TITLE:	**Emissions from LNG Regasification Terminals**
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Project:	**Technical Manual on Emissions from LNG Regasification Terminals**

Summary:

The movement of natural gas around the world from natural gas sources to where market demand exists often takes the form of liquefied natural gas (LNG) importation. The ability to receive, store, and regasify the LNG is provided in the form of LNG importation terminals, the operational nature of which results in emissions released to land, air, and water. This document is a technical manual which outlines the key sources of emissions within an LNG regas terminal and their expected destination. The document approaches emissions from a technology point of view by recognising that there are a number of functions which are satisfied using a number of different technologies by terminals across the world which all have their own unique emissions profile. The data which is presented only considers an LNG terminal which is under normal operation within its useful life phase and does not consider construction, commissioning or decommissioning activities which form part of the terminal's life cycle.

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Forward

The movement of natural gas around the world from natural gas sources to where market demand exists often takes the form of liquefied natural gas (LNG) importation. The ability to receive, store, and regasify the LNG is provided in the form of LNG importation terminals, the operational nature of which results in emissions released to land, air, and water. This document should be used as a 'Technical Manual' for emissions from LNG regasification terminals, it aims to provide information to the reader to facilitate a more informed and structured approach to technology utilisation with a focus on the characteristic emissions to land, air and water from a specific technology as a result of the operation of that technology. It can be navigated from a technology aspect grouped under key processes which are carried out within the terminal. This document only captures emissions to Land, Air, Water, and Noise as a result of the normal operation of an LNG regasification terminal which is within its useful life phase.

A guide on use

The technologies which are used in the LNG importation process differ from region to region and terminal to terminal which often impacts on the level and nature of the emissions. The nature of these differences is a result of the prerequisite requirements of that technology (for instance a submerged combustion vaporisers requires the availability of fuel gas for thermal generation), the regulatory philosophy under which these terminals operate (for instance a terminal might have a tight restriction on emissions to air), together with the environment under which the terminal operates (climate, business model, etc). Each technology demonstrates unique emissions profiles in terms of nature, quantity, and emissions destination (land, air, water, and noise).

For instances where the reader is seeking to find a technology which best suites their requirements for a given process, the document can be navigated through the high level processes to the key processes to give a list of the technologies which are currently used within the industry for this application across different terminals and regions. Additional information can be found with the text for these technologies which gives an outline of the prerequisite requirements for the technology, the details of the emissions and destinations of the emissions from the normal operation of this technology, along with a discussion of the benefits and downfalls of this technology. Furthermore, a high level summary of the technologies currently employed within the industry for a given function is provided at the back of this manual.

Disclaimer

1. This document is not intended as an aid to risk assessment or the selection of process equipment. It is intended as a reference document for the evaluation of the technologies but does not give a definitive solution.
2. This document is intended only to cover emissions through the normal operation of an LNG terminal which is within its useful life stage and does not cover tank design or the containment of the product. Issues pertaining to this should be addressed through the technical specifications of the individual equipment. It is assumed that the terminal is constructed and operated to standards applicable for the region.
3. This document does not consider emissions at source. It is solely focused on primary emissions which are generated at emitted to land, air, and water from the site.
4. It is the responsibility of the reader to carry out their own risk assessment and where necessary consult MSDS sheets where specific substances are used.
5. Any cost benefit analysis or demonstration of best available technology is the responsibility of the reader.
6. No liability can be taken by GIIGNL for any inaccuracies in this document or any actions by the reader as a result of the information presented within this document.

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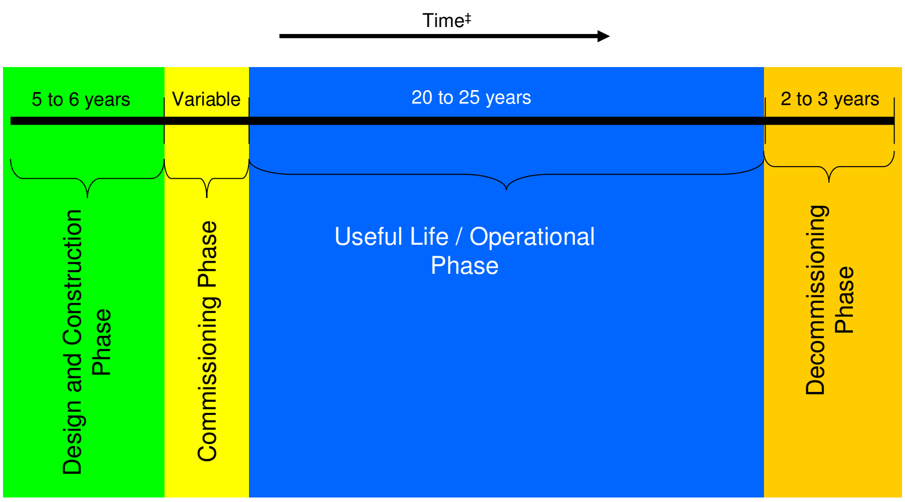
Introduction and Overview

Background

The movement of natural gas around the world from natural gas sources to an area of demand often takes the form of liquefied natural gas (LNG) importation. When liquefied, natural gas undergoes a 600:1 volume reduction which ensures it is economically viable to transport in large quantities over great distances. Natural gas importation in the liquid form removes the constraints of the more conventional piped gas and opens up a truly global market for natural gas trading. The supply chain requires the natural gas to first be located and drilled (exploration and production). It is then transported to a liquefaction plant where the natural gas undergoes a transformation from a gas to a liquid (production) from which point onwards it is known as liquid natural gas (LNG). The LNG is then loaded onto LNG carriers and transported from the gas source to the point in the world where there is a demand for natural gas. The LNG is then pumped from the LNG carrier into storage tanks located at the demand site where it is finally warmed back to a gas and exported to the gas transmission system for use by the end user. The ability to receive, store, and regasify the LNG is provided in the form of LNG importation terminals, the operational nature of which results in emissions released to land, air, and water. This document focuses solely on the emissions from an LNG importation terminal and does not consider emissions from any other point in the supply chain.

Terminal Life Cycle

The construction, commissioning, operation, and decommissioning of an LNG regas terminal will lead to emissions to the environment as a result of the various activities associated with



Notes

(‡ - Typical periods, times may vary from terminal to terminal due to a number of factors)

Figure 1 – Different Phases of Terminal's Life

these different phases of the terminal's life (see Figure 1). The nature and level of emissions is highly varied and dependent on the activity and the life phase of the terminal. Whilst each phase can affect the emissions profile of the other phases, each phase should be considered independently of each other for clarity.

Design and Construction Phase

Design and construction of an LNG terminal generates emissions to land air, water and through noise. The typical emissions expected from the design and construction phase can be summarised as follows:

Emissions Destination	**Predominant Species**	**Typical Source**
Land	Solid construction wastes	Typically expected to come from fabrication activities on site including but not limited to steel work fabrication, civil works, and cabling activities.
Air	Carbon dioxide	The major sources of emissions to air can be articulated as emissions from construction traffic and concrete curing as a result of the construction process.
Water	Variable depending on water quality and land quality	Water emissions can vary highly depending on the quality of water which is used in the construction phase together with the contaminants in the land which could be picked up through water run off. If a hydrotest is employed to prove the welding on the LNG storage tanks or other mechanical components, contaminants from construction could be released to the environment if the water is discharged without pre-treatment.
Noise	Noise from construction	Noise from construction can take many forms but is typically limited to construction traffic and the act of construction its self. If the land quality requires piling for foundation purposes, significant noise levels could be produced during the piling process (dependent on the method employed).

Commissioning Phase

The commissioning of an LNG terminal will generate emissions as a result of the various activities to bring the various equipment items associated with an LNG terminal from the construction phase into the operational phase. Modern terminals are generally constructed to minimise the level of emissions associated with these activities, however there is still a significant emission which is unavoidable. The commissioning of an LNG storage tank requires the tank to first be purged to nitrogen and then purged with natural gas. The interface between the nitrogen and natural gas layers is typically vented to the atmosphere which leads to emissions of methane to the environment. The level of this emission is highly dependent on the size of the tank which is being commissioned. Other purging activities on site will also lead to emissions of methane to the environment but these will be at much lower levels than those associated with the tank commissioning.

Operational Phase

The operational phase of an LNG terminal can also be termed the 'useful life' and is the period under which the terminal is fulfilling the function for which it was designed, i.e.

regasification and export of LNG. This phase if by far the longest phase in the life cycle of an LNG terminal and leads to emissions for a number of sources and complex processes. The level and nature of these emissions is highly dependent on the technology which is selected at the design phase of the terminal which is further a function of the operational environment of the terminal (business, weather system, size of operation, steady and upset conditions, etc). The operational phase is the phase which is document in detail within this technical manual.

Decommissioning Phase

The decommissioning phase of the terminal is the period in which the equipment is removed from service and disposed of following the useful life of the asset. The decommissioning phase will again lead to a large emission of natural gas due to the purging of the LNG storage tank (the reverse of the commissioning process). The level of emissions can be limited through the method which is adopted for the purge process. In addition to the emissions of methane from purging operations, process fluids such as compressor lube oils will also need disposal along with the equipment items which formed the LNG regas terminal asset. Recycling of the terninal assets can often reduce the disposal costs and the associated emissions to land that comes with the decommissioning of LNG assets.

All of the emissions sources discussed above should be considered by the terminal operator and the appropriate steps taken to limit the level of these emissions wherever possible.

In addition to the phases of the terminal operation which each lead to emissions from LNG regas terminals as discussed above, the different phases of associated equipment and processes can also lead to emissions which could affect the LNG regas terminal. An example of these would be the re-commissioning of an LNG carrier. This process is similar to the process of commissioning an LNG storage tank and will lead to similar emissions profiles. These external factors should also be considered by the operator, however these are not considered as normal operation and hence will not be captured under the normal life cycle of an LNG terminal.

Document Scope and Overview

An opportunity for a technical manual which covers emissions from LNG regas terminals was been identified by GIIGNL (Groupe International des Importateurs Gaz Natural Liquife). The aim of the document was to provide information to the reader to facilitate a more informed and structured approach to technology utilisation with a focus on the characteristic emissions to land air and water from a specific technology. The intention was for the document to cover only the useful / operational life phase of the terminal.

Objectives

The objectives of the Technical Sub Group with regard the generation of a manual on the Emissions from an LNG Regasification Terminal were as follows:

- Determine the portfolio of technologies (including the prerequisite conditions) which are currently used for different aspects in the processing of natural gas in an LNG regasification terminal.
- Characterise the emissions from these technologies to land, air and sea both in terms of nature and quantity.
- Generate a manual on emissions from an LNG regasification terminal which will allow members to analyse the technologies available to them in a more structured and informed manner through the use of prerequisite conditions.

Overview of Final Manual

A document map was generated which broke the process of LNG Importation down into 5 high level processes / categories which have the potential to lead to emissions to the environment. These 5 high level processes / categories were as follows:

- Product Delivery
- Storage and Maintenance
- Regasification and Export
- Process Ancillaries
- Fugitive Releases

The 5 high level process / categories were then further broken down into key categories associated with that high level activity. It was recognised that different terminals employ different technologies to satisfy the various key processes identified within the document map; the technology which is employed is highly dependent on the operating environment of the terminal (environmental considerations, regulatory philosophy, economics, etc). Members were invited to populate the document map further with the technologies they employ to satisfy the key processes identified with the document map. A proforma was then completed for each technology which allowed the data for the final manual to be collected in a structured manner. The proformas were then used to complete the relevant sections of the technical manual which was arranged to give the reader the flexibility to investigate typical emissions one could expect from an LNG regas terminal from a technology stand-point which allows one to further personalise a portfolio of emissions for an operational terminal.

In further support of this technical manual, an appendix section has been included which contains a high level summary of the technologies presented within the manual allowing the reader to quickly analyse emissions from the aspect of destination in contrast to a technology stand point.

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Fugitive Releases

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Accidental Spills & Releases

Accidental Spills / Releases

Description

Accidental spills and releases cannot be discounted from the normal operation of an LNG terminal. The ancillary processes needed to support the importation and regasification of LNG require additional fuels and chemicals for operation which are delivered in small quantities, compared to the LNG inventory, to storage facilities on site. It is these transfer operations which pose the biggest risk of an accidental spill or release. Additionally, the normal maintenance of these pieces of equipment can involve manual handling of chemical substances which can easily lead to an accidental spill.

General Emissions Details

Land ☒

Air ☒

Water ☒

Noise ☐

Environmental Risks

An environmental risk is posed by the uncontrolled release of potentially hazardous substances to the environment. An accidental release or spill of this type could lead to emissions to land, air, or water. Any transfer equipment should be maintained in accordance with the site maintenance policy and should be used in accordance with local operating procedures. The risk to the environment in the event of an accidental release or spill of a liquid can be reduced through the availability and use of spill kits which act by soaking up the spilled substance for correct storage and disposal through the correct routes. In addition, staff awareness training could help in reducing this risk to the environment. Releases of LNG would lead to emissions of methane 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]. In the event that a leak does occur in the process, the flow of LNG or gas in that line should be isolated and the appropriate action taken to stop the leak.

Appropriate Measures to Protect Against Safety Risks

A safety risk could be presented through an accidental spill or release of a substance should this substance be hazardous to health. To avoid this risk, the appropriate personnel protective equipment highlighted by the material safety data sheet (MSDS) for the substance should be worn. Should such an event occur, the MSDS sheet for the specific substance should be consulted and the appropriate action taken by a competent person.

A release of LNG or gas to the environment could lead to the formation of a flammable vapour cloud. Care should be taken the limit any release by isolation of the line in which the leak has occurred. Hazardous area classification should be in place to ensure that any electrical equipment with potentially hazardous zones could not act as a source of ignition for a flammable mixture. LNG impoundment basins can be employed in areas with the potential for large releases of LNG. The impoundment basis should be located away from the spill area and away from other plant; spilled LNG is routed to these basins for the controlled handling of the spill. Foam generators or foam glass blocks as described in the emergency provisions section of this document can be used to help to control the pool of spilled hydrocarbons.

Open section on novel ideas

None considered.

Pictures and (or) Drawings of Process Equipment

References

1. US Environmental Protection Agency Website, *accessed on 18 November 2009*, available from ethane/

Leaking Flanges

Leaking Flanges

Description

The use of flanged joints can be common practice on an LNG terminal on both liquid and gas services. The flange represents a weakness in the pipeline where leakages could occur in the event that the seal between the two flange faces is broken. In a cryogenic service, this event can be easily realised through the uncontrolled cooldown of a line which results in the flange cooling down at a different rate to the rest of the pipework which leads to different shrinkage rates and hence a poor seal between the two flange faces. Flanges can also be found to be leaking due to age as a result of the nuts and bolts used to tighten the flange becoming looser with time and thermal cycles. Gaskets are generally used between the flange faces (which could be greased to provide additional sealing) which provides the possibility of a tight seal of the joint through the compressibility of the flange material. A flange and bolting policy should be in place and followed to ensure that the risk of a flange leak is minimised.

General Emissions Details

Land ☒

Air ☒

Water ☒

Noise ☒

Environmental Risks

An environmental risk is presented by flanges due to the potential for leakages to occur which can lead to a release of the process fluid to land, air, or water depending on the nature of the leaking fluid. If LNG or natural gas is the leaking fluid, methane will be predominant species which is released. 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].

The risk posed to the environment can be reduced by a slow and controlled cooldown of cryogenic services in line with the site policy and procedures which will ensure that the rate of contraction of these joints is consistent and controlled. Flanged joints should be subjected to regular maintenance, in line with the site maintenance policy, to inspect and change the gaskets and nuts and bolts where necessary and to ensure that the bolts are tightened to the correct torque to ensure a good seal is achieved.

Appropriate Measures to Protect Against Safety Risks

Flanges which fail in high pressure cryogenic services can demonstrate a safety risk to site staff in the area. The effects of these failures can be reduced by wrapping stainless steel mesh from specialist suppliers around the flange. This allows the process fluid released from the leak to be expelled from the pipe but immediately dampens the momentum and provides increased rates of evaporation meaning personnel in the area remain safe but the leak does not go undetected.

In addition, the release of LNG or natural gas from leaking flanges could lead to the generation of a flammable vapour cloud which if ignited could have damaging consequences to the surrounding personnel and assets. To ensure that the risk of a flammable vapour cloud is reduced, the line in which the leaking flange is identified should be isolated as soon as possible. The use of hazardous area classification should be employed to ensure that the electrical equipment within areas of potential flammable atmospheres are correctly designed and maintained to minimise the possibility of an ignition source. Inspection and maintenance of flange joints should be common practice for proactive management of flanged joints to avoid leaks.

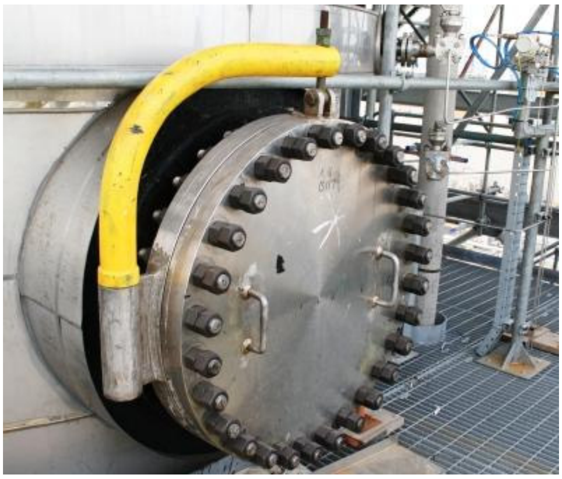
Open section on novel ideas

Technology has been developed which uses laser scanners to locate gas clouds on site. This technology has been demonstrated to be compatible for use in conjunction with closed circuit television systems to give the operator a tool for scanning the plant to identify gas clouds and therefore potential leaks from flanges on the site. This real-time gas detector would be invaluable to an operator as a tool for use to reduce the impact on the environment and any potential safety risks by the timely identification of a leak and reduce the safety risk posed by the leak to personnel in the area. A small selection of LNG terminals have current use of this technology, however, it is identified here as it has potential for widespread use in the industry in the coming years.

References

1. US Environmental Protection Agency Website, *accessed on 18 November 2009*, available from ethane/

Pictures and (or) Drawings of Process Equipment



Leaking Valve Glands

Leaking Valve Glands

Description

The valve gland on a valve is generally located at the point through which the spindle for the valve control interface passes through the bonnet of the valve. The valve gland forms the seal between the internal fluid and the external environment. The gland is critical to the function of the valve as it ensures the valve retains containment of the internal fluids.

Environmental Risks

Regular leaks from valve glands are common if the valve gland is not correctly maintained. A leak from a valve gland results in releases of the internal fluid to the environment. If the internal fluids are LNG then the resultant leaking valve gland will see methane released 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]. The seal on the gland needs regular attention to ensure the continued containment of the internal fluids is retained.

Appropriate Measures to Protect Against Safety Risks

A safety risk is presented by a leaking valve as it means that loss of containment has occurred. Release of cryogenic LNG to carbon steel supports of equipment would lead to cold embrittlement of that equipment and potential for further uncontrolled releases. The leaking valve gland is therefore a danger to personnel and could lead to an escalation which could result in a serious process incident. Care should be taken in design to ensure that carbon steel could not come into contact with cryogenic fluids from leaking valve glands. In addition, there is a risk that a flammable vapour cloud could be formed if loss of containment is realised. To ensure that the risk of a flammable vapour cloud is reduced, the line in which the leaking valve gland is identified should be isolated as soon as possible. The use of hazardous area classification should be employed to ensure that the electrical equipment within areas of potential flammable atmospheres are correctly designed and maintained to minimise the possibility of an ignition source.

The valve glands should be correctly maintained to ensure that the gland seal is always retained.

Open section on novel ideas

None.

Pictures and (or) Drawings of Process Equipment

References

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

Pipe Failure

Pipe Failure

Description

A pipe failure on an LNG terminal is not necessarily limited to the main process steams. Failure a pipe in a supporting process can have and equally detrimental effect on the environment. The root causes of pipe failure can be identified as but is not limited to corrosion, overpressure, erosion, mechanical fatigue, and embrittlement. These root causes can lead to a failure of the pipe ranging from a small pinhole to a catastrophic failure of the pipe where the whole inventory is released to the environment.

General Emissions Details

Land ☒

Air ☒

Water ☒

Noise ☒

* The emissions to land, air, and water is dependent on the fluid which was contained in the failed pipe.

Environmental Risks

The level of environmental risk which is presented by a pipe failure is largely dependent on the fluid which is being transported in the failed pipe, for instance the failure of a potable water pipe demonstrates a much lower risk than the failure of pipe which is transporting caustic solution. The risk to the environment can be reduced through the design, pipework routing and associated pipework support, in addition to maintenance and inspection in line with the site maintenance policy and statutory regulation. In addition, controlled commissioning, decommissioning and cooldown of and pipes should be practiced to reduce the risk to the environment. Pressure relief systems which protect the pipe from overpressure should be set below the design pressure of the pipe to ensure that overpressure to the point of mechanical failure is not possible. Pigging operations on the most critical pipelines in the plant will provide information on the state and integrity of the pipe internals.

Should a release in an LNG or natural gas line occur, methane would be the primary component which is released to the atmosphere. 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 failure of the pipe poses a safety risk to any personnel in the area. The measures discussed to protect against the environmental risks of a pipe failure are also adoptable as the measures to protect against the safety risks of a pipe failure.

An addition, the failure of a pipe containing a flammable substance could lead to the generation of a flammable vapour cloud. The impact of a flammable vapour cloud can be increased in congested areas and pipeways by allowing the acceleration of the flame speed in the event that an ignition source is found; attention should be paid to pipework congestion at design. To ensure that the risk of a flammable vapour cloud is reduced, the line in which the failure has occurred should be isolated as soon as possible. The use of hazardous area classification should be employed to ensure that the electrical equipment within areas of potential flammable atmospheres are correctly designed and maintained to minimise the possibility of an ignition source. Gas / leak detection should be employed across the site where necessary to ensure that any leak (both gas or liquid) can be detected to allow the operator to minimise the impact that this leak might have on the environment and surrounding plant and pipework.

Open section on novel ideas

Technology has been developed which uses laser scanners to locate gas clouds on site. This technology has been demonstrated to be compatible for use in conjunction with closed circuit television systems to give the operator a tool for scanning the plant to identify gas clouds and therefore potential leaks from failed pipes on the site. This real-time gas detector would be invaluable to an operator as a tool for use to reduce the impact on the environment by the timely identification of a leak and reduce the safety risk posed by the leak or failure to personnel and assets in the area. A small selection of LNG terminals have current use of this technology, however, it is identified here as it has potential for widespread use in the industry in the coming years.

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

Process Ancillaries

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Emergency Power

Diesel Powered Generators

Equipment description

Diesel powered generators (combination of diesel engine and electric generator) can be used for power generation on an LNG regas terminal. The amount of electricity which is generated can be sufficient to support the terminal during normal operation or could be solely to support emergency power requirements to safely shut the plant down in the event of an electrical failure. Diesel storage is required where diesel generators are present to provide the fuel with which the generators operate.

General Emissions Details

- Land ☐
- Air ☒
- Water ☐
- Noise ☒

Prerequisites requirements of equipment

Diesel storage

A prerequisite of diesel generation is diesel storage and associated transfer facilities.

Electrical Connection

An electrical connection is required to supply the power from the generator to the main switch board for the site.

Emissions details

LAND

There are no emissions to land as a result of the normal operation of diesel powered generators.

AIR

The operation of diesel engines leads to diesel exhaust fumes which are a mixture of gases, vapours, liquids, aerosols and particulates [1]. The exhaust fumes contain the products of the combustion step which occurs in the engine cylinders which include carbon dioxide, water, carbon monoxide, carbon (soot), aldehydes, nitrogen oxides, sulphur dioxide, and polycyclic aromatic hydrocarbons [1]. The carbon or soot content of the exhaust gases can vary depending on the type of engine and the fuel which is used. Most of the contaminants are absorbed onto the soot particulates [1]. The composition of the exhaust gases is highly dependent on the fuel, engine type, and conditions of operation [1].

WATER

There are no emissions to water as a result of the normal operation of diesel powered generators.

NOISE

The operation of a diesel engine is inherently noisy as a result of the combustion of diesel fuel (diesel clatter, diesel nailing, diesel knock). The noise which a diesel engine makes can be considered at the design stage or can be improved by using a different fuel mix which can reduce the diesel clatter.

Environmental Risks

The use of a diesel generator requires the storage of diesel fuel which presents an environmental risk. The biggest risk is presented through the transfer of diesel oil from the delivery tank to the storage tank on site. This is normally done through a flexible hose. A diesel spill will seep into the land on which it falls and can also be emitted through water as a result of surface water run-off. Only 8 ppm of oil is visible as a coloured sheen on the surface of water. The risk of a release from diesel storage can be reduced through the use of bunding. The impact of a diesel spill can be reduced by deploying readily available spill kits in the event of a spill.

Appropriate Measures to Protect Against Safety Risks

The noise which is generated in a diesel generator house can be significant. Ear protectors should be worn if the noise level can be demonstrated to be above acceptable levels.

Benefits of Technology

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

The operating cost of diesel generators is relatively low as a result of the energy efficiency of a diesel engine.

<u>Operational</u>

An operational benefit is realised through the use of diesel generators as an emergency power supply. They provide sufficient power to allow the operator to safely shut-down the plant in the event of a power failure and maintain visibility of the essential pieces of plant on the site.

<u>Environmental</u>

None considered.

Downfalls of Technology

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

None considered.

<u>Operational</u>

None considered.

<u>Environmental</u>

The emissions which are released to air as a result of the combustion of diesel oil can be considered a downfall of the technology.

Development / History of Technology

The diesel generator is a combination of two different historical discoveries or inventions. The first of these is the demonstration of electro magnetic induction by Michael Faraday in 1831. The second was the invention and subsequent patent of the diesel engine by Rudolph Diesel in 1892. It was the coupling of these two technologies together which gave rise to the diesel generator as we know it today.

Open section on novel ideas

None.

Pictures and (or) Drawings of Process Equipment

References

1 UK Health and Safety Executive Websites, available from http://www.hse.gov.uk/pubns/indg286.htm, accessed on 12 April 2010

Emergency Provisions

Foam Generators

Equipment description

In the event of a spill of LNG, accumulation may occur in areas such as tank bunds or impoundment basins. For areas of accumulation such as these, it is good practice to install high expansion foam generators. High expansion foam generators allow the operators to remotely control the blanketing of the spilt liquid pools to either extinguish a pool fire or reduce the flame size and consequential radiation from the pool fire on adjacent equipment [1]. These systems are normally supplied by specialist fire protection companies and are designed and tailored for the specific circumstances and application [1]. One could expect a foam generation system to consist of the following elements [1]:

- High expansion foam generators
- Stop valves
- Foam concentrate storage tanks
- Foam inductors

Foam generation systems can be powered through a variety of means including water, electricity, or diesel engine. Typical foam mixtures can be expected to constitute alcohols, mono-butyl ethers, ether sulphates, and balance water in varying quantities.

General Emissions Details

Land ☒

Air ☒

Water ☒

Noise ☒

Prerequisites requirements of equipment

Power Source

The method by which the foam system is to be powered (including water, electricity, or diesel engine) should be readily available. Water or electricity could be available from the firewater or electrical system in the terminal. Diesel would have to be externally sourced and delivered to the diesel storage tanks which make-up the foam generation system.

Emissions details

LAND

Foam generators can result in foam being released to the land as a result of wind in the area. The specific details of the emissions depend on the chemical make-up of the foam alcohols, mono-butyl ethers, ether sulphates, and balance water in varying quantities.

AIR

There are no emissions to air associated with foam generators.

WATER

The use of foam generators will inevitably lead to emissions to water. The emissions from the foam systems can be released to water as a result of the conditions under which these systems are used; if the situation arises where the foam is used, the presence and use of firewater cannot be discounted. The firewater will carry the foam through the drainage system and leave the terminal through the water effluent. It should be noted that the quantity of water used in foam systems compared to a sprinkler system is significantly less meaning the run-off is reduced.

NOISE

The operation of the foam generators will lead to noise emissions as a result of the system operation. The noise levels experienced will depend on the method by which the generators are powered. Water powered generators are expected to generate significantly less noise than the diesel or electrically powered systems.

Environmental Risks

The environmental risks presented by foam generation systems revolve around the direct release of the foaming compound. Where possible, this risk could be reduced by using a compound which is proven to be biodegradable. The foam system will not affect the level to which the released / spilled component is emitted to the environment, however, it is expected to reduce the risk of additional releases from other pieces of plant as a result of the radiation from a possible pool fire. Diesel powered systems present an environmental risk from the filling operation of the diesel storage tanks; spill kits should be used in the event of a spill to reduce the environmental impact should a spill occur.

Appropriate Measures to Protect Against Safety Risks

Foam generation systems should be designed for a hazardous environment as a result of the conditions under which they operate. The foam compound can be harmful and the appropriate safety measures outlined on the MSDS should be observed.

Benefits of Technology

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

The capital and operating costs are considered to far out-weight the impact on adjacent plant equipment in the absence of foam generation systems. For this reason, the relative cost of installation and operation of the foam systems is considered a benefit of the technology.

<u>Operational</u>

Foam generation systems require very little operational input once the system has been started. They can generally be used around many types of electrical equipment due to the low quantities of water which are used for the generation of the high expansion foam.

<u>Environmental</u>

The use of foam systems will reduce the thermal radiation resulting from a spill of LNG should the pool be ignited. This will in turn reduce the impact on adjacent equipment and therefore any subsequent releases which could increase the environmental impact.

Downfalls of Technology

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

None considered.

<u>Operational</u>

None considered.

<u>Environmental</u>

A downfall of foam generation is the release of the foam compound to the environment following the use of the technology. The use of a biodegradable substance will help to reduce this impact.

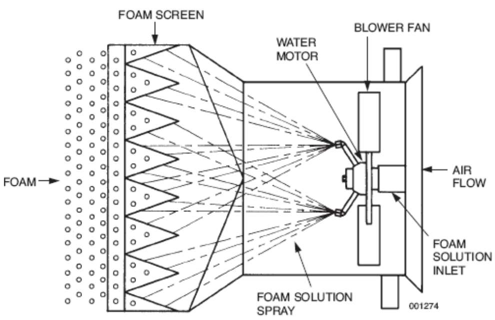
Development / History of Technology

None.

Open section on novel ideas

None.

Pictures and (or) Drawings of Process Equipment



References

1 Guide to Storage Tanks and Equipment, **Bob Long & Bob Gardener**, *John Wiley and Sons*, 2004

Foam Glass Blocks

Equipment Description

In the event of a spill of LNG, accumulation may occur in areas such as tank bunds or impoundment basins. For areas of accumulation such as these the LNG concentration dictates high rates of boil off due to thermal radiation from the surrounding area. The use of foam glass blocks which are placed in the base of LNG spill control areas like impoundment basins and bunds can reduce the heat ingress to the LNG pool and reduce the boil off rates and hence the risk of a gas could formation (Note that the foam glass blocks should be procured from specialist suppliers and should come with a water proofed barrier to protect the foam glass from the elements during the periods where they are 'dormant'). In the event of an LNG spill and subsequent pool formation in the LNG spill control areas, the foam glass blocks will float to the top of the pool forming an insulated layer which has the effect of reducing the boil off rates of the pool significantly.

General Emissions Details

- Land ☐
- Air ☐
- Water ☐
- Noise ☐

Prerequisites requirements of equipment

Emissions details

LAND

There are no emissions to land from the use of foam glass blocks in LNG spill control areas.

AIR

There are no emissions to land from the use of foam glass blocks in LNG spill control areas. There will however be emissions to air as a result of the LNG spill which is considered under the fugitive releases section of this document.

WATER

There are no emissions to water from the use of foam glass blocks in LNG spill control areas.

NOISE

There are no noise emissions from the use of foam glass blocks in LNG spill control areas.

Environmental Risks

There are no environmental risks directly associated with the use of foam glass blocks in areas of LNG spill accumulation. The nature of the spilled material may have environmental impacts which are considered within the fugitive releases section of this document.

Appropriate Measures to Protect Against Safety Risks

Impoundment basins and other LNG spill control areas can act as accumulation points for water. Care should be taken that the foam glass blocks do not mask the accumulation of water and regular checks should be made of these areas and water accumulation should be pumped out of the control area.

Benefits of Technology

Cost (Capital and Operating Costs)

The capital cost of foam glass blocks for use in LNG spill control areas is small. There are no operating costs associated with these systems aside from regular inspection by the operator.

Operational

Operationally, these systems require little operational input.

Environmental

There are no environmental benefits associated with the use of foam glass blocks for spill control, however, the spill control areas can offer environmental benefits by containing any spilled substance.

Downfalls of Technology

Cost (Capital and Operating Costs)

There are considered to be no downfalls of this technology in respect of cost.

Operational

There are considered to be no operational downfalls of this technology.

Environmental

There are no environmental downfalls associated with the use of foam glass blocks for spill control.

Development / History of Technology

None.

Open section on novel ideas

None considered.

Pictures and (or) Drawings of Process Equipment

None.

References

None.

Fuel Gas & Process Heating

Electrical Heating and Tracing

Equipment description

Electrical heat tracing can be used in a number of areas of the plant for the purpose of process heating. The general principle in the process is the use of the heat which is a by-product of electrical resistance. The heat can be used for trace heating pipework or equipment to maintaining or raise the temperature of that system. It can also be used in process plants to counteract the Joule Thompson effect or to raise the temperature of the gas produced from cryogenic liquid boil off.

General Emissions Details

- Land ☐
- Air ☐
- Water ☐
- Noise ☐

Prerequisites requirements of equipment

<u>Electricity</u>

A pre-requisite requirement of electrical process heating is the availability of electricity. The electricity is used as the means with which to produce the heat.

<u>Insulation</u>

Thermal insulation is required to prevent heat losses from the pipe or equipment on which the electrical process heating is acting. Heat generated by the heating system is intended to raise or maintain the temperature of a specific piece of equipment.

Emissions details

<u>LAND</u>

There are no emissions to land from electrical trace / process heating.

<u>AIR</u>

There are no emissions to air from electrical trace / process heating within the boundary of the site. The use of electricity can be associated with the emissions of carbon dioxide at the point of electricity generation.

<u>WATER</u>

There are no emissions to water from electrical trace / process heating.

<u>NOISE</u>

There are no noise emissions from electrical trace / process heating.

Environmental Risks

There are no environmental risks associated with electrical trace and process heating within the boundary of the terminal. The use of electricity does have an impact on the environment through emissions of carbon dioxide at the source of the electricity generation. The efficient use of electrical heating will therefore limit the environmental impact of this process.

Appropriate Measures to Protect Against Safety Risks

Electrical heating systems can act as an ignition source should a gas cloud form unless designed and operated correctly. Electrical heating systems used on a gas storage site should be designed, constructed, and maintained to the relevant safety standards for their application.

Benefits of Technology

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

The capital cost of electrical heating systems is much lower than equivalent steam heating systems.

Operational

Operationally, electrical heating systems are relatively simple pieces of equipment when compared to steam heating systems. This simplicity is considered an operational benefit.

Environmental

Environmentally, the emissions of carbon dioxide is localised when using electrical heating. This facilitates the possible carbon capture and storage of the carbon dioxide which is considered an environmental benefit.

Downfalls of Technology

Cost (Capital and Operating Costs)

The majority of the operating cost of electrical heating systems is made-up of electricity costs and associated equipment. The operational cost of an electrical heating system failure can be costly.

Operational

There are not considered to be any operational downfalls of electrical heating technology when compared to other technologies.

Environmental

There are not considered to be any environmental downfalls of electrical heating technology when compared to other technologies.

Development / History of Technology

None.

Open section on novel ideas

None.

Pictures and (or) Drawings of Process Equipment

References

None.

Steam Heating and Tracing

Equipment description

Industrial boilers are steam generators that provide power, steam or both to an industrial plant. Boiler systems are indirect-fired units which consist of sets of tube bundles arranged inside a furnace. Fuel gas and air are drawn into the furnace and ignited by burners. Heat is transferred through the tube walls to the water in the tubes causing it to evaporate firstly to a vapour and secondly to dry saturated steam in a primary and secondary super-heater bundle. An economiser exists to extract heat from discharged flue gases thus maximising efficiency. The steam generated may then be circulated around the site to be used for heating purposes.

Steam tracers exist to prevent temperature drop in lines where thermal losses could result in damage to piping, interference with operation caused by congealing process fluids, increase in viscosity, or separation of components/phases in the fluid below certain temperatures, or when there is risk of formation of corrosive substances or water due to condensation in the line.

Steam tracing may be done in one of two ways. Bare steam tracing is the most popular choice as it is easily installed and maintained and it is ideally suited to lower temperature requirements. It is simply composed of a pipe (sized depending on process requirements) carrying pressurised steam at up to 270℃, attached to the process fluid pipe by straps. The assembly is then wrapped in thick insulation to reduce losses by conduction before being covered with a polished, metallic jacket to reduce radiation heat losses. The alternative method is to make use of cemented steam tracing. This method employs heat conductive cement which is placed around the steam tracer running parallel to the process fluid pipe, in an attempt to increase the contact area available for heat transfer, between the tracer and the process fluid pipe. The number of steam tracers depends on the requirements of the application (line size, thermal requirements, etc).

General Emissions Details

Land ☐

Air ☒

Water ☒

Noise ☐

Prerequisites requirements of equipment

<u>Boiler Fuel Gas</u>

In order to generate steam for heating purposes it is necessary to combust natural gas inside a boiler. Therefore a prerequisite of the process is natural gas as fuel for heat generation.

<u>Chemical Dosing</u>

The inlet water to the boiler is pre-treated to manage its corrosion/erosion properties. Treatment chemicals should be stored in sealed bunded areas in a suitable location and can include the following:

Sodium Bisulphate (30 – 60 wt%)
Potassium Hydroxide (10 – 30 wt%)
Sodium Hydroxide (30 – 60 wt%)
Cyclohexylamine (10 – 30 wt%)
Morpholine (5 – 10 wt%)
Diethylthanolamine (5 – 10 wt%)
Common salt (NaCl) can be added to soften the water from the local supply.

Electricity

An electricity supply to the boiler is required to supply power to the motors in the air intake fan and also for the process water pumps. Electricity is also required for instrumentation equipment and controllers on both the boiler and traced processing lines.

Instrument Air

Instrument air is required to power control valves to facilitate control of the boiler and supply of steam to tracing lines.

Emissions details

LAND

There are no emissions to land as a result of operating a steam boiler for heating purposes on site.

AIR

Flue gases from gas combustion are released through a vent stack. Such gases may include carbon dioxide, carbon monoxide and NOx. NOx emissions from boilers must be maintained at or below the specific levels detailed on the environmental permit for the terminal. CO_2 releases should be maintained in accordance with the site environmental permit.

WATER

Emissions to water may arise from boiler blow down or from emptying the boiler for maintenance. Due to dosing chemicals used to control the corrosion/erosion properties of water this effluent may affect target water pH, suspended solids content and Chemical Oxygen Demand (C.O.D.) of the effluent water streams. The majority of water from the steam system is recycled back to the boilers to save on dosing requirements.

NOISE

Some noise is generated by the pumps and combustion air fans in the boiler assembly. However these noise emissions are considered minimal in comparison to other noise sources on an LNG regasification terminal.

Environmental Risks

The use of chemicals for water quality control is considered an environmental risk. All chemical additives should be held in bunded storage vessels. The bunds should be fully sealed and be capable of containing 110% of the vessel contents. The vessels are typically filled via tanker, a process which should be controlled by permits and suitably competent personnel. Procedures should be in place which requires the checking of transfer hoses, nozzles and couplings prior to fluid transfer.

Appropriate Measures to Protect Against Safety Risks

Regular maintenance checks should be carried out on a preventative basis. The equipment is fitted with SIL rated control systems to prevent overfilling of the vessel and any potential risk from over pressure; particular attention should be paid to these systems to ensure their ongoing integrity is maintained.

Benefits of Technology

Cost (Capital and Operating Costs)

Steam tracing adds the benefit that processing lines are maintained within desired process conditions, reducing heat losses and increasing plant efficiency. Bare tracing is the simplest and cheapest method of tracing therefore capital expenditure is minimised.

Operational

Due to the nature of this technology, multiple boilers are online simultaneously with at least one in full operation and another firing on standby should the primary unit fail. Therefore, holding to the double jeopardy concept the equipment should be available for use 24/7. Maintenance work on the tracing system is usually only preventative or in line with inspections. The tracers should be clad with lagging and therefore not exposed to atmospheric corrosion.

Environmental

The energy efficiency of the equipment is low, however, constant monitoring in accordance with the environmental permits entails that the machines can still deliver both process and statutory requirements. The actual tracing system does not constitute any emissions to air land or water.

Downfalls of Technology

Cost (Capital and Operating Costs)

The operation of the boiler requires the use of natural gas as a fuel. An electricity supply to the air inlet fan and water circulation pumps adds additional costs to the operator. The cost of chemical dosing agents must also be taken into account, however, this is based on source water specification as opposed to boiler type and hence would be identical whichever boiler was installed.

Operational

A large amount of utilities and additional equipment are required to operate and maintain a boiler system including fuel gas, electricity, instrument air and also chemical dosing. These costs can be substantial.

Environmental

The high emissions from burner flue gas are the inherent draw back of this technology. Emissions of carbon dioxide, carbon monoxide, NOx and particulates entail a high environmental impact.

Development / History of Technology

Steam-tracing systems were developed during the early days of the refining industry. In the early 1900s when the first continuous-type processing plants were developed, these systems were essential in keeping petroleum residues, tars and waxes flowing. During this era, energy conservation was of little concern. Insulation systems generally provided a minimum of thickness to allow the available steam-tracing methods to hold the process fluids at a desired temperature. High-temperature rigid insulating materials were widely used, and they were generally hygroscopic. To further complicate matters, weather barriers were also less than optimal. All of these factors affected the thermal performance of the heat-tracing systems. The early steam-tracing methods included steam jacketed and gut-line systems and convection tracers using bare tubing or small-diameter pipes.

Open section on novel ideas

Combustion Optimisation

The easiest way to optimise boiler efficiency is to analyse the burner and more specifically the fuel to air ratio inside the burner.

By far the most common reason for energy inefficiencies in a boiler can be attributed to the use of excess air during combustion at the burners. When there is more air than is required for combustion, the extra air absorbs some of the heat of combustion which is discharged to flue.

Adjusting the fuel-air ratio for combustion can be tricky. If the fuel concentration is in excess compared to the air, incomplete combustion occurs. This will give rise to carbon soot deposits inside the combustion chamber or even over the boiler tubes reducing heat transfer efficiency.

It is thus worthwhile to analyse air intake and adjust the intake fan accordingly. The air intake can also be routed via the flue gas to gain heat as hot air will increase combustion efficiency.

It may be possible to retrofit the equipment with a low NOx burner consisting of multiple fuel or air injection points which will result in a stage wise combustion profile. This lowers peak flame temperature resulting in a reduction in formation of thermal NOx. NOx reductions in the order of 50 – 70% are possible by changing the burner design [3]. Similarly recirculation of the flue gas will have the same effect on peak flame temperature whilst also recycling unused fuel should this be in excess of the air intake. Again, boiler temperatures can be reduced by using catalytic combustion, however the capital involved in installing a catalytic combustion chamber on top of the investment in catalyst replacement and extra work this brings may make it uneconomical.

Emissions

Emissions to air from flue gases can be reduced by fixing a water quench system to the vent stack thus dissolving acid gases from the flue. The downside to this technology is the production of acidic water which will require dosing by caustic before it can be discharged. A cost-benefit analysis would be required to determine if site caustic supplies can be economically increased to accommodate this.

Pictures and (or) Drawings of Process Equipment

None.

References

1. http://www.steamonline.com/tracing.html
2. Perry, R.H. and Green, D.W. Perry's Chemical Engineers' Handbook 7th Edition; McGraw-Hill 1997.
3. IChemE Interactive Training on Waste Minimisation (1995). Various Authors. ISBN: 1 898945 314.

Instrument Air Supply

Dry Air Compression

Equipment description

Dry air compression uses a feed stock of air which has been dried by a process elsewhere in the terminal. The dry-air compression process therefore simply utilises a compressor to boost the pressure from the feed pressure on the outlet of the air driers to the pressure required within the instrument air system. The compressor usually feeds a dry air accumulator which acts as a buffer for the instrument air supply. The compressed air leaving the dry air accumulator passes into a system of pipe-work which distributes the air around the plant to the end users.

General Emissions Details

- Land ☐
- Air ☐
- Water ☐
- Noise ☒

Prerequisites requirements of equipment

Source of dry air

A prerequisite of dry air compression is a dry air source. To produce a dry air source, an air processing system is required upstream of the dry air compression system to remove the humidity and impurities from the wet air source.

Electricity

Electricity is required to operate the compressor which lifts the pressure of the dry air from the source temperature to the instrument air system operating pressure for distribution to the end users.

Emissions details

LAND

There are no emissions to land considered from the operation of this equipment.

AIR

There are no emissions to air considered from the operation of this equipment.

WATER

There are no emissions to water considered from the operation of this equipment.

NOISE

The operation of a compressor for the compression of the dry air up to the operating pressure of the instrument air system will result in the release of noise to the surrounding environment.

Environmental Risks

The compressors which provide the pressure differential between the feed and the end user are considered the only source of an environmental risk from the process. The compressors utilise lube oil to maintain the lubrication of the moving parts, which pose an environmental risk if released. The equipment should be maintained in line with an acceptable maintenance policy to ensure that this risk to the environment is not realised. All necessary precautions should be taken to ensure that the transfer of any lube oil during maintenance activities does not result in a release to the environment.

Appropriate Measures to Protect Against Safety Risks

Dry compressed instrument air systems operate in an environment in which gas may be present in the surrounding air. The compression of a gas-air mixture could result in an explosion. This risk should be addressed in the air-drying package where gas detection systems should be utilised to avoid the introduction of gas into the dry air system. To ensure that the air feeding the compressor is gas free, a gas detection system sited at the air intake filters should be used to act on the compressor and alert the operator. Additionally, the failure of this equipment to operate could lead to a loss of control of the process which is considered a safety risk. A back-up instrument air supply system should therefore be present through consideration during design or through an alternative source, for instance form the site nitrogen system.

Benefits of Technology

Cost (Capital and Operating Costs)

The cost of dry-air compression for instrument air is preferable to the use of nitrogen for instrument air supply. The extra processing steps associated with nitrogen production means that the costs for nitrogen are far greater than dry air production and compression.

Operational

The operational input required by the system is relatively low. The system is self sufficient once operational and only requires periodic maintenance (which includes the replacement of filters) and inspection to ensure the continued operation of the system.

Environmental

Emissions from dry air compression are low with only the emissions designation of ‘noise’ identified.

Downfalls of Technology

Cost (Capital and Operating Costs)

There are not considered to be any downfalls of this technology with respect to cost.

Operational

There are not considered to be any downfalls of this technology with respect to operation.

Environmental

There are not considered to be any downfalls of this technology with respect to the environment.

Development / History of Technology

None.

Open section on novel ideas

None to declare.

Pictures and (or) Drawings of Process Equipment

References

None.

Wet Air Compression

Equipment description

Instrument air supplied through the wet air compression process involves wet air compressors, wet air receivers, and air dryer units. The process involves the compression of wet air which has been drawn through a particle filter up to operating pressure. The compressed air is then passed to a wet air receiver before moving to the drying stage. The wet air is normally dried through pressure swing adsorption before passing into an air distribution system for use in the process.

General Emissions Details

- Land ☐
- Air ☐
- Water ☒
- Noise ☒

Prerequisites requirements of equipment

Electricity

A wet air compression instrument air package has a pre-requisite of electricity. Electricity is required by the instrument air package to operate the compressors which pressurise the wet air for processing and distribution to end users.

Drainage

A connection to the site drainage system is required for the discharge of potential liquids generated through the drying process.

Emissions details

LAND

There are no emissions to land from a wet air compression instrument air package.

AIR

There are no emissions to air from a wet air compression instrument air package.

WATER

Water is generated as a by-product from the process. The water which is generated is a result of the drying of the wet air received from the surrounding environment. The water which is present in the air cannot be contaminated due to the phase this water is in. No additional components are released to the water during the process. Therefore, it is considered that there are no emissions to water from a wet air compression instrument air package.

NOISE

Noise is emitted from the process as a result of the compressors used to provide the pressure differential from which the process operates.

Environmental Risks

The compressors which provide the pressure differential from which the process operates are considered the only source of an environmental risk from the process. The compressors utilise lube oil to maintain the lubrication of the moving parts, which pose an environmental risk is released. The equipment should be maintained in line with an acceptable maintenance policy to ensure that this risk to the environment is not realised. All necessary precautions should be taken to ensure that the transfer of any lube oil during maintenance activities is not released to the environment.

Appropriate Measures to Protect Against Safety Risks

Wet compressed instrument air systems operate in an environment in which gas may be present in the surrounding air. The compression of a gas-air mixture could result in an explosion. This safety risk should be addressed through the use of a gas detection system sited at the compressor intake filters which will act on the compressors and alert the operator to this risk.

The instrument air supplied by wet air compression provides the instrument air which is used in the process for critical pieces of equipment. Failure of the wet air compression package would not lead to any dangers as a direct result of its failure; however it could result in safety risks posed by the critical pieces of equipment to which it supplies instrument air. These critical pieces of equipment should therefore be designed to be 'fail safe' in the event of a loss of instrument air. The instrument air package should be maintained against an acceptable maintenance policy to reduce the risk of this failure. A connection point for nitrogen supply from the site's nitrogen supply would facilitate the continued operation of these critical pieces of equipment in the event that the wet air compressor was to fail.

Benefits of Technology

Cost (Capital and Operating Costs)

The cost of wet-air compression for instrument air is preferable to the use of nitrogen for instrument air supply. The extra processing steps associated with nitrogen production means that the costs for nitrogen are far greater than wet air compression.

Operational

The operational input required by the system is low. The system is self sufficient once operational and only requires periodic maintenance (which includes replacement of filters) and inspection to ensure the continued operation of the system.

Environmental

Emissions from the wet air compression instrument air system is low with the only destination of emissions considered to be through noise from the compressors.

Downfalls of Technology

Cost (Capital and Operating Costs)

None considered.

Operational

The air is dried through pressure swing adsorption. This process uses packed columns which will require occasional replacement of the packing material to ensure the continued operation as designed.

Environmental

There are not considered to be any downfalls with respect of the environment of this technology.

Development / History of Technology

None.

Open section on novel ideas

None considered.

Pictures and (or) Drawings of Process Equipment

References

None.

Nature Conservation Area

Nature Area

Description

A nature area consists of a piece of land which is dedicated to nature conservation and provides a safe haven for the natural biodiversity of the area to flourish. It allows the terminal to offset the impact of the terminal operation on the environment and - to some extent - the carbon footprint. A nature area could consist of a water body or area of land that is managed or simply set-aside to allow flora and fauna to flourish in an area of protection. It may provide a position to relocate any wildlife to a safe location where habitat is disturbed during the construction or subsequent operation of the terminal.

General Emissions Details

- Land ☐
- Air ☐
- Water ☐
- Noise ☐

Prerequisites requirements

Land

The only prerequisite of a nature area is a plot of land which can be dedicated to nature conservation. Ideally it should be away from areas where it can be disturbed and should not affect the normal operation of the terminal.

Environmental Benefits

The environmental benefits offered by a nature area are huge. As there is no requirement for human intervention in this area and only natural biodiversity co-existing, there are not considered to be any emissions. These areas allow the natural biodiversity to be maintained and offset the impact that the terminal construction and operation has on the environment. It ensures that a safe haven is provided for all species in the area for conservation of the land as it was before the terminal was constructed.

Pictures and (or) Drawings of Process Equipment

References

None.

Office and Administration

Office & Administration

Description

The operation of an LNG importation terminal is maintained by full time operational and administrative staff. As a result, office and well-being facilities are required to support their day to day work activities. Well-being facilities include toilet and changing facilities, and kitchen and break-out areas. The presence of these necessary facilities for the continued operation of the terminal leads to the generation of waste and emissions through various activities including heating of the office facilities, toilet facilities, waste collection and disposal, etc.

General Emissions Details

- Land ☒
- Air ☒
- Water ☒
- Noise ☒

Emissions details

LAND

Emissions are generated to land through the collection and disposal of rubbish. The endpoint for this waste is usually a landfill site located off of the site. Waste deposited in landfill includes but is not limited to, Paper, Cardboard, Metal, Wood, Food Wastes, Textiles, etc.

AIR

Depending on the location of the terminal and the associated office facilities, emissions can be released to the air. These can be through the air condition / heating requirements which can be met by gas boilers or gas powered air conditioning units which predominantly emit carbon dioxide to the air along with traces of carbon monoxide, nitrous oxide and particulates depending on the conditions and design of the equipment. In addition, the kitchen facilities could include gas fired cookers which would again lead to similar emissions as the heating / air conditioning requirements although at much lower quantities.

WATER

The presence of toilet facilities leads to emissions to water through drains and sewers. The exact composition of this waste stream is difficult to quantify but will be high in organic matter which will have a high biological oxygen demand. In addition to the organic matter, detergents (generally phospholipids) will be present in this waste stream but in trace amounts compared to the organic matter. Oils and traces of food waste would be expected from the kitchen facilities along with detergent components in varying quantities.

NOISE

Noise can be generated for a number of sources within the office and administration facilities which include fans used for extraction and ventilation, air conditioning units, and water pumps. The level of noise from these facilities is expected to be considerably lower than the noise generated by the process equipment used by the terminal.

Environmental Impact

The impact of the office facilities on the environment can be large. This impact can be reduced by staff awareness campaigns which promote the use of recycling facilities to reduce the amount of waste which is sent to landfill. Further more, water re-use technologies can be installed in the toilet and kitchen facilities to reduce the amounts of water which is used by the office and administration facilities. Water harvesting can be adopted to further reduce the environmental impact. Whilst the electricity usage is not a direct emission from the terminal, it does affect emissions outside of the terminal boundary. More efficient use of the electricity usage in the office and administration facilities can help to reduce the overall carbon footprint of the terminal.

Pictures and (or) Drawings of Process Equipment

References

None.

Process Control & Instrumentation

Cold Vent

Equipment description

During the normal operation of an LNG terminal, heat ingress to the system leads to the generation of boil off gas within the tank (the pressures inside the tank can range from 0.050 and 0.500 barg); the rate of production increases significantly during the ship unloading phase.

An LNG plant can be provided with a venting system consisting of two different piping collectors; typical sizes could be a 30" pipe and a 20" pipe with an operating temperature of -120 ° C. The first system collects the boil off being generated within the tank (low pressure), should the dedicated BOG recovery system fail. The second system collects all the potential release of natural gas (high pressure) from the pressure safety valves (see relief valves under Process Ancillaries for more information).

If the boil off gas recovery system is out of service, there is a requirement to use the cold vent. This leads to natural gas release to the atmosphere to relieve the tank pressure and avoid over pressure of the system.

"Roll-over" is an example of a significant case of boil off gas generation which can overwhelm the existing recovery system. This phenomenon is more likely to occur when production is stopped for a long time; the roll-over event is due to a sudden mixing of LNG layers characterized by different density. In this case the amount of boil off gas which is produced is too great for even the cold vent to be used to relieve pressure and hence the pressure relief valves installed on the roof of the LNG storage tanks are required to become operational.

General Emissions Details

Land ☐

Air ☒

Water ☒

Noise ☒

Prerequisites requirements of equipment

<u>Purge gas</u>

The cold vent is continuously purged with an inert gas to ensure that a positive pressure is maintained in the vent to avoid the back-flow of oxygen into the system. Due to the possible presence of hydrocarbons in the cold vent, an explosive atmosphere must be averted through purging.

Emissions details

<u>LAND</u>

No emissions.

<u>AIR</u>

The essential aim of the cold vent is to send out to the atmosphere the BOG produced during emergency conditions or during extraordinary maintenance. Furthermore, during the usual activity of the plant, there is a continuous flow of purging gas (usually nitrogen). All this can represent a source for air pollution.

<u>WATER</u>

Water can collect at the base of the vent stack leading to a liquid level in the open lute. Anti-freeze can be used to reduce the risk of the liquid freezing and plugging the stack. The collected water should be drained periodically which could lead to a small release of anti-freeze to the environment.

<u>NOISE</u>

The excess process gas which is released through the vent stack is relived down a pressure gradient to atmosphere. As a result, the noise of the gas being vented is emitted for the duration of the venting operation. When the equipment is not being used for emergency venting, there is no noise emission from the process equipment.

Environmental Risks

The predominant material released to the atmosphere through the cold vent is methane. 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]. This risk can be reduced by minimising the use of the cold vent, however; one should note that this is the ultimate safety device to avoid overpressure in the process.

Appropriate Measures to Protect Against Safety Risks

Vent pipe collectors and the related supporting structure are designed and constructed in accordance with the relevant codes and standards.

Preventative maintenance, field inspections and proper instrumentation should be implemented to ensure the continued safe operation of the vent stack.

The gases which are vented through the cold vent are often cold vapours and as a result can have a tendency to sink to the ground prior to their dispersion into the atmosphere. The oxygen free environment produced by this vapour cloud would not be life supporting. As a result, an exclusion zone which is sufficiently sized for the capacity of the vent stack should be implemented, and assurance made that no ignition sources are present within this exclusion zone.

The outlet of the cold vent to atmosphere must not be obstructed and as a result is not sealed against water ingress. This can lead to a liquid level at the base of the vent stack which could freeze and plug the line in the event of emergency use. Routine checks of the open lute level should be practiced to protect against this risk. Anti-freeze can also be used to reduce this risk.

Benefits of Technology

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

The cold vent is not a high cost unit in comparison to other venting technologies. The operating cost of the equipment is also very low and only noticeable through the small nitrogen purge and maintenance.

<u>Operational</u>

The cold vent is of benefit operationally as it allows one to actively remove the risk of over pressure to a controlled zone, thereby removing the risk of pressure relief through local relief valves whilst still protecting the assets.

<u>Environmental</u>

None considered.

Downfalls of Technology

Cost (Capital and Operating Costs)

The cold vent incurs a cost through the lost opportunity to sell gas in the market place. This cost is however considered acceptable when balanced against the risk to the assets in the absence of the cold vent.

Operational

The operational input to the cold vent is minimal and there are not considered to be any downfalls of this technology from an operational point of view.

Environmental

The downfall of the cold vent technology is the emissions of methane to the environment. The associated effect is an increase in the green house effect which is considered to be responsible for Global Warming.

Development / History of Technology

In the past the BOG produced inside the LNG tanks was systematically flared or vented.

Nowadays, recovering the BOG by means of various systems is mandatory, meaning the cold vent is just an emergency safety device used for extraordinary events.

Open section on novel ideas

In order to avoid the emissions of Natural gas to the atmosphere, it is possible to use nitrogen as purging gas, instead of methane.

Storage tanks for liquid nitrogen and equipment for regasification or for nitrogen production on-site are usually present in an LNG plant and the stored quantity is typically enough to purge the vent. A possible downfall of using liquid nitrogen is the requirement for frequent nitrogen tankers when compared to on-site generation.

In terms of environmental impact the use of nitrogen instead of methane can improve the emissions of green house gases by the plant significantly.

Pictures and (or) Drawings of Process Equipment

References

1. US Environmental Protection Agency Website, *accessed on 18 November 2009*, available from ethane/

Elevated Flare

Proforma under completion.

Ground Flare

Equipment description

A ground flare acts as a vent through which excess process gas can be released to avoid overpressure of the system. The gas being vented is combusted prior to release to reduce the greenhouse effects of the methane which is the predominant constituent of the vented gas and is some 20 times more efficient at trapping heat as a greenhouse gas than carbon dioxide over a 100 year period [1]. Many different designs of ground flares exist including enclosed chamber flares, enclosed chamber flares with first stage assistance through air or steam, and multi point open designs.

General Emissions Details

Land	☐
Air	☒
Water	☐
Noise	☒

Prerequisites requirements of equipment

Gas for pilot ignition

The ignition of the process fluids facilitated completed via piloted ignition. A gas for the pilot ignition system is therefore required. The gas for this ignition could either be a dedicated pilot gas or could be provided from the fuel gas system on the terminal. If fuel gas is to be used for the pilot ignition system, a tie-in to the fuel gas system will also be required. Caution should be made to ensure that if process fluids are to be used for pilot ignition, that there is no possibility of liquid pass through to the ground flare.

Steam for momentum provision

Some systems use steam for momentum provision in low or variable flow systems. If these systems are to be employed, a source of steam would be required.

Electricity

The combustion air and purge air is taken for the surrounding air. Electricity is required to operate the gas blowers which are used to provide these flows of air through the system if the nozzle design has not accounted for this. Electricity is also required for ignition. The operator should consider the use of a UPS to ensure the reliability of the ground flare system is sufficient.

Process Tie-Ins

In addition to those prerequisite requirements identified above which require tie-in to the main process, a number of other process tie-ins would also be required including:

- Vent system
- Service nitrogen
- Instrument air
- Site control system

Emissions details

LAND

There are not considered to be any emissions to land resulting from the operation of a ground flare.

AIR

The operational nature of the ground flare results in emissions to air. These emissions consist primarily of carbon dioxide as a result of the combustion of hydrocarbons. The use of a ground flare offers the potential for a conversion greater than 98% of the hydrocarbons in the feed gas. Water vapour, a by product of combustion, will also be released to the air along with nitrous oxides and carbon monoxide in much lower quantities which are generated as a result of the combustion process. If the fuel source contains odour, additional emissions will be generated which will also lead to emissions to air which are odour specific.

WATER

There are not considered to be any significant emissions to water resulting from the operation of a ground flare.

NOISE

The process of venting gas releases noise due to the movement of the gas particles down a pressure gradient through a restriction. The use of steam as a driver for the process will result in an elevation of the noise levels.

Environmental Risks

Whilst the use of a ground flare by its nature releases carbon dioxide which is a green house gas, the natural gas which would otherwise be released is considered to have a higher impact on the environment [1]. Therefore, the release of carbon dioxide to the environment in this situation is considered to be an environmental benefit and not an environmental risk.

Appropriate Measures to Protect Against Safety Risks

A safety risk is present at start-up of a potentially explosive atmosphere being present in the ground flare. The start-up routine should therefore require the purge of the combustion chamber and the flare enclosure with air to ensure that any explosive atmospheres are eliminated form the ground flare before the pilot ignition system is initiated. Additionally, the use of a ground flare results in thermal radiation to the surroundings. An exclusion zone should therefore be implemented under normal operation which is suitably sized for the capacity of the ground flare.

Benefits of Technology

Cost (Capital and Operating Costs)

A ground flare is not considered to offer benefits in capital or operating costs when compared to other technologies available for emergency venting operations.

Operational

Operationally, a ground flare requires little input. The process is self sustaining through the use of a pilot ignition which is required as the system is an emergency device.

Environmental

A ground flare offers environmental benefits when considered against other technologies available for emergency venting. Methane is considered 20 times more potent as a green house gas than carbon dioxide over a 100 year period [1]; conversion of the vented products from hydrocarbon to carbon dioxide which occurs at a molar basis (considered for carbon) illustrates benefit to the environment.

Downfalls of Technology

Cost (Capital and Operating Costs)

The capital cost and operating cost of a ground flare is considered high when compared to other equipment for emergency venting operations, however the benefits realised in terms of the environment should also be considered in a cost benefit analysis.

Operational

These systems can require high operational input during start-up to ensure a stable pilot ignition is achieved following maintenance.

Environmental

Inherent in the operation of a ground flare, carbon dioxide is emitted to the environment. Carbon dioxide is emitted in small quantities on an ongoing basis due to the requirement for a pilot ignition system due to its critical nature as a safety device. Note that continuous carbon dioxide emissions can be reduced by maintaining the equipment in an offline state with the pilot ignition system off line.

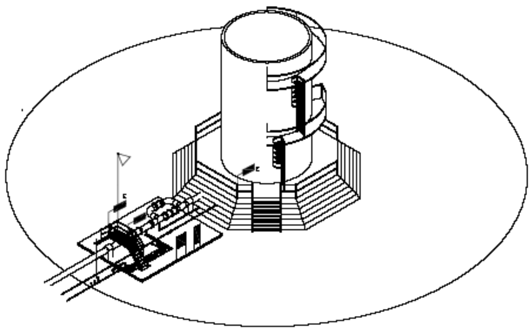
Development / History of Technology

This technology was originally developed in the land fill industry where ground flares are required to combust the waste gases. This technology was later adapted for application in the LNG industry for the purpose of reducing the environmental impact of venting operations.

Open section on novel ideas

The use of catalytic combustion for this operation will facilitate an increase in conversion performance. The use of catalytic combustion could reduce the thermal radiation emitted as a result of the process. This is due to the lower activation energy for oxidation inherent in catalytic combustion when compared with conventional combustion. A study would need to be completed to assess the suitability and reliability of this equipment for this application.

Pictures and (or) Drawings of Process Equipment



References

1. US Environmental Protection Agency Website, *accessed on 18 November 2009*, available from http://www.epa.gov/methane/

Pressure Relief Valves

Equipment description

Pressure relief valves or other relieving devices are used to protect piping and equipment from excessive pressure. Relief valves ensure that the piping or equipment does not see pressures greater than those for which they were designed. Several mechanisms for pressure relief exist which are certified for use as over pressure protection including spring-loaded relief systems, pilot operated relief systems, and rupture disks. The choice of relief mechanism should be compatible with the service and the equipment it is being used to protect from over-pressure. Pressure relief valves can generally be distinguished from their smaller cousin (thermal relief valves) by their larger size due to their requirement to relieve higher volumes of fluid than thermal relief valves.

General Emissions Details

- Land ☐
- Air ☒
- Water ☐
- Noise ☒

Prerequisites requirements of equipment

There are no service pre-requisites on a relief valve. For the correct operation of the valve at the desired conditions, the valve should be calibrated and designed to those conditions.

Emissions details

LAND

There are no emissions to land from relief valves.

AIR

Relief valves on an LNG re-gasification terminal will emit the hydrocarbons which are contributing to the elevated pressures to cause a relief situation. Liquid or gaseous hydrocarbons could be relieved to atmosphere; whilst the liquid will not immediately be emitted to air, the volatility of LNG dictates that should any pool form, it will rapidly evaporate and ultimately lead to emissions to air. The composition of the hydrocarbon mixture will represent the composition of the LNG which is being processed at that moment in time. The primary component of LNG is methane, whilst nitrogen, ethane, propane, butane, and pentane also contribute in small fractions to the LNG composition.

WATER

There are no emissions to water from relief valves.

NOISE

Due to the nature of operation of a relief valve, noise will be generated when a relief valve is in operation. This is a consequence of high pressure process fluids passing through a constricted opening to ambient pressures.

Environmental Risks

The predominant species released to the atmosphere through the use of a relief valve is methane. 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]. This risk can be reduced by minimising the number of times these valves relief under high pressure; however, one should note that relief valves are critical safety devices to avoid overpressure of process equipment and piping.

Appropriate Measures to Protect Against Safety Risks

Given the criticality of relief valves to the safety of the system, relief valves should not be isolated unless done under the correct control of works procedures following a full risk assessment. To ensure the continued safe operation of the relief valves, they should be maintained in line with statutory requirements for pressure systems. Equipment which could be exposed to the relieved streams from cryogenic services should be capable of withstanding cryogenic temperatures and may require stainless steel or other suitable alloys. Finally, the system should not be relieved in the direction of personnel walkways / access routes.

Benefits of Technology

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

Relief valves represent higher cost than conventional service valves owing to the low tolerances to which they are designed. The statutory requirement for their maintenance means a higher operating cost is seen against conventional service valves. There are no suitable alternatives to relief valves and the cost benefit they represent against the loss or damage of equipment means that these are considered benefits of the technology.

<u>Operational</u>

Operationally, different relief mechanisms may be preferred; however the protection of the associated equipment is of high operational importance.

<u>Environmental</u>

Relief valves by their nature ensure that any process fluids which are relieved are minimised to those which return the pressures to within the acceptable pressure limits. This is considered a benefit when taking into consideration the potential environmental effects in the absence of a relief valve.

Downfalls of Technology

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

None considered.

<u>Operational</u>

None considered.

<u>Environmental</u>

The downfall of the relief valves is the emissions of hydrocarbons, predominantly methane, to the environment. The associated effect is an increase in the green house effect which is considered to be responsible for Global Warming.

Development / History of Technology

The earliest and simplest form of relief valves were developed and used in the on a steam digester 1679 [2]. This design used a weight to counteract the pressure of the steam which is the principle on which steam cookers are still operated today. A sprung trigger system was then developed which used a screw mechanism to vary the sensitivity of the valve to pressures beyond the design conditions of the equipment. In 1856 a tamper proof sprung safety system was developed which became universal on railways [2].

Open section on novel ideas

None.

Pictures and (or) Drawings of Process Equipment

References

1. US Environmental Protection Agency Website, *accessed on 18 November 2009*, available from http://www.epa.gov/methane/
2. Wikipedia Website, *accessed 01 March 2010*, available from http://en.wikipedia.org/wiki/Safety_valve

Thermal Relief Valves

Equipment description

A thermal relief valve uses the same mechanism of operation as a pressure relief valve. The characteristics which define the difference between the valves are generally the size. A thermal relief valve is used to protect pipe-work and equipment from the steady build-up of pressure resulting from the lock-in of cryogenic liquid. The sizing of these valves is therefore much smaller than a pressure relief valve in the same line; the latter would tend to be larger due to the larger volume or relief required from the potential process change the valve is used to protect against. The calculations for sizing between the two valves are therefore very different.

General Emissions Details

- Land ☐
- Air ☒
- Water ☐
- Noise ☒

Prerequisites requirements of equipment

There are no service pre-requisites on a relief valve. For the correct operation of the valve at the desired conditions, the valve should be calibrated and designed to those conditions.

Emissions details

<u>LAND</u>

There are no emissions to land from thermal relief valves.

<u>AIR</u>

Relief valves on an LNG re-gasification terminal will emit the hydrocarbons which are contributing to the elevated pressures requiring a relief situation. Liquid or gaseous hydrocarbons could be relieved to atmosphere, whilst the liquid will not immediately be emitted to air; the volatility of LNG dictates that should any pool form, it will rapidly evaporate and ultimately lead to emissions to air. The composition of the hydrocarbon mixture will represent the composition of the LNG which is being processed at that moment in time. The primary component on of LNG is methane, whilst nitrogen, ethane, propane, butane, and pentane also contribute in small fractions to the LNG composition.

<u>WATER</u>

There are no emissions to water from relief valves.

<u>NOISE</u>

Due to the nature of operation of a relief valve, noise will be generated when a relief valve is in operation. This is a consequence of high pressure process fluids passing through a constricted opening to ambient pressures.

Environmental Risks

The predominant species released to the atmosphere through the use of a relief valve is methane. 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]. This risk can be reduced by minimising the number of times these valves relief under high pressure; however, one should note that relief valves are critical safety devices to avoid overpressure of process equipment and piping.

Appropriate Measures to Protect Against Safety Risks

Given the criticality of relief valves to the safety of the system, relief valves should not be isolated unless done under the correct control of works procedures following a full risk assessment. To ensure the continued safe operation of the relief valves, they should be maintained in line with statutory requirements for pressure systems. Equipment which could be exposed to the relieved streams from cryogenic services should be capable of withstanding cryogenic temperatures and may require stainless steel or other suitable alloys. Finally, the system should not be relieved in the direction of personnel walkways / access routes.

Benefits of Technology

Cost (Capital and Operating Costs)

Relief valves represent higher cost than conventional service valves owing to the low tolerances to which they are designed. The statutory requirement for their maintenance means a higher operating cost is seen against conventional service valves. There are no suitable alternatives to relief valves and the cost benefit they represent against the loss or damage of equipment means that these are considered benefits of the technology.

Operational

Operationally, different relief mechanisms may be preferred; however the protection of the associated equipment is of high operational importance.

Environmental

Relief valves by their nature ensure that any process fluids which are relieved are minimised to those which return the pressures to within the acceptable pressure limits. This is considered a benefit when taking into consideration the potential environmental effects in the absence of a relief valve.

Downfalls of Technology

Cost (Capital and Operating Costs)

None considered.

Operational

None considered.

Environmental

The downfall of the relief valves is the emissions of hydrocarbons, predominantly methane, to the environment. The associated effect is an increase in the green house effect which is considered to be responsible for Global Warming.

Development / History of Technology

The earliest and simplest form of relief valves were developed and used on a steam digester 1679 [2]. This design used a weight to counteract the pressure of the steam which is the principle on which steam cookers are still operated today. A sprung triggers system was then developed which used a screw mechanism to vary the sensitivity of the valve to pressures beyond the design conditions of the equipment. In 1856 a tamper proof sprung safety system was developed which became universal on railways [2].

Open section on novel ideas

None.

Pictures and (or) Drawings of Process Equipment

References

3. US Environmental Protection Agency Website, *accessed on 18 November 2009*, available from http://www.epa.gov/methane/
4. Wikipedia Website, *accessed 01 March 2010*, available from http://en.wikipedia.org/wiki/Safety_valve

Powder Snuffed Relief Systems

Equipment description

Fires in pressure relief valve tailpipes have been observed, and for this reason it is common practice to fit dry powder systems to the large relief valve tail pipes [1]. Generally, these systems are applied to the relief valves on the roof of the LNG storage tanks. The relief systems are fitted local to the relief valves and are capable of remote or local operation [1]. The powder snuffered relief systems use a conventional relief valve which follows the principles outlined in the pressure relief section under process ancillaries coupled with a snuffering system which is capable of injecting dry extinguishing powder into the tail pipe in the event of a fire. The propellant for the dry powder injection is provided through pressurised bottles of gas, typically nitrogen, held local to the relief valve.

General Emissions Details

Land ☒

Air ☒

Water ☒

Noise ☒

Prerequisites requirements of equipment

Powder snuffed relief systems are generally the product of specialist companies and are often supplied as skid mounted units with the propellant gas cylinders [1]. As such, the prerequisite requirements for these systems are minimal.

Instrumentation

An instrumentation loop to the control room to inform the operator of the status of the system is recommended.

Emissions details

LAND

Powder snuffed relief systems result in the powder used for extinguishing purposes to be released to the surrounding land following operation.

AIR

Powder snuffed relief systems result in emissions to air in the form of the process fluid they are relieving and the propellant gas. In the LNG industry, the process gas would consist of boil off gas of which the typical constituents are nitrogen and methane. The relative quantities of the nitrogen and methane varies depending on the composition of the LNG being processed in the terminal and the scenario under which the terminal is operating. Typically the drive gas would be nitrogen however carbon dioxide is also used for this purpose in some systems.

WATER

The emissions of from the powder snuffed relief systems can be released to water as a result of the conditions under which these systems are used. If the situation arises where the snuffer system is used, the presence and use of firewater cannot be discounted. The firewater will carry the powder through the drainage system and leave the terminal through the water effluent.

NOISE

Due to the nature of operation of a relief valve, noise will be generated when a relief valve is in operation. This is a consequence of high pressure process fluids passing through a constricted opening to ambient pressures. In addition, the dry powder system will generate a certain level of noise on operation as a result of the high pressure propellant gas used for the operation.

Environmental Risks

An environmental risk is presented from the release of the dry extinguishing powder to the environment. A typical powder used in a dry powder extinguishing system could include Potassium Bicarbonate as the majority constituent and traces of other chemicals used for the conditioning and identification of the substance in varying quantities. The predominant species released to the atmosphere through the use of a relief valve is methane. 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]. The propellant gas will pose an environmental risk if carbon dioxide is used due to global warming properties of this gas when released to the atmosphere; the use nitrogen as the propellant gas does not pose any additional environmental risks. These risks can be reduced by minimising the number of times these powder snuffed valves relieve under high pressure, however, one should note that relief valves are critical safety devices to avoid overpressure of process equipment and piping.

Appropriate Measures to Protect Against Safety Risks

Powder snuffed relief systems can present a safety risk to the operator in the event that the system initiates whilst the operator is in the vicinity. Local operation points for the system should take account of this fact.

Benefits of Technology

Cost (Capital and Operating Costs)

Relief valves represent higher cost than conventional service valves owing to the low tolerances to which they are designed. The statutory requirement for their maintenance means a higher operating cost is seen against conventional service valves. There are no suitable alternatives to relief valves or snuffing systems and the cost benefit they represent against the loss or damage of equipment means that these are considered benefits of the technology.

Operational

Operationally, different relief mechanisms may be preferred, however the protection of the associated equipment is of high operational importance.

Environmental

Relief valves by their nature ensure that any process fluids which are relieved are minimised to those which return the pressures to within the acceptable pressure limits. This is considered a benefit when taking into consideration the potential environmental effects in the absence of a relief valve.

Downfalls of Technology

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

None considered.

<u>Operational</u>

Operationally, the powder system leads to increased operational input from a maintenance point of view over and above a standard relief system which does not use powder snuffering, however standard relief systems do not offer the same level of protection for large relief scenarios.

<u>Environmental</u>

The downfall of powder snuffed relief systems is the emissions of the contents of the extinguishing medium to the environment in addition to the hydrocarbons released through the relief valve.

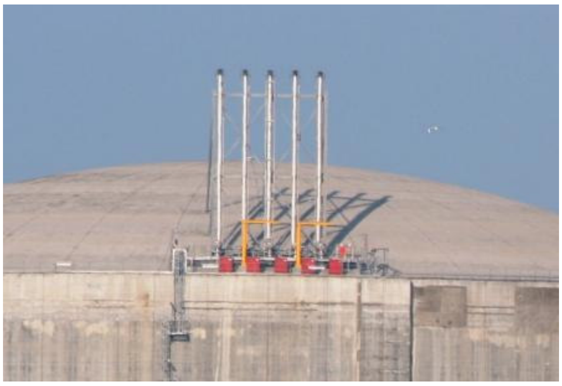
Development / History of Technology

None.

Open section on novel ideas

None.

Pictures and (or) Drawings of Process Equipment



References

1 Guide to Storage Tanks and Equipment, **Bob Long & Bob Gardener**, *John Wiley and Sons*, 2004

Warm Vent

Proforma under completion.

Process Power

Electrical Switch Gear Insulation

Equipment description

Electrical switch gear is insulated to allow the safe operation of the equipment. The arc energy associated with switching on live circuits is controlled safely via the use of oil, air blast, vacuum, or SF6 equipment. These insulation materials allow large currents of power levels to be safely controlled. The most commonly used electrical switch gear insulation equipment is oil filled circuit breakers or SF6 equipment. SF6 has a much higher di-electric strength than air or nitrogen meaning the equipment is much smaller. Vacuum circuit breakers are replacing SF6 circuit breakers in industry due to their inherent safety and their reduced maintenance requirements over equivalent technologies.

General Emissions Details

- Land ☐
- Air ☐
- Water ☐
- Noise ☐

Prerequisites requirements of equipment

Instrumentation

A tie-in to the instrumentation system is recommended for pressurised insulated switch gear. This will allow the operator to be alerted in the event that the pressure is lost in the equipment which could pose a hazard due to the loss of insulation around the electrical arcing.

Emissions details

LAND

None considered under normal operation.

AIR

None considered under normal operation.

WATER

None considered under normal operation.

NOISE

None considered under normal operation.

Environmental Risks

Leakage of SF6 to the environment can occur over time. SF6 is considered to be 22,800 times more potent that carbon dioxide as a greenhouse gas by the Intergovernmental Panel on Climate Change. Any leakage of SF6 poses a significant risk to the environment as a result of the global warming effects this can produce. Oils which are used in oil insulated switch gear are normally high in polychlorinated biphenyls (PCBs) which are highly stable compounds and lead to bioaccumulation. PCB containment is difficult and their release to the environment can have toxic effects on organisms. Generally, PCB disposal requires high temperature or catalytic oxidation to degrade these compounds.

Appropriate Measures to Protect Against Safety Risks

High voltage electrical arcing is dangerous. Whilst the insulation itself does no pose a direct safety risk, its absence does. To protect against this, pressurised systems should be alarmed to alert the operator to any loss of insulation in the switch gear. Regular maintenance should be carried out on these systems to ensure that they remain operational and fit for purpose.

Benefits of Technology

Cost (Capital and Operating Costs)

None considered.

Operational

None considered.

Environmental

None considered.

Downfalls of Technology

Cost (Capital and Operating Costs)

None considered.

Operational

Depending on the technology which is chosen for electrical insulation, maintenance requirements can be considered a downfall.

Environmental

Depending on the specific insulation which is chosen, the environmental effects can be considered a downfall in the event of a loss of containment. This is particularly true for systems which use SF6 or oils with PCBs.

Development / History of Technology

Electrical switch gear insulation has taken many forms over the years ranging from oil filled insulation to various forms of gas insulation. The development of this technology over the years has allowed switch gear systems to become smaller and require less and less maintenance to maintain their integrity.

Open section on novel ideas

None.

Pictures and (or) Drawings of Process Equipment

References

None.

Transformers

Equipment description

It is the role of the transformer to match the voltage and current levels from one area to another by using the concept of electromagnetic induction.

Transformers consist of a magnetic steel core which maximises electrical inductance in two sets of conducting coils arranged concentrically around it. The core is constructed of a series of plates or "laminations" of around 0.3mm thick which reduce electrical eddy currents thus maximising inductance efficiency. A fluctuating magnetic field forms around the primary coil and induces a flow of electricity in the secondary coil proportional to the surface area of the coil. A reduction in the number of turns in the secondary coil will induce a reduction in voltage while an increase in coil turns propagates a voltage increase. Thus electricity supplies from high voltage transmission lines can be matched to safe operating levels for the equipment or area in question. At constant power supply a reduction in voltage will cause current to rise and vice versa.

General Emissions Details

- Land ☒
- Air ☐
- Water ☐
- Noise ☐

Prerequisites requirements of equipment

<u>Cooling fluid</u>

The transformer has a prerequisite of transformer oil. This is a form of mineral oil which acts both as a cooling fluid and electrical insulation. The main constituent is usually a light Naptha based hydrocarbon consisting of C15 – C30 hydrocarbons. They are very stable and only combust at high temperatures of over 140°C [2].

<u>Electricity</u>

The transformer has the obvious requirement of electricity to process; however, it also requires a surplus supply to power instrumentation equipment and displays.

Emissions details

<u>LAND</u>

Emissions to land can arise from oil leaks. The material itself can be toxic to small wildlife although does not severely affect humans with the only obvious effects being eye irritation or vomiting which may arise due to ingestion. The material should be prevented form entering waterways in accordance with environmental permits.

The transformer oil does not contain any PCB (Polychlorinated Biphenyl) which was banned in 2000 after studies had shown its carcinogen effects as well as being a toxic compound which can cause skin rashes, nausea, headache and fatigue.

<u>AIR</u>

The only emission from a transformer is its insulating oil which is very stable. Only if subjected to high temperatures will a vapour form which is denser than air.

<u>WATER</u>

The transformer oil may find its way to off-site water ways via site drains. The specific gravity of the fluid is 0.88-0.89 thus the oil will float on the water surface.

Because oil floats on top of water, less light penetrates into the water, limiting the photosynthesis of marine plants and phytoplankton. This, as well as decreasing the fauna populations, affects the food chain in the ecosystem. Ingestion of oil by small mammals and birds can cause severe kidney and liver damage, whilst also affecting animal mobility.

NOISE

The noise output of the transformer is around 20dB(A) and is thus not considered an environmental concern.

Environmental Risks

The transformer itself is situated indoors in a sealed bund which can contain 110% of the transformer oil volume. The changing of oil is covered by method statements and permit-to-work forms whilst also being carried out under the supervision of a competent person; thus the risk of leakage is minimal. The transformer oil does not contain any PCB (Polychlorinated Biphenyl) in accordance with a total UK ban in 2000. The oil itself may circulate by natural convection from absorbed heat however it is not mechanically circulated thus there are no leakage points from that respect.

Appropriate Measures to Protect Against Safety Risks

The transformer is constructed and maintained to comply with the relevant design codes and standards. The casing of the machine is electrically insulated and bolted closed to prevent access. Access can only be obtained with a permit to work and under the permission of the shift engineer.

Oil samples are taken on a monthly basis and are sent away for analysis to ensure the oil is maintaining is cooling and electrical insulation properties.

Benefits of Technology

Cost (Capital and Operating Costs)

The transformer does not represent a high capital cost and has a very low operating cost. Operators are only involved in taking oil samples and carrying out routine inspections. As the transformer itself unit contains no moving parts it is not likely to be subject to failure.

Operational

The transformer is a stand alone unit which only requires oil change once every 10-15 years subject to test results from the oil samples.

Environmental

The unit is 80 – 90% efficient with only very small voltage losses. In terms of environmental emissions, the risk is low and the subsequent complications are minimal and easily resolved.

Downfalls of Technology

Cost (Capital and Operating Costs)

The small electricity supply to the unit for monitoring equipment incurs a small charge to the user; however, in respect to overall site costs this is negligible.

Operational

There are no operational downfalls to the technology. Routine inspections and maintenance are in line with all types of transformer on the market.

Environmental

As has been previously stated an insulating oil leak could pose an environmental hazard and a permit breach if it finds its way into the local ship canal. However, with multiple oil catch pits and a large three chamber oil interceptor pit prior to release this is highly unlikely.

Development / History of Technology

The phenomenon of Electromagnetic Induction was jointly discovered by Michael Faraday and Joseph Henry in 1831. Faraday was the first to publish his findings and is thus accredited with its discovery.

The first type of transformer to see wide use was the induction coil, invented by Rev. Nicholas Callan of Maynooth College, Ireland in 1836. He was one of the first researchers to realize that the more turns the secondary winding has in relation to the primary winding, the larger is the increase in EMF.

Induction coils evolved from scientists' and inventors' efforts to get higher voltages from batteries. Since batteries produce direct current (DC) rather than alternating current (AC), induction coils relied upon vibrating electrical contacts that regularly interrupted the current in the primary to create the flux changes necessary for induction. Between the 1830s and the 1870s, efforts to build better induction coils, mostly by trial and error, slowly revealed the basic principles of transformers.

Open section on novel ideas

Transformers are mechanically simple and highly efficient items of equipment with efficiencies of 80-90% being common. The design and construction of transformers to design codes and standards includes provisions for optimisation. For instance the conducting core of the equipment is constructed of a series of thin laminations to prevent electrical eddy currents in the machine.

Thus the only further way to optimise a transformer is to carry out an analysis and optimization of the turns ratio in the coils. This may involve a redesign however the new unit will be more suitable to the current process and need only be retrofitted. A costing exercise will highlight whether this will be viable.

Winding losses can also be reduced via the use of larger diameter wires in the coil to allow current to flow more easily.

Pictures and (or) Drawings of Process Equipment

References

1. Norris, W.T. Transformers and Power Systems. Power Transformer Theory
2. Transformer Oil MSDS. (www.conncoll.edu/offices/ehs/EnvhealthDocs/Transformer_Oil.pdf)

Site Drainage

Site Drainage

Description

Drainage at an LNG re-gasification terminal consists of a series of drainage ditches and holding ponds which facilitate the collection and correct disposal of surface water run-off, process water, and ground water. Typically, process and surface water run-off can be expected to be cleaner than ground water which could bring with it unknown contaminants. The holding ponds are usually emptied with electric pumps feeding either towards another holding pond or to direct disposal from the site. The holding ponds act as buffers during periods when water accumulation is high and also impose a certain residence time for the natural clean-up and settling of the water.

General Emissions Details

Land ☐

Air ☐

Water ☒

Noise ☐

Prerequisites requirements of equipment

Electricity

The water which is collected by the drainage system is moved around the system using electric water pumps. The pumps are usually situated in the holding ponds and require electricity with which to operate.

Emissions details

LAND

There are no emissions to land from drainage systems.

AIR

There are no emissions to air from drainage systems.

WATER

Site drainage leads to emissions to water as a result of the species which are collected by the run-off water on route to the drainage system or which are released directly to the drainage system. Discharge of water from the site must be incompliance with local authority requirements which would be expected to place limits on temperature, biological oxygen demand (BOD), suspended solids, and hydrocarbon content of the discharge water.

NOISE

The only part of the system which emits noise is the water pumps used to move the water around the system and off site.

Environmental Risks

An environmental risk exists for the potential to discharge pollutants which are present in the drainage / run-off water from the site and into the local habitat. The pollutant species which are present in the drainage / run-off water is largely dictated by the site (location and land quality) and the technologies which are being used on the site; for instance, the use of submerged combustion vaporisers is expected to result in caustic ions being present in the effluent water from the site as a result of process water discharge, or the transfer and storage of diesel can lead to emissions of diesel oil as a result of accidental spills which are liberated through surface water run-off. The impact of accidental spills and releases on the environment as a result of discharge through the drainage system can be reduced by using spill kits in the event of spill. The risk of high levels of pollution through the drainage systems on the site can be reduced through the sampling and testing of the effluent stream. In-line systems can be configured to measure the known species which are emitted from the site and inform the operator of their concentration in the effluent stream. In-line systems are useful as they will alert the operator at the moment the concentrations of certain species exceed the limits set by the site through continuous monitoring; this is not possible using manual sampling methods. In the absence of in-line systems, manual sampling methods must be adopted to ensure that the level of emissions from the site through the effluent water stream is known and in compliance with the relevant limits placed on the terminal.

Pictures and (or) Drawings of Process Equipment

References

None.

Water Quality Control

Reverse Osmosis

Equipment description

A problem can be encountered when operating submerged combustion vaporisers (SCVs) where-by the temperature of the burner rises to a level that results in the oxidation of atmospheric nitrogen and the formation of nitrous oxides (NOx). This can (if left unchecked) manifest its self as a brown smoke from the vaporiser stacks. To control this phenomenon and reduce the formation of NOx, the burner temperature can be controlled through the injection of water onto the burner. The water has a cooling effect and allows the operator to keep the burner temperature below the level at which significant NOx is formed. This process requires demineralised water for this purpose to avoid the potential for scaling of the burner should ionised water be used.

Reverse osmosis is a process which kinetically utilises a membrane to exclude solutes whilst allowing the solvent to penetrate the membrane and thereby separating the two constituents [1]. The reverse osmosis process is used to remove the ions from a potable water stream producing de-ionised water (scale and colloids removed) suitable for the control of NOx production rates through regulating the burner temperature of the SCV. The membrane arrangement can either be flat-sheet or fibre form as deemed appropriate at design [1]. Reverse osmosis is defined by the ability to exclude particulates up to approximately 10 angstrom units as a result of the fine porosity of the separation layer [1]. The driving force (pressure) is provided by a pump which discharges the water into the membrane assembly. High pressures are required to overcome the osmotic pressure due to the fine porosity of the membrane.

Some pre-treatment might be required depending on the quality of the water and the components which make-up this water stream. Some membrane materials might not be compatible with some feed components (e.g. Chlorine) and therefore these should be eliminated using a pre-treatment step.

General Emissions Details

- Land ☐
- Air ☐
- Water ☒
- Noise ☒

Prerequisites requirements of equipment

<u>Potable Water</u>

A potable water stream is required as a feed to the reverse osmosis plant. The potable water source conditions/composition should be articulated for the purpose of design.

<u>Electricity</u>

The driving force for the reverse osmosis separation is the pressure provided through a feed pump. The feed pump is normally electrically powered and therefore requires an electricity feed.

<u>Drainage</u>

The concentrate from the reverse osmosis process is the waste stream, with the product being the permeating de-ionised water. A disposal route for the concentrate must be available which is usually through the site drainage system.

Emissions details

<u>LAND</u>

There are no emissions to land through normal operation of a reverse osmosis plant.

AIR

There are no emissions to air through normal operation of a reverse osmosis plant.

WATER

The concentrate stream can be considered as a direct emission to water. This stream is normally discharged direct to the site drainage system. The stream will consist of a concentrated solution of the scale and colloids present in the potable water feed stream. Specific components of this concentrate stream will depend on the composition and components of the potable water source. Some suppliers might require a continual dosing of chemicals to ensure the membrane remains in the correct operating conditions. These chemicals will be present in the concentrate stream and therefore will be a direct emission to water. Vendor advice should be sought on this aspect.

The membranes should be cleaned regularly which normally involves a closed circulation of set volume of purified water along with a cleaning agent. The cleaning agent constitutes an additional emission to water. The specifics of the cleaning agent should be sought from the vendor and is generally specific to the membrane material.

NOISE

The requirement for a pump to provide the driving force for the separation leads to a generation of noise as a result of its operation.

Environmental Risks

An environmental risk is present through the storage and handling of any chemicals used for pre-treatment of the water feed or for the cleaning of the membrane. These chemicals should be stored in suitable containers with secondary containment where necessary. Care should be taken when handling these chemicals and spill kits should be available in the event of spill.

Appropriate Measures to Protect Against Safety Risks

A safety risk is presented by the chemicals used in the pre-treatment of the feed and the chemical cleaning of the membrane system. The material safety data sheets for the chemicals used should be consulted and personnel protective equipment used where appropriate. The technology its self does not represent a safety risk.

Benefits of Technology

Cost (Capital and Operating Costs)

The chemicals used for cleaning and pre-treatment represent a small operating cost with the operating costs dominated by membrane replacement and power [1]. The membrane replacement is still relatively acceptable when compared to the cost of the electricity of the plant [1].

Operational

Reverse osmosis plants are relatively simple with operator input only required during cleaning. These units often come as skid mounted units which make them very easy to install and move around a process.

Environmental

Given the application of this technology for the reduction of NOx production in the importation of LNG, reverse osmosis as a technology is considered an environmental benefit. The use of this technology to control burner temperatures can have a significant reduction on the rate of production of NOx which is a precursor to eutrophication and localised acidification.

Downfalls of Technology

Cost (Capital and Operating Costs)

The capital costs of a reverse osmosis plant usually dominate the economics of this technology as a result of the process equipment which is required [1]. The electrical cost of reverse osmosis technology is relatively high and dominates the operating costs. A high electricity demand is the result of the high pressures necessary to overcome the osmotic pressures experience in membranes of this selectivity.

Concentrate disposal costs vary highly depending on the composition of the concentrate and the pre-treatment required [1]. This could be considered a downfall of this technology.

Operational

There are not considered to be any operational downfalls of this technology.

Environmental

The chemicals which are emitted to water as a consequence of the operation of this technology can be considered a downfall of this technology with regards the environment.

Development / History of Technology

None.

Open section on novel ideas

None considered.

Pictures and (or) Drawings of Process Equipment

References

1 Perry's Chemical Engineers' Handbook, **Robert H. Perry, and Don W. Green**, *Seventh Edition*, McGraw-Hill, New York

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Product Delivery

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Gas Quality Characterisation

Continuous Sampling

Equipment description

A small LNG flow is continuously taken (during the loading operation) from the unloading headers and is vaporised in a dedicated vaporiser cabinet. The small gas flow is diverted towards a big cylinder (gas holder of about 300 liters). Depending on the total LNG volume to be discharged and the expected average discharge rate, the sampled gas flow rate is adjusted: as soon as 75% of the expected discharge rate is reached, the filling of the cylinder starts and the gas flow rate is controlled so that the cylinder is 100% filled just before the unloading operation has been completed.

Upon completion of the loading operation, several sampling gas bottles are filled with gas from the cylinder. These gas bottles are then transported to a (internal) certified laboratory and analyzed.

General Emissions Details

- Land ☐
- Air ☒
- Water ☐
- Noise ☐

Prerequisites requirements of equipment

Electricity

Electricity is needed for the vaporizer cabinet, some electrically controlled valves and instrumentation equipment. Because the GC is used for commercial purposes, it is critical equipment: in case of power failure, the power supply is switched over to UPS (batteries).

Inert gas

A cylinder (or external source) of inert gas is needed to fill up the sample gas bottles from the cylinder (see annex). In our case Argon is used.

LNG or gas (to be analyzed)

Emissions details

LAND

There are no emissions to land.

AIR

When the cylinder is emptied into the sample gas bottles and the bottles are disconnected, a very small amount of gas is released into the air. After filling up the sample bottles, the remainder of the gas in the cylinder is vented through the Terminal's low pressure flare system.

WATER

There are no emissions to water.

NOISE

There are no noise emissions.

Environmental Risks

Emissions of small amounts of natural gas into the air requires safe working in order to prevent a flammable mixture of gas and air.

Appropriate Measures to Protect Against Safety Risks

The sampling point (a pitot tube in the LNG unloading line), the vaporizer cabinet, and the tubing towards the gas holder should be designed and constructed according to the applicable codes and standards (special attention has to be put on the welding of the sampling point).

Benefits of Technology

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

The sampling system itself (sampling points, vaporizer cabinet, gas holder and controller logic) is low cost.

<u>Operational</u>

Continuous LNG sampling during the whole representative time span of the discharge operation (from 75% of the expected discharge rate) - if the LNG quality should change for a certain time span, a proportional amount of sample gas will be present in the cylinder. Very reliable and easily maintainable equipment.

<u>Environmental</u>

(Almost) no emissions in comparison with gas chromatographs.

Downfalls of Technology

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

Analysis of the sample gas bottles in a certified laboratory is high cost.

<u>Operational</u>

None considered.

<u>Environmental</u>

None considered.

Development / History of Technology

This continuous sampling system is home-made and according to ISO 8943 and EN 12838.

Open section on novel ideas

None.

Pictures and (or) Drawings of Process Equipment

None.

References

None.

Gas Chromatography

Equipment description

A small LNG flow is taken from the unloading headers and is vaporised in a dedicated vaporiser cabinet. The small gas flow is diverted towards the analysis instrument: the gas chromatograph. A gas chromatograph is a chemical analysis instrument for separating different components in a complex sample (in this case the different components of natural gas). A gas chromatograph uses a flow-through narrow tube known as the column, through which different chemical constituents of a sample pass in a gas stream (carrier gas, mobile phase) at different rates depending on their various chemical and physical properties and their interaction with a specific column filling, called the stationary phase. As the chemicals exit the end of the column, they are detected and identified electronically. The function of the stationary phase in the column is to separate different components, causing each one to exit the column at a different time (retention time).

General Emissions Details

- Land ☐
- Air ☒
- Water ☐
- Noise ☐

Prerequisites requirements of equipment

Electricity

Electricity is needed for the vaporizer cabinet, the gas chromatograph itself and the computer (on which the analysis software is running). Because the gas chromatograph is used for commercial purposes, it is classed as critical equipment and therefore, in case of power failure, the power supply is switched over to UPS (batteries).

Carrier gas

A cylinder (or external source) of carrier gas is needed (see equipment description). Helium and argon are commonly used.

LNG or gas (to be analyzed)

Emissions details

LAND

There are no emissions to land.

AIR

The analyzed gas (together with the carrier gas: helium, argon…), as well as the bypass stream (*) are vented into the air.

(*) In order to get a real-time analysis, there is a continuous flow towards the GC. Because it takes some time to perform an analysis, a sample is only analyzed every 5 minutes. The rest of the gas flow bypasses the GC, directly into the air.

WATER

There are no emissions to water.

NOISE

There are no noise emissions.

Environmental Risks

Emissions of natural gas into the air, 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 unloading line), the vaporizer cabinet, and the tubing towards the gas chromatograph should be designed and constructed according to the applicable codes and standards (special attention has to be paid to the welding of the sampling point).

Benefits of Technology

Cost (Capital and Operating Costs)

A gas chromatograph is not low cost (CAPEX), but once calibrated and running, the operational costs (OPEX) are quite low. A re-calibration has to be done on a regular basis (or an update of the analysis software).
The costs are considered low in comparison to other technologies, e.g. Raman Spectroscopy, analysis in a certified laboratory.

Operational

Almost immediate results (once every 5 minutes) 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 GC is needed for every flow).

Operational

Although the technology is quite fast, real-time analyzing is not possible with gas chromatographs.

Environmental

Emissions of natural gas into the air. If possible the analyzed gas and bypass stream should be recuperated in the low flare system to reduce the green house effect of the vented gas.

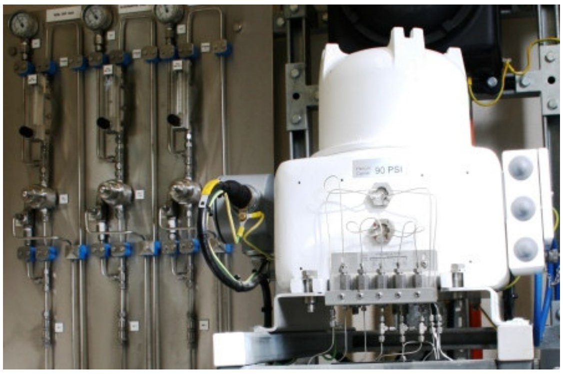
Development / History of Technology

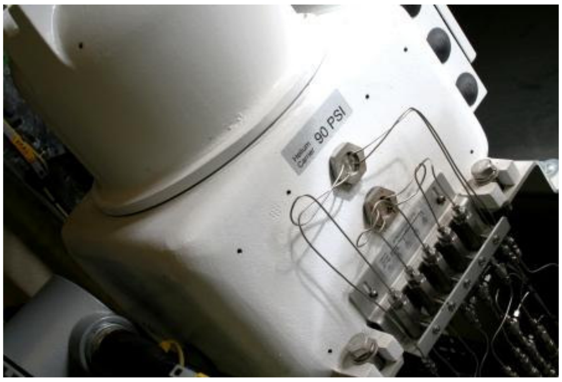
Chromatography dates to 1903 in the work of the Russian scientist, Mikhail Semenovich Tswett. German graduate student Fritz Prior developed solid state gas chromatography in 1947. Archer John Porter Martin, who was awarded the Nobel Prize for his work in developing liquid-liquid (1941) and paper (1944) chromatography, laid the foundation for the development of gas chromatography and later produced liquid-gas chromatography (1950). Erika Cremer laid the groundwork, and oversaw much of Prior's work.

Open section on novel ideas

None.

Pictures and (or) Drawings of Process Equipment





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

Cost (Capital and Operating Costs)

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.

Operational

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

Environmental

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

Cost (Capital and Operating Costs)

None considered.

Operational

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.

Environmental

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

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

Nitrogen Purge Production

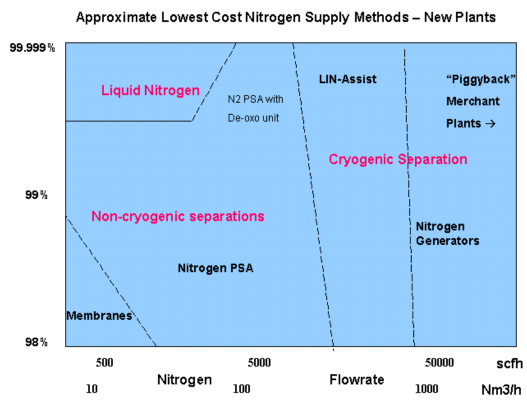
Nitrogen Purge Production (from liquid storage)

Equipment description

Production of gaseous nitrogen can either be done using near-ambient-temperature separation processes or through cryogenic separation of air. There are two major types of non-cryogenic processes, using either selective adsorption or differential permutation through membranes to produce relatively pure oxygen or nitrogen. These processes use differences in properties such as molecular structure, size and mass to achieve the desired degree of separation.

Non-cryogenic separations processes are most commonly used when high purify nitrogen is not needed (e.g. nitrogen which is 98 to 99.5% oxygen-free, and when product demand is relatively low (nitrogen at production rates less than about 20,000 scfh / 500 Nm^3). Nitrogen demand greater than this tends to lead to cryogenic separation processes being used.

Nitrogen is used for purging, inerting of equipment, draining, and gas conditioning purposes in the LNG terminal. The following graph shows the relationship between required nitrogen purity, production rate and nitrogen production processes.



Liquid Nitrogen Storage and Vaporisation

Nitrogen for purging operations can be supplied via vaporization of liquid nitrogen. This process uses a liquid nitrogen vessel for storage, ambient nitrogen vaporisers, potentially an electric heater and pressure let-down valves, together with some liquid nitrogen pumps depending on the demand pressure of the nitrogen. The installation of an electric heater is only required if gaseous nitrogen temperatures need to be above 0 deg.C and ambient temperatures can drop below this temperature for prolonged periods of time.

Typically two vaporizers are installed, an operational and a spare. Typical operating pressures of the nitrogen system are around 7 barg and typical operating temperatures of the gaseous nitrogen are equivalent to the ambient temperature.

The liquid nitrogen storage vessel and the process piping in contact with the liquid nitrogen is made out of stainless steel, the gaseous nitrogen distribution system is typically low temperature carbon steel. Instrumented protective functions prevent the breakthrough of cold gaseous nitrogen with the potential of cold embrittlement.

A typical liquid nitrogen storage and vaporisation unit would consist of:

- Liquid nitrogen storage vessel ~ 50 m^3
- Two nitrogen vaporisers ~ 500 to 600 Nm^3/hr each
- Two pressure control valves
- Two liquid nitrogen pumps (depending on the required pressure at the demand site)

General Emissions Details

Land ☐

Air ☒

Water ☐

Noise ☐

Prerequisites requirements of equipment

Instrument Air
Depending on the type of pressure control valves instrument air might be required to control the supply pressure of the gaseous nitrogen.

Electricity
When a downstream electric heater is installed to increase the gaseous nitrogen temperature if the ambient temperature is low for prolonged periods of time, electricity is required. Electricity will also be required for the liquid nitrogen pumps if these are required in the system.

Distribution Network and Flexible Hoses

A nitrogen distribution network and flexible hoses are required to ensure that the nitrogen which is generated can be distributed to the demand location for purging operations.

Emissions details

LAND

There are no emissions to land.

AIR

Vaporisation of the liquid nitrogen with air will decrease the air temperature. When the air is humid, this will result in mist as a result of the water present in the air. (It should also be noted that liquid nitrogen production outside of the terminal boundary will require large amounts of electricity which have an associated carbon footprint)

WATER

There are no emissions to water.

NOISE

If liquid nitrogen pumps are used, noise will be generated, however this will be small compared to the background noise from the rest of the plant on the terminal.

Environmental Risks

Cold liquid nitrogen spills. Nitrogen is an asphyxiant and can lead to suffocation of living organisms if inhaled.

Appropriate Measures to Protect Against Safety Risks

Instrumented protective function to protect downstream piping against cold embrittlement when cold gaseous nitrogen breaks through.

Benefits of Technology

Cost (Capital and Operating Costs)

The operating costs of maintaining a liquid nitrogen vaporisation system for purging operations is small.

Operational

The liquid nitrogen vaporisation system requires little operational input is and has a high turndown to meet different operational needs.

Environmental

None considered.

Downfalls of Technology

Cost (Capital and Operating Costs)

None considered.

Operational

This technology leads the requirement for regular liquid nitrogen deliveries as the ability to generate the nitrogen on site from ambient air is not possible. This brings with it additional risks of liquid nitrogen transfer.

Environmental

None considered.

Development / History of Technology

None.

Open section on novel ideas

None.

Pictures and (or) Drawings of Process Equipment

Typical ambient air liquid nitrogen vaporisers

References

None.

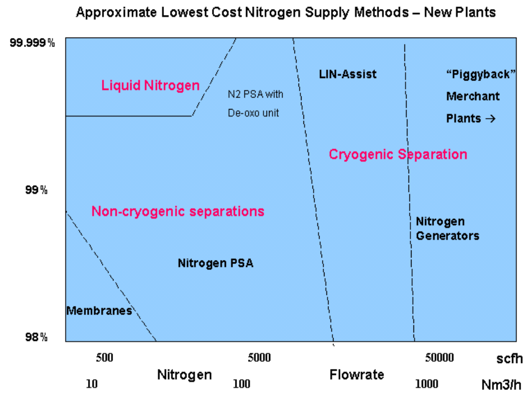
Nitrogen Purge Production (from air)

Equipment description

Production of gaseous nitrogen can either be done using near-ambient-temperature separation processes or through cryogenic separation of air. There are two major types of non-cryogenic processes, using either selective adsorption or differential permutation through membranes to produce relatively pure oxygen or nitrogen. These processes use differences in properties such as molecular structure, size and mass to achieve the desired degree of separation.

Non-cryogenic separations processes are most commonly used when high purify nitrogen is not needed (e.g. nitrogen which is 98 to 99.5% oxygen-free, and when product demand is relatively low (nitrogen at production rates less than about 20,000 scfh / 500 Nm^3). Nitrogen demand greater than this tends to lead to cryogenic separation processes being used.

Nitrogen is used for purging, inerting of equipment, draining, and gas conditioning purposes in the LNG terminal. The following graph shows the relationship between required nitrogen purity, production rate and nitrogen production processes.



Gaseous nitrogen production

Membrane nitrogen generations units are used to produce nitrogen from the surrounding atmosphere. A membrane nitrogen generation unit consists of an air compressor, an air pre-treatment unit, a nitrogen unit separator (membrane type), a nitrogen pre-cooler and a nitrogen compressor. These usually come as packaged units from the manufacturer.

The atmospheric air is feed through a suction filter and then 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. The pre-treated gases are then passed through the membrane where oxygen and nitrogen are separated from one another. The product stream of nitrogen is then compressed to the required pressure to be used for the purging operations.

General Emissions Details

- Land ☐
- Air ☒
- Water ☒
- Noise ☒

Prerequisites requirements of equipment

Electricity

Electricity is required to operate the nitrogen generation plant. The major consumer of electricity is the compressor used to pass the pre-treated air through the compressor.

Instrument Air

Instrument air is required to operate the various valves and instrumentation within the membrane nitrogen generation unit.

Distribution Network and Flexible Hoses

A nitrogen distribution network and flexible hoses are required to ensure that the nitrogen which is generated in the nitrogen generation unit can be distributed to the demand location for purging operations.

Emissions details

LAND

There are no emissions to land as a result of operating a membrane type nitrogen generation unit.

AIR

Nitrogen is vented to atmosphere during start-up and shut-down operations on the unit. The nitrogen which is generated within the unit will lead to emissions when purging operations are practiced – see purging operations for details of these emissions.

WATER

There are no emissions to water as a result of operating a small membrane type nitrogen generation unit for the purpose of generating nitrogen for purging operations.

NOISE

The operation of the compressors within the membrane type nitrogen generation unit will lead to noise emissions to the atmosphere. The noise levels of the system can be controlled at design.

Environmental Risks

The oil which is used for lubrication of the compressor within the nitrogen generation unit could be considered an environmental risk. This oil would normally be contained but could be accidentally released to the environment during maintenance tasks. If this were to occur, spill kits and drain blockers should be used to ensure that the risk to the environment of the oil spill is minimised.

Appropriate Measures to Protect Against Safety Risks

The nitrogen which is generated by the nitrogen generation unit can be an asphyxiate. Care should be taken when working on the system to ensure that asphyxiation is avoided – the system should be purged to air before any intrusive works are done on the membrane type nitrogen generation plant.

Benefits of Technology

Cost (Capital and Operating Costs)

The benefit of this technology is that there requires no raw materials to be brought into the plant. The nitrogen can be taken direct from the atmosphere and does not require vessel transfer as one would find with liquid nitrogen systems.

Operational

These systems are generally self regulating and once on-line do not generally need any operator intervention.

Environmental

The benefit of this technology is that the nitrogen is generated at the demand and does not required road transport to bring liquid nitrogen to site realising a benefit in carbon footprint. The system also avoids the need for a phase change which requires large amounts of electrical energy which brings with it an in-direct carbon dioxide emission.

Downfalls of Technology

Cost (Capital and Operating Costs)

The initial capital of these systems are much higher than the simpler liquid nitrogen storage and regasification systems.

Operational

None considered.

<u>Environmental</u>

None considered.

Development / History of Technology

None.

Open section on novel ideas

None.

Pictures and (or) Drawings of Process Equipment

None.

References

None.

Product Delivery to Storage

Liquefaction

Equipment description

Some LNG storage facilities have the capability to produce LNG on site from gas which is taken from the gas grid into which the storage facility exports. This process utilises the mixed refrigerant liquefaction cycle which proves to be more efficient than liquefaction plants based on a solely nitrogen refrigerant.

The first step in the liquefaction process is a gas pre-treatment step. This is often done using Selexol which has a high affinity for carbon dioxide but also removes some of the heavy ends from the feed gas. The Selexol process operates using pressure swing absorption to strip the impurities from the natural gas. The treated gas is then passed through a pre-purification process which uses mole-sieves to remove any moisture from the pre-treated gases. If the moisture was allowed to enter the cold box, ice formation within the cold box would lead to a blockage in the cold box and could also result in mechanical damage to the exchanger. The pre-purification units operate on a temperature swing adsorption cycle to effect the moisture removal.

The pre-treated and dried natural gas is then passed to liquefaction step. The liquefaction step uses a mixture of refrigerants including nitrogen, methane, ethane, butane, propane, and pentane depending on the design and manufacturer of the system. The separate refrigerant components are mixed and passed through a mixed refrigerant compressor. The mixed refrigerant compressor compresses the refrigerant mixture before it is cooled and expanded to produce the ‘cold’ with which the liquefy the natural gas feed stream. The warmed refrigerant mixture then leaves the cold box and is returned to the mixed refrigerant compressor to begin the cycle again. On the natural gas side of the cold-box, the pretreated and dried natural gas enters the cold box at near ambient temperature. The heat exchange process with the cold mixed refrigerant leads to a cryogenic LNG leaving the cold-box for delivery to the LNG storage tanks. Some systems utilise a cryogenic distillation column mid-stage in the liquefaction process to split the natural gas using the density difference effected by the cold-box to produce a rich sub-cooled natural gas which is returned to the cold-box for final cooling and liquefaction.

General Emissions Details

- Land ☐
- Air ☒
- Water ☐
- Noise ☒

Prerequisites requirements of equipment

<u>Grid Connection</u>

A connection to the gas grid is required to allow the off-take of natural gas from the grid for the purpose of liquefaction. An agreement might be necessary with the network operator and metering (possible of fiscal quality) would be required to ensure the amount of gas removed is measured.

<u>Electricity</u>

Electricity is required to operate a wide range of machinery and equipment involved in the gas pre-treatment and liquefaction steps. The machinery includes compressors, vacuum blowers, Selexol pumps, and heaters (if electrical heaters are utilised in preference to gas heaters).

<u>Refrigerant Storage</u>

A refrigerant storage area is required for the storage of the components which make up the refrigerant mixture. These are normally similar to LPG storage systems.

Effluent Gas Disposal Method

The pre-treatment of the gas and gas quality control (if used mid-stage in the cold box) generates a waste gas stream which is predominantly made-up of impurities and heavy ends. A method for disposing of this waste gas should be in-place. This could involve combustion in a gas combustion unit or disposal back to the network (although the quality of this gas will be far removed from the quality of the gas which is taken off of the grid).

Fuel Gas

Depending on the heating method which is adopted within the gas pre-treatment and liquefaction processes, fuel gas could be required. The fuel gas is burnt to produce the heat with which to heat the process stream which requires heating.

Instrument Air

Instrument air is required for the control and instrumentation within the various processes.

Emissions details

LAND

There are no emissions to land from the operation of a mixed refrigerant liquefaction plant for the purpose of LNG production.

AIR

There are no direct emissions to air from the operation of a mixed refrigerant plant for the purpose of LNG production, however, depending on the refrigerant mixture which is used, the storage vessels could require venting occasionally to relief the pressure built-up within them. This is usually true of ethylene storage during period when the liquefaction process is not being used by there is ethylene in the storage.

WATER

There are no emissions to water from the operation of a mixed refrigerant liquefaction plant for the purpose of LNG production.

NOISE

There are various sources on noise as a result of operating a mixed refrigerant liquefaction plant for the purpose of LNG production. These include compressors, vacuum blowers, and pumps. The noise emitted from the plants should be designed to be with noise levels acceptable to the environment in which the LNG storage facility operates.

Environmental Risks

There is an environmental risk associated with the operation of a mixed refrigerant liquefaction plant for the purpose of LNG production. The various refrigerant components will require top-up occasionally which is normally done by tanker. The process of filling from an LNG tanker can be considered an environmental risk as a result of the use of flexible hoses and temporary joints. The operation should be controlled by a procedure and should only be completed by competent personnel to reduce the risk to the environment of the operation. In addition, the use of Selexol for the gas pre-treatment process would also require top-up and occasional replacement. This process is again done by tanker and should be controlled by a suitable procedure and only completed by competent personnel. In addition, drain blockers and spill kits should be available to limit the effect on the environment in the event of a spill.

Appropriate Measures to Protect Against Safety Risks

The transfer of the mixed refrigerant components and Selexol to the storage facilities presents a safety risk to the operators. The operators completing these processes should be fully competent for the operation they are completing and should wear the appropriate PPE at all times as determined by the Material Safety Data Sheet (MSDS) for the substance which is being transferred.

Benefits of Technology

Cost (Capital and Operating Costs)

The mixed refrigerant compressor system is the most efficient of the commercially available liquefaction processes and brings with it a lower operating cost due to the lower electricity demand by the system.

Operational

None considered.

Environmental

None considered.

Downfalls of Technology

Cost (Capital and Operating Costs)

The initial capital investment for the mixed refrigerant plant is high in comparison to similar nitrogen cycle liquefaction plants.

Operational

The mixed refrigerant system is more complex to operate than the much simpler nitrogen cycle plant, however, a modern control system could be used to simplify the operation of these systems.

Environmental

The requirement to vent the refrigerant storage (dependent on the mixed refrigerant mixture) could be considered to be an environmental downfall.

Development / History of Technology

The development of this technology has lead to gains in efficiency over the years whilst the general principles of the system remain unchanged.

Open section on novel ideas

None considered.

Pictures and (or) Drawings of Process Equipment

None.

References

None.

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 both within the terminal and on-board the LNG tankers. 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 which operate at much higher pressures.

General Emissions Details

- Land ☐
- Air ☐
- Water ☐
- Noise ☒

Prerequisites requirements of equipment

Electricity

Electricity is used to power the LNG pumps which are integral to the LNG storage tanks [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 pump 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.

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.

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 for high pressure applications and tanks were bottom drain to provide the suction head required for these pumps [1]. The introduction of the SEMPS technology saw an increase in the safety of the industry surrounding the pumping operations and made top liquid discharge tanks possible. 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.

Pictures and (or) Drawings of Process Equipment

None.

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*

Ship Process Venting

Cold Vent

Equipment description

During the normal operation of an LNG tanker, heat ingress to the LNG storage tanks on-board leads to a generation of boil off gas. Ships have a variety of ways of dealing with this boil off gas including on-board liquefaction, gas combustion units, and combustion in gas turbine engines. The boil off gas handling system can sometimes become unavailable or can be isolated during discharge. An event can occur on the terminal or onboard the LNG tanker which means that the tank pressures start to rise due to the boil off evolution with no means to handle this gas in the usual ways. In these situations it is necessary for the vessel to vent the gas to atmosphere to relieve the pressures in the tanks. This is usually done through the terminals on-shore vent stack which is safely located away from all hazards with an appropriate exclusion zone. The ships will connect a line dedicated to this venting operation and the control of that vent system should remain in the control of the ship operator.

General Emissions Details

Land ☐

Air ☒

Water ☒

Noise ☒

Prerequisites requirements of equipment

Purge gas

Purge gas is required in order to maintain a positive pressure in the vent stack to avoid back-flow of oxygen into the system.

Emissions details

LAND

No emissions.

AIR

The essential aim of the cold vent is to relieve to the atmosphere the BOG produced in emergency conditions or during extraordinary maintenance. In addition, purge gas is vented during periods where the vent is not operational ensure an oxygen free environment in the vent system.

WATER

Water can collect at the base of the vent stack leading to a liquid level in the open lute. Anti-freeze can be used to reduce the risk of the liquid freezing and plugging the stack. The water which is collected should be drained periodically which could lead to a small release of anti-freeze to the environment.

NOISE

The excess process gas which is released through the vent stack is done so down a pressure gradient to atmosphere. As a result, the noise of the gas being vented is emitted for the duration of the venting operation. When the equipment is not being used for emergency venting, there is no noise emission from the process equipment.

Environmental Risks

The predominant species released to the atmosphere through the cold vent is methane. 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]. This risk can be reduced by minimising the use of the cold vent, however, one should note that this is the ultimate safety device to avoid overpressure in the process.

Appropriate Measures to Protect Against Safety Risks

Vent pipe collectors and the related supporting structure are designed and constructed in accordance with the relevant codes and standards.

Preventative maintenance, field inspections and proper instrumentation should be implemented to ensure the continued safe operation of the vent stack.

The gases which are vented through the cold vent are often cold vapours and as a result can sometimes have a tendency to sink to the ground prior to their dispersion into the atmosphere. The oxygen free environment produced by this vapour cloud would not be life supporting. As a result, an exclusion zone which is sufficiently sized for the capacity of the vent stack should be implemented, and assurance made that no ignition sources are present within this exclusion zone.

The outlet of the cold vent to atmosphere must not be obstructed and as a result is not sealed against water ingress. This can lead to a liquid level at the base of the vent stack which could freeze and plug the line in the event of emergency use. Routine checks of the open lute level should be practiced to protect against this risk. Anti-freeze can also be used to reduce this risk.

Benefits of Technology

Cost (Capital and Operating Costs)

The cold vent is not a high cost unit in comparison to other venting technologies. The operating cost of the equipment is also very low and only noticeable as the small nitrogen purge and maintenance.

Operational

The cold vent is of benefit operationally as it allows one to actively remove the risk of over pressure to a controlled zone, thereby removing the risk of pressure relief through local relief valves whilst still protecting the assets.

Environmental

None considered.

Downfalls of Technology

Cost (Capital and Operating Costs)

The cold vent incurs a cost through the lost opportunity to sell gas in the market place. This cost is however considered acceptable when balanced against the risk to the assets in the absence of the cold vent.

Operational

The operational input to the cold vent is minimal and there are not considered to be any downfalls of this technology from an operational point of view.

Environmental

The downfall of the cold vent technology is the emissions of methane to the environment. The associated effect is an increase in the green house effect which is considered to be responsible for Global Warming.

Development / History of Technology

In the past the BOG produced inside the LNG tanks was systematically flared or vented.

Nowadays, recovering the BOG by means of various systems is mandatory, meaning the cold vent is just an emergency safety device used for extraordinary events.

Open section on novel ideas

In order to avoid the emissions of Natural gas to the atmosphere, it is possible to use nitrogen as purging gas, instead of methane.

Storage tanks for liquid nitrogen and equipment for regasification or for nitrogen production on-site are usually present in an LNG plant and the stored quantity is typically enough to purge the vent. A possible downfall of using liquid nitrogen is the requirement for frequent nitrogen tankers when compared to on-site generation.

In terms of environmental impact the use of nitrogen instead of methane can improve the emissions of green house gases by the plant significantly.

Pictures and (or) Drawings of Process Equipment

References

1. US Environmental Protection Agency Website, *accessed on 18 November 2009*, available from http://www.epa.gov/methane

Ground Flare

Equipment description

A ground flare acts as a vent through which excess process gas can be released to avoid overpressure of the system. The gas being vented is combusted prior to release to reduce the greenhouse effects of the methane which is the predominant constituent of the vented gas and is some 20 times more efficient at trapping heat as a greenhouse gas than carbon dioxide over a 100 year period [1]. Many different designs of ground flares exist including enclosed chamber flares, enclosed chamber flares with first stage assistance through air or steam, and multi point open designs.

General Emissions Details

Land ☐

Air ☒

Water ☐

Noise ☒

Prerequisites requirements of equipment

<u>Gas for pilot ignition</u>

The ignition of the process fluids facilitated completed via piloted ignition. A gas for the pilot ignition system is therefore required. The gas for this ignition could either be a dedicated pilot gas or could be provided from the fuel gas system on the terminal. If fuel gas is to be used for the pilot ignition system, a tie-in to the fuel gas system will also be required. Caution should be made to ensure that if process fluids are to be used for pilot ignition, that there is no possibility of liquid pass through to the ground flare.

<u>Steam for momentum provision</u>

Some systems use steam for momentum provision in low or variable flow systems. If these systems are to be employed, a source of steam would be required.

<u>Electricity</u>

The combustion air and purge air is taken for the surrounding air. Electricity is required to operate the gas blowers which are used to provide these flows of air through the system if the nozzle design has not accounted for this. Electricity is also required for ignition. The operator should consider the use of a UPS to ensure the reliability of the ground flare system is sufficient.

<u>Process Tie-Ins</u>

In addition to those prerequisite requirements identified above which require tie-in to the main process, a number of other process tie-ins would also be required including:

- Vent system
- Service nitrogen
- Instrument air
- Site control system

Emissions details

<u>LAND</u>

There are not considered to be any emissions to land resulting from the operation of a ground flare.

<u>AIR</u>

The operational nature of the ground flare results in emissions to air. These emissions consist primarily of carbon dioxide as a result of the combustion of hydrocarbons. The use of a ground flare offers the potential for a conversion greater than 98% of the hydrocarbons in the feed gas. Water vapour, a by product of combustion, will also be released to the air along with nitrous oxides and carbon monoxide in much lower quantities which are generated as a result of the combustion process. If the fuel source contains odour, additional emissions will be generated which will also lead to emissions to air which are odour specific.

WATER

There are not considered to be any significant emissions to water resulting from the operation of a ground flare.

NOISE

The process of venting gas releases noise due to the movement of the gas particles down a pressure gradient through a restriction. The use of steam as a driver for the process will result in an elevation of the noise levels.

Environmental Risks

Whilst the use of a ground flare by its nature releases carbon dioxide which is a green house gas, the natural gas which would otherwise be released is considered to have a higher impact on the environment [1]. Therefore, the release of carbon dioxide to the environment in this situation is considered to be an environmental benefit and not an environmental risk.

Appropriate Measures to Protect Against Safety Risks

A safety risk is present at start-up of a potentially explosive atmosphere being present in the ground flare. The start-up routine should therefore require the purge of the combustion chamber and the flare enclosure with air to ensure that any explosive atmospheres are eliminated form the ground flare before the pilot ignition system is initiated. Additionally, the use of a ground flare results in thermal radiation to the surroundings. An exclusion zone should therefore be implemented under normal operation which is suitably sized for the capacity of the ground flare.

Benefits of Technology

Cost (Capital and Operating Costs)

A ground flare is not considered to offer benefits in capital or operating costs when compared to other technologies available for emergency venting operations.

Operational

Operationally, a ground flare requires little input. The process is self sustaining through the use of a pilot ignition which is required as the system is an emergency device.

Environmental

A ground flare offers environmental benefits when considered against other technologies available for emergency venting. Methane is considered 20 times more potent as a green house gas than carbon dioxide over a 100 year period [1]; conversion of the vented products from hydrocarbon to carbon dioxide which occurs at a molar basis (considered for carbon) illustrates benefit to the environment.

Downfalls of Technology

Cost (Capital and Operating Costs)

The capital cost and operating cost of a ground flare is considered high when compared to other equipment for emergency venting operations, however the benefits realised in terms of the environment should also be considered in a cost benefit analysis.

Operational

These systems can require high operational input during start-up to ensure a stable pilot ignition is achieved following maintenance.

Environmental

Inherent in the operation of a ground flare, carbon dioxide is emitted to the environment. Carbon dioxide is emitted in small quantities on an ongoing basis due to the requirement for a pilot ignition system due to its critical nature as a safety device. Note that continuous carbon dioxide emissions can be reduced by maintaining the equipment in an offline state with the pilot ignition system off line.

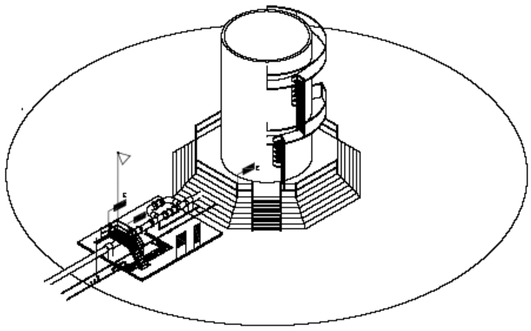
Development / History of Technology

This technology was originally developed in the land fill industry where ground flares are required to combust the waste gases. This technology was later adapted for application in the LNG industry for the purpose of reducing the environmental impact of venting operations.

Open section on novel ideas

The use of catalytic combustion for this operation will facilitate an increase in conversion performance. The use of catalytic combustion could reduce the thermal radiation emitted as a result of the process. This is due to the lower activation energy for oxidation inherent in catalytic combustion when compared with conventional combustion. A study would need to be completed to assess the suitability and reliability of this equipment for this application.

Pictures and (or) Drawings of Process Equipment



References

1. US Environmental Protection Agency Website, *accessed on 18 November 2009*, available from http://www.epa.gov/methane/

Vapour Blower

Equipment description

During the normal operation of an LNG tanker, heat ingress to the LNG storage tanks on-board leads to a generation of boil off gas. Ships have a variety of ways of dealing with this boil off gas including on-board liquefaction, gas combustion units, and combustion in gas turbine engines. The boil off gas handling system can sometimes become unavailable or can be isolated during discharge. An event can occur on the terminal or onboard the LNG tanker which means that the tank pressures start to rise due to the boil off evolution with no means to handle this gas in the usual ways. In these situations it is necessary for the vessel to vent the gas to atmosphere to relieve the pressures in the tanks. This venting process is usually done through the terminals boil off gas handing systems. Depending on the distance of the terminal where the main processing plant is located and the jetty, a vapour blower could be required. A vapour blower can simply be thought of as a fan which will draw boil off from the ship tanks and push the vapour towards the terminal for processing along with the usual boil off gas. The vapour blower allows the pressure drop down the pipeline to be overcome and ensure flow through the line – the storage tank pressure on board the LNG tanker is often very low (in the region of 300 mbar).

General Emissions Details

- Land ☐
- Air ☐
- Water ☐
- Noise ☒

Prerequisites requirements of equipment

Electricity

Electricity is required to operate the blower. An electric motor is used to drive the blower internals which draw the vapour from the ship and pass it through to the terminal for processing.

Tie-in to Boil off Gas System

A tie-in to the terminal boil off gas system is required in order for the tanker boil off drawn by the blower to be deposited in the boil off header of the terminal for processing in the normal way (i.e. through boil off gas compression, combined heat and power plants, etc).

Emissions details

LAND

There are no emissions to land from the operation of a vapour blower.

AIR

There are no emissions to air from the operation of a vapour blower.

WATER

There are no emissions to water from the operation of a vapour blower.

NOISE

The use of an electric motor to drive the blower internals will generate noise. The noise will be emitted to the surrounding area and the levels of noise should be controlled appropriately.

Environmental Risks

There are no environmental risks associated with operating a vapour blower.

Appropriate Measures to Protect Against Safety Risks

A safety risk is presented by the location of electrical equipment in a hazardous zone. The equipment should be suitably designed for operation in a hazardous area.

Benefits of Technology

Cost (Capital and Operating Costs)

There is a cost benefit realised by installing a vapour blower as it allows the shipper to realise the value of gas vented from the ship through processing and export to the gas network. Other methods of ship process venting require the vented gas to be released to the environment directly or through combustion which does not allow the shipper to realise the market value of this gas.

Operational

Operationally a vapour blower brings benefits by ensuring containment of the process fluids is still maintained event though a vent has taken place.

Environmental

Environmentally a vapour blower is of benefit as it removes the requirements for gas release to the atmosphere either in the form of methane or carbon dioxide.

Downfalls of Technology

Cost (Capital and Operating Costs)

Environmentally a vapour blower is of benefit as it removes the requirements for gas release to the atmosphere either in the form of methane or carbon dioxide.

Operational

An operational downfall of this technology is the introduction of another unit operation for the operator to handle.

Environmental

There are no environmental downfalls of this technology in comparison to other ship process venting handling methods.

Development / History of Technology

None.

Open section on novel ideas

None.

Pictures and (or) Drawings of Process Equipment

None.

References

None.

Ship to Shore Transfer

Discharge Piping

Equipment description

The Jetty structure and the causeway connect the unloading jetty to the Terminal on-shore area with a standard configuration of three cryogenic lines: a unloading line of 36"(typical), a recirculation line of 10" (typical) and a vapour return line of 12 " (typical). During ship unloading both liquid transport lines of 36"/10" (typical) are used to unload LNG ships to the LNG storage tanks at an average pressure of 4 barg, a temperature of -160ºC at a flow rate between 8.000 and 14.000 m^3/h (on average). The vapour return line of 12" is used to return gas to the ship tank of at a pressure up to 0.7 barg, a temperature around -120ºC at a flow rate of 10 t/h (average).
Between unloading ships, the liquid lines are kept cold by a recirculation flow of LNG and the vapour return line is kept at the LNG storage tanks pressure (220 mbarg, on average).
The cryogenic piping installed in the Terminal is in stainless steel and has a carbon content that doesn't exceed 0.035%, possessing appropriate mechanical properties for the flowrate. The piping design should be in accordance with the norm ASTM A312/A530 and it is built and installed following a rigorous process of quality control. This piping has an operation interval between -196ºC and -40ºC, although it can operate upto a temperature of 50ºC.

General Emissions Details

Land ☐

Air ☐

Water ☐

Noise ☐

Prerequisites requirements of equipment

Not Applicable.

Emissions details

<u>LAND</u>

None considered under normal operation.

<u>AIR</u>

LNG vaporizing in case of an incident scenario, please see land details above.

<u>WATER</u>

There are no possible emissions to water

<u>NOISE</u>

There are no significant noise levels produced.

Environmental Risks

The rupture of piping causing the leak of LNG is a very unlikely incident. The main causes of incidents are external impacts; corrosion; construction defects, and soil movements. Such an incident may provoke the release of LNG. The high constructability standards in the LNG industry together with emergency isolation valves system make this scenario highly unlikely and in case of incident limit the mass quantity released. Based on the causes analysis previously presented, it is accepted a rupture global frequency of 8 x 10^{-6} per km year

Appropriate Measures to Protect Against Safety Risks

In light of the methods of protection existing as described in the LNG Terminal safety standards worldwide, it is assumed a 2 minute maximum reaction time from the beginning of the leakage until the unloading operation shutdown:

- Fire, Gas and leakage detectors are distributed by the installation in close proximity to the flanges. In the case of an important spill, the detectors will detect a gas cloud in 30 seconds;
- In the case of two detections of any type in one zone of the fire risk area, the unloading operation automatic shutdown (ESD1) will begin in one minute;
- The time to bolt the ESD valves is less than 30 seconds;
- If the detection doesn't work for any reason, there are present operators on site all the time in the Monitoring Room of the jetty, that can detect the spillage visually;
- Additionally, the unloading operation is also monitored at the Control Room.

More important are all the high quality construction rules and standard used in LNG industry. The industry of LNG has, since the beginning, promoted and maintained a high level of safety to reduce the risks associated with its activity, and therefore maintaining a very low incident index and limiting their consequences.

Benefits of Technology

Cost (Capital and Operating Costs)

No significant benefits.

Operational

There are no significant operational problems.

Environmental

No impact in the environment.

Downfalls of Technology

Cost (Capital and Operating Costs)

There is a significant cost related with the high quality of the materials used.

Operational

No downfalls.

Environmental

There are no environmental issues except a very unlikely rupture scenario (see previous remarks).

Development / History of Technology

The LNG industry has since the beginning used high quality standards. The use of more developed calculation tools together with learned experience is leading to more effective pipework. The location of the isolation valve along the discharge lines is one of the most critical issues. The figure shows, in a schematic way, the plan of the piping referred to above and the location of the emergency section valves (ESD).

Open section on novel ideas

None.

Pictures and (or) Drawings of Process Equipment

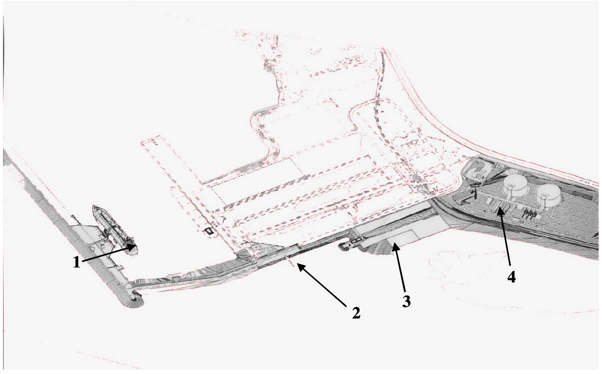


FIGURE 1 - Location of section valves along the Piping (TYPICAL)

References

None.

Pipeline Connection with Bellows

Equipment description

A pipeline with bellows can be used in place of a pipeline with expansion loops. The bellows is a mechanical joint which allows expansion and contraction of the pipework during cooldown and warm-up stages to avoid thermally stressing the pipework. During these cooldown and warm-up phases, the pipework expands and contracts along the length of the pipe. The bellows act to allow for this movement whilst still retaining an operational pipeline. Generally bellows will only allow movement in a single direction.

General Emissions Details

- Land ☐
- Air ☐
- Water ☐
- Noise ☐

Prerequisites requirements of equipment

Pipework Support

The pipeline in which the bellows are installed requires pivot and anchor supports. This is to allow small movement of the pipework without putting additional stresses on the bellows arrangement. The supports should account for movement of the pipework along the length of the pipe but restrain movement in the lateral direction.

Water Vapour Proof Insulation

The movement of the bellows system would be restricted if it were to become 'iced' up due to water ingress. In order to protect the integrity of the bellows and ensure mechanical movement is retained, insulation with is impermeable to water vapour must be used.

Emissions details

LAND

There are no emissions to land of the bellows arrangement.

AIR

There are no emissions to air of the bellows arrangement.

WATER

There are no emissions to water of the bellows arrangement.

NOISE

There are no noise emissions as a result of operating a bellows arrangement.

Environmental Risks

The bellows arrangement requires the ability to move freely to ensure that the expansion and contraction of the pipework into which the bellows have been installed can be accounted for. If this movement is not allowed then failure of the bellows arrangement is likely. Due to the cryogenic nature of LNG, the freezing of the bellows arrangement is likely which would restrict or even stop movement of the system. Should a bellows arrangement freeze, the bellows is likely to fail and release the process fluids 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]. To avoid this occurring, vapour barrier insulation should be used to ensure that the bellows remain moisture free and as such freezing would not be possible.

Appropriate Measures to Protect Against Safety Risks

Failure of a bellows arrangement would lead to an uncontrolled release of LNG to the immediate vicinity which would have a relatively high consequence. To ensure the integrity of the bellows arrangement is maintained, vapour barrier insulation should be used to ensure that the bellows remain moisture free and as such retaining its function.

Benefits of Technology

Cost (Capital and Operating Costs)

The use of bellows avoids the requirement for additional high cost stainless steel pipework to construct expansion loops. Bellows also reduce the amount of pipe support steel work required by reducing the amount of pipework.

Operational

None considered.

Environmental

The function of the bellows ensures that an uncontrolled release of LNG is removed by allowing thermal expansion and contraction of the pipework.

Downfalls of Technology

Cost (Capital and Operating Costs)

None considered.

Operational

The use of bellows requires regular maintenance to ensure a water-tight seal of the bellows system is retained and therefore the integrity of the pipeline.

Environmental

None considered.

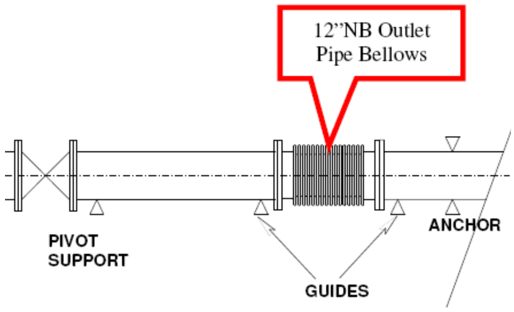
Development / History of Technology

None.

Open section on novel ideas

None.

Pictures and (or) Drawings of Process Equipment



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 Unloading Arms

Equipment description

The LNG unloading from ship to shore is achieved by means of Unloading Arms. The use of other means, such as flexible hoses, is not permitted under current standards. Normally there is also one vapour return arm included to return vapour generated by the unload back from the shore to the ship.

These Arms are equipped with powered emergency release couplings in line with the requirements of EN 1474. The Unloading Arms are made in stainless steel 316SS (C <0.03%) and comply with the specifications of OCIMF 1999 "Design and Construction Specification for Marine Loading Arms".

The LNG industry standard specifies an unloading system which is fully equipped with a DBV/ERC (double block valve/emergency release coupling) and with a manual QC/DC (quick connect/disconnect coupler) which allows the safe disconnection between ship and shore in the event of an emergency.
These Arms are equipped with their own position monitoring system (PMS). This regularly computes the co-ordinates of the arm and compares them to the acceptable arm operating envelope. There are also proximity switches that in extreme cases can trigger the emergency release system. The swivel joints in each arm are continuously purged with nitrogen to ensure their operability.

General Emissions Details

Land ☐

Air ☐

Water ☐

Noise ☒

Prerequisites requirements of equipment

Each arm is fitted with a hydraulic power unit, which is equipped with two electrical motor pump units, one pneumatic motor pump and a hand pump. Each arm is equipped with its own hydraulic unit consisting of an accumulator and a valve cabinet to allow emergency disconnection (ERC ball valve and emergency release function). The unloading arm can be manoeuvred both from a fixed console and from a portable unit. The fixed console is located on the Ship Gangway where the best view on the crossover is given. Therefore the requirements are:

- Low voltage (400 V) power supply:
- Nitrogen continuous supply;
- Integration in Plant main control system.

Emissions details

LAND

There are no possible emissions to land

AIR

None considered in normal operation.

WATER

None considered in normal operation.

NOISE

Significant noise levels may be achieved during cooldown operations. However the fact that all the jetties are located in remote areas together with the mandatory use of PPE by operation personnel during cooldown places the noise emissions levels inside an acceptable range

Environmental Risks

The rupture of an unloading arm causing the leak of LNG to the sea is a very unlikely incident. Historical records demonstrate that a frequency of a rupture occurrence can be assumed to be 7,0 x 10^{-5} for the unloading arms. The most credible scenario is the unexpected ship movement. The emergency shutdown valves together with the emergency release coupling would limit the maximum LNG spill for this incident scenario to values around 5 tonnes of LNG with the actuation of emergency disconnection or 40 LNG tonnes for a failure in the disconnection system and solely actuation of isolation valves.

The hydraulics required to effect motion of the arm require oil at high pressure. An environmental risk exists in the event that this oil is released due to a pipe failure which will lead to a visible film on the water below the jetty. Only 8 ppm of oil is enough for the oil to be visible on the surface of water. This risk can be reduced by positioning trays to collect any oil in the unlikely event of a release.

Appropriate Measures to Protect Against Safety Risks

A safety risk is presented by the unexpected vessel motion during an LNG unloading operation. Several prevention mechanisms exist to mitigate this risk as follows:

- Prohibition of vessel movement in the proximity of any LNG vessel in manoeuvre or unloading;
- Environmental Monitoring System (EMS). All of the relevant environmental conditions, such as wind (intensity and direction) and temperature should be measured in the Terminal meteorological station. When they approach the alarm levels, the system should alert the Operator for the need to performe correcting actions;
- A Marine Monitoring System (MMS). The speed of LNG vessel's final approach to the mooring position will be specified and monitored. Communication will exist with the pilot aboard of the LNG vessel, indicating the distance and the speed of approach of the ship;
- LNG vessels mooring will follow several rules and codes of good practice. An example is "OCIMF-Guidelines and Recommendations for the Safe Mooring of Large Ships at Piers and Sea Islands";
- A tension monitoring system on the fastening cables and hooks for fast disengagement that allow the ship to leave the jetty rapidly in an emergency case;
- A seismic acceleration monitoring system with a visible display for general start and stop;
- A Position Monitoring System (PMS) of the unloading arms showing in real time the position of all of the arms within the operating envelope;
- An Emergency Release Coupling connecting the unloading arms to the ship which allows automatically release and avoids LNG spills in an emergency case. The PERC system is initiated by sensors installed in the unloading arm which stop the unloading operation when the arm reaches its operating limit.

Benefits of Technology

Cost (Capital and Operating Costs)

No significant benefits.

Operational

The safety is an important operational advantage.

Environmental

This technology has no impact on the environment.

Downfalls of Technology

Cost (Capital and Operating Costs)

There is a significant cost for this technology, however the LNG Terminals safety standards make this technology mandatory

Operational

No downfalls.

Environmental

There are no environmental issues except a very unlikely rupture scenario which would release large volumes of LNG.

Development / History of Technology

For modern Arms a Position Monitoring System (PMS) is installed for monitoring the unloading arms conditions, in relation to its position within the acceptable operating window. In the event that the unloading arms reach the extremities of their acceptable operating limits, several actions are carried out (see Figure 1):

- When the unloading arm reaches the extremities of the operating envelope, a pre-alarm is sent to the Terminal Jetty Monitoring Room and Control Room;
- When the unloading arm reaches the emergency stop area, an ESD1 is activated which shuts down the ship pumps, closes the ship distributor valves and the ESD valves.
- When the unloading arm reaches the emergency release area, an ESD2 is activated which closes the PERC valves within 5 seconds and release the unloading arm within 2 seconds.

Although statistical data does not exist for these monitoring systems failure, experience indicates it demonstrates a high level of reliability. A failure value of 0.01 was allocated by technicians with experience of these types of protection devices and the system redundancy.

Open section on novel ideas

A Powered Emergency Release Coupler (PERC) with double ball valves (DBV) IS included in the unloading arms, which is effective when the cause of the leak is an unexpected vessel motion. The most critical part in the system PERC is the hydraulic piston. The failure frequency of a hydraulic piston system is of the order of 36 x 10^{-6} per hour [1]. Given the time of annual operation of about 700 hours a year of unloading (example for 3 unloading arms), the probability of failure of the PERC system can be calculated to be about 7.56 x 10^{-2}. More specific standards and guidelines for this issue should be created.

Pictures and (or) Drawings of Process Equipment

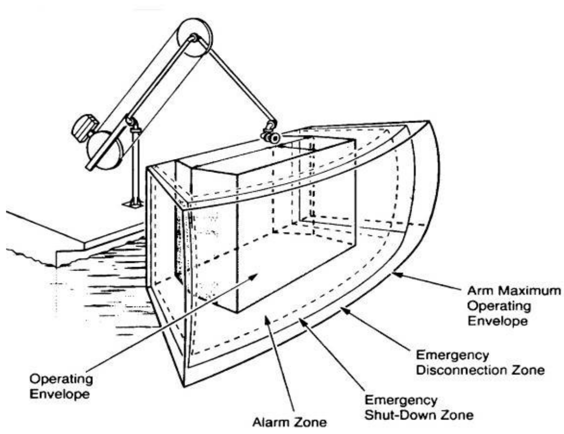


FIGURE 1 – Typical Operating Envelope

Figure 2

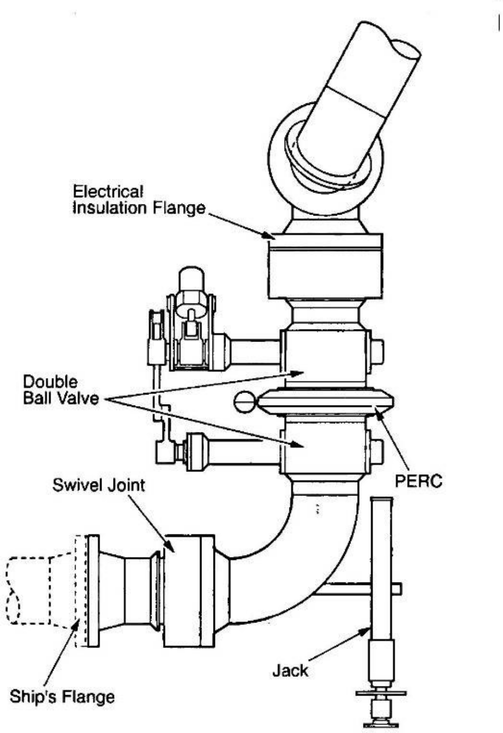


Figure 3

References

1. David J Smith, Reliability and Maintainability in Perspective, 3rd edition, 1988, page 246

Ship Tug Associated Activities

Ship Engine

Equipment Description

Propulsion System

There are three categories of propulsion system for LNG tankers – steam turbine, diesel and dual fuel diesel electric (DFDE).

Steam turbine: Boilers, which are fired on heavy fuel oil (HFO) and/or boil off gas (BOG) from the cargo, generate steam which is supplied to steam turbines that propel the tanker. Exhaust steam from the LP turbine is condensed under vacuum and recycled to the boilers. Many LNG tankers are steam turbine powered.

Diesel: a low speed diesel engine, firing HFO, propels the tanker. Q-Flex and Q-Max tankers have these direct-drive diesel engines.

DFDE: a medium speed diesel engine, capable of firing boil off gas from the cargo and / or marine gas oil (MGO), generates electricity which is then used to power motors hat propel the tanker. In some modern applications, the medium speed diesel is designed to accept triple fuel: gas, MGO, and HFO.

When a laden LNG tanker is in the open sea, typical emissions data are as follows:

LNG tanker type	HFO usage (tepd)	LNG (tepd)	CO_2 (tepd)	SOx (tepd)
Steam turbine	90	90	530	7
Diesel	173	0	542	13
DFDE	0	140	386	0

Maximum Allowable Sulphur Content of Fuel

Under EU (European Union) Directive 2005/33/EC, the maximum allowable sulphur content of fuel oil used by tankers 'at berth' in EU ports is 0.10%wt. 'At berth' covers tankers at anchor, on buoys or alongside, whether or not they are working cargo. This covers all types/grades of fuel and all types of combustion machinery, including main and auxiliary boilers. Tankers are not required to comply with the 0.10%wt sulphur limit while manoeuvring, but must comply as soon as possible after arrival in port and must continue to comply until as late as possible before departure. It is normal practice for LNG tankers calling at EU ports to ensure that they have an adequate quantity of compliant fuel oil on board on arrival.

As a result of this EU Directive, together with the requirements of the existing Baltic and North SOx Sea Emission Control Area (SECA), tankers visiting EU ports need to have suitably flexible fuel storage and handling systems.

Boiler combustion control systems may be modified to accept the safe burning of compliant distillate fuel or to allow fuel gas burning. Under an amendment dated 13 Dec 2010 to the EU directive referred to above, LNG tankers with BOG firing capability are allowed to continue to fire HFO provided BOG and HFO are fired in dual fuel mode such that the overall SOx emissions are equal to or less than those emitted if 0.1 %wt sulphur fuel had been used.

Power Generation when Moored in the Terminal

When an LNG tanker approaches or leaves a berth, although the tanker's main propulsion train is in operation, it is running well below full power, with tugs providing the majority of the motive force to guide to tanker up to/away from the berth.

Shortly after an LNG tanker has been moored, the main propulsion train is stopped, and it is not re-started until the tanker is ready for departure after offloading the cargo.

For the period of time that an LNG tanker is moored at a berth, power is required on board the tanker for cargo pumps, control/instrumentation systems, lighting, HVAC, services etc. For a tanker with a boiler and steam turbines, this power is generated by a steam turbine generator, sized specifically for this purpose. A direct drive diesel tanker has to have an auxiliary diesel generator to supply the power when in port. For a tanker with a dual fuel diesel electric power train, this power is generated by using the main diesel generator system at part load.

For an LNG tanker in port, the maximum power demand is typically in the range 3 to 5 MW. To put this into perspective, it equates to approximately 3 to 6% of the total thermal (i.e. fuel burning) capacity of the tanker.

When a tanker is in a port, the Port Authority (or equivalent) is likely to insist that emissions to atmosphere from the vessel are minimised. But in some ports there are rules/guidelines that prohibit a tanker from emitting any flue gas/exhaust gas to atmosphere when it is moored. A potential solution to this is 'cold ironing' - see below.

<u>Cold Ironing for Zero Ship Emissions for Power Generation</u>

When a tanker is moored, the Port Authority (or equivalent) can be expected to insist that emissions to atmosphere from the vessel are minimised. But in some ports, certain vessels are not allowed to emit any flue gas/exhaust gas to atmosphere when moored. Under these circumstances, these ports provide a power supply (normally 6.6KV) at each berth for connection to the ship. This arrangement is commonly referred to as 'cold ironing'.

At certain ports/terminals (e.g. Port of Long Beach, California), cold ironing is currently in use for oil tankers. To be able to import power from onshore, the tanker must have a suitable connection and power system infrastructure onboard.

Given that LNG tankers and the associated marine facilities are designed such that in an emergency situation, an LNG tanker can be rapidly disconnected from the berth (i.e. disconnection of loading arms and mooring lines) and move away under its own power, the use of cold ironing for LNG tankers introduces additional complications, both design and operational. Specifically, the need to retain the capability for rapid disconnection adds greatly to the complexity associated with the ESD systems. In addition to the power supply itself being designed for remote disconnection in an emergency situation, and the tanker must have a system that automatically starts-up/boosts the tanker propulsion system. For all types of LNG tanker (steam turbine, direct drive diesel, DFDE), cold ironing represents an engineering and operational challenge.

As of December 2010, although there are some LNG tankers/terminals in service that have been designed for, and are capable of utilising cold ironing, there are no LNG tanker/ LNG terminal combinations where cold ironing is normal practice.

General Emissions Details

Land ☐

Air ☒

Water ☒

Noise ☒

Prerequisites requirements of equipment

Not Applicable.

Emissions details

LAND

None considered under normal operation.

AIR

The use of engines in port will lead to emissions to air as a result of burning fuel oils. The major emissions are through carbon dioxide and sulphur dioxides released to the environment at the levels indicated by the table under equipment description.

WATER

The central cooling system on an LNG tanker meets the cooling requirements of major equipment. This includes not only the propulsion train and power generation facilities, but also reliquefaction equipment (if installed onboard) and HVAC systems etc. The cooling duty is met using sea water which sees the water return slightly warmer as a result of the cooling duty.

NOISE

A typical noise specification for an LNG tanker might state that noise levels on the external decks of the accommodation block, engine casing, and aft mooring deck shall be no higher than 70 dB at a height of 1.0 m above the deck, with the ballast or cargo system running. On this basis, the emissions of noise from a moored LNG tanker berth should be negligible if not undetectable onshore, provided the tanker was designed / specified to this, or an equivalent standard. But, in order to achieve the negligible / undetectable noise levels, appropriate silencers / mufflers may need to be installed on the exhaust gas outlet of each power generation system that can be in continuous service for the period that the tanker is in port. Power generation systems can also produce low frequency noise.

Environmental Risks

The operation of engines on board LNG carriers leads to emissions of carbon dioxide and sulphur dioxide to the environment which present an environmental risk. Sulphur dioxide emissions to the environment can lead to acid rain which can be devastating to vegetation. Carbon dioxide is also a greenhouse gas which leads to global warming.

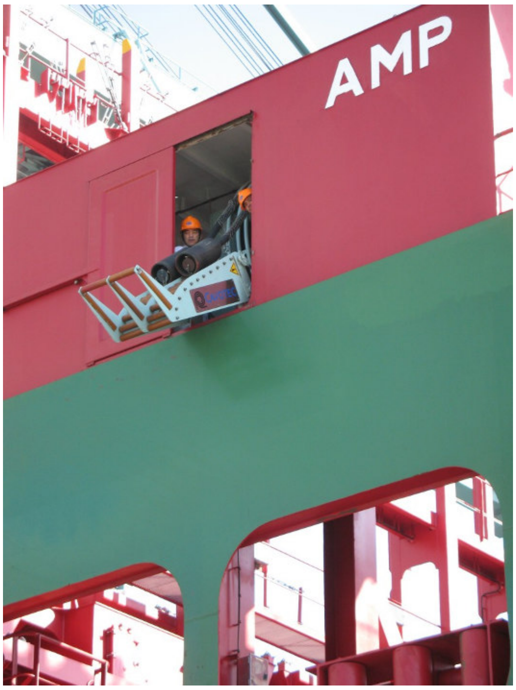
Appropriate Measures to Protect Against Safety Risks

None considered.

Open section on novel ideas

None.

Pictures and (or) Drawings of Process Equipment



References

None.

Ship Process Noise

Equipment Description

During LNG tanker movements at a Terminal - coming into port, mooring at the berth, and departing - there are a number of activities/processes that can lead to the generation of significant and highly variable levels of noise. These activities/processes include, but are not limited to:

- propulsion system
- power generation systems
- gas combustion units
- onboard reliquefaction units / gas compressors
- HVAC units / ventilation fans
- deck hydraulics (for mooring equipment etc.)

Cargo pumps are not included in this list, as the noise from these submerged in-tank pumps is negligible.

The noise levels from the propulsion system and power generation system are covered in the Section on the Ship Engine.

There are recommendations from the IMO (International Maritime Organisation) for measures to reduce onboard noise levels, but these recommendations are made primarily for the benefit of the crew onboard. Noise levels on the external decks of the accommodation block, engine casing, and aft mooring deck are typically specified during ship design as being no higher than 70dB at a height 1.0m above the deck, with the ballast or cargo systems running. On this basis, the onshore noise level arising from an LNG tanker should be very low.

Having said this, Gas Combustion Units and Reliquefaction Units can be a significant source of noise, as follows:

Gas Combustion Units

An LNG tanker must control / manage the pressure in its tanks, and must do this in a manner that is safe and in compliance with applicable laws, rules and regulations (local, national and industry).

When an LNG tanker is in a designated port area, it is not permitted to vent gas to atmosphere, other than in an emergency situation. Hence if there is a need to dispose of excess gas (in order to control tank pressure), an alternative means of using / disposing of the gas is required. For the LNG tankers that have boilers/steam turbines or are DFDE (dual fuel diesel electric), excess gas can be routed to these systems and used to generate power (thereby reducing the amount of liquid fuel needed in order to generate the required power). For some LNG tankers that can only burn HFO in the vessel’s diesel engines, an alternative disposal route for the gas is required. It is common for such vessels to have a gas combustion unit comprising a gas burner located within the engine housing of the ship. It is the fans that form part of this system that are generally the source of noise.

Onboard Reliquefaction Units / Gas Compressors

Some modern LNG tankers have onboard re-liquefaction facilities. By reliquefying boil-off gas (BOG) during the voyage, good control of tank pressure can be achieved, gas losses can be reduced/eliminated and weathering of the LNG cargo during the voyage is reduced/eliminated. The compressors that are an integral part of a re-liquefaction unit are the most significant source noise within the unit. Before off-loading commences, it is possible that a ship will occasionally wish to operate its re-liquefaction unit whilst in the discharge port. But once off-loading has started, re-liquefaction units are generally not operated.

Open section on novel ideas

None.

Pictures and (or) Drawings of Process Equipment

None.

References

None.

Ship Waste

Waste Description

LNG ships generate a wide range of solid waste / garbage materials, including plastics, packaging materials, paper, cardboard, rags (including oil soaked waste / rags), glass, metal, food waste, medical / sanitary waste, etc. MARPOL 73/78 Annex V 'Prevention of Pollution by Garbage from Ships (which came into force on the 31st December 1988) gives definitions of types of waste and specifies under what circumstances waste can be disposed of at sea.

Depending on the category of the waste, the distance offshore, and whether a ship is in a 'special area' (in accordance with regulation 5(4)(b) of Annex V of MARPOL 73/78), garbage can be disposed of at sea or incinerated onboard (with certain restrictions if the ship's incinerator does not meet MEPC 76 (40)). If garbage cannot be disposed of at sea or incinerated onboard, then it must be disposed of in port.

It should noted that MARPOL 73/78 Annex V is due to be updated/revised in 2011.

General Information

The amount of garbage from an LNG ship for disposal onshore can vary widely, depending on

- The utilisation of the ship.
- The length of the last voyage.
- How much of the voyage was or was not in a MARPOL 'special area'.
- The amount of waste that was incinerated onboard or was disposed of (subject to MARPOL regulations) at sea during the last voyage.
- The number of crew members.
- The maintenance activities carried out onboard during the last voyage.

MARPOL 73/78 states that all garbage disposed of from the ship - whether at sea, incinerated onboard, or in port - shall be recorded in a Garbage Disposal Record Book.

Using 2010 data from the Garbage Disposal Record Books of the seven LNG ships in BP's fleet, indicative figures for the quantities of garbage from an LNG ship offloading at an LNG terminal are as follows:

	Cat.1 (cub.m)	Special (kg)	Other (cub.m)
Low	1	0	0
Average	2	10	3
High	3	20	8

General Emissions Details

Land ☒

Air ☐

Water ☐

Noise ☐

Prerequisite Requirements for Dealing with Waste

Reception and Disposal of Garbage

Although it is not compulsory for a terminal operator to accept the garbage that a ship wants to off-load, for ships that are operating on routes which are totally or predominantly within MARPOL 'special areas', a terminal operator must be able to offer onshore garbage disposal. An LNG terminal should have the facilities / resources to receive garbage from ships, whilst maintaining segregation of the garbage, thereby enabling garbage to be recycled and reducing the amount of garbage that is disposed of as landfill.

Emissions Details

LAND

The categories/types of garbage that a Terminal should be able to receive and dispose of - in accordance with MARPOL 73/78 Annex V definitions - are summarised below. Food waste is not included in the table, as the normal practice is to dispose of food waste (with all packaging removed) at sea, in accordance with MARPOL 73/78 Annex V. Within the three categories given below - Category 1, Special, and Other - it is normal practice for the types of garbage to be segregated for disposal/recycling as follows:

Garbage Category	Types of Garbage / Description
Category 1	• plastics • garbage mixed with plastics • plasticized containers.
Special Waste	• aerosols • batteries • fire detector heads • test gas cylinders • viton seals and 'O' rings • ash from the onboard incineration of plastics • chemical waste • fluorescent tubes • medical & sanitary waste • other potentially harmful substances
Other	• paper • cardboard • rags • glass • crockery • metal • ash from the onboard incineration, other than incineration of plastics • floating waste such as wood, packaging, sacking and other materials which do not fall within any other category • oil soaked rags/wood/other absorbent material

AIR

There are not considered to be any emissions to air.

WATER

There are not considered to be any emissions to water.

NOISE

There are not considered to be any noise emissions.

Environmental Risks

Garbage from ships at LNG terminals should always be segregated by category, and by type as appropriate. Whenever possible, the terminal should maintain the same degree of garbage segregation, so that the garbage disposal can be managed in the most environmentally friendly way.

It is the LNG Terminal's interest to ensure that all garbage from a ship is well segregated and correctly labelled/tagged for disposal; it is the Terminal's responsibility to ensure that all garbage leaving the Terminal is disposed of in compliance with local/national guidelines/law. If garbage received from a ship is not well segregated and as a result bags of garbage contain materials with different disposal requirements, more stringent disposal requirements must be applied.

Appropriate Measures to Protect Against Safety Risks

Not applicable.

Open Section on Novel Ideas

None considered.

Pictures and (or) Drawings of Process Equipment

None.

References

1. MARPOL International Convention for the Prvention of Pollution from Ships, *accessed on 07 February 2011,* available from: http://www.imo.org/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-(MARPOL).aspx

Ship Vapour Return

Boil off Gas Compression (Ship Vapour Return)

Equipment description

During the normal operation of an LNG plant, there is a continuous production of boil off gas (BOG) within the process due to heat ingress; the rate of boil off gas generation increases significantly during a ship unloading operation. Insulation is installed in order to maintain the temperature and minimize the BOG; it should be noted that the higher the operating pressure of the tank, the lower the BOG production rate.

An LNG plant is typically characterized by a BOG recovery system consisting of:

- Low flow rate compressors for the recovery of usual BOG production
- High flow rate compressors for the recovery of BOG produced during unloading operations – this mode represents the biggest boil off rates due to vapour displacement and these compressors can either be used to feed the normal boil off gas recovery mechanisms or can be used for ship vapour return.
- A recondenser.

The high capacity boil off gas compressors normally operate during the ship offload when the highest vapour evolution rates are observed due to vapour displacement from the tanks. The boil off from the tanks is fed to the high capcity boil off gas compressors which can operate at discharge pressures between 5 barg and 39 barg depending on the design of the terminal. The boil off gas can be returned to the ship for the purpose of 'vapour return' which allows the ship to balance the tank pressure during the unload procedure. Some LNG tankers have the ability to produce their own vapour for this purpose and hence choose not to use boil off return in this way.

The high capacity compressor typically has three stages of compression, provided with a control system allowing the equipment to operate at different conditions

General Emissions Details

Land ☒

Air ☐

Water ☒

Noise ☒

Prerequisites requirements of equipment

Electricity

The power needed for the operation of the low capacity compressors is supplied by a 6 KV electric motor; there is also an auxiliary electrical pump for lube oil, operating at 380 V, and several other utilities (e.g. heaters, instrumentation, etc).

Instrument air

The instrument air is supplied by the terminal's instrument air system and it facilitates the control of the BOG compressor instrumentation.

Cooling system

The process of compressing natural gas leads to an increase in temperature of the gas. This leads to a requirement for cooling systems to retain the cylinders at a safe operating temperature. Some terminals have a dedicated cooling system which uses seawater within an exchanger; some terminals adopt a water-glycol mixture together with fin-fan coolers to carry out this function.

Oil

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

Emissions details

LAND

The mechanical system is lubricated by lube oil which ensures the equipment remains lubricated during operation. In the event of failure of some parts of the oil system, lube oil would be released and could lead to pollution of the land if the collecting basin is not adequately sized to collect the entire leak amount.

AIR

There are no emissions to air.

WATER

Where sea water is used as the cooling medium, the temperature of which must be carefully controlled before final discharge in order to avoid significant effects on the marine environment. The local Authorities usually set the maximum allowed value in terms of temperature variation of the discharged sea water.

NOISE

The noise levels (measured 1 m from the noise source) are typically 80 db (A). This level must be lower than the maximum limit permitted by the regulating body (usually 85 db A).

Environmental Risks

It is possible that an oil release due to a failure affecting the oil circuit can pollute the land. Environmental risks can also occur as a consequence of spillage of lube oil during the transfer operation necessary for the maintenance of the equipment.

Appropriate Measures to Protect Against Safety Risks

A fault tree analysis demonstrates that there could be a high consequence event:

- Damage of the mechanical seal with leakage of high pressure gas;

This would lead to a gas cloud which, if ignited, would lead to a major accident event. Regular maintenance and inspections are necessary to guarantee the efficiency and reliability of compressors and maintain the necessary safety levels.

In order to avoid any risk related to the occurrence of a seal failure, the compressors are equipped with safety valves to prevent any possible failure and the plant fire fighting system, is designed to minimize the effects of a possible ignition.

In the event of an oil spill due to failure of the oil system, collection trays should be in-place to collect the oil spillage and avoid it being released to the surrounding environment. The trays should be suitably designed to contain the maximum credible release volue.

It should be noted that natural gas compressors should be designed and constructed following the relevant codes and standards.

Benefits of Technology

Cost (Capital and Operating Costs)

Boil off gas compression for the purpose of ship vapour return allows the shipper to recover boil off gas from the terminal and reduce the volume of gas which is exported from the terminal which could be at a low market price. This system therefore allows the shipper to realise the maximum value on his LNG stock.

Operational

There's no need for boil off gas conditioning of the large volumes of boil off gas which are generated for export to the gas main.

Environmental

Low energy consumption when compared with other similar technologies.

Downfalls of Technology

Cost (Capital and Operating Costs)

Depending on the distance of the terminal from the jetty and the cross-sectional diameter of the vapour return pipework, the operating costs can be considerable. High pressure drops can be experienced if the diameter of the pipework is too small and/or the distance is great. Boil off gas compressors are also expensive items of equipment with long lead times.

Operational

None considered.

Environmental

If the boil off gas compression systems fail, venting could be required in order to relieve pressure build-up in the boil off gas system.

Development / History of Technology

In the past the BOG produced inside the LNG tanks was systematically flared or vented. Nowadays, recovering the BOG by means of various systems is mandatory, and gas venting or flaring is only used as emergency safety device for extraordinary events.

Open section on novel ideas

As the maintenance costs for reciprocating BOG compressor can be significant (high costs of spare parts, reduced MTBM etc..) it would be interesting, as far as this is concerned, to make a comparison between different technologies (for instance comparison between vertical and horizontal reciprocating compressors, a sensitivity analysis regarding the level of discharge pressure, the compressor flow rate etc..)

Pictures and (or) Drawings of Process Equipment

References

None.

Regasification & Export

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Boil off Gas Handling

Boil off Gas Liquefaction

Equipment description

During the storage of LNG on a terminal, a small amount of boil off gas is generated through the boiling of LNG as a result of heat ingress to the system. The phenomenon of boil off is unavoidable on an LNG terminal and is affected by the operational position of the plant (pumps run on spill back will increase the boil off rate) and the ambient weather conditions. The boil off gas which is generated is predominantly methane and nitrogen which are the two most volatile components in the LNG mixture. If nothing is done with the boil off which is generated on the terminal, the LNG storage tanks would see a rising pressure which would eventually reach the setting of the pressure relief valves on the tanks. One method of dealing with the boil off gas which is generated is through boil off gas liquefaction.

Boil off gas liquefaction uses a small scale liquefier to re-liquefy the boil off gas and return it to the LNG storage tanks. These liquefaction systems generally use nitrogen as the refrigerant and are based on the Brayton Cycle. The equipment consists of a 2 to 3 stage nitrogen compressor, an expander (normally the compressor and expanders work in tandem and are termed a 'compander'), and a coldbox where the liquefaction step occurs. Boil off gas which has been removed from the LNG storage tanks is fed direct to the cold box. The cryogenic temperature of the cold box is maintained by the closed loop nitrogen refrigerant system. This system operates using the Joule-Thompson principle to generate the 'cold' for the cold box. The refrigerant system is a close-loop system with a small inventory of nitrogen for make-up purposes.

General Emissions Details

Land ☐

Air ☒

Water ☐

Noise ☒

Prerequisites requirements of equipment

Electricity

Electricity is required to drive the compression step in the refrigerant cycle. The compander is used to recover as much energy as possible back from the expansion step. Electricity is also used to drive the LNG pumps which are used to return the re-liquefied boil off gas back to the LNG storage tanks.

Instrument Air

Instrument air is required to operate the various valves and instrumentation integral to the boil off gas liquefaction plant.

Boil off Gas Compression Method

A method with which to extract the boil off gas from the LNG storage tanks and direct it to the boil off gas liquefaction plant for re-liquefaction is required. This can often be done using simple cold-suction boil off gas compressors.

Emissions details

LAND

There are no emissions to land as a result of operating a boil off gas liquefaction plant.

AIR

Depending on the nitrogen content of the boil off gas relative to the design conditions of the liquefaction plant, emissions to air could be observed. If the nitrogen content in the boil off gas is greater than that for which the system was designed, complete liquefaction cannot be guaranteed. If complete liquefaction is not achieved, some gas would require venting to the atmosphere. The gas would be a mixture of nitrogen and methane with nitrogen being at a higher concentration. A flared vent could be used to reduce the impact of the methane on the environment.

WATER

There are no emissions to water as a result of operating a boil off gas liquefaction plant.

NOISE

The operation of a boil off gas liquefaction plant will lead to noise emissions to the environment. Noise is generated by the operation of the compander and the LNG pumps in the system.

Environmental Risks

An environmental risk is presented if the nitrogen content in the boil off gas is greater than the design conditions of the boil off gas liquefier – this could lead to methane emissions to the environment. Methane is a green house gas which is 20 times more efficient at trapping heat than carbon dioxide over a 100 year period [1]. This risk can be reduced by burning the methane upon release or better still by ensuring the design conditions of the liquefaction plant would capture all credible scenarios in terms of nitrogen content in the boil off gas.

Appropriate Measures to Protect Against Safety Risks

There is no safety risk considered to be associated with the operation of a boil off gas liquefaction plant using a nitrogen refrigerant.

Benefits of Technology

Cost (Capital and Operating Costs)

Commercially, a boil off gas liquefaction plant is attractive as it ensures the shipper can maximise the value realised on the LNG. The boil off gas liquefier allows all of the LNG imported to the terminal to be retained in the LNG storage tanks until the price on the gas market is sufficient to justify export – it removes the requirement for a continual export or alternative use for the boil off gas which is generated. The units can come skid mounted which would reduce the installation costs.

Operational

Operationally a boil off gas liquefaction plant is attractive as it removes the requirement for a continual sendout from the plant. It also has the ability to reach very high turndown ratios ensuring it is adaptable to any plant operating scenario.

Environmental

There are no environmental benefits considered for a boil off gas liquefaction plant.

Downfalls of Technology

Cost (Capital and Operating Costs)

The initial capital investment for a boil off gas liquefier is expensive relative to other boil off gas handling techniques.

Operational

The operational downfall of a boil off gas liquefier is the cool-down time which is required to safely cooldown the cold-box to avoid thermal fatigue to the system.

Environmental

An operational downfall of the technology is realised if the nitrogen content in the boil off gas is higher than the design conditions for the liquefier – this would lead to venting of gas which can contain methane.

Development / History of Technology

Nitrogen cycle liquefaction plants have been in existence for many years. They were often second preference to mixed refrigerant plants due to the efficiency savings realised by moving to a mixed refrigerant cycle. However, developments over the years has lead to an improved efficiency of nitrogen cycle plants (still not as efficient as the mixed refrigerant systems) and the development of much smaller packaged units. These developments have brought the technology back into favour for smaller scale liquefaction duties such as boil off gas liquefaction applications.

Open section on novel ideas

None considered.

Pictures and (or) Drawings of Process Equipment

None.

References

2. US Environmental Protection Agency Website, *accessed on 18 November 2009*, available from http://www.epa.gov/methane/

Combined Heat and Power

Equipment description

During the normal operation of an LNG plant, there is a continual generation of boil off gas. The boil off gas is the result of heat in-leak to the system which warms the LNG up and leads to the evolution of vapour as the LNG boils. The boil off gas which is generated must be dealt with to avoid the pressure in the tank rising to the point where the tank relief valves are called into action or the use of the cold vent is required.

The boil off gas which is generated can be handled using a Combined Heat and Power plant. These systems use small gas turbine engines to generate power using the raw boil off gas as a fuel for the power generation step. The operation of these plants leads to heat generation in addition to the power which is generated. The heat that is produced is then used for the vaporisation of the LNG which is being exported from the terminal.

General Emissions Details

- Land ☐
- Air ☒
- Water ☐
- Noise ☒

Prerequisites requirements of equipment

Boil off Gas Fuel

Boil off gas for use as fuel should be available to the terminal. Depending on the commercial operations of the terminal, this could require agreements with the shipper for the use of the boil off gas in this manner.

Tie-in to Electrical System

The combined heat and power plant generates electricity. Depending on the amount of electricity which is produced (this is a function of the boil off rate and the associated size of the combined heat and power plant), the electricity can either be consumed on site or could be exported to the local grid – there may be periods where there are lower power requirements on the terminal which means there is an excess of electricity.

Instrument Air

Instrument air is required to operate the various valves and instrumentation on the combined heat and power plant.

Emissions details

LAND

There are no emissions to land associated with the operation of a combined heat and power plant.

AIR

The requirement to burn the boil off gas which enters the system to generate the electricity leads to waste gases which are released to the environment. These gases will be predominantly carbon dioxide but may also contain carbon monoxide, and oxides of nitrogen.

WATER

There are no direct emissions to water from the operation of a combined heat and power plant. If an open loop heating system is adopted, emissions to water should be considered.

NOISE

The operation of mechanical equipment within the combined heat and power plant will lead to emissions of noise to the local environment.

Environmental Risks

The requirement to burn the natural gas for the process leads to the generation and emissions of carbon dioxide which is a greenhouse gas and is considered a risk to the environment.

Appropriate Measures to Protect Against Safety Risks

There are no safety risks associated with operating a combined heat and power plant.

Benefits of Technology

Cost (Capital and Operating Costs)

The use of a combined heat and power plant can be beneficial by producing electricity for consumption on the terminal thereby reducing the electricity bills considerably. The by product of the electricity generation step (heat) can also be used to vaporise the LNG removing the requirement to consume additional fuel gas or electricity for this process. The operating costs can therefore be significantly reduced and money could be made through the export of excess electricity.

Operational

None considered.

Environmental

None considered.

Downfalls of Technology

Cost (Capital and Operating Costs)

The requirement to burn the boil off gas means that the market value of that boil off gas is not realised. The market value of the boil off gas could be higher than the value of the electricity generated and hence the shipper realises a loss through the process.

Operational

Operationally, the process introduces additional complexities by an interlinked dependency between processes (power generation and vaporisation).

Environmental

The use of this technology leads to releases of carbon dioxide to the environment which is a green house gas and can lead to global warming.

Development / History of Technology

None.

Open section on novel ideas

None.

Pictures and (or) Drawings of Process Equipment

None.

References

None.

Low Capacity Boil off Gas Compressor

Equipment description

During the usual operation of an LNG plant, there is a continuous production of boil off gas (BOG) due to heat ingress to the system; this production increases significantly during the ship unloading phase. Insulation is used to maintain the temperature and minimize the BOG; it is to be noted that the higher the tank pressure, the lower the BOG production rate.

An LNG plant is typically characterized by a BOG recovery system consisting of:

- Low flow rate compressors for the recovery of usual BOG production
- High flow rate compressors for the recovery of BOG produced during unloading operations
- Recondenser

The following is a typical example of layout for low capacity compressors.

The compressor works during the normal activity of the plant to recover the quantity of BOG produced inside the tank during this phase. They compress the BOG to a maximum pressure of 28 barg and send it to a recondenser where the BOG is mixed with fresh liquid LNG in order to bring it back into the liquid phase. BOG compressors are usually reciprocating compressors, directly coupled with an electric motor.

The low capacity compressor typically has three stages of compression, provided with a control system allowing the equipment to operate at different conditions

Technical data:

Suction temperature	- 130 °C			
Suction pressure	bara	1,014	3,95	11,8
Discharge temperature	°C	-46	149	114
Discharge pressure	bara	4,03	12,1	28
Engine power	360 KW			
Flow rate	2.000 Kg/ h			

General Emissions Details

Land ☒

Air ☐

Water ☒

Noise ☒

Prerequisites requirements of equipment

<u>Electricity</u>

The power needed for the operation of the low capacity compressors is supplied by a 6 KV electric motor; there is also an auxiliary electrical pump for lube oil, working at 380 V, and several other utilities (e.g. heaters, instrumentation, etc).

<u>Instrument air</u>

The instrument air is supplied by the terminals instrument air system and it allows the instrumentation and control of the BOG compression system.

Cooling system

The process of compressing natural gas leads to an increase in temperature of the gas. This leads to a requirement for cooling systems to retain the cylinders at a safe operating temperature. Some terminals have a dedicated cooling system which uses seawater within an exchanger; some terminals adopt a water-glycol mixture together with fin-fan coolers to carry out this function.

Oil

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

Emissions details

LAND

The mechanical system is lubricated by lube oil which ensures the equipment remains lubricated during operation. In the event of failure of some parts of the oil system, lube oil would be released and could lead to pollution of the land if the collecting basin is not adequately sized to collect the entire leak amount.

AIR

There are no emissions to air.

WATER

Where sea water is used as the cooling medium, the temperature of which must be carefully controlled before final discharge in order to avoid significant effects on the marine environment. The local Authorities usually set the maximum allowed value in terms of temperature variation of the discharged sea water.

NOISE

The noise levels (measured 1 m from the noise source) are typically 80 db (A). This level must be lower than the maximum limit permitted by the regulating body (usually 85 db A).

Environmental Risks

It is possible that an oil release due to a failure affecting the oil circuit can pollute the land. Environmental risks can also occur as a consequence of spillage of lube oil during the transfer operation necessary for the maintenance of the equipment. If an oil leak does occur, the spill should be suitably controlled using spill kits and drain blockers and the spill should then be suitably cleaned-up and disposed of correctly.

Appropriate Measures to Protect Against Safety Risks

A fault tree analysis demonstrates that there could be a high consequence event:

- Damage of the mechanical seal with leakage of high pressure gas;

This would lead to a gas cloud which, if ignited, would lead to a major accident event. Regular maintenance and inspections are necessary to guarantee the efficiency and reliability of compressors and maintain the necessary safety levels.

In order to avoid any risk related to the occurrence of a seal failure, the compressors are equipped with safety valves to prevent any possible failure and the plant fire fighting system should be designed to minimize the effects of a possible ignition.

In the event of an oil spill due to failure of the oil system, collection trays should be in-place to collect the oil spillage and avoid it being released to the surrounding environment. The trays should be suitably designed to contain the maximum credible release volume.

It should be noted that natural gas compressors should be designed and constructed following the relevant codes and standards.

Benefits of Technology

Cost (Capital and Operating Costs)

As the discharge pressure to the recondenser and as a consequence, the size of compressors can be much lower (5-6 bar) than the case of direct compression to the gas network (70-75 bar), the operating costs for this technology (compression with recondensation), in particular relating to electric power consumption is lower when compared to other technologies (direct compression, liquefaction, etc).

Operational

Low discharge pressures can be easily handled. There is no need for boil off gas conditioning.

Environmental

Low energy consumption when compared with other similar technologies.

Downfalls of Technology

Cost (Capital and Operating Costs)

Capital costs: the installation cost of this equipment can be high and indeed it is considered a long lead item and a capital part of the whole plant.

Operating costs: there can be significant costs related to preventative and on condition maintenance (spare parts for cryogenic applications – piston rings, rider rings, etc – can be particularly expensive)

Operational

None considered.

Environmental

Necessity of venting in case of shut down of the plant

Development / History of Technology

In the past the BOG produced inside the LNG tanks was systematically flared or vented. Nowadays, recovering the BOG by means of various systems is mandatory, and gas venting or flaring is only used as emergency safety device for extraordinary events.

Open section on novel ideas

As the maintenance costs for reciprocating BOG compressor can be significant (high costs of spare parts, reduced MTBM etc..) it would be interesting, as far as this is concerned, to make a comparison between different technologies (for instance comparison between vertical and horizontal reciprocating compressors, a sensitivity analysis regarding the level of discharge pressure, the compressor flow rate etc..)

Pictures and (or) Drawings of Process Equipment

References

None.

High Capacity Boil off Gas Compressors

Equipment description

During the usual operation of an LNG plant, there is a continuous production of boil off gas (BOG) due to heat ingress to the system; this production increases significantly during the ship unloading phase. Insulation is used to maintain the temperature and minimize the BOG; it is to be noted that the higher the tank pressure, the lower the BOG production rate.

An LNG plant is typically characterized by a BOG recovery system consisting of:

- Low flow rate compressors for the recovery of usual BOG production
- High flow rate compressors for the recovery of BOG produced during unloading operations
- Recondenser

The following is a typical example of layout for high capacity compressors.

Two twin compressors work alternatively or simultaneously during the LNG unloading from the ship and recover the high quantity of BOG produced inside the tank during this phase. They compress the BOG to a maximum pressure of 28 barg and send it to a recondenser where the BOG is mixed with fresh liquid LNG in order to bring it back into the liquid phase. BOG compressors are usually reciprocating compressors, directly coupled with an electric motor.
The high capacity compressors typically have three stages of compression, provided with a control system allowing the equipment to operate at different conditions.

Technical data:

Suction temperature	- 130 °C			
Suction pressure	bara	1,014	4,81	12,1
Discharge temperature	°C	-32	53	111
Discharge pressure	bara	4,03	12,6	28
Engine power	1.400 KW			
Flow rate/each compressor	8.000 Kg/ h			

General Emissions Details

Land ☒

Air ☐

Water ☒

Noise ☒

Prerequisites requirements of equipment

Electricity

The power needed for the operation of the high capacity compressors is supplied by a 6 KV electric motor. There is also an auxiliary electrical pump for lube oil, operating at 380 V, and several other utilities (e.g. heaters, instrumentation etc).

Instrument air

The instrument air is supplied by the terminal's instrument air system which allows the instrumentation and control of the BOG compression system.

Cooling system

The process of compressing natural gas leads to an increase in temperature of the gas. This leads to a requirement for cooling systems to retain the cylinders at a safe operating temperature. Some terminals have a dedicated cooling system which uses seawater within an exchanger; some terminals adopt a water-glycol mixture together with fin-fan coolers to carry out this function.

Oil

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

Emissions details

LAND

The mechanical system is lubricated by lube oil which ensures the equipment remains lubricated during operation. In the event of failure of some parts of the oil system, lube oil would be released and could lead to pollution of the land if the collecting basin is not adequately sized to collect the entire leak amount.

AIR

There are no emissions to air.

WATER

Where sea water is used as the cooling medium, the temperature of which must be carefully controlled before final discharge in order to avoid significant effects on the marine environment. The local Authorities usually set the maximum allowed value in terms of temperature variation of the discharged sea water.

NOISE

The noise levels (measured 1 m from the noise source) are typically 80 db (A). This level must be lower than the maximum limit permitted by the regulating body (usually 85 db A).

Environmental Risks

It is possible that an oil release due to a failure affecting the oil circuit can pollute the land. Environmental risks can also occur as a consequence of spillage of lube oil during the transfer operation necessary for the maintenance of the equipment. If an oil leak does occur, the spill should be suitably controlled using spill kits and drain blockers and the spill should then be suitably cleaned-up and disposed of correctly.

Appropriate Measures to Protect Against Safety Risks

A fault tree analysis demonstrates that there could be a high consequence event:

- Damage of the mechanical seal with leakage of high pressure gas;

This would lead to a gas cloud which, if ignited, would lead to a major accident event. Regular maintenance and inspections are necessary to guarantee the efficiency and reliability of compressors and maintain the necessary safety levels.

In order to avoid any risks related to the occurrence of a seal failure, the compressors are equipped with safety valves to prevent any possible failure and the plant fire fighting system is designed to minimize the effects of a possible ignition.

In the event of an oil spill due to failure of the oil system, collection trays should be in-place to collect the oil spillage and avoid it being released to the surrounding environment. The trays should be suitably designed to contain the maximum credible release volume.

It should be noted that natural gas compressors should be designed and constructed following the relevant codes and standards.

Benefits of Technology

Cost (Capital and Operating Costs)

As the discharge pressure to the recondenser and as a consequence, the size of compressors can be much lower (5-6 bar) than the case of direct compression to the gas network (70-75 bar), the operating costs for this technology (compression with recondensation), in particular relating to electric power consumption is lower when compared to other technologies (direct compression, liquefaction, etc).

Operational

Low discharge pressures can be easily handled. There is no need for boil off gas conditioning.

Environmental

Low energy consumption when compared with other similar technologies.

Downfalls of Technology

Cost (Capital and Operating Costs)

Capital costs: the installation cost of this equipment can be high and indeed it is considered a long lead item and a capital part of the whole plant.

Operating costs: there can be significant costs related to preventative and on condition maintenance (spare parts for cryogenic applications – piston rings, rider rings, etc – can be particularly expensive)

Operational

None considered.

Environmental

Failure of these systems would lead to a requirement to vent the boil off gas to the atmosphere.

Development / History of Technology

In the past the BOG produced inside the LNG tanks was systematically flared or vented. Nowadays, recovering the BOG by means of various systems is mandatory, and gas venting or flaring is only used as an emergency safety device for extraordinary events.

Open section on novel ideas

As the maintenance costs for reciprocating BOG compressor can be significant (high costs of spare parts, reduced MTBM etc..) it would be interesting, as far as this is concerned, to make a comparison between different technologies (for instance comparison between vertical and horizontal reciprocating compressors, a sensitivity analysis regarding the level of discharge pressure, the compressor flow rate etc..).

Pictures and (or) Drawings of Process Equipment

References

None.

Recondenser

Equipment description

During the usual operation of an LNG plant, there is a continuous production of boil off gas (BOG) due to heat ingress to the system; this production increases significantly during the ship unloading phase. Insulation is used to maintain the temperature and minimize the BOG; it is to be noted that the higher the tank pressure, the lower the BOG production rate.

An LNG plant is typically characterized by a BOG recovery system consisting of:

- Low flow rate compressors for the recovery of usual BOG production
- High flow rate compressors for the recovery of BOG produced during unloading operations
- Recondenser

The recondenser system consists of an absorption tower in which the BOG pressurized by the BOG compressors are mixed with fresh LNG drawn from cryogenic pumps, in order to return it to the liquid phase. This is usually a column which is packed with structured packing to provide the contact area between the warmer boil off gas and the colder LNG.

The following is some typical technical data for a recondenser:

Height	12, 805 m
Operating temperature	- 160 ° C
Operating pressure	24 bar
Capacity	21.000 Kg/ h Nat.Gas

General Emissions Details

Land ☐

Air ☐

Water ☐

Noise ☐

Prerequisites requirements of equipment

BOG Compressors

Boil off gas compressors are required in order to supply the boil off gas which is generated on the plant to the recondenser for the purpose of boil off gas handling.

Emissions details

LAND

There are no emissions to land

AIR

There are no emissions to air.

WATER

There are no emissions to water.

NOISE

There are no noise emissions.

Environmental Risks

There are no significant environmental risks.

Appropriate Measures to Protect Against Safety Risks

The safety risks associated with the recondenser are mainly related to the possibility of overfilling and/or overpressure. Proper protection systems (safety valves, high level and high pressure devices, etc) as well as the continuous training of personnel represent the appropriate measures to avoid the above mentioned risks. In addition, the recondenser should be designed and constructed following the relevant codes and standards in order to avoid any reliability problems.

Benefits of Technology

Cost (Capital and Operating Costs)

None considered.

Operational

A recondenser has the capability to recondense a great quantity of BOG at relatively low pressures (5 – 6 bar). The larger the sizes of the tower the lower the operating pressure. Therefore, in those plants in where there is limited room available and it is necessary to install a recondenser with limited dimensions, the operating pressure must be higher, with implications on the sizes and resultant operating conditions of the BOG compressors.

Environmental

None considered.

Downfalls of Technology

Cost (Capital and Operating Costs)

None considered.

Operational

High pressure drops can be experienced in smaller dimension towers which leads to higher capital and operating costs.

Environmental

None considered.

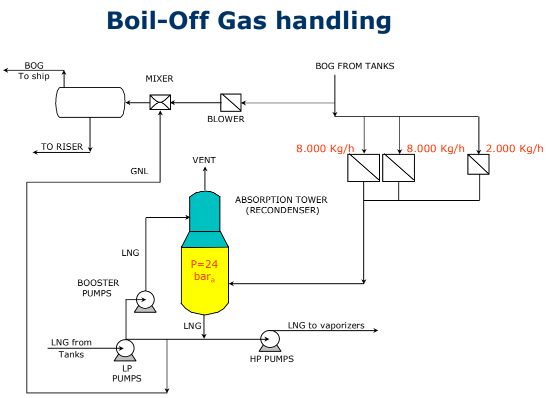
Development / History of Technology

None.

Open section on novel ideas

None.

Pictures and (or) Drawings of Process Equipment



References

None.

Export Gas Processing

Gas Odorising System

Equipment description

Typically a gas odorizing system consists of :

- Odorant dosing electric pumps coupled with specific injection units (spray diffusers, injection quills), cartridge filters and Knock Out (KO) drums;
- Underground odorant (double walled) nitrogen pressurized storage tanks. Nitrogen is used to propel the odorant to the pump suction line.
- Drain tanks installed within a pit.
- Gas chromatographs (GC) measuring odorant concentration in the odorized gas.
- Computer (PC) for process supervision and data acquisition.

The dosing pump regulation (odorant injection) takes into account instant gas flow as well as send-out gas odorant concentration. Odorant is usually supplied by truck and discharged into storage tanks. Odorizing system Programmable Logic Controllers (PLC) which regulate the pumps are linked to the send-out gas flow meters/computers and the terminal's Distributed Control System (DCS); instant gas flow values are used in order to elaborate the mean flow values which are used to calculate the amount of odorant needed in order to reach the setpoint concentration. Pumps discharge the defined amount of odorant in an intermittent way (spray) or continuous way (diffusers). Odorized gas is analyzed to check whether it fits within the acceptable odorant concentration range. The system can also optimize the odorant dosing with respect to the downstream odorant concentration. The gas flow measurement availability and validity are crucial for odorizing. Moreover, alarms are also set in order to notify operation teams of any incident affecting the function of the odorizing system. Given the importance of gas odorizing, redundancy is required for dosing pumps, chromatographs and injection pipes. In the event that the odorizing of the export gas is interrupted, the terminals ESD system is deployed to stop LNG export to the network.

General Emissions Details

Land ☐

Air ☒

Water ☐

Noise ☒

Prerequisites requirements of equipment

Electricity

Electricity is needed for the dosing pumps, the gas chromatograph (GC), the valves, the computer as well as the connexions between the different systems (counting, DCS, etc.). Because the GC is used for commercial purposes, it is a critical equipment item. In the event of a power failure, the power supply is switched over to the UPS supply (batteries).

Industrial Gases

Standard gas and carrier gas (such as helium, argon, etc.) are necessary for the gas chromatographs. These are commonly supplied as cylinders.

Nitrogen

Nitrogen is used to pressurize the odorant storage tanks and drive odorant from the tanks to the pump suction lines. The same scheme is applied for truck discharging into the storage tanks.

Nitrogen is available on LNG regas terminals usually in gaseous state and is transported through a dedicated distribution network.

Odorant

Most odorant substances such as THT, TBM, MES, MSH, EtSH contain sulphur. Operators can also opt for predefined mixtures of the above substances such as the Scentinel E, BE, etc.

Odorant in France is THT and the set-point is 25 mgTHT/cub.m(n). However, the acceptance range is between 15 mgTHT/m3(n) and 40 mgTHT/cub.m(n).

Emissions details

LAND

There are no emissions to land.

AIR

Analyzed odorized gas as well as the carrier gases are vented to air. Drain tanks and KO drums are equipped with vents coupled with activated carbon filters which capture sulphur compounds.

WATER

There are no emissions to water.

NOISE

Emission of noise can be attributed to dosing pumps. However, those emissions remain extremely low (small size pumps constrained within a dedicated room).

Environmental Risks

In case of accidental liquid odorant release, soil pollution can be caused as most odorant substances present a certain level of toxicity. Release can occur either while unloading the odorant from the truck to the storage tanks or during transport.

In order to prevent dispersion of possible leakages during unloading, the operation should take place within a specific impounding area where trucks are parked. The unloaded odorant is transferred to and stored in double containment odorant storage tanks.

The content of drain and purge drums is usually sent to external treatment centres unless the terminal is equipped with a sulphur wastewater treatment technology.

Appropriate Measures to Protect Against Safety Risks

Most odorant substances are flammable. In the event of an accidental release the terminal should be equipped with the appropriate measures to limit the spread of the odorant spill.

Drums full of odorant capture chemical agents, such as activated carbon, sodium hypochlorite and permanganate of potash, should be installed at the points where a leak is likely to occur. Fire fighting equipment should also be available at those points.

Risks to the integrity the odorant storage tanks is insignificant as these are double walled tanks. Moreover, the tanks are contained within a pit.

Lastly, the terminal's odorizing system should be designed in compliance with standards and regulations concerning pressure equipment, explosive atmospheres, natural gas and LNG systems.

Benefits of Technology

Cost (Capital and Operating Costs)

Gas odorizing is rarely an obligation for a terminal operator. Indeed, if performed, odorizing is normally part of the downstream TSO obligations. The terminal operator can perform it on behalf of the TSO.

Average cost for the installation of an odorizing system is about 8.4 million € (2009) representing less than 1% of the total CAPEX budget necessary for the construction of a new 4 million tonne - LNG receiving terminal.

Operational

The technology described enables the operator to regulate the odorant flow as a function of the gas flow while at the same time taking into account the downstream odorant concentration (odorant injection set-point optimization).

Environmental

None considered.

Downfalls of Technology

Cost (Capital and Operating Costs)

None considered.

Operational

Injection quills, when cleaned with nitrogen, have to be completely purged of nitrogen to avoid nitrogen being injected in place of odorant.

The system is highly dependent on the availability of the flow measurement signal.

Environmental

Should a small amount of the export gas be used by the terminal (in the buildings for example), combustion of odorized gas creates SOx emissions.

Development / History of Technology

Export gas odorizing is not always a requirement for an LNG terminal. It all depends on the national regulations and the requirements imposed on the TSO.

The benefits of a centralized odorisation scheme (odorizing in entry points) from the TSO's point of view is reduced CAPEX, a pretty reliable and stable odorant concentration in the gas as well as a reduced level of environmental pollution (reduced odorant supply points, reduced number of odorizing points).

The technology described hereinabove is developed by the French TSO.

Open section on novel ideas

None considered.

Pictures and (or) Drawings of Process Equipment

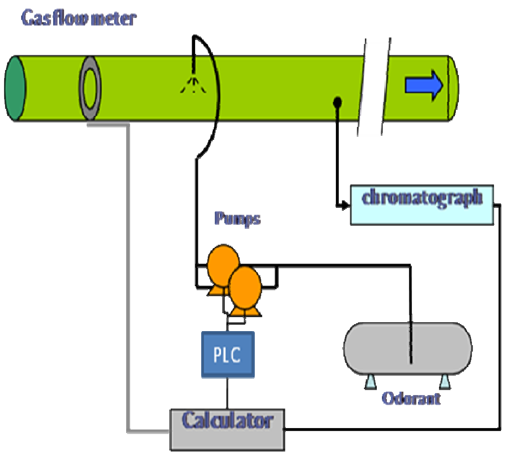
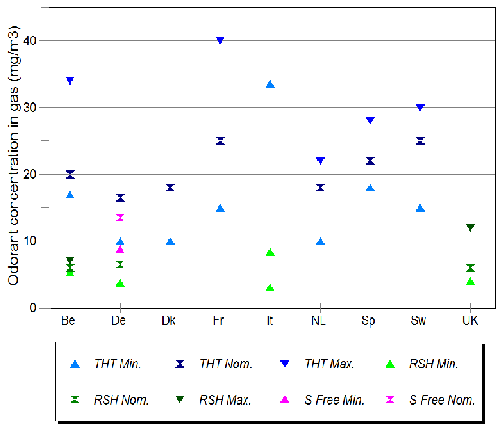


Diagram of a gas odorizing system



Types of odorant per European country

Impounding area for truck unloading

Chromatographs

Top facilities above the buried storage tanks

Odorising unit

References

1. GDF SUEZ – Elengy

Temperature Correction

Equipment description

The gas pipelines into which LNG regas terminals export gas can have limitations surrounding the conditions of the gas which they can receive. This is often driven by the internal coating of these pipelines which can be damaged by excursions, specifically high temperatures, from agreed conditions. Some terminals benefit from export routes which do not require LNG to be vaporised but instead used compressors to export the boil off gas which is generated as a result of storage. The process of gas compression raises the temperature of the gas which can be higher than the acceptable discharge temperatures from the terminal. Inter and after coolers are used to reduce the temperature increased between the compression steps, however there can remain a requirement to further reduce the temperature of the exported gas. This can be done through LNG injection via a device known as a desuperheater.

A desuperheater utilises an injection nozzle to disperse cold LNG droplets within a flowing gas stream. The cold LNG is vaporised by the warm gas stream but in doing this the temperature of the gas stream is reduced as a result of the latent heat of vaporisation of the cold LNG droplets. A desuperheater will generally consist of a small pipe from a source of pressurised LNG which feeds a nozzle which is located in the centre of the pipe containing the warm gas stream which requires cooling. A valve which is controlled by a temperature controller down stream of the desuperheater nozzle is regulated to control the flow of LNG into the system and thereby controlling the temperature.

General Emissions Details

Land ☐

Air ☐

Water ☐

Noise ☐

Prerequisites requirements of equipment

<u>Source of pressurised LNG</u>

A source of pressurised LNG is required. The pressurised LNG is injected through the desuperheater nozzle to the gas stream to reduce the temperature of the gas stream. The pressure of the LNG source should be greater than that of the gas stream into which the LNG is being injected to allow for pressure losses in the transfer pipe and through the injection nozzle and to ensure that the flow of LNG is in the correct direction.

<u>Method of Mixing</u>

Depending on the flowrate of the gas stream which is being cooled, a method of suspending the LNG in the gas stream is required to ensure the even cooling of the gas stream and avoid LNG pooling at the base of the pipe. Generally, this would be done through the design of the desuperheater nozzle. It can be found that the variable flowrate of the gas stream could lead to problems which this nozzle design. A static mixer could be used for the purpose of dispersion in the case of low flowrate gases by agitating the gas stream and increasing the Reynold’s number of the stream.

Emissions details

<u>LAND</u>

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

<u>AIR</u>

There are no emissions to air as a result of operating a desuperheater.

WATER

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

NOISE

There are no direct noise emissions as a result of operating a desuperheater, however, the requirement for a source of pressurised LNG would generally require the use of a pump. An operational LNG pump will generate small emissions of noise due to its operation. See ‘LNG Pumping’.

Environmental Risks

There are no environmental risks associated with operating an LNG desuperheater.

Appropriate Measures to Protect Against Safety Risks

An LNG desuperheater can produce a safety risk in the form of LNG pooling which can lead to embrittlement of carbon steel pipework. The material of construction of pipework into which LNG terminals export is generally carbon steel which has an embrittlement temperature of -20 deg.C. If the LNG stream is not fully entrained in the gaseous phase of the warm gas stream, LNG pooling is observed on the base of the pipework which would lead to catastrophic failure of carbon steel pipework if this were to occur. The material of construction of pipework immediately after the desuperheater and for a short distance afterwards should be stainless steel to avoid this phenomenon damaging the pipework. Low temperature trips situated on the base of the pipework should be utilised to close the desuperheater valve in the event that a low temperature is observed. If a desuperheater is installed, suitable risk assessment of the system is required to justify its safety with respect to the downstream equipment with particular attention to the material of construction.

Benefits of Technology

Cost (Capital and Operating Costs)

The capital costs of installing a desuperheater are low given the small diameter pipework which is required and the relative simplicity of the system. The operating costs are minimal if a source of pressurised LNG is found from the normal recirculation systems of the terminal where LNG pumps are already running.

Operational

The LNG desuperheater is a relatively simple system and easy to operate. Once the system has been initiated, it is generally self regulating.

Environmental

None considered.

Downfalls of Technology

Cost (Capital and Operating Costs)

The use of an LNG desuperheater can lead to lost value of LNG by requiring a small amount to be exported to regulate the temperature of the export gas streams. This LNG would otherwise be available to the shipper for sale in the gas market when the price is favourable.

Operational

In the event that LNG pooling is realised, the operational disruption to recover the situation would see an export route lost to the operator.

Environmental

None considered.

Development / History of Technology

None.

Open section on novel ideas

None.

Pictures and (or) Drawings of Process Equipment

None.

References

None.

Gas Quality Characterisation

Gas Chromatography

Equipment description

A small LNG flow is taken from the unloading headers and is vaporized in a dedicated vaporizer cabinet. The small gas flow is diverted towards the analysis instrument: the gas chromatograph. A gas chromatograph is a chemical analysis instrument for separating different components in a complex sample (in this case the different components of natural gas). A gas chromatograph uses a flow-through narrow tube known as the column, through which different chemical constituents of a sample pass in a gas stream (carrier gas, mobile phase) at different rates depending on their various chemical and physical properties and their interaction with a specific column filling, called the stationary phase. As the chemicals exit the end of the column, they are detected and identified electronically. The function of the stationary phase in the column is to separate different components, causing each one to exit the column at a different time (retention time).

General Emissions Details

- Land ☐
- Air ☒
- Water ☐
- Noise ☐

Prerequisites requirements of equipment

Electricity

Electricity is needed for the vaporizer cabinet, the gas chromatograph itself and the computer (on which the analysis software is running). Because the gas chromatograph is used for commercial purposes, it is classed as critical equipment and therefore, in case of power failure, the power supply is switched over to UPS (batteries).

Carrier gas

A cylinder (or external source) of carrier gas is needed (see equipment description). Helium and argon are commonly used.

LNG or gas (to be analyzed)

Emissions details

LAND

There are no emissions to land.

AIR

The analyzed gas (together with the carrier gas: helium, argon…), as well as the bypass stream (*) are vented into the air.

(*) In order to get a real-time analysis, there is a continuous flow towards the GC. Because it takes some time to perform an analysis, a sample is only analyzed every 5 minutes. The rest of the gas flow bypasses the GC, directly into the air.

WATER

There are no emissions to water.

NOISE

There are no noise emissions.

Environmental Risks

Emissions of natural gas into the air, 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 unloading line), the vaporizer cabinet, and the tubing towards the gas chromatograph should be designed and constructed according to the applicable codes and standards (special attention has to be paid to the welding of the sampling point).

Benefits of Technology

Cost (Capital and Operating Costs)

A gas chromatograph is not low cost (CAPEX), but once calibrated and running, the operational costs (OPEX) are quite low. A re-calibration has to be done on a regular basis (or an update of the analysis software).
The costs are considered low in comparison to other technologies, e.g. Raman Spectroscopy, analysis in a certified laboratory.

Operational

The gas chromatograph allows the almost immediate results to be attained (once every 5 minutes) and is a very reliable piece of 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 GC is needed for every flow).

Operational

Although the technology is quite fast, real-time analyzing is not possible with gas chromatographs.

Environmental

Emissions of natural gas into the air. If possible the analyzed gas and bypass stream should be recuperated in the low flare system to reduce the green house effect of the vented gas.

Development / History of Technology

Chromatography dates to 1903 in the work of the Russian scientist, Mikhail Semenovich Tswett. German graduate student Fritz Prior developed solid state gas chromatography in 1947. Archer John Porter Martin, who was awarded the Nobel Prize for his work in developing liquid-liquid (1941) and paper (1944) chromatography, laid the foundation for the development of gas chromatography and later produced liquid-gas chromatography (1950). Erika Cremer laid the groundwork, and oversaw much of Prior's work.

Open section on novel ideas

None.