10. TECHNICAL DESCRIPTION

A. CONDITIONING

i. BOOSTING

A VFD is used to control the speed of the blower. Control is carried out by a regulation. The intake pressure to the MP compressor is fixed and provides a setpoint for the downstream pressure of the booster. The booster is used to overcome the pressure drops that rise in the equipment between the blower and the compressor.

ii. DRYING CHILLER

A first drying step is operated in order to remove the water contained in the saturated biogas. This step is done through a chilled water / biogas heat exchanger.

iii. DRYING SEPARATOR

The condensate separator is used as removal media for the water droplets that have been formed through the drying step. The water droplets are brought to the condensate collector.

B. LOW PRESSURE TREATMENT

i. DESULFURIZATION

H2S removal is done through activated carbon media on which physical and chemical adsorption occurs. There are two vessels in series with a lead-lag configuration allowing a continuous operation during saturated carbon load change, and allowing a better load of the carbons (a mettre seulement si dans scope principale).Please refer to Appendix 4.

ii. VOC PURIFICATION

Biogas is removed from its VOC through this sub-module. Activated carbons adsorb them through an exothermic reaction which allows heating gas.There are two vessels in series with a lead-lag configuration allowing a continuous operation during saturated carbon load change, and allowing a better load of the carbons (a mettre seulement si dans scope principale).Please refer to Appendix 4

iii. DUST FILTER

Once a new load of activated carbons has been installed, fine carbon particles can be found in the desulfurized biogas. That is why the dust filter is installed in order to protect the MP compressor. A pressure drop measurement allows surveying the cleanliness of the filtering media.

C. MEDIUM PRESSURE COMPRESSION

A lubricated oil screw compressor raises the pressure of the biogas in order to reach the best CH4/CO2 separation pressure. Since the compressor is a volumetric one, the pressure of the compressed gas is adjusted via a regulation valve. The compressor throughput is adjusted via a variable frequency driver, and a recycle valve.

The throughput is the quantity of gas that the unit compresses at MP between its minimum and its maximum flow rates. It is represented by a value between 0 and 100%, 0 being the minimum flow rate from the MP compressor and 100 its maximum flow rate. It is important not to confuse throughput and production; for example a biogas with low input quality may generate low production at high throughput as it requires a high rate of recycling.

Four different ways to manage throughput are possible:

-**1st case: the operator chooses a set point value:** the operator sets an injection set point value 3101_FIC_OUT6 between 0 and 100%. This set point value will be applied only if the upgrading unit is in « injection » mode. In the other upgrading unit configurations, throughput is defined by start-up (3101_FIC_OUT0), process room heating (3101_FIC_OUT3) and awaiting injection (3101_FIC_OUT5) parameters.

-**2nd case: regulation based on digester level (gas bag):** throughput set point is adapted linearly and automatically regarding gas level in customer gas bag.

-**3rd case: regulation based on network injection pressure:** throughput set point is adapted linearly and automatically regarding network injection pressure.

-**4th case: regulation based on customer request:** the customer Programmable Logic Controller (PLC) defined a throughput set.

In each case, the chosen regulation is maintained until:

- Either a plant shutdown (normal shutdown or emergency shutdown): for a restart-up, the throughput will be automatically brought back to the value of the throughput startup parameter 3101_FIC_OUT0

- Or a quality loss while the unit state was « awaiting injection » or « injection »: the throughput is then automatically brought back to the value of the throughput startup parameter 3101_FIC_OUT0

The flow control of the installation is a split range. When the VFD is at its minimum value, the valve adjusts its opening to recycle a larger or smaller quantity of gas downstream of the compressor. Beyond the minimum speed of the VFD (for higher flow rates), the recycling valve is closed and the flow rate is varied by the speed of the compressor.

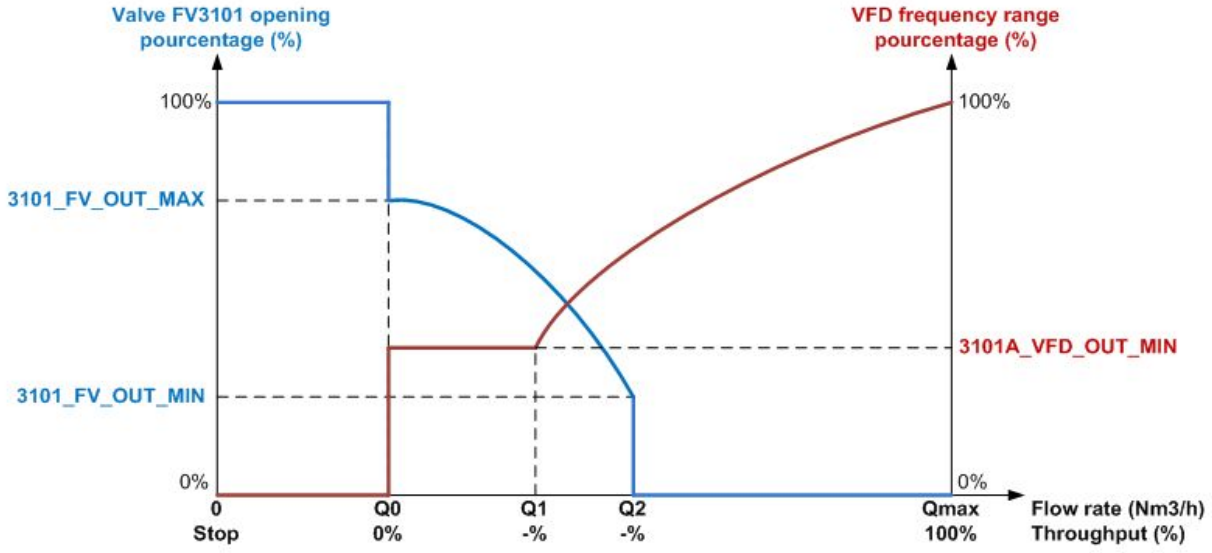

Figure 4: Split range valve, VFD and compressor flow rate

D. DRYING

i. AIR PRECOOLER

After it has been compressed, biogas is cooled by an air/gas heat exchanger.

ii. DRYING CHILLER

After the first step of cooling, the gas is cooled a second time with the gas/cooled water heat exchanger.

A regulation valve adjusts cooled water flow in the way the gas temperature measured with the temperature transmitter will be at the set point value defined.

iii. CONDENSATE SEPARATOR

After a second step of cooling, the gas is dried by separating the liquid water with a vessel.

iv. HEAT EXCHANGER

After the double stage filtration the gas is heated with a gas/hot water heat exchanger to be sure the gas will be free of liquid water at the inlet of the membranes.

A regulation valve adjusts hot water flow in the way the gas temperature measured with the temperature transmitter will be at the set point value defined.

v. Filtration

Two filters on line removed particles and oil from the gas. The pressure drop measurement allows surveying the cleanliness of the filter.

vi. Heat recovery

A water/oil heat exchanger is used to recover heat from the compressor oil. It allows to provide hot water.

E. Medium pressure treatment

i. Oil removal system

To reduce at a ppm level the remaining oil in the compressed gas downstream the compressor, an oil removal system is installed. The media is a non activated carbon, which is very efficient for adsorbing hydrocarbons like oil. Downstream this carbon filter, the residual oil level is below 0.01 mg/Nm3.

ii. Final filtration

In order to remove carbon dust, a filter is installed. The pressure drop measurement allows surveying the cleanliness of the filter.

F. Carbon dioxide removal

The produced biomethane quality is adjusted with pressure at the inlet of the membranes. The control of pressure is done via a pressure control valve. A pressure increase leads to a CO2 concentration decrease: therefore biomethane quality increases.

In normal operation, the biomethane is injected to the grid. During transitory phases, produced biomethane can be sent back in the digester or to the vent in order to prevent the loss of methane molecules.

i. First stage of membranes

The ALAT technology to remove carbon dioxide from methane is based on polymer membranes. One membrane is composed of several polymer hollow fibers. The gas to be treated is fed to one side of the membrane, at a medium pressure. Then two streams are produced by the membrane:

1. A retentate at a pressure equal to the inlet pressure minus the pressure drop across the membrane. This retentate is enriched in CH4.

2. A permeate, at low pressure. This permeate is enriched in CO2.

The CO2/CH4 separation is done inside the polymer fiber, by a solution and diffusion mechanism.

First stage is composed of several membranes. The 1st stage retentate is directed to the 2nd stage inlet, whereas the 1st stage permeate is directed to 3rd stage.

One or several of these membranes can be isolated automatically to adjust performances and adjust to ongoing conditions.

ii. Second stage of membranes

Second stage is composed of several membranes. The 2nd stage retentate is the biomethane, and is directed to the grid injection, whereas the 2nd stage permeate is recycled to the compressor suction.

One or several of these membranes can be isolated automatically to adjust performances and adjust to ongoing conditions.

iii. Second stage temperature control

A heat exchanger manages the gas temperature between the 1st and the 2nd stage, in order to optimize process performances.

iv. Third stage of membranes

Third stage is composed of several membranes. The 3rd stage retentate is directed to the 4th stage inlet, whereas the 3rd stage permeate is mixed with the 4th stage permeate, and vented or sent back to the digester.

One or several of these membranes can be isolated automatically to adjust performances and adjust to ongoing conditions.

v. Fourth stage of membranes

Fourth stage is composed of 1 membrane. The 4th stage retentate is recycled to the compressor C3101A suction, whereas the 4th stage permeate is mixed with the 3rd stage permeate, and vented or sent back to the digester.

G. Injection

This function enables:

-To return both biomethane and CO2 rich stream to the customer (digester or gas bag)

-To return the CO2 rich stream only to the customer. It can then be coupled with the biomethane returned to the digester by non-Air Liquide devices downstream of the purifier (injection station, others, etc.)

-To return biomethane only: the CO2 rich stream is then sent to lean gas processing.

H. Secondary streams management injection

i. CO2 enriched gas

This sub-module is piping connections to send off gas to the vent.

ii. Safety vents

This sub-module is piping connections to collect safety devices and gas flow to the vent.

iii. Purge vents

This sub-module is piping connections to collect process and maintenance purge gas flow to the vent.

iv. Condensates

This sub-module is piping connections to collect condensates to the condensates vessel (customer scope of work).

I. Utilities

i. Air supply

This sub-module is used to supply compressed air in order to operate On/Off and control valves.

On/Off valves need air occasionally to be opened or to be closed, depending on their fallback position.

Control valves need for their part a continuous air supply to be able to constantly adjust their position.

ii. Nitrogen supply

Nitrogen (N2) is an inert gas used to ensure installation safety states (purges and inertings). It is supplied in the form of frames of 200 barg cylinders.

In order to ensure safety and security and to make operations easier, two pressure networks are available.

iii. Analysis

Several analysis points are available on the process. They have three different objectives:

- To measure raw biogas and biomethane gas concentrations,
- To control active carbons loading/ageing,
- To control biomethane quality at injection.

iv. Chiller

The chiller provides chilled water used in biogas/water exchangers which permit to control biogas temperature according to process needs.

A capacity after this equipment allows a defined water quantity storing according to chilled water design.

v. Hot water

Many calories are available on the compressor oil network. By recovering them thanks to an oil/water exchanger, a hot water network is obtained. This water is then used to supply biogas/water exchangers which permit to control biogas or biomethane temperature according to process needs, and the rest is supplied as a free heat to you, that you can use in your methanation process for example.

APPENDIX 2 : TYPICAL GENERAL LAYOUT

An important part of AIR LIQUIDE's equipment is in a container. The unit is pre-skidded, which makes installation on site easier, thus reducing the associated cost for the client. The list of the main equipment is given as an example.

- Equipements in the main container :
  - Biogas compressor
  - Membrane modules
  - Post compression filtration
  - Hot water module for heat recovery
  - Electrical cabinet and PLC in a separated control room, in order to respect ATEX specifications

- Equipements outside the main container :
  - Blower and drying module
  - Chiller
  - Adsorption vessels for H2S & VOCs removal

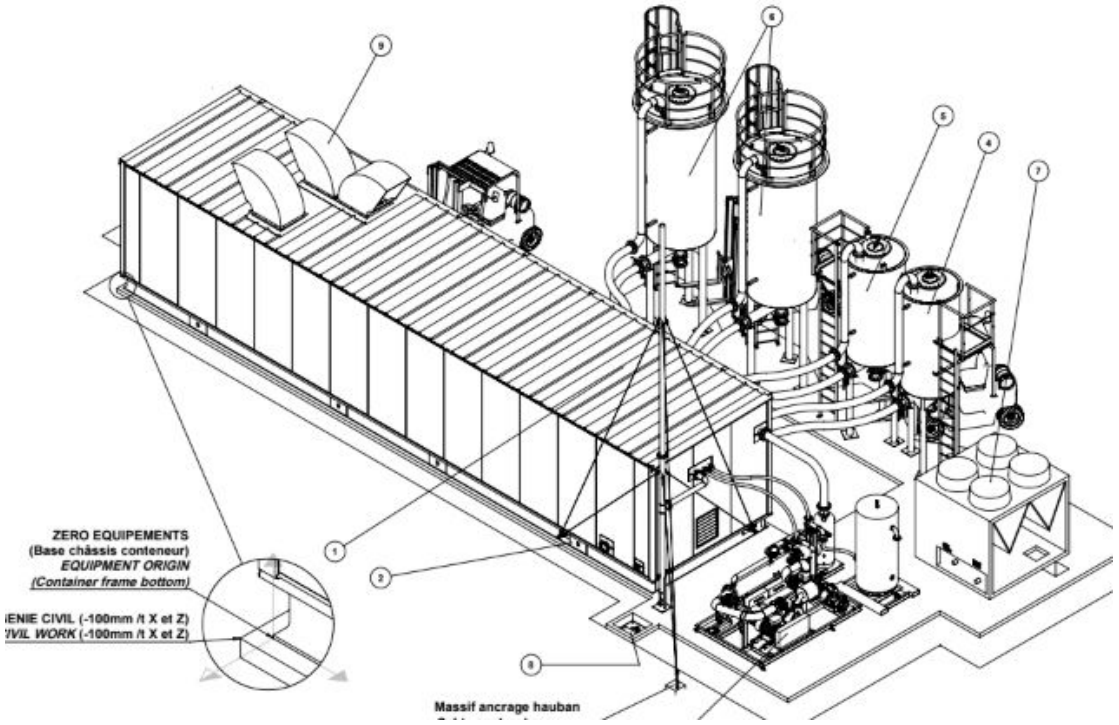

***Figure 6**: Example of layout similar to the unit*

APPENDIX 3 : OPERATION AND PREVENTIVE MAINTENANCE

- **Monitoring of operation parameters**

The following parameters shall be monitored and registered according to the method and periodicity referred in the operating and maintenance manuals:

- Pressure, temperature and composition of inlet raw biogas as defined in §4
- H2S and NH3 concentrations post H2S and NH3 removal-units < 10 ppmv
- Biogas temperature at the entrance of membrane modules between 5 and 40°C
- Absence of oil vapor and VOC upstream membrane modules
- Absence of liquid condensate upstream membrane modules

All data here above must be available at any time.