump is stand-by when:

- When the pump is activated via the HMI panel AND
- There are no alarms from the pump selected pump (including E-motor) AND
- There is no requirement for the pump to switch on (e.g. level re-boiler reached, drain mode, manual mode)

6.4.2. Normal mode

In normal operation, the CO2 re-boiler level or the O2 level in the re-boiler may start the CO2 pump.
The CO2 pump always operates in combination with the outlet valve.
The CO2 pump always starts time delayed (5 sec) in recirculation, after a 10 sec time delay the valve opens to the CO2 tank.

The pump status depends on:

- O2 -level in the re-boiler. O2 level > O2 set point re-boiler in circulation and pump on
- CO2 level re-boiler < start re-boiler level set point. Pump is off (re-boiler control).
- CO2 level re-boiler > start re-boiler level set point. Pump is on (re-boiler control).
- The re-boiler set to manual.
- Release of the CO2 tanks.

6.4.3. Manual mode.

It is possible to control the re-boiler pump manually.

- Manually turn on/off the pump

6.4.4. High Level Alarm

When the re-boiler level transmitter has reached the high alarm set point, the CO_2 pump control and the control of the re-boiler heating remain active.

6.4.5. CO_2 pump valve and valve position feedback

Valve position feedback signals are checked, if the feedback is not given with-in 15 seconds an alarm is given and the pump is stopped. The valve may be switched to manual (set in the HMI, level Supervisor). There are 2 positions:

- To CO_2 tanks (Open)
- Close

If the pump control is automatically and the re-boiler level is “> start re-boiler level set point”, the CO_2 pump is switched on and the valve position changes (time delayed) to CO_2 tank fill. When the re-boiler level is “< start re-boiler level set point”, the pump switches off and the valve will close.

The CO_2 tank release signal is checked prior to starting of the pump and releasing the valve to fill the tank.

7. NH_3 Cooling Unit

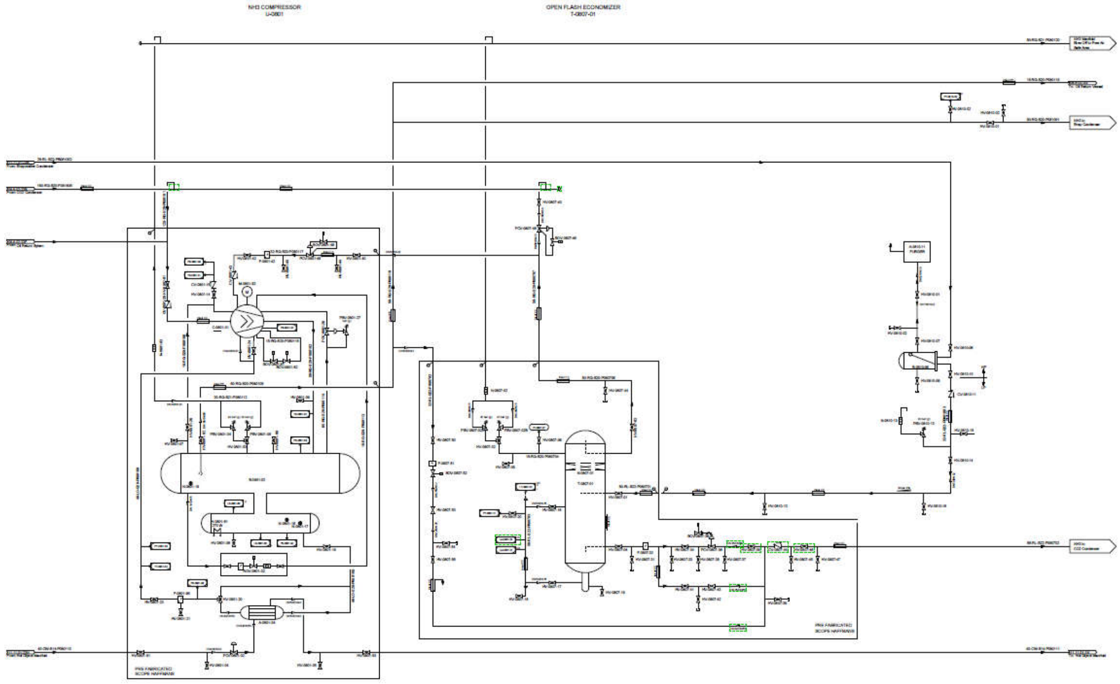

Figure 7-1. Cooling Compressor P&ID.

7.1. Sabroe Compressor Start and stop Sequence

7.1.1. Description control system NH3 compressor

The cooling system is equipped with Sabroe screw compressors and an open flash eco system. The compressor has his own OEM control unit (Unisab) and frequency controller. The Unisab does control the complete NH3 compressor and frequency controller. Based on the evaporating pressure transmitter at the suction of the cooling, the control system gives a start signal and input on the required capacity.

7.1.2. Capacity control

Based on the evaporating pressure the Haffmans control system will give a signal to increase or decrease capacity. The first cooling compressor in sequence will start. Basically, the compressor will first start on minimum speed and with the capacity slide on minimum. If more capacity is required, the Unisab will move the slide to max capacity and stay on min speed. If more capacity is required, the eco port can be opened (will only open if suction pressure is below certain value). As the compressor runs with open eco port and slide moved to max capacity, the compressor is ramped up to max speed for more capacity.

The required capacity is based on the evaporating pressure. The higher the evaporating pressure, the higher the capacity of the NH3 compressor.

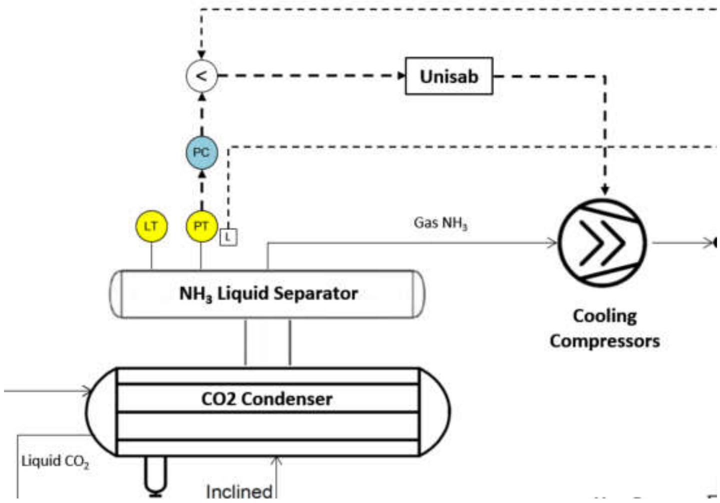

Figure 7-2. Typical Cooling Capacity Control Loops.

7.1.3. NH3 condenser

The NH3 condenser cools down and liquefy the high-pressure refrigerant gas coming from the compressor (the pressure and temperature depend on the cooling plant configuration). The heat of condensation is extracted from the refrigerant in the heat exchanger by water previously cooled down in the cooling tower.

7.1.4. Economizer

In systems where there is a big difference between suction pressure and discharge pressure (condensation pressure) a economizer can be used to run the cooling system more (energy) efficient.
In the economizer is the Liquid NH3 before entering the CO2 condenser cooled down. The type of economizer is an Open flash.

In the open flash systems a small flow of Liquid NH3 is evaporated to cool down the main flow of liquid NH3 for the CO2 condenser.
The NH3 which is evaporated in the Economizer can go:

- To the inlet of the NH3 compressor, called “eco inlet compressor”.
- To the suction of the NH3 compressor, called “eco to suction”.

Note: or the eco to suction is open or the eco inlet on 1 or more compressors is open. They are never both opened together or never all closed (eco to suction closed and eco inlet compressor closed).

The eco heat exchanger is always controlled by mechanical control valves (outside control systems).

7.1.5. NH3 Level (CO2 condenser)

The CO2 condenser is a flooded NH3 evaporator. This means that the CO2 tubes should be in a bath of liquid NH3. The control valve, at the economizer outlet will control the filling level of the NH3 in the CO2 condenser. All liquid NH3 that does enter economizer is expanded and flows into the CO2 condenser. This system works with the control system. For this system is precise filling of NH3 required.

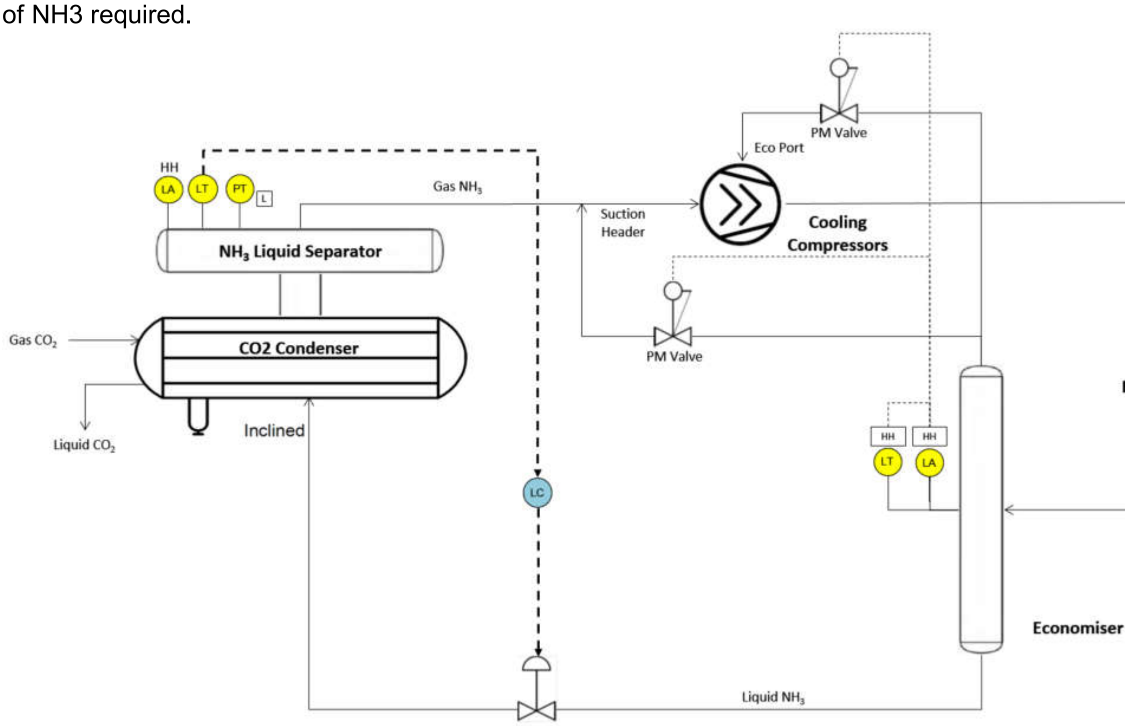

Figure 7-3. Typical Condenser Level Control Loops.

7.2. NH_3 Pump Down

During standstill of the CO_2 condenser (i.e. when not in operation) the NH_3 pressure will rise due to heat ingress from the ambient surroundings.

When the NH_3 suction pressure rises above the “NH_3 PUMP DOWN SUCTION START SP” then the NH3 compressor will start. The Haffmans system will provide a “FIXED NH_3 PUMP DOWN SP.” When the suction pressure drops below the “NH_3 PUMP DOWN SUCTION STOP SP” the NH_3 compressor will stop.

“NH_3 PUMP DOWN SUCTION START SP”, “FIXED NH_3 PUMP DOWN STOP SP” are all adjustable on the HMI.

8. CO2 Evaporator

8.1. General introduction

The CO2 evaporator is used to evaporate the liquid CO2 from the storage tanks to use the CO2 in gas form for ACF/Dryer regeneration and other possible consumers.

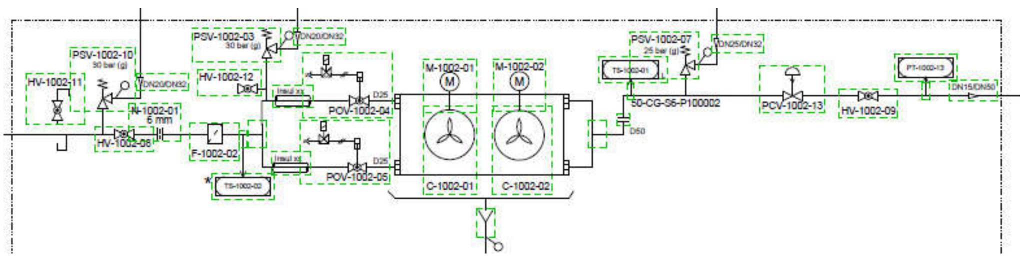

Figure 8-1. CO_2 Evaporator P&ID.

The forced air, ambient air, CO2 evaporator draws heat from the ambient to evaporate CO2.
The minimum ambient temperature inside the room should be 10˚C.
When the ambient temperature drops below 10˚C the pre-heater automatically switches on (optional).

8.2. Description

The evaporator is controlled as a stand-alone system, and it can run completely independent of the CO2 recovery process. When the evaporator is in operation, the fans are switched on, the liquid inlet valves changeover system is activated, and the control valve is released to keep the outlet pressure to the desired setting.

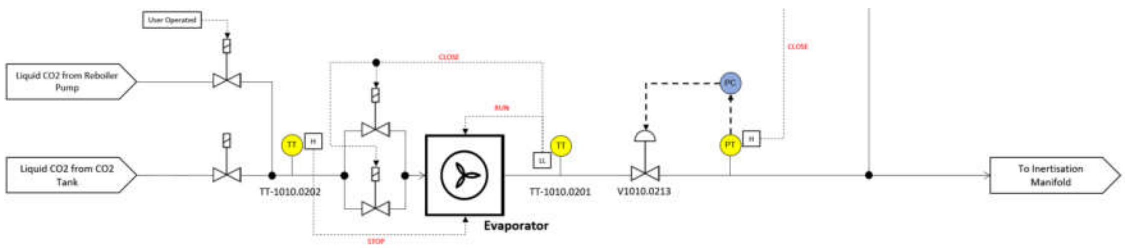

Figure 8-2. Typical Evaporator Control Loops.

8.2.1. Temperature low evaporator mode

If the CO2 outlet temperature is too low, the CO2 inlet valves are closed but the ventilators stay running. The alarm will be automatically reset with a dead-band.

8.2.2. Valve changeover system

The CO2 liquid inlet valves are opened after each other at a fixed interval to prevent ice accumulation on the active tube side.

When the evaporator is switched on, the fans start when the CO2 inlet temperature drops below a setpoint indicating that there is liquid going into the evaporator. Once the temperature increase (liquid is pushed back to tank) above the setpoint, the ventilators will be switched off and the valves will keep on functioning.