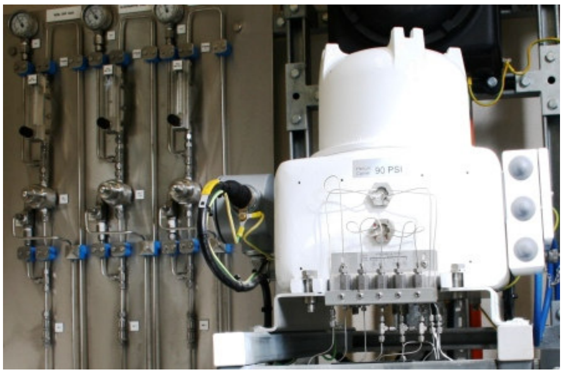
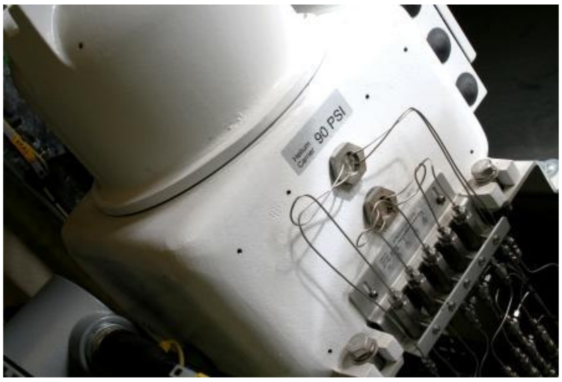
Pictures and (or) Drawings of Process Equipment





References

None.

Wobbe Meters

Equipment description

A small LNG or gas flow is taken from the Low Pressure LNG headers (before the recondenser, thus before ballasting) and the High Pressure Gas Send-Out headers (after ballasting through liquid nitrogen injection). The LNG is vaporised in a dedicated vaporizer cabinet. The small gas flows are diverted towards the analysis instruments: the wobbe measuring system.
A wobbe measuring system is a gas quality analyser that performs infrared absorption and thermal conductivity measurements. The primary target variables are the gross calorific value, standard density and wobbe index. The entire system consists of two components: the sensor system and the evaluation computer. The sensor system contains two infrared sensors for measuring the absorption of the hydrocarbons (and carbon dioxide) contained in the natural gas. Another sensor determines the thermal conductivity and thus also measures gas components such as nitrogen for example, which cannot absorb infrared light. Finally the evaluation computer evaluates all three measurements. As a result, the gross calorific value, standard density and CO_2 content of the natural gas are supplied. Other variables such as the Wobbe and methane numbers are also determined.

General Emissions Details

- Land ☐
- Air ☒
- Water ☐
- Noise ☐

Prerequisites requirements of equipment

Electricity

Electricity is needed for the vaporizer cabinet, the sensors and the evaluation computer (on which the analysis software is running). Because the wobbe meter is used for commercial purposes, it is a critical piece of equipment - in the event of a power failure the power supply is switched over to the UPS power supply (batteries).

LNG or gas (to be analyzed)

Emissions details

LAND

There are no emissions to land.

AIR

The analyzed gas is vented to air. This will predominantly be lighter hydrocarbons with the majority of those hydrocarbons being methane.

WATER

There are no emissions to water.

NOISE

There are no noise emissions.

Environmental Risks

Emissions of natural gas to air which requires venting at safe locations in order to prevent a flammable mixture of gas and air.

Appropriate Measures to Protect Against Safety Risks

The sampling point (pitot tube in LNG low pressure headers and send-out gas headers), the vaporizer cabinet, and tubing to the measuring device should be designed and constructed according to the applicable codes and standards (special attention should be paid to the welding of the sampling point).

Benefits of Technology

Cost (Capital and Operating Costs)

A wobbe measuring system is high cost (CAPEX), but once calibrated and running, the operational costs (OPEX) are quite low. Recalibration should be performed on a regular basis (or an update of the analysis software).

Operational

Almost immediate results (once every couple of seconds) and very reliable equipment.

Environmental

None considered.

Downfalls of Technology

Cost (Capital and Operating Costs)

Quite expensive, certainly when there are a lot of gas and/or LNG streams that must be analyzed (one measuring system is needed for every flow).

Operational

High variable readings between gas chromatographs and wobbe meters with respect to the wobbe and clourific value measurements can be experienced if the two are operating simultaneously. A change in composition (relative change) however is observed much faster with the Wobbe measuring devices (one sample every couple of seconds, meanwhile the GC samples only once every 5 minutes). This is considered to be the reason why the wobbe measuring devices are used for fast-forward controlling while ballasting, and the GC's are used for fine tuning.

Environmental

Emissions of natural gas into the air. If possible the analyzed gas and bypass stream should be recuperated in the low flare system.

Development / History of Technology

None.

Open section on novel ideas

None.

Pictures and (or) Drawings of Process Equipment

None.

References

None.

Raman Spectroscopy

Equipment description

A Raman Spectroscopy LNG analyser uses laser technology to predictably measure the composition directly from a stream of LNG. The system is comprised of a probe, a fiber optic cable and a base unit. The probe is inserted into a transfer pipe at the desired sampling location. The light from a laser in the base unit is transmitted to the sampling location through a fiber optic cable to the optical probe and released into the LNG sample. The light which is reflected back to the cryogenic optical probe is then transmitted back to the base unit via the fiber optic cable. The returned light is analyzed in the base unit and the composition of the LNG is determined from the shift of the wavelength between the initial light source and the reflected light.

General Emissions Details

- Land ☐
- Air ☒
- Water ☐
- Noise ☒

Prerequisites requirements of equipment

<u>Electricity</u>

A Raman Spectroscopy LNG analyser requires a source of electricity for operation. The electricity is required by the base unit for the operation of the laser light emitter and the analysis machine.

<u>Purge Gas</u>

If the system is to be installed in a hazardous environment, purging of the base unit is required. A source of purge gas should therefore be available which could typically come from the terminals instrument air system or a dedicated nitrogen system.

Emissions details

<u>LAND</u>

There are no emissions to land as a result of the operation of this technology.

<u>AIR</u>

If the equipment is installed in a hazardous area, purging of the base unit would be required. Depending on the gas which is used for the purge, this operation could lead to an emission to air of the purge gas.

<u>WATER</u>

There are no emissions to water as a result of the operation of this technology.

<u>NOISE</u>

There are no direct emissions of noise from this equipment of significance. The method which is adopted to produce the purge gas if the equipment is located in a hazardous area could lead to a generation of noise.

Environmental Risks

There are no environmental risks associated with the operation of this technology.

Appropriate Measures to Protect Against Safety Risks

A safety risk is presented by the possible back flow of gas from the sampling point to the base unit. This risk is avoided through hermetically sealed barriers.

In addition, if the equipment is to be installed in a hazardous area, the electrical equipment could pose a safety risk. In this instance, the equipment should be suitably rated for use in a hazardous area with suitable arrangement for emergency shutdown of the equipment.

Benefits of Technology

<u>Cost (Capital and Operating Costs)</u>

As the equipment is still an emerging technology, capital costs are hard to compare to other established technologies. The operating costs of the equipment are considered very small owing to the make-up of the system.

<u>Operational</u>

The system is constructed of optical and solid state devices which means that the system is very robust and requires very little maintenance.

<u>Environmental</u>

Environmentally, Raman Spectroscopy LNG analyser devices offer good benefits over similar technologies. The system is able to analyse the LNG without the requirement to vaporise a sample which in the case of gas chromatography usually leads to a release of that gas to the environment generating an emission. With Raman Spectroscopy LNG analysis, the only tangible emissions are the gases which are released due to purging the base unit for systems which are installed in hazardous areas.

Downfalls of Technology

<u>Cost (Capital and Operating Costs)</u>

None considered.

<u>Operational</u>

This system is a new and emerging technology which means that operational awareness and knowledge of the system is relatively low. However, the robustness of the system in terms of simplicity would dictate that this should not materialise as an issue in operating the equipment.

<u>Environmental</u>

None considered.

Development / History of Technology

The Raman Spectroscopy LNG analysis system is based upon equipment that had been successfully deployed at industrial sites for different applications for several years. These systems were then modified in the late 2000’s to be applicable for use in the cryogenic natural gas industry. This involved re-engineering of the hardware and development of new algorithms to coupe with the various gas compositions experienced in the LNG industry.

Open section on novel ideas

This technology could be coupled with densitometer devices which are used to gather data on the density of LNG layers within an LNG storage tank to help with prediction and prevention of a phenomenon known as roll-over. Should this technology be utilised in tandem with densitometer technology, the gas composition across the depth of the tank could also be ascertained to further inform the operator.

Pictures and (or) Drawings of Process Equipment

None.

References

2. Raman Gas Analyzer System Publicity Brochure, *Scientific Instruments*, **October 2010**

LNG Ballasting

Air Injection

Equipment description

The calorific value of the gas that is vaporized and sent to the Transmission gas Network must be precisely controlled and can be neither too high nor to low (LNG ballasting). The purpose is to avoid technical and safety problems to the final users (industrial and domestic heaters etc..)
The parameter that is commonly used in order to control this particular aspect of the process is called the Wobbe Index:

$$Wobbe = \frac{\text{Gross Calourific Value}}{(\text{density of gas} \div \text{density of air})^{0.5}}$$

The Wobbe Index values must be kept within a precise interval that can be slightly different from country to country.

One of the methods that is used to lower the Wobbe Index in the event that it is too high (LNG characterised by significant presence of heavy hydrocarbons like propane, butane etc. with respect to methane), is to reduce the GCV by adding compressed air (the injected air must reach the same pressure as gas network).

Two twin screw rotary compressors can supply the first stage of compression (up to 11 bar) and two further twin alternative compressors raise the pressure of the injected air up to the final value (72 bar).

Both the rotary and alternative compressors typically have two stages of compression, and are provided with a control system allowing the equipment to operate at different operating conditions.

Technical data (n. 2 rotary compressors – 2 stages each):

Suction temperature	°C	ambient
Suction pressure	bar A	1
Discharge temperature	°C	30
Discharge pressure	bar A	11
Engine power	630 KW	
Flow rate/each compressor	4.300 Ncub.m/ h	

Technical data (n. 2 alternative compressor – 2 stages each):

Suction temperature	°C	30
Suction pressure	bar A	11
Discharge temperature	°C	142
Discharge pressure	bar A	72
Engine power	460 KW	
Flow rate/each compressor	4.300 Ncub.m/ h	

General Emissions Details

Land ☐

Air ☐

Water ☒

Noise ☒

Prerequisites requirements of equipment

Electricity

The power needed for the operation of the compressors is supplied by 6 KV electric motors; there are also auxiliary electrical pumps for lube oil, working at 380 V, and several other utilities (e.g. heat exchangers, instrumentation etc..).

Instrument air

The instrument air is supplied by the plant's instrument air system which facilitates the instrumentation and control of the whole ballasting system.

Water

Cooling water is necessary to cool the cylinders and other mechanical parts of the compressors and it is supplied by the cooling water system of the plant (usually there is not a cooling system specifically dedicated to the air compressors).

Oil

Lube oil is essential to lubricate all the rotating parts of the equipment.

Air Dryer

The air compression system is equipped with a Dryer that controls and lowers the air humidity ratio in order to avoid rusting of the internal metal parts of the various equipment items. The dryer induces the desired effect by lowering the air temperature. This is obtained by means of a refrigeration system.

Oxygen Membranes

For safety reasons, it is also important to control the oxygen concentration of the final gas flowing into the gas network. As a consequence, it could be necessary to reduce the oxygen concentration of the injected air. To do this, a couple of molecular Membranes are used to remove some of the oxygen in the air in order to keep its concentration within acceptable limits.

Emissions details

LAND

The whole mechanical system is lubricated by lube oil to ensure the continued operation of the equipment.

In the unlikely event of a failure of some parts of the oil system, lube oil could be released and can lead to pollution of the land if the collection basin is not adequately designed in order to safely contain any possible oil release.

AIR

The Refrigeration system that is part of the air dryer uses a fluid which, in case of release or replacement, can have detrimental effects on the ozone layer.

Some types of refrigerating fluids have been abandoned in recent years due to their effects on the ozone layer. It is therefore important to use fluids that have little or no environmental impact.

WATER

An LNG plant is usually provided with a cooling water system. The water is cooled inside a heat exchanger with sea water, the temperature of which must be carefully controlled before final discharge in order to avoid impact on marine life. The local Authorities usually set the maximum allowed value in terms of temperature variation of the discharged sea water.

NOISE

The level of noise directly measured (1 m from the noise source) near the whole system of compression is typically 76 db (A) .

This level must be lower than the maximum allowed limit set by regulation (usually 85 db A)

Environmental Risks

It's possible that an oil release due to a mechanical failure affecting the oil circuit can pollute the land.

Environmental risks are also prevented by the potential spillage of lube oil during the transfer operation necessary for the maintenance of the equipment.

The use of inadequate refrigerating fluids (used inside the Air Dryer) can have an impact on the ozone layer should they be released. It is important to select the refrigerant fluids carefully to ensure that the impact on the environment is reduced and that regulations are complied with.

Appropriate Measures to Protect Against Safety Risks

Regular maintenance and inspections are fundamental to guarantee the efficiency and reliability of compressors and maintain adequate safety levels.

In order to avoid any risk related to the occurrence of an incident, the compressors are equipped with safety valves to prevent any possible failure. The air compressors should be designed, constructed, and operated in line with the relevant codes and standards.

The air compressors which provide the ballasting system for the terminal are vital to the safety of the network in terms of maintaining an acceptable gas quality level to protect downstream users. An automatic shut-down system should be installed which will shut-down the production from the terminal in the event of a gas quality excursion to protect the downstream users.

Benefits of Technology

<u>Cost (Capital and Operating Costs)</u>

Air injection systems are not required to operate under cryogenic conditions as with liquid nitrogen systems which means that the material costs are much lower than cryogenic compression systems. In addition these systems have relatively low operating costs as they do not require the delivery of raw materials as they are able to use the surrounding air to produce the ballasting fluid.

<u>Operational</u>

The technology for air compression is simple and mature.

<u>Environmental</u>

None.

Downfalls of Technology

<u>Cost (Capital and Operating Costs)</u>

Capital cost: the installation cost of this equipment can be high when compared with liquid nitrogen injection that can be done with cryogenic pumps working at much lower pressure.

Operating costs are high due to the power required to operate the air compressors (high discharge pressures). Maintenance costs are also high due to the requirement for preventative maintenance of the piston rings, rider rings, etc.

<u>Operational</u>

None.

<u>Environmental</u>

None.

Development / History of Technology

None.

Open section on novel ideas

None.

Pictures and (or) Drawings of Process Equipment

References

None.

Nitrogen Injection

Equipment description

The calorific value of the gas that is vaporized and sent to the Transmission gas Network must be precisely controlled and can be neither too high nor to low (LNG ballasting). The purpose is to avoid technical and safety problems to the final users (industrial and domestic heaters etc..)
The parameter that is commonly used in order to control this particular aspect of the process is called the Wobbe Index:

$$Wobbe = \frac{\text{Gross Calourific Value}}{(\text{density of gas} \div \text{density of air})^{0.5}}$$

The Wobbe Index values must be kept within a precise interval that can be slightly different from country to country. One way of controlling this aspect of the gas is through nitrogen injection.

A nitrogen injection train typically consists of an air compressor, an air pre-treatment unit, a nitrogen unit separator (membrane type), a nitrogen pre-cooler and a nitrogen compressor. Each train is integrated as a package by the manufacturer.

The atmospheric air is filtered in the suction filter and compressed through a centrifugal compressor; before entering the membrane, the air is treated to remove condensed water, water vapour and reactive oxidants such as ozone which can damage the membranes. Oxygen and nitrogen is separated as the air passes through the membranes. The nitrogen is then compressed to the required pressure to be injected into the natural gas pipeline

General Emissions Details

Land ☐

Air ☒

Water ☒

Noise ☒

Prerequisites requirements of equipment

Electricity

Electricity is used to operate the nitrogen injection plant; 6.6 MW of power is required.

Instrument Air

Instrument air is used to operate control valves, and instrumentation in general within the systems.

Water

Seawater is required during the compression process as a secondary cooling media (open loop). A closed loop of fresh water is used for cooling the compressor. The seawater is pumped from the sea and discharged into the outfall. The seawater is filtered to remove solids.

Emissions details

Land

There are no emissions to land.

Air

The N_2 Gas is discharged to the atmosphere during start up and shutdown as part of the operations procedure to control compressor pressure.

Water

Chlorine in the form of sodium hypochlorite is used to protect the seawater systems against fouling by macro and micro marine organisms. Residual chlorine is 0.02 ppm in concentration.

Noise

The nitrogen process system noise level was designed in line with the requirements of NOM-081-SEMARNAT-1994 and NOM-011-STPS-2001. A noise survey has reported 68 Db for daytime and 65 Db during the night as well as at 90 Db.

Environmental Risks

Sea Water

Chlorine is a well-known toxicant; high intermittent doses of chlorine will kill most marine life and plant growth, except some that can close their shells such as mussels and anemones. These can survive intermittent doses of chlorine but not continuous dosing. Therefore by maintaining trace chlorine residual in the discharge of any system will ensure that the possibility of fouling by any marine organism is eliminated.

The two Continuous Dosing Pumps are provided downstream of the storage tank. Each pump is rated for 31.7 cub.m/hr and 200 kpa discharge pressure. There are also two 'shock' dosing pumps downstream of the storage tank, in addition to the 'continuous' dosing pumps. The shock dosing pumps are rated for 100.2 cub.m/hr and 200 kpa discharge pressure. During continuous dosing one continuous dosing pump is operating. When the shock dosing cycle begins, one shock dosing pump starts running whilst the continuous dosing pump continues operating. Thus one continuous dosing pump and one shock dosing pump are in operation during shock dosing, for a total shock dosing flow rate of 131.9 cub.m/hr.

Appropriate Measures to Protect Against Safety Risks

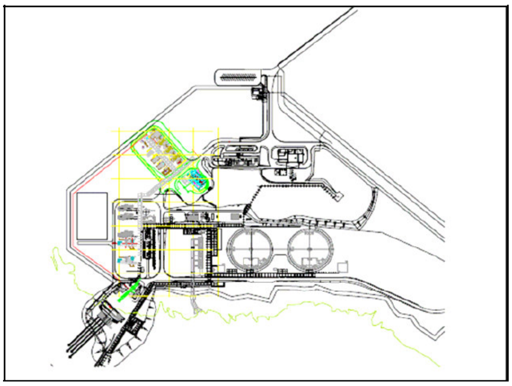
Sea Water

Periodic monitoring is performed in the seawater within the affected zone in line with NOM-01-SEMARNAT-1996 and the Monitoring Program of the Seawater Quality evaluated by the federal certificated laboratory.

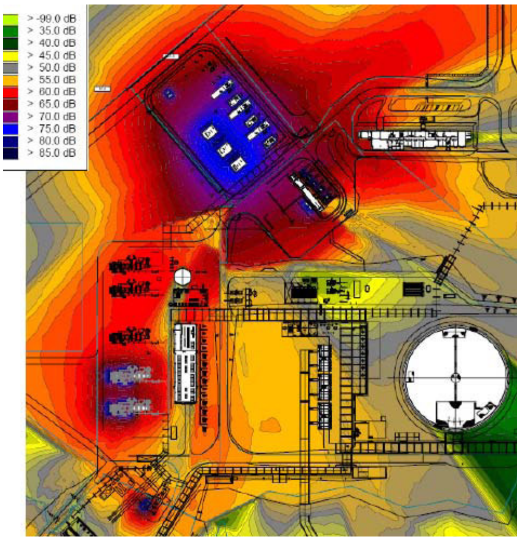
The samples are taken at three different points for three different depths between 0.5 and 10 m four times a year. The sea water is also tested for PH, conductivity, dissolved oxygen and residual chloride. A history of the level of contaminants in the zone is kept. The trends are analysed to allow preventive and corrective action to be taken in order to keep the environment within optimal conditions

Noise

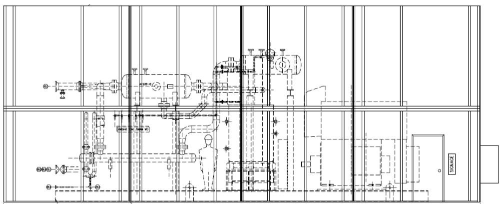
The model used to describe the propagation of sound corresponds to an outdoor environment, taking into account the effect of environmental conditions such as temperature, relative humidity, and prevailing winds. The computer model used in the propagation calculations was set up using CadnaA software by digitizing various physical elements comprising the facility and the most important area topography. Each noise-radiating element was modelled based on its geometry and noise emission pattern.



NIF Plant located in ECA, Reference Only



According to the model (Three N2 Generation Trains in operation: 3 air compressors, 3 nitrogen generators units and 3 nitrogen compressors), the results of the noise level contour configuration generated in the NIF plant was, 70 Db on the air compressors for the five surfaces of the enclosure (complete enclosures) and N2 compressor at 64 Db to the four surfaces of the enclosure (partial enclosures, without a roof for each and inlet silencers for the air compressors). Therefore, 17 points of measurements were taken for this test and measures were made on the Northwest boundary exactly in front of the nitrogen injection plant which represents the most Critical Zone at 30 centimetres of the property limit and an elevation of at least 1.2 meters



Enclosure for Compressors , Reference Only

Benefits of Technology

Cost (Capital and Operating Costs)

This technology needs no raw materials to produce N_2 as it is available from the atmosphere.

Operational

Minimal operational personnel are required to operate the nitrogen injection plant as a result of the DCS control. Nitrogen is not toxic but is an asphyxiating gas with a density slightly lower than air. Nitrogen is non-combustible.

Environmental

There are zero NO_x emissions to the atmosphere from the facility.

Downfalls of Technology

Cost (Capital and Operating Costs)

This technology requires a large capital investment.

Operational

None Considered.

Environmental

The heat exchange of the seawater and the residual chloride dissolved within it is considered to be an environmental downfall of the technology. Minor noise generated close to the units and process area.

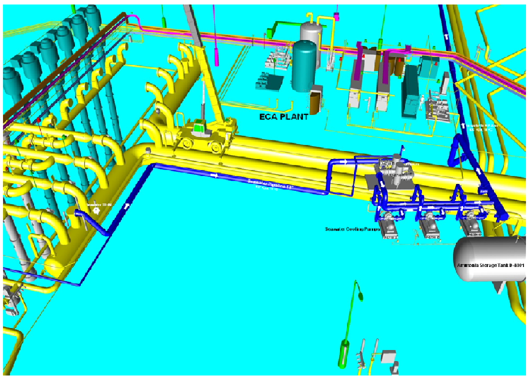
Development / History of Technology

None.

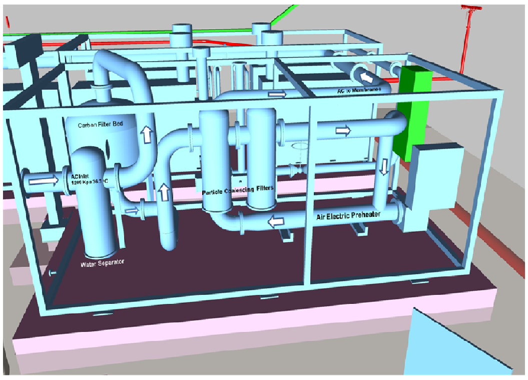
Open section on novel ideas

None.

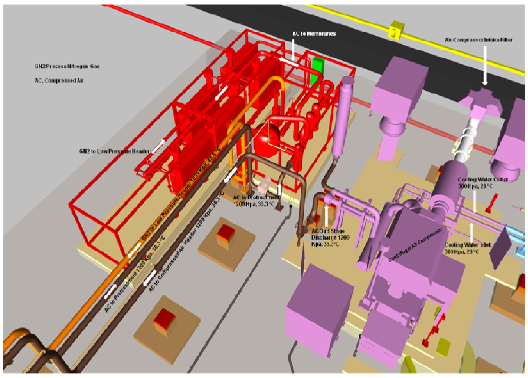
Pictures and (or) Drawings of Process Equipment



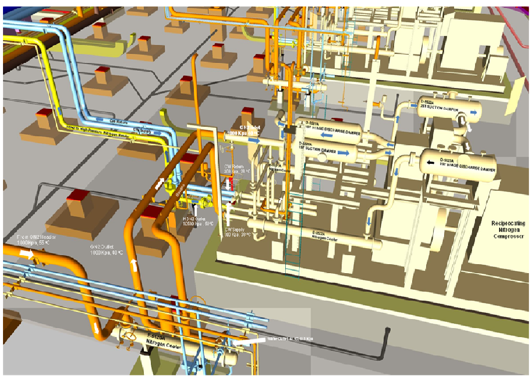
Seawater cooling system



Air Pre treatment skid



Membrane, Air pre treatment skid &
Centrifugal air Compressor



Nitrogen Compressor

References

1. ECA P&ID
2. ECA Study of the LNG Receiving Terminal
3. ECA Design Basis and Narrative
4. ECA Standard Operational Procedures
5. ECA Enviromental Reports and Test Reports

Propane Injection

Equipment description

Depending on the region in which the terminal operates, restrictions could be placed on the quality of the gas which is exported. This generally requires the terminal to ensure that any gas which leaves the site is acceptable to the gird in terms of wobbe number, calorific value, sooting index, etc. Depending on the extent of these limitations, LNG cargos can be received which fall short of the calorific value requirements. In these situations, propane can be injected to 'enrich' the LNG and thereby increase the calourific value of the exported gas.

Propane is delivered to the site through road tankers and stored at moderate pressures (< 10 bar) as a liquid. The liquid propane can then either be vaporised and introduced to the gaseous stream through the use of a recondenser, or could be pressurised and injected directly into the liquid phase. The introduction of propane in this manner will raise the calorific value of a low calorific value cargo to within acceptable limits for the grid.

General Emissions Details

- Land ☐
- Air ☐
- Water ☐
- Noise ☒

Prerequisites requirements of equipment

Road Tanker Unloading Facilities

Propane is usually delivered to the site through road tankers and as such a facility for unloading the road tankers to the propane storage tanks is required.

Propane Storage Tanks

The propane which is used to control the calorific value of the boil off gas must be stored in suitable storage tanks. Propane is usually stored at moderate pressures (< 10 bar) where it is in the liquid form.

Heating medium

The propane is stored on the site as a liquid and as such requires a heat input when required to vaporise the propane if the propane is to be introduced as a gas.

Means of Pressurisation

Depending on the point at which the propane is injected into the system and the pressures of the gas network, a means of pressurisation could be required.

Emissions details

LAND

There are no emissions to land considered from the normal operation of propane injection for ballasting purposes.

AIR

There are no emissions to air considered from the normal operation of propane injection for ballasting purposes.

WATER

There are no emissions to water considered from the normal operation of propane injection for ballasting purposes.

NOISE

Noise would be generated if the stored propane requires pressurisation for inclusion in the system. This noise can be limited by changing the injection point to a location in the process where the gas pressure is lower than the storage pressure of the propane.

Environmental Risks

The storage of propane and transfer of propane to that storage poses a risk to the environment. If propane were to be released, it would quickly vaporise and disperse to the atmosphere. To limit this risk, the propane storage should be designed to acceptable design standards and maintained and inspected in line with manufacturer recommendations. The unloading of a propane tanker should be closely controlled by trained personnel working to an acceptable unload procedure.

Appropriate Measures to Protect Against Safety Risks

A propane release can cause asphyxiation of any personnel in the area and could form a gas cloud which if ignited would lead to explosion. Care should be taken when transferring and storing propane in line with accepted industry practices to ensure that a loss of containment is avoided.

Benefits of Technology

Cost (Capital and Operating Costs)

None considered.

Operational

An operational benefit of propane injection is realised if limits of export gas quality are in place by providing the capability to accept a larger variety of LNG compositions, specifically low calorific value cargos.

Environmental

None considered.

Downfalls of Technology

Cost (Capital and Operating Costs)

Capital cost of installing propane unloading, storage, and injection equipment.

Operational

None considered.

Environmental

None considered.

Development / History of Technology

None.

Open section on novel ideas

None.

Pictures and (or) Drawings of Process Equipment

References

None.

LNG Export as a Liquid

LNG Tanker Filling (not road tankers)

Equipment description

Some LNG regasification terminals can offer LNG loading services. In these scenarios, LNG which is stored in the LNG storage tanks on the terminal is transferred back to an empty LNG carrier for transport to another demand source for the LNG.

The LNG is pumped from the LNG storage tanks to the LNG carrier using the in-tank pumps within the LNG storage tanks on the terminal. The unloading lines are used for loading purposes as 'loading lines'. The rate at which the tankers are loaded is usually much lower than the conventional unloading rates from the carriers. The rate at which the tankers can be loaded is dependent no the number of in-tank pumps and capacity of these pumps which are available on the terminal end. The vapour return generated by the loading operation is returned to the terminal using the heavy duty compressors which are situated on-board the LNG carrier using the conventional vapour return route. The rate of vapour return can be high and is dependent on the temperature and saturated vapour pressure of the LNG within the terminal's storage tanks together with the pressure at which the LNG tanks on the tanker are maintained during the loading operation. The vapour return is then handled by the terminal using the usual boil off gas handling methods.

General Emissions Details

Land ☐

Air ☒

Water ☐

Noise ☒

Prerequisites requirements of equipment

Electricity

Electricity is needed for operation of the in-tank pumps.

Instrument Air

Instrument air is required for the operation of the instrumentation and control systems including the emergency shut-down system operation.

Hydraulics

Hydraulics are required for manoeuvring the LNG arms and ERS (emergency release system). The hydraulics use oil as the pressurised medium.

Emissions details

LAND

There are no emissions to land as a result of operating this technology.

AIR

The LNG transfer lines require a connection to be made to the ship each time a loading operation is started. Due to the nature of the joints, spurious emissions to air cannot be discounted.

WATER

There are no emissions to water as a result of operating this technology.

NOISE

The cooling operation of the LNG transfer lines and the piping onboard the ships can generate some noise due to the flow of fluids within the system. The in-tank pumps which are operated within the LNG storage tanks can also generate noise.

Environmental Risks

The requirement for hydraulic arms at the jetty brings with it a risk of oil release to the environment. Only 8 ppm of oil are sufficient to form a visible film on water and can cause damage to the natural ecosystems. The requirement to make and break a connection to the ship each time the loading operation is practiced can also lead to spurious releases of gas to the environment. Methane, when released to the atmosphere, acts as a greenhouse gas which is 20 times more efficient at trapping heat than carbon dioxide over a 100 year period [1].

Appropriate Measures to Protect Against Safety Risks

The possibility of a leak of LNG from the LNG transfer arms cannot be discounted. Should this event occur, personnel could be injured and a flammable atmosphere could be generated. When a leak is detected, the LNG transfer arm should be taken out of service and the flange connection bolts tightened if possible. In some cases it may be necessary to replace the seal. This should be done to limit the loss of containment and ensure the continued safe operation of the unloading arms.

Benefits of Technology

Cost (Capital and Operating Costs)

The modifications to the plant in order to support the loading of LNG tankers are minimal as the equipment would have already been installed as part of the terminal construction - as such have very low capital costs. A small amount of instrumentation changes are required including the shutdown and ESD systems. The operation opens up commercial opportunities to the shipper by offering the flexibility with the LNG they trade. The export from a terminal can thus be treated as an extra commercial opportunity.

Operational

Operationally, the loading operation is similar to the unloading operation and therefore does not give any additional operational problems to the operators.

Environmental

Aside from the small amount of noise and the possibility of spurious leaks, the environmental emissions from this operation is negligible.

Downfalls of Technology

Cost (Capital and Operating Costs)

None considered.

Operational

When loading a ship, the vapour return flow from the ship to the terminal can be quite high (depending on the temperature and saturated vapour pressure of the LNG in the Terminal's storage tanks and the pressure maintained in the cargo tanks during loading). This vapour flow has to be handled in the Terminal and puts demands on the conventional boil off gas handling processes i.e. boil off gas compression with a recondenser or boil off gas compression to a local distribution zone.

Environmental

The possible spurious leaks of gas from the LNG unloading arms during the operation could be considered to be an environmental downfall.

Development / History of Technology

The process does not use any new technology, it simply utilises the existing technology on the LNG terminal for an alternative use.

Open section on novel ideas

Installation of dedicated “loading pumps” in LNG storage tanks, aside from the “send-out” pumps. This would give much greater pumping capacity from pumps with a nominal flow rate of about 1,500 cub.m/h which are similar the ones used in the ship’s cargo tanks.

Installation of pipeline compressors to compress big boil-off and/or vapour return flows directly up to the grid pressure. This would reduce the minimum send-out flow rates of LNG regasification terminals (more flexibility for the LNG traders, but expensive for the terminal operator in terms of capital and operational expenditure.

Pictures and (or) Drawings of Process Equipment

None.

References

1 Technical Guidance, **The Council of Gas Detection and Environmental Monitoring**, February 2002, available from http://www.cogdem.org.uk/Files/ApplicationofPortableGasDetectorsInPetroindust.pdf

LNG Truck Filling

Equipment description

The export of LNG as a liquid from an LNG importation terminal is accomplished through the physical loading of a tanker or container at the import terminal. Transportation of the tanker or container to and from the import terminal is usually accomplished by a third party or by a dedicated transportation group within the operating organization of the import terminal. The overland transportation of LNG to end users from the import terminal is outside the scope of this study. Additional information on such transportation can be found in GIIGNL's 2009 report on the "Overland Transport of LNG".

The export of LNG as a liquid is accomplished by transferring LNG from the import terminal's LNG storage tanks to LNG loading facilities within the Terminal. In most cases the transfer of LNG to the loading facilities is facilitated by the use of the same, or very similar, LNG storage tank's in-tank pumps or gravity based feeds that supply the regasification systems of the Terminal.

At the LNG loading facilities the LNG from storage is transferred to the tanker or container through the use of "loading arms". These loading arms and their associated valving and controls allow the operator to safely and efficiently connect, load and disconnect to the tankers or containers. Over 80% of the known loading arms are of a designed called "flexible arms" which are essentially cryogenic hoses. The remaining loading arms are of a design called "hard arms" which are very similar in design to the loading arms used to connect the Terminal to a cargo vessel. Basically they are hard piping with mechanical swivels designed to operated at the required cryogenic temperatures.

General Emissions Details

Land ☐

Air ☒

Water ☒

Noise ☒

Prerequisites requirements of equipment

<u>Electricity</u>

In the cases were the loading facilities are supplied LNG by in tank LNG pumps electricity is required for the pumps. Electricity is also required for the controls associated with the loading facilities "weight bridges" or scales.

<u>Nitrogen (inert gas)</u>

To safely and efficiently disconnect the loading arms from the tanker or container and to minimize residual LNG/vapour from being released to the atmosphere nitrogen is used to purge the loading arms of product.

<u>Instrument Air</u>

Instrument air is used to facilitate the control of the loading stations valves.

<u>Steam (optional)</u>

Steam is used at times help with the opening and closing of valves and to help facilitate the vaporization of residual LNG in the loading facilities sumps (closed loop system with vapour return to LNG storage tanks).

<u>Fire Water (available on demand)</u>

Pressurized fire water available on demand to supply "water curtains" and fire water "monitors" required in the case of an incident.

Emissions details

LAND

There are no emissions to land from LNG Truck Filling*. (* - See Water)

AIR

Minute quantities of methane emissions to the air result from the residual LNG/vapour that is not entirely "purged" during the connection or disconnection process. Any methane released is done si in combination with larger amounts of nitrogen. Total qualities of emissions are limited to the small quantities of gas that remain blocked in the piping between the valving on the loading facility and the valving on the tanker or container.

WATER

Small quantities of steam condensate associated with the loading facilities "sumps" (vessels in which loading arms are purged too) is released. Condensate is directed to the ground.

NOISE

Limited noise due to flow of LNG/vapour and the piping configuration of the loading facility are realised. The highest noise levels are associated with the "purging process" but are expected to have maximum values of 80-85dB(A) at 1 meter from the equipment.

Environmental Risks

The transfer of LNG from storage to the tanker or container posses an environmental risk through the spillage of the LNG during the transfer operation. A procedure for the transfer operation which requires constant manning exists which helps to minimise the risks posed to the environment. Appropriately designed loading facilities with suitable materials of construction and a rigorous maintenance program are employed to ensure that accidental releases are minimised.

Appropriate Measures to Protect Against Safety Risks

The LNG loading facilities should be constructed to the relevant design codes and standards. Where appropriate site grading and impoundment should be utilized to control spilt LNG and minimize the surface area exposed to the product.

Water curtains or other vapour control methods should be employed to help control the resulting vapour generated from potential spills.

Water monitors or other fire control methods (foam) should be considered in the area of the loading facilities.

Benefits of Technology

Cost (Capital and Operating Costs)

The cost of LNG loading facilities could be considered minimal when considering the potential markets for export that can be opened with their installation. There is a wide variety of loading facility designs that are currently in use. It is estimated that a two bay loading facility could range anywhere from $250,000 USD to $2,000,000 USD[1] depending upon the operational complexities and site specific requirements.

Operational

Most LNG loading facilities can be designed to require minimal operational efforts. Older systems can require dedicated operational involvement throughout the loading process. However, the loading process itself is very basic and intuitive.

Environmental

The environmental impacts of the LNG loading facilities in LNG import Terminals are considered negligible. Within the context that LNG distributed from LNG import terminals will displace fuels that are currently being used, and that such fuels have greater environmental impacts (drawbacks) it is considered to be an environmental benefit.

Downfalls of Technology

Cost (Capital and Operating Costs)

The incremental cost of pumping LNG to the loading stations is minimal. The majority of the infrastructure (storage, pumping, etc.) required to export LNG as a liquid is in place and used for other purposes in most Import terminals. Incremental cost of Loading facilities would only be considered a downfall if underutilized.

Operational

To the extent that dedicated operators are required to load LNG tankers and containers it may be considered an operational challenge to appropriately match staffing levels with loading demands.

Environmental

The scope of the study did not find any significant environmental impacts. Environmental impacts associated with the transportation (internal combustion engines) of the LNG could be considered.

Development / History of Technology

In the 1960's in both the UK and the USA saw the emergence of overland transportation of LNG as a viable alterative to expansion and extensions of pipelines. In the preceding four decades there have been significant improvements in the design and construction of all components involved in the transportation of LNG. For the purposes of this study, only the LNG Loading facilities within the LNG Terminals have been considered.

The earliest LNG terminals predominately utilized "Flexible Arms" or hoses for the loading on LNG into tankers or containers. Minimal changes in materials or the design of such "hose" has been observed.

As advancements in the technology behind swivels and piping joints were made the emergence of "hard arms" has been realized. Such technological advancements associated with the "hard arms" have also led to a reduction in capital cost requirements making such arms more competitive with the "flexible hose" alternative.

Advancements in controls (PLC's, DCS, etc.) have allowed for a greater level of automation. In some cases such automation has also provided additional layers of safety (alarms, shutdowns, etc.) to the loading process.

Open section on novel ideas

The export of LNG from LNG terminals via pipeline rather than through overland transport of tankers or containers is a concept that may become more viable as the cost and complexity of "cryogenic pipelines" comes down.

ITP (Interpipe), Chart (VIP), Technip (PIP), GTT, and Flour are all pursuing pipe-in-pipe, or even pipe-in-pipe-in-pipe, piping systems that may allow the export/transportation of LNG from LNG terminals to end users located significant distances from the LNG import terminals.

Pictures and (or) Drawings of Process Equipment

None.

References

1. Study of the Overland transportation of LNG, GIIGNL, September 1, 2009, pages 70-78.

Zero Sendout & Recirculation

LNG Pumping

Equipment description

LNG pumps are used to move liquid natural gas which exists at cryogenic temperatures around the process. The pumps are typically electrically driven and feature an integral shaft with the entire motor, bearings and all other components completely flooded with LNG [1]. Pumps of different sizes and discharge conditions are used at different stages in the importation and regasification process. Generally, the pumps consist of ‘primary pumps’ and ‘secondary pumps’. Primary pumps are of the submerged motor, retractable type and would be located in the LNG storage tank at the bottom of a discharge column. These pumps only require one or two impeller stages sufficient to transfer the LNG out of the primary containment and into the secondary system [1]. The secondary pumps are used as the vaporiser feed and would be expected to have a much higher duty than the primary pumps as they would be expected to lift the LNG to a much higher pressures to account for the pressure drop across the vaporiser and the pressure of the gas network into which the terminal is exporting. The secondary pumps are installed in their own self contained suction vessel.

General Emissions Details

- Land ☐
- Air ☐
- Water ☐
- Noise ☒

Prerequisites requirements of equipment

Electricity

Electricity is used to power the pumps and for the secondary pumps, the voltage of the motor could be expected to be up to 6600 volts [1]. The electrical cables which provide power to the motor should be closed systems pressurised with an inert gas which will alarm in the event that the pressure in the system is lost.

Instrument Air

Instrument air is required to provide the means by which the pump instrumentation operates.

Emissions details

LAND

There are no emissions to land from LNG pumps.

AIR

There are no emissions to air from LNG pumps.

WATER

There are no emissions to water from LNG pumps.

NOISE

The motor which drives the LNG leads to the emission of noise from the system. Since the entire assembly is submerged in liquid, the noise is dampened and these pumps operate very quietly.

Environmental Risks

Given the design of the pumps which almost completely eliminates the potential release of flammable gases or liquids into the environment, there are not considered any environmental risks of this technology.

Appropriate Measures to Protect Against Safety Risks

Submerged electric motor pumps (SEMPS) have almost exclusively been used in LNG applications since the early 1960's [1]. These pumps display an inherently safe design compared to the external motor type used previously in the industry [1]. The motor and common shaft is completely submerged in LNG which is an oxygen free environment and therefore classed as a non-hazardous area. The interface of the pumps with the associated pipework is generally flanged which offers the potential for high pressure LNG releases. Maintenance of the systems inline with the site maintenance policy should be practiced to remove this safety risk.

Benefits of Technology

Cost (Capital and Operating Costs)

The cost of the submerged electric motor pump is considered reasonable. The operating cost of the equipment is considered a benefit due to the simplicity and reliability of these pumps.

Operational

Operationally, the submerged electric motor operated pump displays huge benefits. The system is self lubricating meaning that maintenance is reduced over conventional pump design which uses external motor locations. There are also no alignment problems which are experienced with pumps which use couplings. These systems are generally reliable if they are well designed with the only problems being experienced through cavitation around the impeller and operation for extended periods of time away from the high efficiency point of the pump.

Environmental

The design of the pumps is such that the leakage of gases or liquids to the environment is almost completely eliminated. The whole assembly is immersed in liquid which acts as sound insulation and significantly reduces the noise emitted from the pump.

Downfalls of Technology

Cost (Capital and Operating Costs)

None considered.

Operational

The self-lubricating nature of the pumps using the process fluid can cause operational problems in the unlikely event that contaminants or debris are present in the process fluid.

Environmental

There are not considered any downfalls of this technology with regard the environment.

Development / History of Technology

Submerged electric motor pumps (SEMPS) was first applied in LNG applications in the early 1960's [1]. Before this point, external motor type pumps with dynamic shaft seals were commonly used [1]. The introduction of the SEMPS technology saw an increase in the safety of the industry surrounding the pumping operations. Since their first adoption in the 1960's, these pumps have been almost exclusively used for the purpose of LNG transfer.

Open section on novel ideas

None considered.

Pictures and (or) Drawings of Process Equipment

References

1 Submerged Motor LNG Pumps In Send-Out System Service – Unique pumps for unique duty…, **Pumps & Systems**, *available from www.pump-zone.com accessed 09 April 2010*

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APPENDIX 1 – Summary of Technologies

High level process	Key process	Equipment / Technology	Age (years)					Equipment Capacity	Emissions Profile				Annaul Utilisation						Energy Efficiency					Maintenance Philosophy		
			1 to 5	5 to 10	10 to 15	15 to 20	20+		Land	Air	Water	Noise	< 20%	20 to 40%	40 to 60%	60 to 80%	80 to 100%	[illegible]	0 to 50%	50 to 75%	75 to 90%	90 to 100%	N/A	Fix on Fail	Preventative	Statutory
Product Delivery	Gas Quality Characterisation	Gas Chromatography	?							?							?						?	?		
		Continuous Sampling	?					318 litres (cylinder)		?				?									?	?		
		Raman Spectroscopy	?					N/A		?		?				?							?		?	
	Product Delivery to Storage	LNG Pumps	?					12,000 cub.m per hour				?				?										?
		Liquefaction	?							?		?		?						?						?
	Ship to Shore Transfer	Unloading Arms		?										?									?		?	
		Pipeline Connection with Bellows					?	12" nominal bore							?								?		?	
		Discharge piping		?										?									?			?
	Ship vapour return	Boil off gas compression		?				8 te/h (per unit)	?		?	?		?					?						?	
	Nitrogen purge production	Nitrogen purge production (from liquid storage)	?							?							?					?				
		Nitrogen purge production (from air)		?						?	?	?		?								?			?	
	Ship Process Venting	Cold Vent				?		12 te/h to 167 te/h		?								?					?		?	
		Ground Flare																								
		Vapour Blower	?									?						?			?				?	
	Ship / Tug Associated Activites	Ship Process Noise						n/a				?					?						?			
		Ship Waste						2 cub.m Cat.1 10 kg Special 3 cub.m Other (values per visit)	?														?			
		Ship Engine		?						?	?	?					?		?						?	
Storage & Maintenance	Zero Sendout & Recirculation	LNG Pumps	?									?				?										?
	Boil off Gas Conditioning	LNG Blending	?									?		?								?			?	
		Calourific Value Control			?							?				?							?			?
	Plant Maintenance	Special Waste (to land, air, & water)						1 to 3 tonnes per annum	?	?																
		General Waste (to land, air, & water)						2 to 3 tonnes per annum	?																	
		Purging Operations						Various depending on length of line or size of eqiupment being purged.		?		?														
		Nitrogen purge production (from liquid storage)	?							?							?					?				
		Nitrogen purge production (from air)		?						?	?	?		?								?			?	
	Boil off Gas Handling	Boil off gas compression		?				8 te/h (per unit)	?		?	?		?					?						?	
		Combined Heat & Power			?			N/A		?		?					?				?				?	
		Boil off gas liquefaction	?					50 tepd to 600 tepd		?		?				?				?					?	?

High level process	Key process	Equipment / Technology	Age (years)					Equipment Capacity	Emissions Profile				Annaul Utilisation						Energy Efficiency					Maintenance Philosophy		
			1 to 5	5 to 10	10 to 15	15 to 20	20+		Land	Air	Water	Noise	< 20%	20 to 40%	40 to 60%	60 to 80%	80 to 100%	Emergency	0 to 50%	50 to 75%	75 to 90%	90 to 100%	N/A	Fix on Fail	Preventative	Statutory
Regasification & Export	Boil off Gas Handling	Boil off Gas Compression (low capacity)		●					●		●	●					●		●						●	
		Boil off Gas Compression (high capacity)		●				8 te/h (per unit)	●		●	●		●					●						●	
		Recondenser				●		21 te/h									●						●			●
		Combined Heat & Power			●					●		●					●				●				●	
		Boil off Gas Liquefaction	●					50 tepd to 600 tepd		●		●				●				●					●	●
	LNG Ballasting	Nitrogen Injection (membrane separation)	●					20,094 Ncub.m/h @ 50 deg.C and 10,500 kPa		●	●	●		●								●			●	
		Propane Injection			●							●			●								●			●
		Air Injection			●			4,300 Ncub.m/h			●	●		●					●						●	
	LNG Vaporisation	Submerged Combustion Vaporiser	●					173 te/h		●	●	●					●					●				●
		Submerged Combustion Vaporisers (with scrubbing towers)																								
		Glycol-Water Air Heater		●								●					●					●			●	●
		Open Rack Vaporisers (ORV)	●					163.3 GJ/h			●	●	●										●		●	
		Hot Water / CHP Heat Pipe	●					sufficient for operation of 14 x 173 teph SCV's				●				●						●			●	●
		Heating Towers																								
	Gas Quality Characterisation	Gas Chromatography	●							●							●						●	●		
		Wobbe meter	●							●							●						●	●		
		Raman Spectroscopy	●					N/A		●		●				●							●		●	
	Export Gas Processing	Odourising	●					30 to 40 kg/h		●		●					●						●		●	
		Temperature Control		●				Various depending on application								●							●		●	
	LNG Pumping	-	●									●				●										●
	LNG Export as Liquid	LNG Truck Filling					●	40 teph (x4)		●	●	●		●				●					●	●	●	●
		LNG Tanker Filling					●	nominal flowrate of 630 cub.m/h		●		●	●					●					●		●	