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Master of Science in Petroleum Engineering

Study of a Risk Assessment methodology for use in potentially explosive atmospheres through its application on a LNG regasification terminal

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Abstract

The European Directive 99/92/EC (ATEX 137A) on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres requires the employer to draw up an explosion protection document, or set of documents, which includes the identification of the hazards, the evaluation of the risks and the definition of the specific measures to be taken to safeguard the health and safety of workers at risk from explosive atmospheres.

The RASE Project – "Explosive Atmosphere: Risk Assessment of Unit Operations and Equipment", a joint industry / European Commission project, developed in 2000 a draft methodology for assessing the risk associated with different types of equipment and unit operations and meeting the abovementioned requirements.

In this study the guidelines of the RASE Risk Assessment methodology are presented and an analysis is conducted on the proposal of utilization of common Risk Assessment techniques (HAZOP, Check-list, Event Tree Analysis) along the RASE procedure for reaching the desired targets.

The analysis is conducted through the direct application of the Risk Assessment methodology on a liquefied natural gas (LNG) regasification terminal so that the concrete effectiveness of the proposed procedure has been evaluated on the basis of the reliability of the results obtained.

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Introduction - field of application and scope of work

This study takes place in the framework of the Directive 99/92/EC (ATEX 137A for installations, workplaces). The Directive requires the employer to draw up an explosion protection document, or set of documents, which includes the identification of the hazards, the evaluation of the risks and the definition of the specific measures to be taken to safeguard the health and safety of workers at risk from explosive atmospheres.

Explosive atmosphere is here defined a mixture with air, under atmospheric conditions, of flammable substances in the form of gases, vapours, mists or dusts in which, after ignition has occurred, combustion spreads to the entire unburned mixture [1].

By the same Directive the employer is required to take technical and/or organizational measures appropriate to the nature of the operation, in order of priority and in accordance with the following basic principles [1]:

- the prevention of the formation of explosive atmospheres, or where the nature of the activity does not allow that,
- the avoidance of the ignition of explosive atmospheres, and
- the mitigation of the detrimental effects of an explosion so as to ensure the health and safety of workers.

These measures must where necessary be combined and/or supplemented with measures against the propagation of explosions and must be reviewed regularly and, in any event, whenever significant changes occur.

The employer is therefore required to conduct a **Risk Assessment** taking account at least of [1]:

- the likelihood that explosive atmospheres will occur and their persistence.
- the likelihood that ignition sources, including electrostatic discharges, will be present and become active and effective.
- the installations, substances used, processes, and their possible interactions.
- the scale of the anticipated effects.

Moreover, to ensure safety and health of workers, he must take the necessary measures so that [1]:

- where explosive atmospheres may arise in such quantities as to endanger the health and safety of workers or others, the working environment is such that work can be performed safely.
- in working environments where explosive atmospheres may arise in such quantities as to endanger the safety and health of workers, appropriate supervision during the presence of workers is ensured in accordance with the Risk Assessment by the use of appropriate technical means.

The employer must ensure that the **explosion protection document** is drawn up and kept up to date. It must demonstrate among other [1]:

- that the explosion risks have been determined and assessed.
- those places which have been classified into zones based upon the frequency of occurrence and duration of explosive atmosphere.
- that the workplace and work equipment, including warning devices, are designed, operated and maintained with due regard for safety.

The explosion protection document must be drawn up prior to the commencement of work and be revised when the workplace, work equipment or organization of the work undergoes significant changes, extensions or conversions.

The present work responds to the necessity of performing a Risk Assessment in areas potentially affected by the presence of explosive atmospheres. A methodology for conducting the Risk Assessment is presented and explained in detail. Moreover, it is reported its direct application on an hydrocarbon processing plant, thus falling under the scope of redaction of the explosion protection document.
The plant under study is represented by a liquefied natural gas (LNG) regasification terminal. The results of the Risk Assessment are reported and commented and an analysis of the effectiveness of the followed methodology is provided.

The procedure here presented has its origin in a methodology for Risk Assessment whose draft was proposed in 200 by the RASE Project – "Explosive Atmosphere: Risk Assessment of Unit Operations and Equipment", a joint industry / European Commission project. The project establishes the foundations of Risk Assessment providing the principal steps to be carried out.
This work enriches and deepen these steps explaining in detailed their content and integrating the general methodology suggested by the RASE Project through the introduction of techniques having the specific target of evaluating all the elements making up the Risk Assessment. In particular the content of the study develops in the following chapters:

- **Chapter 1**: The RASE Project is presented. The objective and scope of the project is described together with the draft of the general Risk Assessment methodology contained in it. Each step of the methodology is outlined and deepened and the integrations given by this study are introduced, leading to the development of an operative Risk Assessment procedure.

- **Chapter 2**: The ATEX zone classification is described. The criteria for the classification of zones on the basis of frequency of occurrence and duration of explosive atmosphere are illustrated. The association of equipment to each zone according to ATEX Groups and Categories is also included.

- **Chapter 3**: the case study is presented and the system described.
  The application of the Risk Assessment procedure to the plant in object and the results obtained are reported.
  An analysis is conducted on the results of the case study after the risk has been evaluated and a series of risk reduction options and safety measures are proposed.

1. The RASE Project – "Explosive Atmosphere: Risk Assessment of Unit Operations and Equipment" [2]

1.1 Project overview

The RASE Project – "Explosive Atmosphere: Risk Assessment of Unit Operations and Equipment" is a joint industry / European Commission project under the dedicated call of the European Commission's Standards Measurement and Testing program concerned with subjects relating to the standardization activities of CEN.

The RASE Project objective was to develop a Risk Assessment methodology for unit operations and equipment to help manufacturers of equipment and protective systems intended for use in potentially explosive atmospheres meet the requirements of the EU Directives 89/392/EC (machinery directive), 2014/34/EU (actualization of ATEX 100A) and 99/92/EC (ATEX 137A). The last in particular (ATEX 137A for installations, workplaces) requires the employer to draw up an explosion protection document.
The completed draft of the Risk Assessment methodology is now being widely circulated for comments and has been passed to the relevant technical committees of CEN and CENELEC for development into an European standard.

1.2 Project intention and normative references

The RASE Project follows the Directive 94/9/EC, now actualized in the Directive 2014/34/EU, the so-called ATEX 100A Directive. Its objective is to eliminate or at least minimize the risks resulting from the use of certain products in or in relation to a potentially explosive atmosphere.
Therefore, ATEX 100A Directive is a risk-related Directive and consequently a Risk Assessment has to be made. This is a challenge, because the traditional approach to safety in the process industries was an ad-hoc one of learning from experience.
Compliance with the essential health and safety requirements of ATEX 100A Directive is imperative in order to ensure that equipment and protective systems do not pose an hazard in explosive atmospheres. The requirements are intended to take account of existing or potential hazards deriving from their design and construction.

It is in both the manufacturer's and user's interest to establish a common methodology for achieving safety, reliability and efficacy in functioning and operating of equipment and protective systems with respect to the risks of explosion. In this respect, Risk Assessment is a tool which provides the essential link between manufacturers and users. Whereas the products must be used in accordance with the equipment Group and Category (ATEX 100A) and with all the information supplied by the manufacturer, often the severity or consequences of an incident can only be defined by the users themselves. Thus both the knowledge base of the manufacturer plus the plant specific experience of the users is required to carry out an effective Risk Assessment.

Detailed harmonized standards cannot be developed for all types of assemblies, therefore the RASE Project standard is intended to help the manufacturer carry out a Risk Assessment and to select one or more appropriate methods of Risk Assessment. The same methods may also be applied by the user, where he is responsible for designing and building a process plant, using components bought from many sources. In this case a Risk Assessment is also required as part of the explosion protection document required under the Directive 99/92/EC (ATEX 137A).

For all machines, equipment and protective systems with a potential explosion hazard, compliance with the requirements of the Machinery Directive and the ATEX Directives can be achieved by following, other than ATEX 100A and ATEX 137A, the principles contained in EN 292 *Machinery Safety*, EN 1050 *Risk Assessment* and EN 1127 *Explosion Prevention and Protection*.
The RASE Project applies the principles contained in these standards to the specific requirement of carrying out a Risk Assessment considering the hazard of an explosion.
The type of equipment that the methodology is aimed at comprises all products covered by the ATEX 100A Directive. The term "**product**" covers equipment, components and protective systems, defined as follows [3]:

- **Components**: any item essential to the safe functioning of equipment and protective systems but with no autonomous function.

- **Equipment**: machines, apparatus, fixed or mobile devices, control components and instrumentation thereof and detection or prevention systems which, separately or jointly, are intended for the generation, transfer, storage, measurement, control and conversion of energy for the processing of material and which are capable of causing an explosion through their own potential sources of ignition.

- **Protective systems**: design units which are intended to halt incipient explosions immediately and/or to limit the effective range of explosion flames and explosion pressures. Protective systems may be integrated into equipment or separately placed on the market for use as autonomous systems.

1.3 Risk Assessment methodology steps

A methodology on Risk Assessment should consider the risk of harm to human as well as environmental and property damage resulting from explosion risks. In the case of an undesired event the effective range of an explosion often depends on a multiplicity of factors some of which are not easy to anticipate.
The RASE Project standard defines the Risk Assessment procedure as composed of five main steps:

1. **Determination of intended use (Functional / State-Analysis)**
    - Description of the system
    - Equipment characteristics
    - Product characteristics
    - Functional / State Analysis

2. **Identification of hazards, hazardous situations and hazardous events**
    - Explosive atmosphere type, frequency of occurrence, location
    - Ignition source type, cause, likelihood, effectiveness

3. **Risk estimation of consequences / likelihood**
    - Frequency Estimation
    - Severity Estimation
    - Risk Level Estimation

4. **Risk evaluation**

5. **Risk reduction option analysis**

Risk Assessment should follow the step-approach in that order of preference given, and it is an iterative process. If, after risk has been evaluated, the decision is made that the risk needs to be reduced it is necessary to re-estimate the risk. A decision can then be made as to whether the measures taken have reduced the risk to an acceptable level.
It is also essential to check that the measures used to reduce the risk have not themselves introduced any new hazards.
Therefore a feedback loop from Risk Reduction Option Analysis to Hazard Identification has to be made.

In the following paragraphs, each of the Risk Assessment steps will be described and adapted to the case study on which the operative procedure here proposed will be applied.

1.4 Determination of intended use (Functional / State-Analysis)

The first step of the Risk Assessment consists of an understanding of the functioning of the equipment and/or unit operations and the way in which an incident or an accident may develop.
The contents of this step have been defined in the present study in a different way with respect to the RASE Project. For the purpose of the procedure here suggested, results useful that all the following information are provided:

1.4.1 Description of the system

According to the RASE Project, in this stage a complete description of the equipment and the products involved has to be performed. For complex pieces of equipment and installations it is requested to provide flow diagrams bearing out the energy involved and the status of the materials being handled.

For the purpose of this study and taking into account the specific installations on which the Risk Assessment has been conducted, the following steps have been here developed for the completion of the requirements of this stage:

- Description of plant aspect and configuration (location, atmospheric conditions, area, layout).
- Identification of operating processes and states including those conditions which are not considered to be part of normal operation.
- Equipment intended use: description of the characteristics of the equipment relevant to achieving its desired function.
- Description of control systems and protection equipment.
- Listing of flammability and explosive characteristics of the materials being handled.

1.4.2 Classification of ATEX zones

Directive 99/92/EC (ATEX 137A) requires the employer to classify places where explosive atmospheres may occur into zones on the basis of the frequency and duration of occurrence of explosive atmosphere.
The classification of ATEX zones has been introduced in the Functional / State-Analysis step according to the Risk Assessment procedure developed in this study.
The definition of each kind of zone according to the Directive 99/92/EC (ATEX 137A) and the estimation of extension according to the Standard EN 60079 *Electrical apparatus for explosive gas atmospheres* are provided in this paper in Section 2.1.

1.4.3 Association of ATEX categories to zones

A description of equipment, protective systems and components Groups, Categories and Temperature Classes and their association to the respective zones according to Directives 2014/34/EU (actualization of ATEX 100A) and the standard EN 1127 *Explosion Prevention and Protection* are provided in Section 2.2.
The choice and installation of any equipment to the respective ATEX zone constitutes the last part of Functional/State-Analysis for the operative procedure of Risk Assessment here presented.

1.5 Identification of hazards, hazardous situations and hazardous events

Any assessment of explosion risks must be based on the likelihood that explosive atmospheres will occur and their persistence, the likelihood that ignition sources will be present and become effective and the scale of the anticipated effects.
The main output from the hazard identification stage is a numbered list of hazardous events, which results from the unit operations and equipment involved and represents the input to the risk estimation stage.

The methodology illustrated in the RASE Project defines this data input as a record having exactly and firmly the structure showed in Table 1:

	Explosive atmosphere			**Ignition source**			
Ref.	Type	Frequency of occurrence or release	Location	Type	Cause	Likelihood	Effectiveness of ignition sources
1							
2							
etc.							

Table 1: Record of Hazard Identification [2]

The type of explosive atmosphere which could occur in the system should be recorded in the "Type" column of the table. The operation which causes its occurrence and an indication of the frequency or when it will occur is recorded in the "Frequency of occurrence or release" column, while the location where it occurs in the system is recorded in the "Location" column.
Similarly any significant ignition source which could cause the ignition of the explosive atmosphere should be entered in the corresponding 'Type' column together with the cause and likelihood of occurrence.
Finally the effectiveness of the ignition source in causing ignition of the explosive atmosphere (ranked as high, medium or low) together with the reason is entered in the final column.

1.6 Risk Estimation

Risk Estimation has to be carried out for each explosion hazard or every hazardous event after Hazard Identification.
Risk in terms of explosion safety is fundamentally made up of two elements: the frequency of occurrence of the possible explosion harm and the severity of that harm.

1.6.1 Frequency Estimation

In terms of explosion occurrence the frequency of each hazardous event is given by the combination between two frequencies:

1) **Frequency of occurrence of explosive atmosphere**

2) **Frequency of ignition of explosive atmosphere**, that is then the result of the combination between:
   - likelihood of the ignition source (frequency)
   - effectiveness of the ignition source (probability)

The definition of the frequency levels provided in the RASE Project is reported in Tab. 2:

FREQUENCY Description	**Specific Individual Item**	**Inventory**
FREQUENT	Likely to occur frequently	Continuously experienced
PROBABLE	Will occur several times in life of an item	Will occur frequently
OCCASIONAL	Likely to occur sometime in life of an item	Will occur several times
REMOTE	Unlikely but possible to occur in life of an item	Unlikely but can reasonably be expected to occur
IMPROBABLE	So unlikely, it can be assumed occurrence may not be experienced	Unlikely to occur, but possible

Table 2: Frequency levels definition [2]

To carry out the frequency estimation trough the RASE Risk Assessment the *Laboratorio Oficial* "*José María de Madariaga (LOM)*" of *Universidad Politécnica de Madrid* developed some tables which act as a tool to determine in a qualitative way the frequency of each hazardous event. The tables, which have been utilized in this work, develop the connections between the elements listed in the previous points and estimate the resulting frequency in question taking into account the principles contained in the Directive ATEX 137A for installations, workplaces.

The estimation of the total frequency follows the steps below:

1) The frequency of occurrence of the explosive atmosphere is utilized to establish a qualitative level of occurrence, called **ATEX level** (ATEX level 1, 2, 3), the definition of whom is:

- ATEX level 1: explosive atmosphere generated by continuous or frequent operations.
- ATEX level 2: explosive atmosphere present occasionally and in a discontinuous form.
- ATEX level 3: explosive atmosphere generated by a fault in the system.

2) For each ATEX level, a matrix correlating the likelihood and the effectiveness of the ignition source is developed.

Likelihood of ignition source in terms of the equipment, protective systems and components, according to the indications of EN 1127-1 is here qualitatively defined:

- NORMAL OPERATION: sources of ignition which can occur during normal operation.
- FAULT: sources of ignition which can occur solely as a result of malfunctions.
- RARE FAULT: sources of ignition which can occur solely as a result of rare malfunctions.

Effectiveness of ignition source, also defined qualitatively as LOW, MEDIUM or HIGH, should be estimated considering the ignition properties of the flammable substance creating the explosive atmosphere. Relevant data are:

- Minimum Ignition Energy (MIE)
- Ignition Temperature

Here follow the three matrices adopted in this study to estimate the frequency of ignition of explosive atmosphere by the ignition source, that is the resulting total frequency, according to each ATEX level:

ATEX level 1	*Effectiveness of ignition source*		
Likelihood of ignition source	LOW	MEDIUM	HIGH
RARE FAULT	Improbable	Remote	Occasional
FAULT	Remote	Occasional	Probable
NORMAL OPERATION	Occasional	Probable	Frequent

Table 3: ATEX level 1 frequency matrix

ATEX level 2	*Effectiveness of ignition source*		
Likelihood of ignition source	LOW	MEDIUM	HIGH
RARE FAULT	Improbable	Improbable	Remote
FAULT	Improbable	Remote	Occasional
NORMAL OPERATION	Remote	Occasional	Probable

Table 4: ATEX level 2 frequency matrix

ATEX level 3	*Effectiveness of ignition source*		
Likelihood of ignition source	LOW	MEDIUM	HIGH
RARE FAULT	Improbable	Improbable	Improbable
FAULT	Improbable	Improbable	Remote
NORMAL OPERATION	Improbable	Remote	Occasional

Table 5: ATEX level 3 frequency matrix

Being the definitions of the resulting total frequency levels according to the RASE Project the ones contained in Tab. 2.

1.6.2 Severity Estimation

Severity can be expressed in terms of injuries or damage to health or system as defined levels. The definition of the severity levels provided in the RASE Project is reported in Tab. 6:

SEVERITY	
Description	**Mishap Definition**
CATASTROPHIC	Death or system loss.
MAJOR	Severe injury, severe occupational illness, or major system damage.
MINOR	Minor injury, minor occupational illness, or minor system damage.
NEGLIGIBLE	Less than minor injury, occupational illness, or system damage.

Table 6: Severity levels definition [2]

To perform the Severity Estimation stage of the Risk Assessment, the following table has been developed by the *Laboratorio Oficial "José María de Madariaga (LOM)"* of *Universidad Politécnica de Madrid* and has been utilized in the procedure proposed by this study:

Severity Estimation	*Confinement and capacity of propagation*		
Quantity and characteristics of product and installation	LOW	MEDIUM	HIGH
LOW	Negligible	Negligible	Minor
MEDIUM	Negligible	Minor	Major
HIGH	Minor	Major	Catastrophic

Table 7: Severity Estimation matrix

The table provides an indication for a qualitative (LOW, MEDIUM, HIGH) estimation of the severity level and is based on the following two elements to be considered:

- **Quantity and characteristics of product and installation**: quantity of processed and stored product, physical and chemical characteristics of the product, proximity of buildings and presence of people.

- **Confinement and capacity of propagation**: confinement of explosive atmosphere, installation geometry and support structure, presence of protection systems.

1.6.3 Risk Level Estimation

The estimation of the risk goes finally through the assignment of a level of risk. The combination between frequency on one side and severity on the other, once they have been estimated as in the previous points, leads to a final phase of ranking the risk, to be performed through this matrix presented by the RASE Project:

Risk levels	*Severity*			
Frequency of Occurrence	Catastrophic	Major	Minor	Negligible
Frequent	A	A	A	C
Probable	A	A	B	C
Occasional	A	B	B	D
Remote	A	B	C	D
Improbable	B	C	C	D

Table 8: Risk Level Matrix [2]

The **risk levels** represent a ranking of risk which enables an evaluation of what further actions are needed if any. In particular A represents the highest risk level and D the lowest one.

1.7 Risk Evaluation

Following the estimation of the risk, Risk Evaluation has to be carried out to determine if Risk Reduction is required or whether safety has been achieved. For each hazard identified a specific study has to be conducted starting from the determined risk level.
If the resulting risk is considered intolerable, than appropriate safety measures must be taken to reduce the risk. If otherwise the risk is considered acceptable the Risk Assessment is complete. For intermediate levels of risk organizational risk reduction measures could be sufficient.

A description for each one of the risk levels here follows:

- A: **Intolerable**. Operations must not start or continue until the risk has been reduced. If risk reduction is not possible, even with the availability of unlimited resources, any work or activity must be prohibited.

- B: **Important**. Efforts must be made to reduce the risk, even considering great capital expenditures. Safety measures must be implemented within a specified time period.

- C: **Moderate**. Safety measures must be considered to reduce the risk that do not involve a great capital expenditure. Organizational risk reduction measures could be sufficient for this case.

- D: **Tolerable**. It is not necessary to improve preventive actions, but affordable refinements can be considered.

1.8 Risk Reduction Option Analysis

In the final step of the Risk Assessment solutions are found to reduce the risk to an acceptable level. Solutions may regard plant design, protection systems, personal protective equipment, organizational and logistical measures. Then, decisions have to be made whether or not the solutions found reduce the risk to an acceptable level. This decisions includes both the technological and economical point of view based on an appropriate classification of equipment category. If the decision is that the risk has not been reduced to an acceptable level then the iterative process has to be done again to find alternative solutions.
In Section 3.4 many risk reduction options present in EU Directive EN-1127-1 have been presented together with their relative application to each of the hazardous scenarios coming out from the Risk Evaluation of the case study.

1.9 Operating procedure – Risk Assessment techniques

The scope of this study is to integrate the Risk Assessment methodology proposed by the RASE Project through the introduction of different techniques in order to properly estimate all the components of the Risk Assessment and develop an operative procedure to be effectively used.

The flow-chart of the following figure shows the general Risk Assessment steps established by the RASE Project:

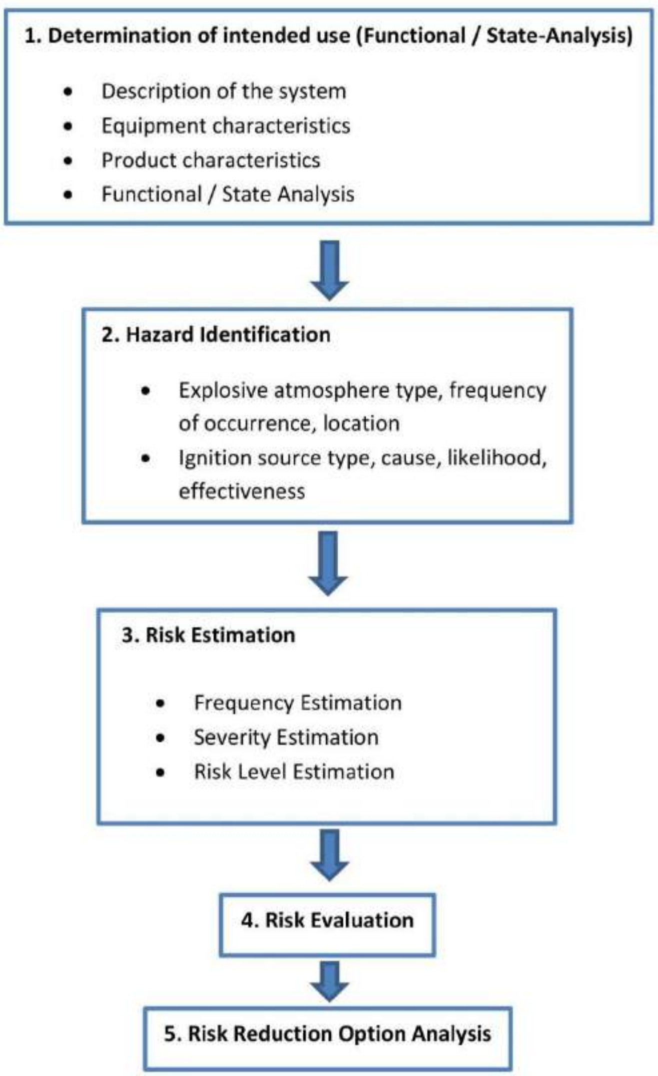

Figure 1: RASE Risk Assessment Steps

The techniques introduced in this work on the case study are here listed together with the aims they have been utilized for:

- **Hazard and Operability Analysis (HAZOP)**: it has been used to estimate explosive atmosphere type, frequency of occurrence and location, then quantity and characteristics of product and installation involved in its formation.

- **Check-list**: a model of check-list contained in the RASE Project has been analyzed and guidelines and recommendations have been given for the use of this technique on the identification of ignition sources type and cause.

- **Event Tree Analysis**: it has been used for identifying the hazardous scenarios, in particular confinement and capacity of propagation of the explosive atmosphere.

The description of each technique and the results obtained from its application on the case study are reported in the relative sections. The following flowchart shows all the steps of the RASE methodology with the modifications and integrations proposed in this study for the development of an operative procedure to adopt for Risk Assessment:

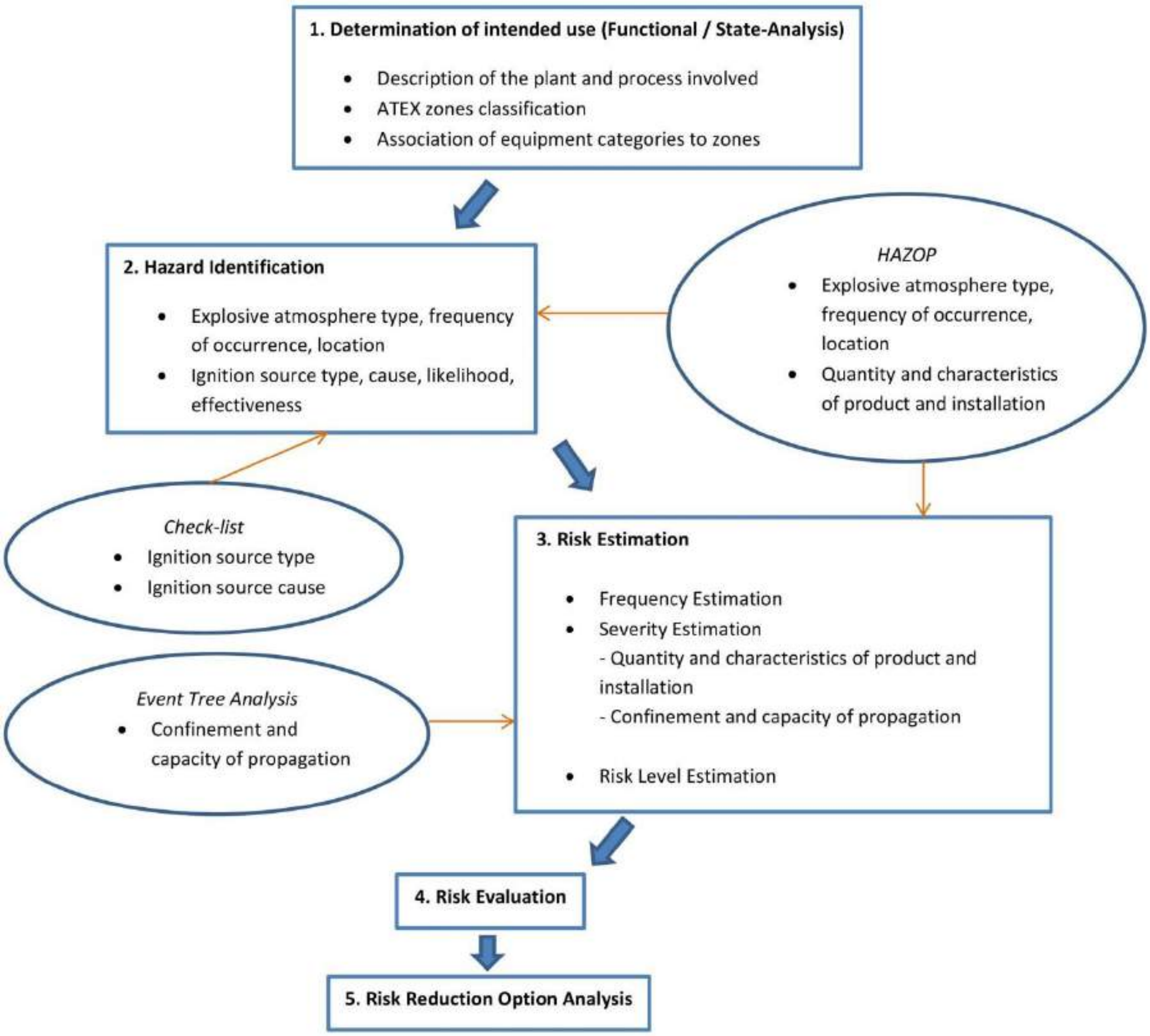

Figure 2: Risk Assessment operating procedure

2. ATEX zone classification

2.1 Classification of zones [4]

Directive 99/92/EC (ATEX 137A) requires the employer to classify places where explosive atmospheres may occur into zones on the basis of the frequency and duration of occurrence of explosive atmosphere.
The directive defines “hazardous” a place in which an explosive atmosphere may occur in such quantities as to require special precautions to protect the health and safety of the workers.
Flammable and/or combustible substances are considered as materials which may form an explosive atmosphere unless an investigation of their properties has shown that in mixtures with air they are incapable of independently propagating an explosion.

In the present work, according with the nature of the substances involved in the case study, the only zone classification for gases has been considered significant, not being of interest the one for dusts.

The zones definition for gases is here provided according to ATEX 137A:

Zone 0
A place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is present continuously or for long periods or frequently.

Zone 1
A place in which an explosive atmosphere consisting of a mixture with air or flammable substances in the form of gas, vapour or mist is likely to occur in normal operation occasionally.

Zone 2
A place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

From the definition it results clear that the zone classification has to be performed considering the normal operation of the system in question, referring to its normal functioning and not taking into account the apparition of faults which may also lead to the presence of an explosive atmosphere. Thus, this stage of classification is preliminary, and can be performed before the Risk Assessment has been finalized.

2.1.1 Sources of release

The basic elements for establishing the hazardous zone types are the identification of the **source of release** and the determination of the **grade of release**.
Since an explosive gas atmosphere can exist only if a flammable gas or vapour is present with air, it is necessary to decide if any flammable material can exist in the area concerned. Generally speaking, such gases and vapours (and flammable liquids and solids which may give rise to them) are contained within process equipment which may or may not be totally enclosed. It is necessary to identify where a flammable atmosphere can exist inside a process plant, or where a release of flammable materials can create a flammable atmosphere outside a process plant.
Each item of process equipment (for example tank, pump, pipeline, vessel, etc.) should be considered as a potential source of release of flammable material.

If it is established that the item may release flammable material into the atmosphere, it is necessary, first of all, to determine the **grade of release** in accordance with the definitions, by establishing the likely frequency and duration of the release. By means of this procedure, each release will be graded as continuous, primary or secondary:

- **Continuous grade of release**: a release which is continuous or is expected to occur for long periods.

- **Primary grade of release**: a release which can be expected to occur periodically or occasionally during normal operation.

- **Secondary grade of release**: a release which is not expected to occur in normal operation and if it does occur, is likely to do so only infrequently and for short periods.

A continuous grade of release normally leads to a zone 0, a primary grade to zone 1 and a secondary grade to zone 2, but it is necessary to determine other factors which may influence the type and extent of the zones. They could be the relative density of the gas or vapour when it is released, the Lower Explosive Limit (LEL), the **release rate**. The last in particular the greater it is the larger the extent of the zone. The release rate depends itself on other parameters, namely:

- Geometry of the source of release
- Release velocity
- Concentration
- Volatility of a flammable liquid
- Liquid temperature

Consideration should always be given to the possibility that a gas which is heavier than air may flow into areas below ground level, for example pits or depressions and that a gas which is lighter than air may be retained at high level, for example in a roof space.

2.1.2 Ventilation

Gas or vapour released into the atmosphere can be diluted by dispersion or diffusion into the air until its concentration is below the LEL. Ventilation, i.e. air movement leading to replacement of the atmosphere in a (hypothetical) volume around the source of release by fresh air, will promote dispersion. Suitable ventilation rates can also avoid persistence of an explosive gas atmosphere thus influencing the type of zone.

Ventilation can be accomplished by the movement of air due to the wind and/or by temperature gradients or by artificial means such as fans. So two main types of ventilation are thus recognized:

- **Natural ventilation**
- **Artificial ventilation**, general or local

Natural ventilation
Natural ventilation is a type of ventilation which is accomplished by the movement of air caused by the wind and/or by temperature gradients. In open air situations, like the ones present in this study, natural ventilation results often sufficient to ensure dispersal of any explosive atmosphere which arises in the area.
The evaluation of ventilation has been conducted on the assumption of a minimum wind speed of 0,5 m/s present continuously (the wind speed will frequently be above 2 m/s).

Artificial ventilation
Artificial ventilation means that the air movement required for ventilation is provided by artificial means, for example fans or extractors. Due to the type and implementation of the installations considered in this study, it has not been taken into account in the present work.

The effectiveness of the ventilation in controlling dispersion and persistence of the explosive atmosphere will depend upon the **degree and availability of ventilation** and the design of the system. For example, ventilation may not be sufficient to prevent the formation of an explosive atmosphere but may be sufficient to avoid its persistence.

The following three **degrees of ventilation** are recognized:

- **High ventilation (VH)**: can reduce the concentration at the source of release virtually instantaneously, resulting in a concentration below the Lower Explosive Limit. A zone of small (even negligible) extent results.

- **Medium ventilation (VM)**: can control the concentration, resulting in a stable situation in which the concentration beyond the zone boundary is below the LEL whilst release is in progress and where the explosive atmosphere does not persist unduly after release has stopped. The extent and type of zone are limited to the design parameters.

- **Low ventilation (VL)**: cannot control the concentration whilst release is in progress and/or cannot prevent undue persistence of a flammable atmosphere after release has stopped.

As regards to the **availability of ventilation**, it is the other factor that needs to be taken into consideration when determining the type of zone, since it has an influence on the presence or formation of an explosive atmosphere. Three levels of availability of ventilation are recognized:

- **Good**: ventilation is present virtually continuously.

- **Fair**: ventilation is expected to be present during normal operation. Discontinuities are permitted provided they occur infrequently and for short periods.

- **Poor**: ventilation which does not meet the standard of fair or good, but discontinuities are not expected to occur for long periods.

The effect of ventilation on the type of zones has been considered in developing the zone classification of this study through the utilization of the following table present in EN 60079 *Electrical apparatus for explosive gas atmospheres*:

Grade of release	**Ventilation**						
	Degree						
	High			**Medium**			**Low**
	Availability						
	Good	**Fair**	**Poor**	**Good**	**Fair**	**Poor**	**Good, Fair or Poor**
Continuous	(Zone 0 NE) Non-hazardous[1]	(Zone 0 NE) Zone 2[1]	(Zone 0 NE) Zone 1[1]	Zone 0	Zone 0 + Zone 2	Zone 0 + Zone 1	Zone 0
Primary	(Zone 1 NE) Non-hazardous[1]	(Zone 1 NE) Zone 2[1]	(Zone 1 NE) Zone 2[1]	Zone 1	Zone 1 + Zone 2	Zone 1 + Zone 2	Zone 1 or Zone 0[3]
Secondary[2]	(Zone 2 NE) Non-hazardous[1]	Zone 2 NE Non-hazardous[1]	Zone 2	Zone 2	Zone 2	Zone 2	Zone 1 and even Zona 0[3]

(1) Zone 0 NE, 1 NE or 2 NE indicates a theoretical zone which would be of negligible extent under normal conditions.
(2) The zone 2 area created by a secondary grade of release may exceed that attributable to a primary or continuous grade of release; in which case, the greater distance should be taken.
(3) Will be zone 0 if the ventilation is so weak and the release is such that in practice an explosive atmosphere exists virtually continuously (i.e. approaching a "no ventilation" condition).

Note: "+" signifies "surrounded by".

Table 9: Influence of ventilation on type of zone [4]

2.2 ATEX equipment categories

2.2.1 Groups and Categories[3]

Directive 2014/34/EU (actualization of ATEX 100A) defines Groups and Categories for equipment, protective systems and components to be used in potentially explosive atmosphere. The definition of the Groups is given as follows:

- **Group I**: comprises equipment intended for use in the underground parts of mines, and to those parts of surface installations of such mines, likely to become endangered by firedamp and/or combustible dust.

- **Group II**: comprises equipment intended for use in other places likely to become endangered by explosive atmospheres.

The Groups are than sub-divided into Categories . For Group I, the categorization depends on (amongst other factors) whether the product is to be de-energized in the event of an explosive atmosphere occurring. For Group II, it depends where the product is intended to be used in and whether a potentially explosive atmosphere is always present or is likely to occur for a long or short period of time.

Categories of Group I will not be listed and described in this study, due to the nature of the plant in consideration not dealing with the mining sector, thus the reader can directly refer to Directive 2014/34/EU.
As regards Group II the following Categories are defined [3]:

- **Category 1**: comprises products designed to be capable of remaining within its operational parameters, stated by the manufacturer, and ensuring a very high level of protection for its intended use in areas in which explosive atmospheres caused by mixtures of air and gases, vapours or mists are **highly likely** to occur and are present continuously, for long periods of time or frequently.
  Equipment of this Category is characterized by integrated explosion protection measures functioning in such a way that:
    - in the event of a failure of one integrated measure, at least a second independent means of protection provides for a sufficient level of safety; or,
    - in the event of two faults occurring independently of each other a sufficient level of safety is ensured.

- **Category 2**: comprises products designed to be capable of remaining within their operational parameters, stated by the manufacturer, and based on a high level of protection for their intended use, in areas in which explosive atmospheres caused by mixtures of air and gases, vapours or mists are **likely** to occur.

The explosion protection relating to this Category must function in such a way as to provide a sufficient level of safety even in the event of equipment with operating faults or in dangerous operating conditions which normally have to be taken into account.

- **Category 3**: comprises products designed to be capable of keeping within its operational parameters, stated by the manufacturer, and based upon a normal level of protection for its intended use, considering areas in which explosive atmospheres caused by mixtures of air and gases, vapours or mists are **less likely** to occur and if they do occur, do so infrequently and for a short period of time only.
  The design of the products of this category must provide a sufficient level of safety during normal operation.

The association of each equipment, protective system or component to the relative classified ATEX zone have to be made according to the European Standard EN 1127 *Explosion Prevention and Protection*. This Directive provides the relation between categories and zones from the point of view of the producer of the equipment itself and from the point of view of the user of such equipment. In this study, only the second aspect will be taken into account, since the purpose is to give a guide for the employer to the right equipment implementation, after the ATEX zone classification has been performed as part of the Risk Assessment, prior to any start of the activities.

On this basis, the relation between Categories and Zones for users is provided in the following table taken from Standard EN 1127. In the table, the letter next to the Group indicates its **Class**, in particular the letter "G" specifies that the equipment has been designed for working in explosive atmospheres generated by the presence of gas. The letter "D" on the other hand, would indicate an equipment for intended use in explosive atmospheres generated by the presence of dust, not considered in this work.

ATEX Zone	Applicable category	Designed for
0	1G	gas/air mixture respectively vapour/air mixture respectively mist/air mixture
1	1G or 2G	gas/air mixture respectively vapour/air mixture respectively mist/air mixture
2	1G or 2G or 3G	gas/air mixture respectively vapour/air mixture respectively mist/air mixture

Table 10: Applicable equipment in different ATEX zones [5]

2.2.2 Temperature Classes

Equipment is classified in **Temperature Classes** according to the sensibility of a substance to be ignited when put in contact with an hot surface at a determined ambient temperature.
The following table reports the temperature classification for equipment belonging to Group IIG considering an ambient temperature of 40°C:

Temperature Class	Maximum Surface Temperature
T1	450°C
T2	300°C
T3	200°C
T4	135°C
T5	100°C
T6	85°C

Table 11: Temperature Classes for equipment belonging to Group IIG [6]

2.2.3 Subgroups

Equipment belonging to Group IIG undergo to an additional subdivision based on the Minimum Ignition Energy (MIE) relative to the one of methane (250 μJ) of the substance involved, in particular the following subgroups are defined:

Subgroup	Relative Minimum Ignition Energy (MIE)
IIA	rel. MIE > 0.8
IIB	0.45 < rel. MIE < 0.8
IIC	rel. MIE < 0.45

Table 12: Relative Minimum Ignition Energy Subgroups [6]

3 Case study – El Musel LNG regasification terminal

3.1 Determination of intended use (Functional / State-Analysis)

Natural gas proved to be the fossil fuel whose life cycle generates minor environmental impacts, the most suitable for the sustainable development of the actual society. This circumstance, with the necessity of covering the energetic demand with different kind of energy resources, led to the increase of natural gas utilization in Spain instead of coal or nuclear power. Spanish natural gas demand, in the last years, reached in this way an annual cumulative growth rate of 13% and it is expected that in the following years the contribution of natural gas to the total primary energy supply will reach the European one of 25% [7].
In order to natural gas market reach this degree of evolution it is necessary the development and implementation of new gas infrastructures that will increase gas entries in the system diminishing in this way the average gas paths up to the points of consumption and reinforcing, in turn, the capacity of storage the energetic resource for every necessity. In this context takes place the construction of the liquefied natural gas (LNG) regasification plant of El Musel, by Enagás, finalized in 2012 and located in Gijón, in the northern Spanish region of Asturias.

3.1.1 Description of the system

El Musel LNG terminal is actually in a state of hibernation, according to the Real Decreto Ley 13/2012, passed by the Spanish government in March 2012. The contract to develop the terminal was awarded to Enagás by the Spanish government in November 2006. The construction started in 2008 and finalized in 2012.
The fact that the plant was immediately mothballed after construction and has not been put in operation makes it particularly suitable for the purposes of this study of conducting a Risk Assessment prior to the possible recommissioning.

The regasification plant was designed to have, in its first construction phase, a capacity of storage of 300 000 m^3 of LNG, with two tanks of 150 000 m^3 each, and a capacity of emission of 800 000 m^3(n)/h equivalent to an annual emission of 7 bcm (billions of cubic meters, using the internationally used terminology).
The second phase, never realized, forecasted an extension by means of two more storage tanks of equal capacity as the first ones and an increase of emission rate of 400 000 m^3(n)/h up to a total of 1 200 000 m^3(n)/h (10,5 bcm) [7].

3.1.1.1 Description of plant aspect and configuration (location, atmospheric conditions, area, layout)

The port of El Musel, in Gijon, is the first bulk carrier port of the Spanish port system. It is located in the North of Spain, in the middle of the Cantabrian front and at East of Cabo de Peñas.

It’s an exterior port, untied from the urban area and located in the side of Cabo de Torres. This natural projection, together with the before mentioned Cabo de Peñas provides protection against the storms proceeding from the West and from the Northwest. The climate of the geographic area where the port is located has got temperate winters and summers, with heavy rainfall all over the year [8].

El Musel LNG terminal is located on an expanded area of El Musel Port of Gijón, between Dique Torres and Muelle Norte and occupies an approximate surface of 18 hectares.
Its emplacement in the Cantabrian basin will enable the reception of liquefied natural gas carriers proceeding from Norway and the natural gas injection in the high-pressure network connecting with three existing lines coming from Cantabria, Galicia and León.

For the placement of the regasification plant the following criteria have been taken into account [7]:

- Minimum impact on surrounding urban zones
- Presence of basic port infrastructures
- Proximity of electric infrastructures
- Proximity of water collection points

Considering these factors, the Gijón port resulted to be optimum for the regasification plant implementation, being located between the regasification plants of Bilbao and Ferrol, sufficiently far from the city itself and not requiring the exploitation and adjustment of additional land to this kind of installations.

The following picture (Fig. 3) shows the localization of the lands of the port extension where the plant was constructed from 2008:

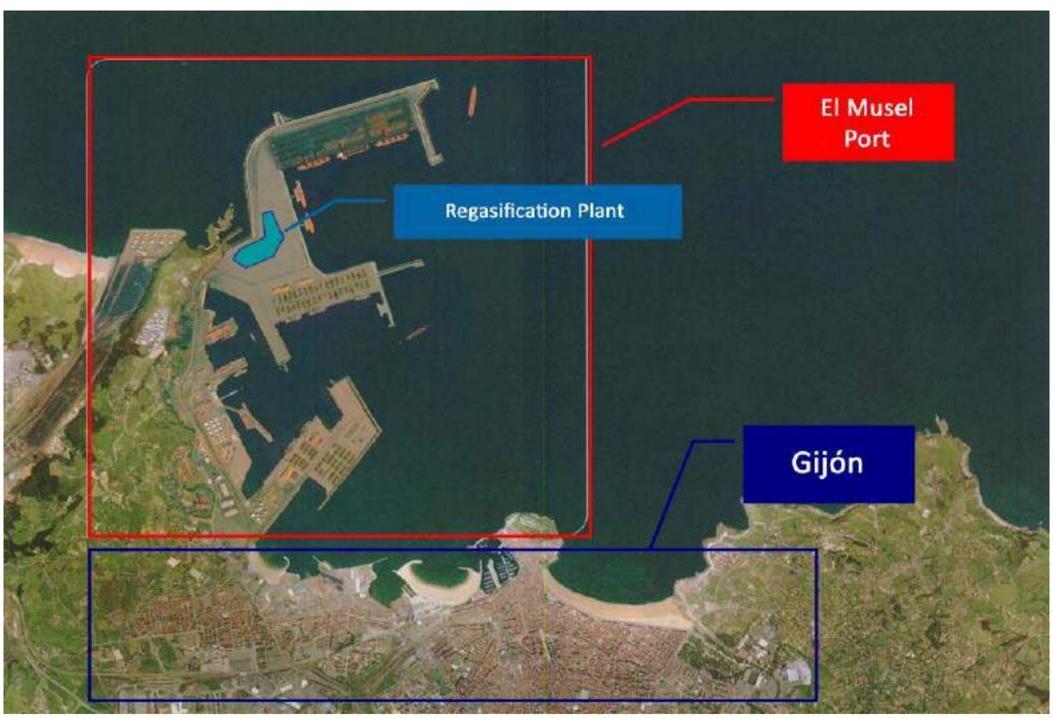

Figure 3: El Musel regasification plant localization [7]

3.1.1.2 Process Description [7]

The process consists of reception, storage and regasification of liquefied natural gas (LNG).
LNG carriers transport the liquefied natural gas from the producing countries up to the regasification plant, where the LNG is unloaded by means of arms present in the plant dock. The LNG is sent then to tanks of storage through a pumping system located on the carrier itself along cooled pipelines of large diameter.

During the transport, a part of the LNG vaporizes due to temperature changes and heat dissipations. This gas, called boil-off gas (BOG), together with the amount risen inside the tank, returns to the carrier passing through a liquid separator, so as to balance the pressure between the tanks and the carrier manifold.

The storage tanks are cryogenic, thermally isolated from the exterior. LNG is stored at approximately -160°C and slightly above the atmospheric pressure. Primary pumps are present immersed in the proper tanks, installed in wells on the bottom. They pump the LNG towards the secondary pumps located in the process zone. The last are those who provide to the LNG the necessary pressure for, once vaporized, its emission to the network. Both groups of pumps are lubricated and cooled by the LNG itself.

The vaporization of the LNG takes place in the Open Rack Vaporizers (ORVs), that is open vertical heat exchangers, where the natural gas circulates along a series of pipes and the seawater, proceeding from the pool of capture, slips on the outside of the pipes. The seawater used in the process of vaporization returns into the sea not suffering any more alteration than a decrease of temperature of some 8°C. To avoid the growth of microorganisms it has to be previously chlorinated and treated again at the end of the process before the devolution to the emissary.
There exists another type of vaporizers, called the Submerged Combustion Vaporizers (SCVs), where the heating fluid is a bath of water warmed by the combustion of part of the flowing natural gas. This type of vaporizers only works in case of fault or maintenance of the ORVs.

To supply LNG to places not reached by the natural gas high-pressure network two loading/unloading platform for LNG trucks are present to transport it to these points (30 trucks filled per day).

Before the injection in the network the natural gas passes through the measuring station and, to facilitate its detection in case of leakages, a small quantity of tetrahydrothiophene (THT) is added as an odorizing agent: this product is that one that provides to the natural gas its typical smell.

The BOG is sent by cryogenic compressors to the reliquefier, where is put in touch with the LNG coming from the primary pumps and condensed joining again the process. In this way its emission to the atmosphere is avoided and the costs of pumping it directly to the high-pressure network are considerably reduced.
In exceptional emergency situations, when the compressors and reliquefier system is not capable of absorbing all the BOG, the last is sent to a torch designed to safely burn the whole surplus of natural gas avoiding direct emissions to the atmosphere. As a last safety measure, in case of extreme emergency, there are safety valves that releases to the atmosphere.

Annex II shows a schematic and simplified flow diagram illustrating the functioning of the process, the principal equipment and the state of the substances involved.

Figure 4: El Musel LNG sotage tanks [9]

3.1.1.3 Equipment intended use [7]

Here follows a list of equipment and installations of the El Musel regasification plant system:

- Port dock allowing the unload of LNG carriers up to 266 000 m^3 of capacity: three unloading arms for liquid transfer and one for vapour devolution to the manifold.

- Two lines of LNG transfer from the carrier manifold to the storage tanks to assure the recirculation of the LNG along both lines for continuous cooling.

- Two storage tanks of 150 000 m^3 useful capacity each: total containment tanks constituted by an internal metallic tank (9% nickel steel) and an external tank of concrete with an internal coating isolating from LNG vapours. The annular space between the two tanks is filled with an isolating material (perlite) and mineral wool to amortize the differential deformations due to temperature changes. Also a bottom slab heating and an insulation system are present.
  The approximate dimensions are 80 meters of external diameter and 45 meters of height at the center of the dome.
  The storage tanks are designed for a differential pressure with the atmospheric one of approximately 15 - 290 mbar ranging the differential pressure of operation between 100 and 250 mbar.
  All the connections of entry and exit of liquid and gas to the tank pass across the dome as an essential safety measure. Spillages of LNG to the environment are avoided even in case of fault or “cold spot” zone occurring.

- LNG primary pumps: centrifugal multistage pumps with an unitary flow of the order of 300 m^3/h and a differential height of 180 meters of column of LNG.

- LNG secondary pumps: centrifugal multistage pumps with an unitary flow of the order of 350 m^3/h and a differential height of 1 600 meters of column of LNG.

- Open Rack Vaporizers (ORVs): four units of 200 000 m^3(n)/h unitary flow with a system of capture and devolution to an emissary of the seawater necessary for the process of thermal exchange (5 500 m^3/h of seawater).

- Submerged Combustion Vaporizers (SCVs): one unit of 200 000 m^3(n)/h unitary flow to be utilized in case of natural gas over demand by the high-pressure network or ORVs unavailability.

- Measuring station constituted by three lines with a potential rate of 400 000 m^3(n)/h each equipped with ultrasound measuring systems (an additional line was forecasted in the second construction phase).

- Reciprocating compressors of 10 000 kg/h unitary flow for BOG recovery.

- Reliquefier of minimum 500 m^3/h unitary flow of LNG for BOG reliquefaction and reincorporation to process.

Annex III shows the original general implementation plant of El Musel Regasification, with a table providing the indication of each equipment and installation on the map. At the time of construction, the placement was decided to be mirrored to the one reported, to the north of the two storage tanks.

3.1.1.4 Description of control system and protection equipment [10]

The regasification plant is provided with a Distributed Control System (DCS) based on the acquisition of field data from production equipment, controls, valves and measuring systems. These are function parameters like flow and mass rates, pressures, temperatures, power consumption data, gas compositions, concentrations, opening and closing of valves etc.
The DCS and its equipment in the Control Room constitute the center of the process control of the plant and allow the regulation of process parameters, the receiving of alarms and the adoption of the corresponding appropriate measures.

The DCS is connected with all the other systems of the plant: the Process Shutdown System (PSD) that proceed to the arrest of single units for process deviation reasons; the Emergency Shutdown System (ESD) that activates in case of irremediable accidents; the Local Control Panels (LCP) with which some of the mayor equipment and units are provided (tanks, compressors, pumps, vaporizers, unloading arms…); and the Fire and Gas System (F&GS).

The installations are provided with safety equipment and protection devices, notably: cryogenic torch of 150 000 kg/h unitary flow for safe natural gas releases combustion; LNG leakages collecting basins; top-entry valves with welded ends (minimum possible number of bridled connections, leaving only the necessary ones for maintenance); pressure safety valves, anti-vacuum valves, venting lines, bursting discs etc.

3.1.1.5 Flammability and explosive characteristics of the materials being handled

The main flammable compound present in the plant is natural gas. Its major components are lower paraffinic hydrocarbons, mainly methane and, in decreasing quantities, ethane, propane, butane etc. It could even contain other gases, like nitrogen, carbon dioxide, hydrogen sulfide, and water vapour.
Natural gas composition could be very different according to its origin, in the following table are reported some compositions of natural gases extracted in different parts of the world:

Natural gas composition								
Components %V Origin	**C_1**	**C_2**	**C_3**	**C_4**	**C_5 +**	**H_2S**	**CO_2**	**N_2**
Dachava-Siberia Russia	98.0	0.7	-	-	-	-	0.1	1.2
Hassi R'Mel Algeria	89.5	7.0	2.0	0.8	0.4	-	0.2	0.1
Slochteren Netherlands	81.9	2.7	0.4	0.1	0.1	-	0.8	14.0
Groningen Netherlands	81.3	2.8	0.3	0.1	0.1	traces	0.9	14.3
Zelten Libya	66.2	19.8	10.6	2.3	0.2	-	-	0.9
Kansas USA	67.6	6.2	3.2	1.3	0.5	-	0.1	21.1
Iran	73.0	21.5	-	-	-	5.5	-	-
Alberta Canada	90.0	-	8.0	-	-	1.0	0.5	0.2
Lacq France	69.5	2.8	0.8	0.6	0.9	15.6	9.7	-
Ekofisk Norway	85.2	8.6	2.9	0.9	0.2	traces	1.7	0.5
North Sea – South UK	95.0	2.8	0.5	0.1	0.1	traces	-	1.2
North Sea – North UK	78.8	10.1	5.7	2.2	1.4	traces	1.1	0.7

Table 13: Compositions of natural gases from different countries [10]

Methane (CH_4) is always the major component, in quantities varying from about 70 to 98% of the total volume of the mixture.

The gas is colorless, odorless, not toxic and highly flammable. It's lighter than air, the approximate relative density being about 0.64 according to composition. It disperses rapidly in air and does not provoke explosions in unconfined volumes.

In its liquid phase as Liquefied Natural Gas (LNG), it is held at a temperature of approximately -161°C occupying a volume some 600 times less than in gas form. It is stored in tanks with special isolation, at a pressure slightly above the atmospheric pressure.

The plant under study is also provided with and odorizing station for the injection of an organosulfur compound, tetrahydrothiophene ($(CH_2)_4S$, commonly known as THT), before natural gas injection in the high-pressure network.

LNG spillages are not pollutant, they evaporate quickly, especially when put in contact with water. They create clouds of cold vapour easily visible because they trap humidity drops. The evaporation doesn't leave residues on ground or water and the vapour starts its ascension when it warms at about -80°C [10].

LNG is a cryogenic liquid, and causes fractures and cracks to other not cryogenic materials. It is extremely dangerous for the skin as it causes cryogenic burns.

Here follow some natural gas physical data relevant to this study, the most varying according to the composition:

- **Lower Explosive Limit (LEL)**: 3.93 – 6.60 %
- **Upper Explosive Limit (UEL)**: 13.20 – 17.50 %
- **Relative density of gas or vapour to air**: 0.587 – 0.707
- **Density of liquid form at -161°C (LNG):** 423 – 485 kg/m^3
- **Boiling point at 1 bar**: -163°C
- **Molar mass (MM)**: 13.734 – 17.850 kg/kmol
- **Ignition temperature**: 482°C
- **Minimum ignition energy (MIE)**: 250 µJ
- **Group and temperature class**[1]: IIAT1

In Annex IV is reported a Material Safety Data Sheet of Liquefied Natural Gas providing all the physical and chemical characteristics together with the hazards identification and safety measures.

[1]For the specific definitions please refer to Section 2.2.

3.1.2 Classification of ATEX zones

As previously state in Section 2.1, Directive 99/92/EC (ATEX 137A) requires the employer to classify places where explosive atmospheres may occur into zones on the basis of the frequency and duration of the occurrence of explosive atmosphere.
The Standard EN 60079 *Electrical apparatus for explosive gas atmospheres* provides guidelines for the calculations to be performed and assumptions to be made for zone classification and determination of their extensions.

The classification leads to the compilation of an **Hazardous area classification data sheet**.
In the first part of this data sheet, all the flammable materials present in the system are listed together with their physical and explosive characteristics.
In the second part the sources of release are listed together with information on grade of release and degree and availability of ventilation, thus the type and extension of the zones classified is provided.

Annex V provides the Hazardous area classification data sheet resulting from the ATEX zone classification of El Musel LNG regasification terminal.

Results useful, then, indicating each type of zone on the layout map of the installation to allow a quick visualization of the dangerous areas. The indication have to be performed, for reasons of consistency, using the following preferred symbols reported in EN 60079:

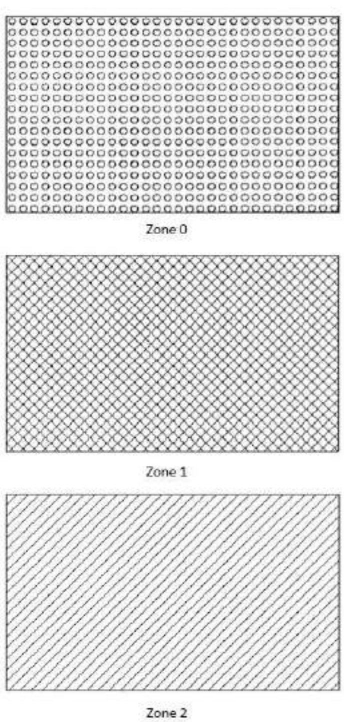

Figure 5: Preferred symbols for ATEX zones indication [4]

The ATEX zone classification and zones extensions on El Musel plant layout is shown in Annex VI.

3.1.3 Relation between categories and zones

The zone classification conducted following the guidelines present in EN 60079 *Electrical apparatus for explosive gas atmospheres* represents a method of analyzing and classifying the environment where explosive gas atmospheres may occur so as to facilitate the proper selection and installation of apparatus to be used safely in that environment.
The selection and installation of any equipment inside the ATEX classified zones of the regasification plant of El Musel should be conducted according to Directive 2014/34/EU (actualization of ATEX 100A) and, into the context of this study, following the definitions of Groups, Subgroups, Categories and Temperature classes provide in Section 2.2 of this paper.

3.2 Hazard Identification

Once the system has been fully described and the zone classification has been performed, it is necessary to focus attention on the occurrences that don't constitute part of normal operation, that is to find all the possible failures, deviations, errors, breakages that are not expected and not desired and may represent an hazard leading to the formation of an explosive atmosphere.
Thus, the next step of the Risk Assessment appearing in the RASE Project standard is Hazard Identification. What the RASE Project provides is only the definition of the purposes to be reached in this step. The way in which the hazards are identified is completely up to the performer of the Risk Assessment, and the same results can be reached with the adoption of different ways and techniques.

It's here reported again the draft of the Record of Hazard Identification provided in the RASE Project; all the single items present in it must necessary be estimated for the accomplishment of assessing the risk.

	Explosive atmosphere			**Ignition source**			
Ref.	Type	Frequency of occurrence or release	Location	Type	Cause	Likelihood	Effectiveness of ignition sources
1							
2							
etc.							

Table 14: Record of Hazard Identification [2]

What clearly emerges from this table is that the hazards to be found are not single events or occurrences, but they result from a combination of factors which are able together to create a possible danger.

The Hazard Identification stage is thus focused on two main components that have to be identified and described. They are:

- **Explosive atmosphere**: it must be determined the type, the frequency of release of the flammable substance that may be able to generate it and its location, that is the space in which it forms and may remain for a certain amount of time in a confined state.

- **Ignition source**: it must be determined its type, that is the origin of the energy generated, cause, likelihood to occur and, very important, its capability to represent or not a danger for starting the explosion.

For finding the hazards resulting from the combination of this two elements, many techniques can be adopted along the Risk Assessment. This study proposes here below a procedure to be followed and provides its specific application on El Musel Regasification plant.

3.2.1 Hazard and Operability Analysis (HAZOP)

Hazard and Operability Analysis (HAZOP) is a risk analysis technique that relies on a logical and schematic approach. Its purpose is to find possible deviations through the scanning of the process of a determined system.
The use of this technique needs a representation of the system working and functioning for being applied and bringing out concrete and practical results. For this reason, a P&ID (Process and Instrumentation Diagram) has been drawn for the system under study. The P&ID shows all the major equipment of the plant along with the regulation and control instrumentation. The components are connected with flow lines representing the materials involved in the process and their physical state. Each equipment is accompanied by a nomenclature which uniquely identify it for the performance of the analysis.
The P&ID of El Musel regasification plant is contained in Annex VII.

The conduction of HAZOP analysis as part of Hazard Identification has been developed following all the steps described as follows.

3.2.1.1 Nodes selection

The first activity performed has been the one of dividing the whole system into single nodes. This to better visualize each stage of the process carried out according to the functional unit in which it is performed.
A node can be practically defined a major vessel or a pipe section; the selection has been done according to the specific function executed by the node in the view of its contribution to the whole process. Each node has then been split into more nodes when necessary for a better classification and understanding.

The following nodes have been defined:

1) LNG transfer line from unloading dock (carrier manifold) to storage tanks
2) LNG secondary recirculation line
3) Vapour devolution line to carrier manifold
4) LNG storage tanks
5) Primary Pumping System
6) Boil-off gas (BOG) compressors
7) BOG Reliquefier
8) Secondary Pumping System
9) Open Rack Vaporizers
10) Seawater System
11) Submerged Combustion Vaporizer
12) Measuring station + odorizing station
13) Venting System to torch
14) LNG truck loading

A representation of nodes identification on the P&ID is shown in Annex VIII.

3.2.1.2 Selection of physical parameters and node intention

Once identified the nodes, their intention has to be clearly state. For doing this, first of all the different modes of operation of the whole system have to be describe.
In the analysis of the present work, two **modes of operation** of the regasification plant have been taken into account:

1) **Normal operation with LNG unloading from carriers**: LNG contained in carriers at the dock is being unloaded and transferred to the total containment storage tanks. The vapour generated during tanks filling is devolved to the carriers through the vapour line. Inside the storage tanks, the pressure is maintained relatively high (170 – 200 mbarg) for minimizing the formation of boil-off gas (BOG). During this operation mode BOG compressors reach their pick in workload.

2) **Normal operation without LNG unloading from carriers**: a small quantity of LNG is continuously recirculated along the unloading pipelines to keep them at cryogenic temperature. BOG formed during this operation mode is much less than during LNG unloading and so the pressure inside the two tanks can be maintained at around 160 mbarg.

Thus, the **intention** of each node inside the single operation mode has been defined. The intention refers to the operation ranges of physical parameters (flow, pressure, temperature, level…), that is the numerical ranges or limits that have to be respected by the node itself.

3.2.1.3 Deviations

The following step consists of developing deviations of the process conducted by the single node. A deviation can be identified by flanking a node intention with a specific **guideword** (MORE, LESS, NO, REVERSE…) and thus obtaining alterations of process parameters creating a dysfunction, for example "more pressure", "less level" etc.
The deviation generated has to be realistic and concerned with the function performed by the equipment.
Found a deviation, the analysis goes on searching for:

- a **cause** of the deviation, it means the events that led to a deviation of a parameter from its design intent: equipment failures, human errors, external events.
- the **safeguards** present in the system for detecting the deviation, preventing the possible consequences and mitigating the possible damages arising.
- the direct **consequences** of the deviations on the equipment, surrounding environment, people.

3.2.1.4 Explosion hazards identification

The last step undertaken in this work was, once all the previous points of the HAZOP analysis have been executed, to wonder for each deviation identified if it could represent an hazard related to the risk of explosion. In particular it has been examined if:

- the deviation, considering the failure of all safeguards, is able to lead to the formation of an **explosive atmosphere** and of which type.
- the deviation, considering the failure of all safeguards, is able to create an **ignition source** capable of ignite a possible present explosive atmosphere.

The full Hazard and Operability Analysis (HAZOP) conducted on the terminal of El Musel is reported in Annex VIII. The tables contain a list of all the realistic deviations found for each node of the system, with the last two columns reserved for the items to be assessed for the Hazard Identification in presence of explosive atmospheres. What emerges from the results is that this technique proved to be extremely effective on the detection of **explosive atmospheres**. In particular, with regard to this item, HAZOP was able to identify and provide information about:

- explosive atmosphere **type**: providing information on the physical state of the substance involved in a particular deviation of a certain process.
- explosive atmosphere **frequency of occurrence**: helping to the qualitative estimation of the frequency of occurrence of a certain explosive atmosphere on the basis of the number and nature of safeguards implemented to avoid a determined deviation.

- explosive atmosphere **location**: indicating the areas of the plant in which a certain deviation leading to the formation of an explosive atmosphere may occur.

- **quantity and characteristics of product and installation** involved in the formation of an explosive atmosphere, reporting the characteristics of the substance and the equipment in which it is processed when the triggering deviation occurs. This information in particular will be examined and utilized in the Severity Estimation stage of the Risk Assessment.

On the other hand, as proved from the results, HAZOP turn out to be much less effective on the detection and characterization of the ignition sources (see Annex VIII).

3.2.2 Check-list of possible ignition sources

3.2.2.1 Ignition source types

To deal with the second major component of Hazard Identification, that is the identification and characterization of the ignition sources, the RASE Project suggests the utilization of a check-list. Before going into the details of the procedure adopted in this work it is considered useful to provide a brief definition of all the possible types of ignition sources presented in the standard EN 1127 *Explosion Prevention and Protection* [5]:

Hot surfaces
If an explosive atmosphere comes into contact with a heated surface ignition can occur.
Not only can a hot surface itself act as an ignition source, but a dust layer or a combustible solid in contact with a hot surface and ignited by the hot surface can also act as an ignition source for an explosive atmosphere.
The capability of a heated surface to cause ignition depends on the type and concentration of the particular substance in the mixture with air. This capability becomes greater with increasing temperature and increasing surface area.
If the explosive atmosphere remains in contact with the hot surface for a relatively long time, preliminary reactions can occur, e.g. cool flames, so that more easily ignitable decomposition products are formed, which promote the ignition of the original atmospheres.

Flames and hot gases (including hot particles)
Flames, their hot reaction products or otherwise highly heated gases can ignite an explosive atmosphere. Flames, even very small ones, are among the most effective sources of ignition. If an explosive atmosphere is present inside as well as outside an equipment, protective system, or component or in adjacent parts of the installation and if ignition occurs in one of these places, the flame can spread to the other places through openings.

Mechanically generated sparks
As a result of friction, impact or abrasion processes such as grinding, particles can become separated from solid materials and become hot owing to the energy used in the separation process. If these particles consist of oxidisable substances, for example iron or steel, they can undergo an oxidation process, thus reaching even higher temperatures. These particles (sparks) can ignite combustible gases and vapours.

Electrical apparatus
In the case of electrical apparatus, electric sparks and hot surfaces can occur as sources of ignition. Electric sparks can be generated, e.g.:

a) when electric circuits are opened and closed.
b) by loose connections.
c) by stray currents.

It is pointed out explicitly in the standard that an extra low voltage (ELV, e.g. less than 50 V) is designed for personal protection against electric shock and is not a measure aimed at explosion protection. However, voltages lower than this can still produce sufficient energy to ignite an explosive atmosphere.

Stray electric currents, cathodic corrosion protection
Stray currents can flow in electrically conductive systems or parts of systems as:

a) return currents in power generating systems - especially in the vicinity of electric railways and large welding systems - when, for example, conductive electrical system components such as rails and cable sheathing laid underground lower the resistance of this return current path.
b) a result of a short-circuit or of a short-circuit to earth owing to faults in the electrical installations.
c) a result of magnetic induction (e.g. near electrical installations with high currents or radio frequencies.
d) a result of lightning.

If parts of a system able to carry stray currents are disconnected, connected or bridged - even in the case of slight potential differences - an explosive atmosphere can be ignited as a result of electric sparks and/or arcs, moreover, ignition can also occur due to the heating up of these current paths.

Static electricity
The discharge of charged, insulated conductive parts can easily lead to incendive sparks. With charged parts made of non-conductive materials, and these include most plastics as well as some other materials, brush discharges and, in special cases, during fast separation processes (e.g. films moving over rollers, drive belts), or by combination of conductive and non-conductive materials) propagating brush discharges are also possible. Cone discharges from bulk material and cloud discharges can also occur.

Lightning
If lightning strikes in an explosive atmosphere, ignition will always occur. Moreover, there is also a possibility of ignition due to the high temperature reached by lightning conductors.
Large currents flow from where the lightning strikes and these currents can produce sparks in the vicinity of the point of impact.
Even in the absence of lightning strikes, thunderstorms can cause high induced voltages in equipment, protective systems and components.

Radio frequency (RF) electromagnetic waves from 10^4 Hz to 3×10^{12} Hz
Electromagnetic waves are emitted by all systems that generate and use radio-frequency electrical energy (radio-frequency systems), e.g. radio transmitters or industrial or medical RF generators for heating, drying, hardening, welding, cutting. All conductive parts located in the radiation field function as receiving aerials.

If the field is powerful enough and if the receiving aerial is sufficiently large, these conductive parts can cause ignition in explosive atmospheres. The received radio-frequency power can, for example, make thin wires glow or generate sparks during the contact or interruption of conductive parts.

Electromagnetic waves from 3 x 10^{11} Hz to 3 x 10^{15} Hz

Radiation in this spectral range can – especially when focused – become a source of ignition through absorption by explosive atmospheres or solid surfaces. Sunlight, for example, can trigger an ignition if objects cause convergence of the radiation (e.g. bottles acting as lenses, concentrating reflectors).

Ionizing radiation

Ionizing radiation generated, for example, by X-ray tubes and radioactive substances can ignite explosive atmospheres (especially explosive atmospheres with dust particles) as a result of energy absorption.
Moreover, the radioactive source itself can heat up owing to internal absorption of radiation energy to such an extent that the minimum ignition temperature of the surrounding explosive atmosphere is exceeded.
Ionizing radiation can cause chemical decomposition or other reactions which can lead to the generation of highly reactive radicals or unstable chemical compounds. This can cause ignition.

Ultrasonics

In the use of ultrasonic sound waves, a large proportion of the energy emitted by the electroacoustic transducer is absorbed by solid or liquid substances. As a result, the substance exposed to ultrasonics warms up so that, in extreme cases, ignition may be induced.

Adiabatic compression and shock waves

In the case of adiabatic or nearly adiabatic compression and in shock waves, such high temperatures can occur that explosive atmospheres (and deposited dust) can be ignited. The temperature increase depends mainly on the pressure ratio, not on the pressure difference.

Exothermic reactions, including self-ignition of dusts

Exothermic reactions can act as an ignition source when the rate of heat generation exceeds the rate of heat loss to the surroundings. Many chemical reactions are exothermic. Whether a reaction can reach a high temperature is dependent, among other parameters, on the volume/surface ratio of the reacting system, the ambient temperature and the residence time. These high temperatures can lead to ignition of explosive atmospheres and also the initiation of smouldering and/or burning.

3.2.2.2 Check-list application

The system should be scanned and examined to find all the possible ignition sources present.
The application of a check-list for ignition sources identification as part of the procedure presented by this study follows the model suggested by the RASE Project. The check-list contains all the types of ignition sources present in the standard EN 1127 *Explosion Prevention and Protection* (ref. to previous section) and shows two columns:

- in the first column it needs to be state if the ignition source could be present in the system, that is if it is **relevant** to the performance of the Risk Assessment. This identification relies on the detailed knowledge of the equipment and installations present in the system and should be performed through:
  - visual inspection, as invasive within the equipment components as the presence of ignition sources is suspected
  - analysis of equipment technical data and design and study of their utilization modes and performances

- in the second column, the relevant ignition sources identified should then be considered with respect to their effectiveness to ignite a possible present explosion atmosphere.
  For doing this, the physical properties of the substances involved in the system should be taken into account: in particular, according to the ignition of an explosive atmosphere, the Ignition Temperature and the Minimum Ignition Energy of the substance (ref. to Sections 2.2.2 and 2.2.3).
  If, therefore, the ignition source has been considered **significant** for the Risk Assessment, the relating reasons should be stated in the column.

The draft of the check-list proposed by this study is here presented together with its corresponding application on El Musel regasification plant:

Ignition Sources			
Type	**Relevant**	**Significant**	
	(Yes/No)	(Yes/No)	Reason
Hot Surface	Yes	Yes	Heat produced by ATEX electric equipment with mobile parts such as bearings, shaft passages, glands by fault or lack of preventive maintenance. In particular: - multistage vertical axle cryogenic centrifugal pumps actuated by asynchronous electrical motors (primary and secondary pumping system) - two stages cryogenic alternative compressors actuated by asynchronous electrical motors (BOG compression system).
Flames and hot gases (including hot particles)	Yes	Yes	Carrying out of welding processes (enlargements, repairs, maintenances etc.) in noncompliance with Directive 92/58/EEC or Directive 2013/35/EU.
	Yes	Yes	Hot gases and hot particles derived from BOG combustion in the natural gas vaporizing system (Submerged Combustion Vaporizers).
Mechanically generated sparks	Yes	Yes	Carrying out of repair, maintenance, cleaning operations with improper instrumentation in noncompliance with Directive 92/58/EEC.
Electrical apparatus	Yes	Yes	Incident, fault or lack of preventive maintenance of the ATEX electrical equipment of the plant.
Stray electric currents, cathodic corrosion protection	No		
Static electricity:			Deterioration and/or lack of continuity of earthing and equipotential union of conductive parts (loose connections). Use of improper shoes, clothing, instrumentation during repair, maintenance, cleaning operations.
Corona discharges	Yes	Yes	Can provide sufficient energy.
Brush discharges	Yes	Yes	Can provide sufficient energy.
Propagating brush discharges	No		
Cone discharges	No		
Spark discharges	Yes	Yes	Can provide sufficient energy.
Lightning	Yes	Yes	Atmospheric phenomena. External installations.
Radio frequency (RF) electromagnetic waves from 10^4 Hz to 3 x 10^{12} Hz	No		
Electromagnetic waves from 3 x 10^{11} Hz to 3 x 10^{15} Hz	No		
Ionizing radiation	No		
Ultrasonics	No		
Adiabatic compression and shock waves	No		
Exothermic reactions	No		

Table 15: Check-list of possible ignition sources of El Musel Regasification

Check-lists are simple and easy-use techniques to be adopted for identification of hazards such as ignition sources of potentially explosive atmosphere. They adopt an empirical approach, relies on experience, and results very useful and time-saving when applied to similar equipment or installations because they allow a quick hazard identification without repeating the whole study conducted for their redaction every time.

As more and more ignition sources belonging to the same type are found, check-lists can increase their level of detail and may lead to the production of specific check-lists redacted for each ignition source type containing a series of question, requiring yes/no answers, to be utilized by operators at each stage in the life of equipment and unit operations. They may both relate to material properties or be equipment specific.
A detailed check-list on static electricity and electrical apparatus has been developed in this study for El Musel terminal and it's available in Annex XIII.

The whole Record of Hazard Identification of El Musel terminal is present together with the Risk Estimation, object of the following section, in Annex IX.

3.3 Risk Estimation

Once the Hazard Identification on the system into account has been completed, Risk Estimation, as previously said in Section 1.6, has to be carried out for each explosion hazard or every hazardous event identified.

3.3.1 Frequency Estimation

As regard the Risk Assessment in explosive atmospheres, two are the elements that need to be estimated in this stage: the frequency of occurrence of the possible explosion harm and the severity of that harm.

After the application of the techniques previously introduced (HAZOP and Check-list) all the elements composing the frequency of hazards have thus been estimated at this point, to recap they are:

- **Frequency of occurrence of explosive atmosphere**
- **Likelihood of the ignition source**
- **Effectiveness of the ignition source**

So that the total resulting frequency can be estimated in the way exposed in Section 1.6.1.

3.3.2 Severity Estimation

The severity of hazardous scenarios has been stated in Section 1.6.2 to be composed of two elements:

- **Quantity and characteristics of product and installation**: quantity of processed and stored product, physical and chemical characteristics of the product, proximity of buildings and presence of people.

- **Confinement and capacity of propagation**: confinement of explosive atmosphere, installation geometry and support structure, presence of protection systems.

For the first of this two items (**quantity and characteristics of product and installation**) indications have already been given by the application of HAZOP in Section 3.2.1 and will be discussed later.
Now the procedure goes on suggesting a technique to be used for estimating the second item (**confinement and capacity of propagation**).

3.3.2.1 Event Tree Analysis

Event Tree Analysis is a technique based on the construction of logical trees showing all the possible accidental sequences deriving from the occurrence of a certain event.
The steps that have been followed with the application of this technique inside this study are:

1) Selection of the events from which all the consequences that may cause possible damages originate. These are called the **Reference Initiating Events (RIE)**.

2) Identification of all **phenomena** (safeguards, materials changes of physical state, ignitions of explosive atmospheres…) that may occur from the RIE to the final caused damage.

3) **Construction of the trees** considering the occurrence or not of all the possible phenomena influencing the accident evolution.

4) Showing of all the possible **outcomes** deriving from the event trees.

The reference initiating events considered here for the Severity Estimation in relation to the plant into account are releases of LNG that could derive from some of the malfunctions and breakages detected in the Hazard Identification stage (HAZOP). In particular the following two RIEs has been taken into account and have been used in the trees construction:

- LNG non-pressurized release: LNG stored at about -163°C and atmospheric pressure taken as reference.

- LNG pressurized release: LNG stored at about -142°C and 4 bar taken as reference.

While all the defined phenomena whose occurrence may affect and influence the development of the RIEs are:

- **Drainage**: the major equipment of the plant that process big quantities of material are all provided with leakages collecting channels draining the liquids into collecting basins.

- **Direct ignition**: some kind of releases (especially the largest ones) can be ignited immediately because the cause or force needed to cause the release may also be capable of igniting the forming vapours.

- **Confinement**: the vapours generated by the release may disperse quickly or be confined by the surrounding equipment or structures. High degrees of confinement may lead the vapour concentration in air to reach the Lower Explosion Limit (LIE). A great role in this respect is played by ventilation (ref. to Section 2.1.2).

- **Delayed ignition**: once the explosive atmosphere is formed it may move until it reaches a good degree of confinement, depending also on its relative density to air. At this point a delayed ignition of the explosive atmosphere may occur.

The Event Tree Analysis conducted for this study as part of the Risk Assessment on El Musel regasification plant is fully showed in Annex X.

From developing the analysis, the following dangerous outcomes has been identified through the construction of the logical trees:

- **Cryogenic damage/injury**: every damage or injury against equipment, structures, people, animals or environment caused by the cryogenic temperature of LNG flowing.

- **Pool Fire**: Turbulent diffusion fire burning above an horizontal pool of vaporizing LNG formed by a liquid release.

- **Flash Fire**: a rapidly moving flame front deriving from the natural gas combustion (heat flux of approximately 80kW/m^2 for relatively short periods of time, typically less than 3 seconds).

- **Jet Fire**: turbulent diffusion flame resulting from the combustion of LNG continuously released with significant momentum in a particular direction.

- **Boiling Liquid Expanding Vapour Explosion (BLEVE)**: an explosion created by a rupture of a vessel in which LNG is stored or flowing under pressure, from which it releases quickly passing its boiling point and rapidly expanding.

- **Vapor Cloud Explosion (VCE)**: The explosion resulting from the ignition of a cloud of flammable natural gas vapour in which flame speeds accelerate to sufficiently high velocities to produce significant overpressure.

The utilization of Event Tree Analysis in the Severity Estimation resulted to be an useful tool for the qualitative estimation of **confinement and capacity of propagation**.
It allows to visualize all the possible dangerous scenarios deriving from a release of natural gas, in vapour or liquid form: vapour can be directly emitted (thus pruning part of the trees) or formed by LNG instantaneous evaporation.

From the HAZOP, we gained information about quantity, physical state and degree of pressurization of natural gas releases within a certain process (**quantity and characteristics of product and installation**) and thus we can select the RIEs. Moreover, we have information on the location of the possible explosive atmosphere and the installations involved, thus we can foresee all the probable scenarios that may arise from an hazard identified in an effective and visual way.

Specific additional trees may than be developed according to specific dangers more expected to occur or that occurred many times in the past dealing with a specific equipment or area.

Of course not all the scenarios identified concern exactly with a proper explosion, but, as they represent severe hazards for the health and safety of workers, their assessment of risk should be included in the explosion protection document.

3.3.3 Risk Level Estimation

Once both severity and frequency have been estimated, the final estimation of the risk has been performed trough the following matrix provided in the RASE Project and previously reported:

Risk levels	*Severity*			
Frequency of Occurrence	Catastrophic	Major	Minor	Negligible
Frequent	A	A	A	C
Probable	A	A	B	C
Occasional	A	B	B	D
Remote	A	B	C	D
Improbable	B	C	C	D

Table 16: Risk Level Matrix [2]

The risk levels represent a ranking of risk which enables an evaluation of what further actions are needed if any.
In particular **A** represents the highest risk level and **D** the lowest one.
In Annex IX the tables containing all the Risk Estimation items and the final risk levels are reported next to the Record of Hazard Identification.

3.3. Risk Evaluation

The tolerability or not of the hazards identified has been made according to the relative risk level coming out from Risk Assessmet; the detailed description of the meaning of each risk level is reported in Section 1.7.

Thus, all the hazards considered not tolerable have been ordered according to the magnitude of their risk level in Annex XI, together with options for reducing the risk associated to them, subject of the next section.

3.4 Risk Reduction Option Analysis

As previously said in Section 1.8, a Risk Reduction Option Analysis must be conducted for each of the identified risk level not considered acceptable once the final risk has been determined. The target of this step is to find options for risk reduction adequate and sufficient so that each risk will result tolerable.

According to the RASE Project standard, the user may need to consider how much the safety of a design improves, if a particular safety feature is included, that is to properly take into account the effectiveness of the various options.
In general the removal of an hazard is more effective than safeguarding it, which in turn is more effective than use of personal protective equipment or safe systems of work. The reliability of any safeguard also needs to be taken into account, in particular any incentives for them to be defeated or circumvented. Moreover, the expected lifetime of the safeguard must match that of the equipment and it must be guaranteed the monitoring and replacement of components which will wear out [2].

Solutions may regard plant design, protection systems, personal protective equipment, organizational and logistical measures. Obviously it should be performed an analysis for comparing the cost effectiveness of the various options, taking into account the capital costs and the operational and maintenance costs also in relation to the expected lifetime of the hazard. For example, a more reliable piece of equipment often has lower maintenance and operational costs as well as being more productive, but in the situation where an hazard may only exist for a short period, a safeguard designed to exist continuously may be inappropriate and also expensive.

In the context of risk reduction, the European Standard EN 1127 *Explosion Prevention and Protection* provides:

- Requirements for the design and construction of equipment, protective systems and components by avoidance of effective ignition sources
- Requirements for the design and construction of equipment, protective systems and components to reduce the explosion effects
- Provisions for emergency measures
- Principles of measuring and control systems for explosion prevention and protection

After all measures have been taken to reduce the probability and consequence of a specific hazardous event, it's also necessary to deal with residual risks. Residual risks are those against which Risk Reduction by design and safeguarding techniques are not, or not totally, effective. The users must be informed about residual risks. Instructions and warnings shall, for example, prescribe the operating modes and procedures to overcome the relevant hazards [2].

The measures adopted should always give priority to eliminate or limit the presence of explosive atmosphere avoiding the mixture of flammable substances with air.
In case this doesn't result to be possible, the measures will be conducted towards the avoidance of ignition of the explosive atmosphere limiting the presence of effective ignition sources.
Only as a last recourse, when it result to be impossible to avoid the presence of effective ignition sources in zones where it is possible the formation of explosive atmospheres potentially dangerous, the measures for protection against explosion, in addition to those of prevention, will be taken into account.

The measures for reducing the risk of explosion applied on El Musel terminal can mainly be classified in two major groups: technical measures and organizational measures.

3.4.1 Technical risk reduction options

3.4.1.1 Avoidance of formation of explosive atmosphere

Among the adoptable measures for avoiding the occurrence of an **explosive atmosphere** potentially dangerous can be listed:

- Utilization of nonflammable substances whenever is possible along the process conducted
- Keeping the quantity and concentration of flammable substances at the lowest possible limits
- Inert gases injection
- Isolation and closure of possible sources of release, especially near installations or working equipment
- Presence of manual override in order to shut down the equipment in case of deviation from the intended operating conditions
- Installation of redundant gas detectors (2oo3 to avoid false alarms) set up as follows:
    - early warning: at concentration equal to 25% of flammable substance LEL
    - alarm: at concentration equal to 50% of flammable substance LEL (activation of ESD, F&G)
- Installation of Open Path gas detectors: detection of flammable substance gases in big areas through transmitters and receptors
- Temperature detectors for LNG leakages (cryogenic temperature)

3.4.1.2 Avoidance of appearance of ignition sources

As regards the prevention of appearance of possible **ignition sources**, all the electrical and nonelectrical equipment should be:

- Placed and put in operation in ATEX zones according to Groups, Categories and Temperature Classes (ref. to Section 2.2).
- Installed according to the instructions given by the manufacturer and the equipment proper EC declaration of conformity according to ATEX 100A (ref. to Directive 2014/34/EU).
- Be brought into service if the explosion protection document indicates that it can be safely used in an explosive atmosphere.
- Protected by the appropriate lightning protection measures (overvoltage protection systems, earth ring electrode systems).

3.4.1.3 Mitigation of explosion

If the measures for the prevention of occurrence of explosive atmospheres and effective sources of ignition cannot be implemented or are not pertinent, measures should be adopted in order to **mitigate** the hazardous effects of explosions inside equipment, protective systems and components.
Technical measures for this purpose may regard:

- Explosion-resistant design
- Explosion relief
- Explosion suppression
- Prevention of flame and explosion propagation

In any case the abovementioned mitigation measures, also the structural ones, have to be chosen and installed according to the ATEX 100A directive (2014/34/EU).

3.4.1.4 Active protection against fire – firefighting system (F&G)

It must be assured water supply for firefighting in adequate quantity and pressure. Water supply includes both water pumps of sufficient capacity and water supply network reaching all the points of the plant if any accident is detected.
For fire-fighting it can be used seawater or industrial water. Industrial water should be considered as a first remedy, being less corrosive, and seawater as a second option.
Inside the firefighting water station there should be present two water pumping systems with independent sources of supply (electric and diesel), each one provided with the total amount of water for firefighting, in case of fault of one of the two systems.

The dimensioning of the firefighting system in all its components should be performed taking into account the worst scenarios deriving from the Risk Assessment for each area of the plant according to the equipment, processes and substances involved.

The fire detection and fire-fighting systems should include:

- Flame detectors
- Smoke detectors
- Hydrants and fireplugs
- Refrigeration system: cooling of surfaces exposed to fire through water injection
- Water curtains: increasing LNG evaporation and allowing vapour clouds dispersion
- Foam generators for flames suppression
- Dry powder system for fire extinction

An example of technical measures adoption for risk reduction is showed in Annex XII. Two Event Trees have been built for pressurized and non-pressurized LNG releases occurring in the plant under study; through the trees construction it is effectively shown the influence of all the technical reduction measures adopted on the developing of the different dangerous scenarios. More will be the measures adopted for reducing the risk and more complex and articulated will be the construction of the trees, thus diminishing the probability of occurrence of the hazardous event.

3.4.2 Organizational risk reduction options

When in a workplace it resulted not possible to eliminate completely the potential risk of an explosion by the adoption of technical measures, it will be necessary to incorporate additional measures regarding work organization.
These organizational measures must establish the way in which activities are performed inside areas with risk of explosion so that the safety and health of workers is guaranteed.

3.4.2.1 Permit to work

Specific written instruction will be provided if inside or in proximity of an area of risk activities will be conducted which may cause an explosion due to:

- they are realized inside an ATEX zone
- they use to generate ignition sources
- they could produce an explosive atmosphere

Such activities should be considered as “Special Works” and it is necessary the redaction of a **permit to work** for their execution. This permit to work will be issued by a person with responsibility for this function prior to the commencement of work.

In the permit to work should be stated:

- Exact location of the works to be executed by the company
- Clear explanation of the works to be executed
- Risks assessed regarding the area of interest
- Necessary precautions to be adopted
- Necessary personal protection equipment
- Planned starting and ending of the works
- Report of previous inspections of the area for which the permit to work is required

For the specific purpose of permit to work, the Standard EN 1127 clearly distinguish two types of tools to be used inside the ATEX zones:

- **a**: tools which can only cause single sparks when they are used (e.g. screw-drivers, spanners, impact screw-drivers).

- **b**: tools which generate a shower of sparks when used during sawing or grinding.

According to the above standard, in zone 0 no tools which can cause sparks should be allowed.
In zones 1 and 2, only steel tools according to (a) should be allowed.
Tools according to (b) should only be permissible if no hazardous explosive atmosphere is present at the workplace. The use of these tools in zones 1 and 2 should, in any case, be subject to a permit to work.

3.4.2.2 Inspection and maintenance of equipment

In addition to the **inspection** of equipment and installations to be performed before the starting of operations, in which it must be verified the realization conforming to the contents of the explosion protection document, the installations must be periodically and regularly inspected.

From the point of view of the inspection executions, inspections are classified in three grades:

- **visual**: inspection that allows to identify evident faults, without the use of tools or access equipment.

- **close**: inspection that allows to identify faults with the use of tools or access equipment but avoiding enclosures opening or equipment disconnections.

- **detailed**: inspection that allows to identify faults requiring the enclosures opening and equipment disconnections for testing.

The time period between subsequent inspections should be adjusted on the basis of the lifetime of equipment and the anomalies detected at each inspection, according to the principles contained in Standard EN 60079-17 *Explosive atmospheres. Electrical installations inspection and maintenance*.
Sample random inspections should be conducted for the evaluation of the proposed inspection frequency and inspection grade.
Therefore, it should be established an inspection plan in which the general preventive program of maintenance of the plant will be included. A register of all the executed inspections should be kept.

Check-lists represent often the most effective and useful tool for performing inspections. As already mentioned in Section 3.2.2.2 they are easy-use and allow to save time and avoid neglecting any element or aspect for a complete and exhaustive inspection. They also result very effective when used to stimulate thought and enquiry through open ended questions rather than in the form that requires yes/no answers.

For the specific application on El Musel terminal, a detailed check-list regarding static electricity and electrical apparatus has been developed to be used as an inspection tool by operators in the pertinent areas of the plant. It can be found in Annex XIII.

As regards **maintenance,** for equipment fitted with the EC declaration of conformity it should be performed strictly complying with the indications contained in the manual of installation, utilization, maintenance and repair provided by the manufacturer.
Maintenance should be performed by specialized operators, adequately prepared and trained on the equipment intended use, performance, installation and protection modes, and with a proper knowledge of the related technical standards.

As a general rule, any substitution of elements regarding the safety of the equipment should be performed through the utilization of identical original components, and the equipment should than be tested for safe working following the same procedure of a new one.

3.4.2.3 Formation and training of workers on protection against explosion

Directive ATEX 137A states that the employer must provide those operators working in places where explosive atmospheres may occur with sufficient and appropriate training with regard to explosion protection.
Formation and training for workers should include:

- Formation on the existing explosion risks over working zones and corresponding safety measures adopted
- Explanation of characteristics and functioning of protection measures
- Training on correct handling of equipment for conduction of safe activities in areas with risk of explosion and their proximity
- Formation on personal protective equipment to be used at work
- Knowledge and training on the emergency plan of the plant

As regards this last step, to improve the safety of workers inside the LNG plant under study, all personnel must be provided with a basic **personal protection equipment**. Additional safety equipment will then be requested for specific working actions (eye and acoustic protection, specific gloves and working clothes…). Areas in which specific additional equipment is required must be clearly marked.
All the protection equipment must always be maintained in a good state.
The **emergency plan** must be decided prior to the start of any operation. This should state a procedure to face emergencies defining the organization structure of the plant, the obligations and responsibilities of the single figures, communication and cooperation with the official authorities and bodies and an the personnel evacuation plan.
Where required by the explosion protection document, escape facilities must be provided and maintained to ensure that, in the event of danger, workers can leave endangered places promptly and safely.

3.4.2.4 Documentation

The **explosion protection document** should be revised and actualized whenever it verifies any of the following cases concerning the plant:

- Putting into service of new equipment
- Utilization of new substances or products
- Application of new technologies or production processes
- Changes in working areas
- Occurrence of any accident or damage to the health of workers related to the explosion risk
- Introduction of new dispositions regarding safety or health of workers

Moreover the following **documentation** should always be available and actualized:

- Register of the changes conducted on the explosion protection document
- Register of the accidents occurred in the plant
- Material safety data sheet of all the substances present and involved in the plant processes
- Emergency plan description

3.4.2.5 Signaling and marking of zones at risk of explosion

According to EU Directives 99/92/EC (ATEX 137A) and 2014/34/EU (actualization of ATEX 100A) it must be signalized any access to zones with risk of formation of explosive atmospheres dangerous for the safety and health of workers through the following warning sign:

Figure 6: Place where explosive atmospheres may occur [1]

The warning sign above must have the following distinctive features:

- Triangular shape
- Black letters on a yellow background with black edging (the yellow part to take up at least 50 % of the area of the sign)

In Annex XI it's present a table in which some reduction options have been proposed for the hazards identified in the Risk Assessment of El Musel terminal that have been considered not acceptable. The hazardous scenarios have been listed on the basis of their risk level. Together with the proposed risk reduction options also a series of safety measures to be adopted have been reported according to EN 1127 *Explosion Prevention and Protection.*
A certain explosive atmosphere hazard in a certain location of the plant can appear many times in the list associated with different risk levels, being related each time to a different type of ignition source whose characteristics contribute to the determination of the different levels.

Conclusions

This study proposed a procedure for the conduction of a Risk Assessment on equipment and installations involved with the possibility of formation of explosive atmospheres.

The object of the study took place within the context of the European Directive 99/92/EC (ATEX 137A for installations, workplaces). This directive requires the employer to draw up an explosion protection document, or set of documents, which includes the identification of the hazards, the evaluation of the risks and the definition of the specific measures to be taken to safeguard the health and safety of workers at risk from explosive atmospheres.

It results clear that for the redaction of a compliant explosion protection document a Risk Assessment have to be conducted. In 2000, the RASE Project – "Explosive Atmosphere: Risk Assessment of Unit Operations and Equipment", a joint industry / European Commission project, developed a draft of methodology for conducting the Risk Assessment with regards to the risk derived from explosion.

The RASE Project, however, provides only general indications about the workflow to be followed along the Risk Assessment and the overall steps to be fulfilled. This study explained the guidelines given by the RASE Project and the content of each of the methodology steps of Risk Assessment in detail. Moreover, it integrated this methodology proposing a series of techniques to be utilized for the estimation of all the components taking part to the assessment of the risk of explosion.

The result of this study is therefore the developing of a detailed procedure that can be utilized by employers for conducting a qualitative Risk Assessment for the specific purpose of redacting an explosion protection document.
A demonstration of the application of this procedure and its effectiveness is provided through the carrying out of a Risk Assessment on a liquefied natural gas (LNG) regasification terminal actually waiting to be put in operation. The LNG terminal chosen is the one of El Musel and it is located in Gijón, Spain.

As first, this study proposed an approach for describing the system into account for the conduction of the Risk Assessment. The outline of the plant starts describing the system intended use, processes involved, equipment and installations present, and follows with the classification of the different zones at risk of explosion (ATEX zones) and the association of equipment to each zone according to ATEX Groups and Categories.

In the second step of Risk Assessment a procedure for the explosion hazards identification was provided. An Hazard and Operability Analysis (HAZOP) was conducted on the process of the LNG terminal. The HAZOP resulted to be extremely effective on the detection of the possible presence of explosive atmospheres and in particular on their type, frequency of occurrence and location. It resulted also able to provide information about the quantity and characteristics of product and installations involved with the formation of explosive atmospheres, but much less effective on the detection of possible ignition sources present in the system.
For the detection of ignition sources, an example of Check-list is proposed. It is explained how the Check-list has to be structured and utilized and its relative application on the identification of the different types of ignition sources present in the plant under study.

The next step of the Risk Assessment dealt with the Risk Estimation, that is the estimation of frequency of occurrence and severity of the possible explosion harm. In this stage, an Event Tree Analysis was carried out to show all the possible dangerous outcomes deriving from releases of LNG along the process. The use of this technique was introduced inside the estimation of the severity of the potential risk, and resulted useful in the evaluation of the confinement and capacity of propagation of the explosive atmosphere.

Therefore, a procedure for the qualitative estimation of the risk was proposed based upon the utilization of matrices correlating respectively frequency of occurrence and severity of the identified hazardous scenarios, and leading to the determination of levels of magnitude of the risk.

In the last part of the Risk Assessment, a series of options for reducing the risk to acceptable levels were proposed associated with the hazards identified in the plant under study and also a series of safety measures to be adopted in the light of the evaluated risk were suggested.

The effectiveness of the procedure presented in this study was demonstrated by the concreteness of the results obtained. The hazards identified relating to the risk of explosion are realistic and reflect the possible dangerous occurrences that could really happen and are most taken into account in the regasification terminals areas considered most critical with regard to safety.

In particular, in the case of some of the techniques introduced in this procedure (HAZOP, Check-list, Event Tree) have to be used anyway by the employer for any other purpose relating to the risk analysis of equipment and installations, this study provides indications on how to exploit their use for the redaction of an explosion protection document, which is in every case required and mandatory to have when the plant or process deals with the risk of explosion.

The Risk Assessment procedure developed turns out to be systematic and easy to use. It is particularly suitable when a quick and qualitative assessing of the risk is required and it provides reliable results without the involvement of complex calculations. It can thus be used directly and effectively by the employers for assessing the risk in presence of explosive atmospheres.

Bibliography

[1] Directive 1992/92/EC of the European Parliament and of the Council of 16 December 1999 on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres

[2] The RASE project (Risk Assessment of Unit Operations and Equipment) is a joint industry / EU Commission project carried out under Contract No: SMT4-CT97- 2169. The project is coordinated by INBUREX in Germany with the participation of FSA, INERIS, HSE, NIRO and CMR

[3] Directive 94/9/ EC of the European Parliament and of the Council of 23 March 1994 on the approximation of the laws of the member states concerning equipment and protective systems intended for use in potentially explosive atmospheres

[4] European Standard EN 60079-10 Electrical apparatus for explosive gas atmospheres: 1996-10

[5] European Standard EN 1127-1 Explosion Prevention and Protection: 2007

[6] Francesc Escuer Ibars, Javier Garcia Torrent, Manuál practico para la clasificación de zonas en atmósferas explosivas, Colegio de Ingenieros Técnicos Industriales de Barcelona, Barcelona, 2005

[7] Planta de regasificación de gas natural licuado de El Musel, Memoria Resumen. Enagás, April 2006

[8] Tecno, Revista Interna de Formación e Innovación. OHL, number 75, June 2010

[9] http://www.enagas.es/enagas/es/Transporte_de_gas/PlantasRegasificacion/El_Musel

[10] Ignacio Martínez Díaz, Manual de plantas de regasificación, Barcelona, SEDIGAS, 2009

ANNEX I

Definitions

Annex I

Definitions

For the exposure purposes of this study, it is considered to be useful to provide the following definitions according to the RASE Project standard, and the standards EN 1127 *Explosion Prevention and Protection* and EN 60079 *Electrical apparatus for explosive gas atmospheres*:

Boiling point: the temperature of a liquid boiling at an ambient pressure of 101,3 kPa (1013 mbar).
For liquid mixtures, the initial boiling point should be used. Initial boiling point is used for liquid mixtures to indicate the lowest value of the boiling point for the range of liquids present, as determined in a standard laboratory distillation without fractionation.

Explosive gas atmosphere: a mixture with air, under atmospheric conditions, of a flammable material in the form of gas or vapour in which, after ignition, combustion spreads throughout the unconsumed mixture. *Although a mixture which has a concentration above the upper explosive limit (UEL) is not an explosive gas atmosphere, it can readily become so and, in certain cases for area classification purposes, it is advisable to consider it as an explosive gas atmosphere.*

Flammable gas or vapour: gas or vapour which, when mixed with air in certain proportions, will form an explosive gas atmosphere.

Flammable liquid: a liquid capable of producing a flammable vapour under any foreseeable operating conditions.

Flammable material: a material which is flammable of itself, or is capable of producing a flammable gas, vapour or mist.

Flammable mist: droplets of flammable liquid, dispersed in air so as to form an explosive atmosphere.

Flashpoint: the lowest liquid temperature at which, under certain standardized conditions, a liquid gives off vapours in a quantity such as to be capable of forming an ignitable vapour/air mixture.

Grades of release[2]: There are three basic grades of release, as listed below in order of decreasing likelihood of the explosive gas atmosphere being present:
A source of release may give rise to any one of these grades of release, or to a combination of more than one.
a) continuous grade
b) primary grade
c) secondary grade

[2]Detailed definitions are provided in Section 2.1.

Hazard Identification: A systematic procedure for finding all of the hazards which are associated with the unit operations and equipment. The process of determining what, why and how things can happen.

Hazardous area: an area in which an explosive gas atmosphere is present, or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of apparatus.

Ignition temperature of an explosive gas atmosphere: the lowest temperature of a heated surface at which, under specified conditions, the ignition of a flammable substance in the form of a gas or vapour mixture with air will occur.

Intended use: The use of equipment, protective systems, and devices in accordance with the equipment group and category and with all the information supplied by the manufacturer which is required for the safe functioning of equipment, protective systems and devices.

Lower Explosive Limit (LEL): the concentration of flammable gas or vapour in air, below which the gas atmosphere is not explosive.

Minimum Ignition Energy (MIE): the minimum energy that, by a discharge, starts the explosion of a mixture of gas or dust in air.

Non-hazardous area: an area in which an explosive gas atmosphere is not expected to be present in quantities such as to require special precautions for the construction, installation and use of apparatus.

Normal operation: the situation when the equipment is operating within its design parameters.
Minor releases of flammable material may be part of normal operation. For example, releases from seals which rely on wetting by the fluid which is being pumped are considered to be minor releases.
Failures (such as the breakdown of pump seals, flange gaskets or spillages caused by accidents) which involve urgent repair or shut-down are not considered to be part of normal operation.

Relative density of a gas or a vapour: the density of a gas or a vapour relative to the density of air at the same pressure and at the same temperature (air is equal to 1,0).

Release rate: the quantity of flammable gas or vapour emitted per unit time from the source of release.

Residual Risk: The remaining level of risk after all actions have been taken to reduce the probability and consequence of risk.

Risk Assessment: A series of logical steps to enable, in a systematic way, the examination of the hazards associated with unit operations and equipment.
Risk Estimation: Determination of the frequency at which the identified hazards could be realized and give rise to specified levels of severity.

Risk Evaluation: Comparison of the risk estimated with criteria in order to decide whether the risk is acceptable or whether the unit operations and/or equipment design must be modified in order to reduce the risk.

Risk Management: The systematic application of management policies, procedures and practices to the tasks of identifying, analyzing, monitoring and controlling risk.

Risk Reduction Option Analysis: The final step of Risk Assessment is the process of identifying, selecting and modifying design changes which might reduce the overall risk from unit operations and equipment.

Risk: Function of Severity (elements: possible harm for the considered explosion hazard) and Probability of occurrence of that harm (elements: frequency and duration of exposure, probability of occurrence of hazardous event, possibility to avoid or limit the harm).

Source of release: a point or location from which a flammable gas, vapour, or liquid may be released into the atmosphere such that an explosive gas atmosphere could be formed.

Upper Explosive Limit (UEL): the concentration of flammable gas or vapour in air, above which the gas atmosphere is not explosive.
For the purpose of this study, the terms "explosive" and "flammable" should be considered synonymous.

Vapour pressure: the pressure exerted when a solid or liquid is in equilibrium with its own vapour. It is a function of the substance and of the temperature.

Ventilation: movement of air and its replacement with fresh air due to the effects of wind, temperature gradients, or artificial means (for example fans or extractors).

Zones[3]: hazardous areas are classified into zones based upon the frequency of the occurrence and duration of an explosive atmospheres.

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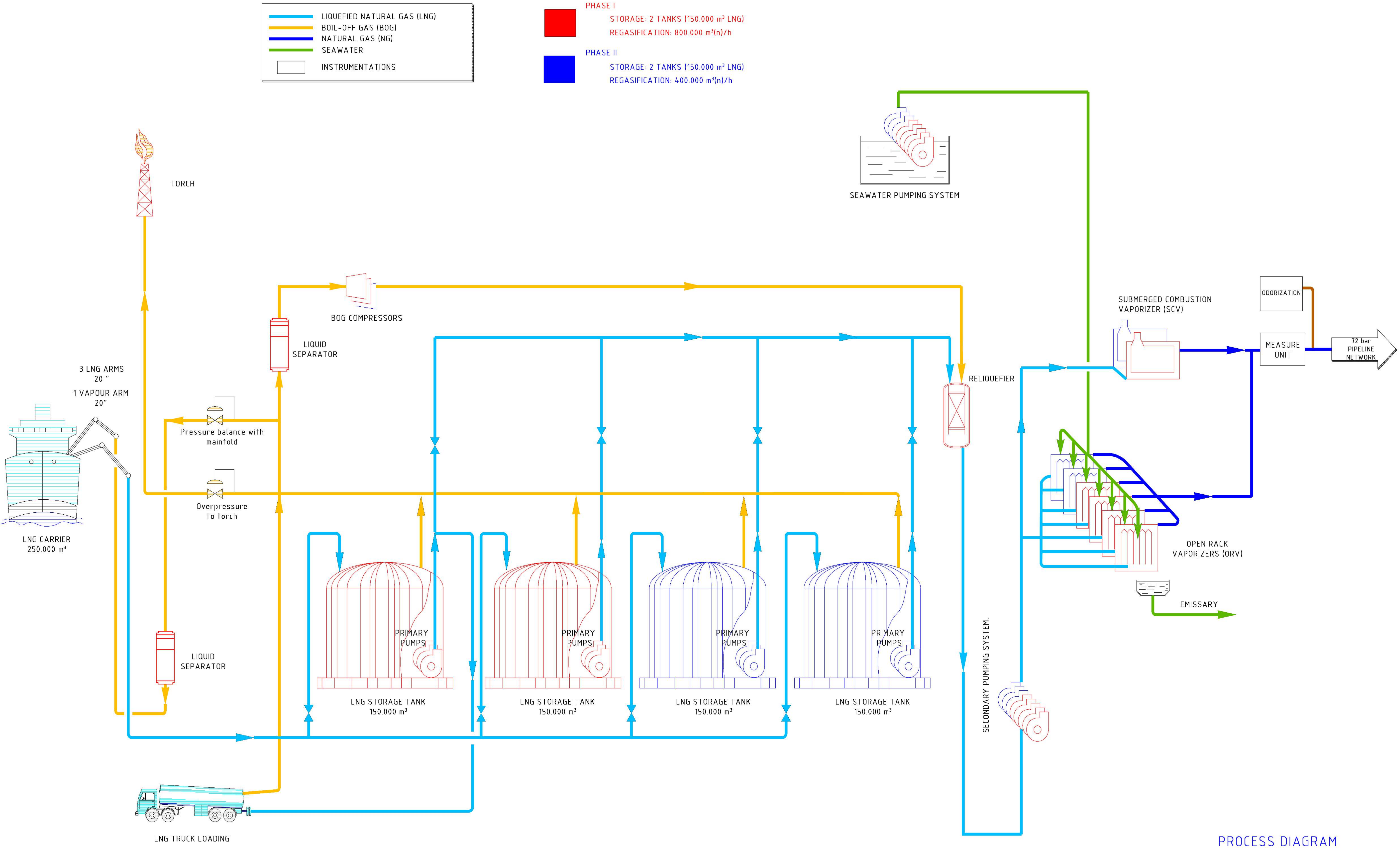
[3]Detailed definitions are provided in Section 2.1.

ANNEX II

El Musel Regasification simplified process flow diagram



PROCESS DIAGRAM

EL MUSEL REGASIFICATIONPLANT

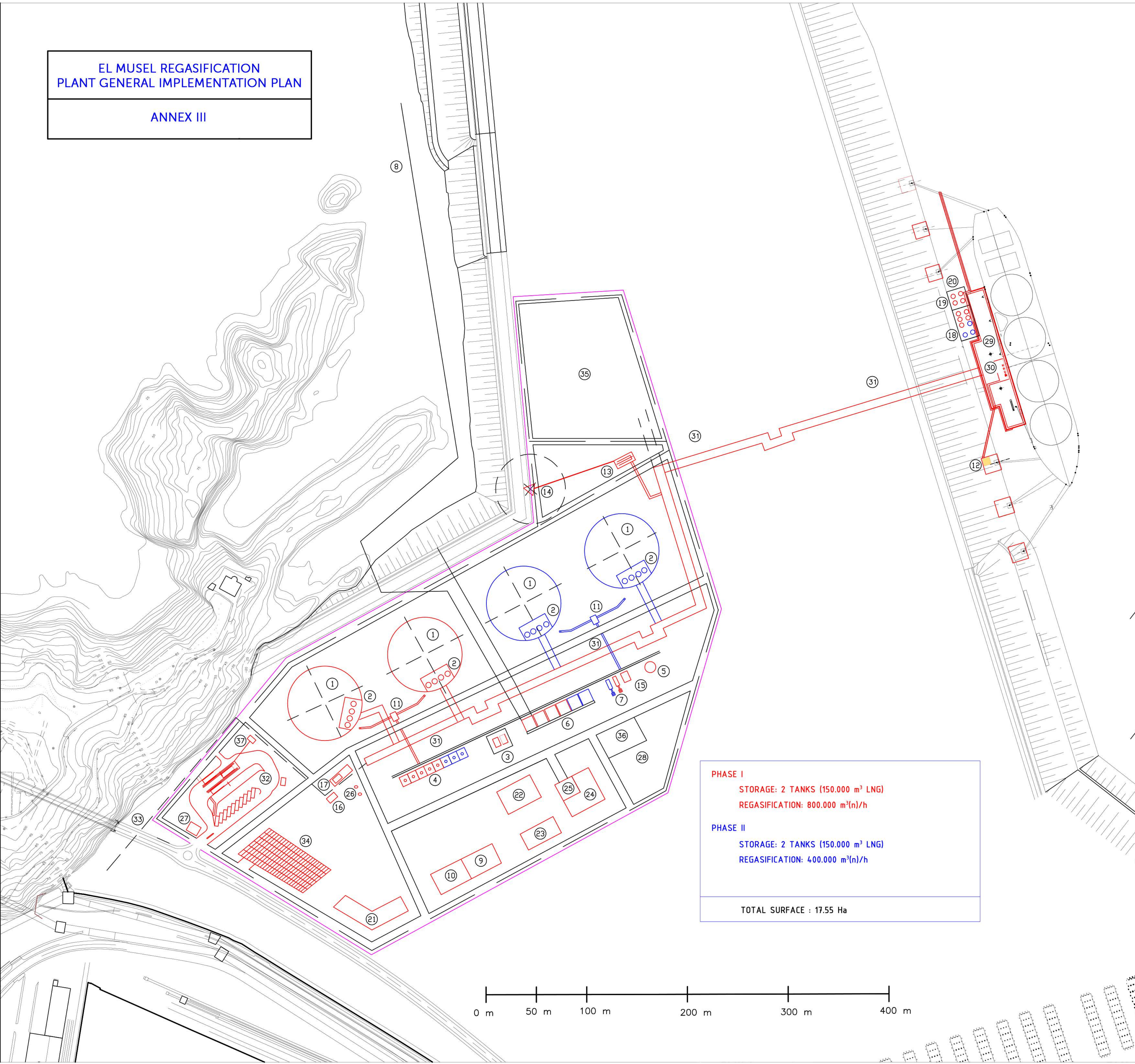
APRIL 2006

ANNEX III

El Musel Regasification original plant layout

EL MUSEL REGASIFICATION
PLANT GENERAL IMPLEMENTATION PLAN

ANNEX III



1	LNG TANKS (3 PUMP WELLS)	Approx. volume 150 000 m^3 of LNG
2	PRIMARY PUMPS	Q = 300 m^3/h LNG
3	BOIL-OFF COMPRESSORS	Q = 10 000 kg/h
4	SECONDARY PUMPS	Q = 350 m^3/h LNG
5	RELIQUEFIER	
6	OPEN RACK LNG VAPORISERS	Approx. Q 200 00 m^3(n)/h
7	SUBMERGED COMBUSTION LNG VAPORIZERS	Approx. Q 200 00 m^3(n)/h
8	EMISSARY	Capacity = 30 000 m^3/h
9	ELECTRIC SUBSTATION	
10	CONTROL ROOM	
11	LEAKAGES COLLECTING BASIN OF TANK AND PROCESS AREA	
12	LEAKAGES COLLECTING BASIN OF DOCKING AREA	
13	TORCH LIQUID SEPARATOR	
14	TORCH	Q = 150 000 kg/h
15	FUEL GAS SYSTEM	
16	ODORIZATION	
17	REGULATION AND MEASURING STATION	3 + 1 lines 400 000 m^3(n)/h
18	SEAWATER CATCHMENT PUMPS	Q = 5 500 m^3/h
19	DCI PUMPS	
20	PLANT WATER AND DCI BASIN	
21	OFFICES	
22	DEPOSITS	
23	STORAGE FACILITIES	
24	WEATHER PROTECTION STORAGE FACILITIES	
25	FIREHOUSE	
26	UTILITIES (WATER, AIR, NITROGEN)	
27	ACCESS	
28	ZONE FOR CONTRACTORS AND MAINTENANCE	
29	LNG UNLOADING PLATFORM / DOCKING	LNG carriers to 250 000 m^3 LNG
30	UNLOADING ARMS	3 x 20" + 1 x 20"
31	LNG TRANSFER LINES	
32	LNG TRUCK LOADING AREA	
33	HIGH-PRESSURE PIPELINE NETWORK	
34	PARKING	
35	TEMPORARY INSTALLATIONS	
36	FUTURE COLD SYSTEM AREA	
37	LEAKAGES COLLECTING BASIN OF LNG TRUCK LOADING AREA	

PHASE I

STORAGE: 2 TANKS (150.000 m^3 LNG)

REGASIFICATION: 800.000 m^3(n)/h

PHASE II

STORAGE: 2 TANKS (150.000 m^3 LNG)

REGASIFICATION: 400.000 m^3(n)/h

TOTAL SURFACE : 17.55 Ha

ANNEX IV

Liquefied natural gas (LNG)
Material Safety Data Sheet

Material Safety Data Sheet

1. Chemical product and company identification

Product name	NATURAL GAS, REFRIGERATED LIQUID (CRYOGENIC LIQUID) (Refrigerated liquid at atmospheric pressure)
MSDS #	0000001593
Historic MSDS #:	None.
Code	0000001593
Product use	Fuel.
Synonyms	Liquefied natural gas (LNG)
Supplier	BP Energy Company 501 WestLake Park Boulevard Houston, TX 77079 USA
EMERGENCY HEALTH INFORMATION:	1 (800) 447-8735 Outside the US: +1 703-527-3887 (CHEMTREC)
EMERGENCY SPILL INFORMATION:	1 (800) 424-9300 CHEMTREC (USA)
OTHER PRODUCT INFORMATION	1 (866) 4 BP - MSDS (866-427-6737 Toll Free - North America) email: bpcares@bp.com

2. Composition/information on ingredients

Ingredient name	CAS #	% by weight
Natural gas, dried; petroleum gas	68410-63-9	100
Contains:		
Methane	74-82-8	85 - 100
Ethane	74-84-0	<15
Propane	74-98-6	<4.5
Butane	106-97-8	<2.5
n-Pentane	109-66-0	<2.5
Nitrogen	7727-37-9	<1.5
Carbon dioxide	124-38-9	<0.05

3. Hazards identification

Physical state	Liquefied gas (Natural gas refrigerated liquid)
Color	Colorless.
Emergency overview	DANGER!

Extremely flammable liquefied gas. Vapors may form explosive mixtures with air in confined spaces. Vapor may cause flash fire.
Inhalation causes headaches, dizziness, drowsiness, and nausea, and may lead to unconsciousness.
At very high concentrations, can displace the normal air and cause suffocation from lack of oxygen.
Extremely cold material; can cause burns similar to frostbite.

Avoid contact with skin and clothing. Do not breathe vapor or mist. Keep away from heat, sparks, flame and other sources of ignition. Keep container closed. Use only with adequate ventilation. Wash thoroughly after handling.

Routes of entry Absorbed through skin. Eye contact. Inhalation.

Potential health effects

Eyes Liquid can cause burns similar to frostbite. Will cause serious damage to the eyes.

Skin Liquid can cause burns similar to frostbite.

Inhalation Inhalation causes headaches, dizziness, drowsiness, and nausea, and may lead to unconsciousness. At very high concentrations, can displace the normal air and cause suffocation from lack of oxygen.

Ingestion Not applicable. Liquefied gas.

Over-exposure signs/symptoms Inhalation of vapors may cause dizziness, an irregular heartbeat, narcosis, nausea or asphyxiation.

See toxicological information (section 11)

4. First aid measures

Eye contact In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. Get medical attention.

Skin contact Contact with liquid: Immediately flush with plenty of tepid water (105-115 F; 41-46 C). DO NOT USE HOT WATER. Get immediate medical attention.

Inhalation If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention immediately.

Ingestion Not applicable. Liquefied gas.

5. Fire-fighting measures

Flammability of the product Extremely flammable.

Auto-ignition temperature 540 °C (1004 °F)

Flash point -188 °C (-306 °F)

Explosion limits Lower: 5 %
Flammable Limits (% in air)

Upper: 15 %
Flammable Limits (% in air)

Products of combustion These products are carbon oxides (CO, CO_2).

Unusual fire/explosion hazards Extremely flammable in presence of open flames, sparks and static discharge or heat. Vapors may form explosive mixtures with air in confined spaces.

Flammable gas and vapor. Gas may accumulate in confined areas, travel considerable distance to source of ignition and flash back causing fire. In extreme heat containers may rupture.

Fire-fighting media and instructions

SMALL FIRE: Use DRY chemical powder.
LARGE FIRE: In case of fire, allow gas to burn if flow cannot be shut off immediately. Do not extinguish a leaking gas flame unless leak can be stopped. Use high expansion foam to suppress flame and radiated heat from pool fire. Do not use water jet directly on liquid pool. Move containing vessels from fire if without risk. If fire can be controlled, cool container with water from unmanned hose holder or monitor nozzles until well after fire is out. Extinguish secondary fire. Handle damaged cylinders with extreme care.

Protective clothing (fire)

Fire-fighters should wear positive pressure self-contained breathing apparatus (SCBA) and full turnout gear.

6. Accidental release measures

Personal precautions

Immediately contact emergency personnel. Eliminate all ignition sources. Keep unnecessary personnel away. Use suitable protective equipment (See Section: "Exposure controls/personal protection"). Follow all fire fighting procedures (See Section: "Fire-fighting measures"). Do not touch or walk through spilled material.

Environmental precautions and clean-up methods

If emergency personnel are unavailable, contain spilled material. Stop leak if without risk. If possible, turn leaking container so that gas escapes rather than liquid. Do not direct water at spill or source. Exclude sources of ignition and ventilate the area. Water spray curtain and monitor fog/spray's to divert/dilute vapor drift.

Personal protection in case of a large spill

Move upwind and away from spill. Splash goggles. Full suit. Boots. Gloves. A self-contained breathing apparatus should be used to avoid inhalation of the product. Suggested protective clothing might not be sufficient; consult a specialist BEFORE handling this product.

7. Handling and storage

Handling

Keep away from heat, sparks and flame. Keep container closed. Do not puncture or incinerate. Use only with adequate ventilation. To avoid fire, minimize ignition sources. To avoid fire or explosion, dissipate static electricity during transfer by grounding and bonding containers and equipment before transferring material.

Storage

Outside or detached storage is preferred. Store in a segregated and approved area. Keep container in a cool, well-ventilated area. Keep container tightly closed and sealed until ready for use. Segregate from oxidizing materials. Avoid all possible sources of ignition (spark or flame).

8. Exposure controls/personal protection

Occupational exposure limits

Ingredient name	Occupational exposure limits
Natural gas, dried; petroleum gas	None assigned.
Contains:	
Methane	**ACGIH TLV (United States, 1/2004).** TWA: 1000 ppm 8 hour(s).
Ethane	**ACGIH TLV (United States, 1/2004).** TWA: 1000 ppm 8 hour(s).
Propane	**ACGIH TLV (United States, 1/2004).** TWA: 1000 ppm 8 hour(s). **OSHA PEL (United States, 6/1993).** TWA: 1800 mg/m^3 8 hour(s). TWA: 1000 ppm 8 hour(s).
Butane	**ACGIH TLV (United States, 1/2004).** TWA: 1000 ppm 8 hour(s).
n-Pentane	**ACGIH TLV (United States, 9/2004).** TWA: 600 ppm 8 hour(s). **OSHA PEL (United States, 6/1993).** TWA: 2950 mg/m^3 8 hour(s). TWA: 1000 ppm 8 hour(s).
Nitrogen	Simple asphyxiant.
Carbon dioxide	**ACGIH TLV (United States, 2003).**

STEL: 54000 mg/m³ 15 minute(s).
STEL: 54000 mg/m³ 15 minute(s).
STEL: 30000 ppm 15 minute(s).
TWA: 9000 mg/m³ 8 hour(s).
TWA: 5000 ppm 8 hour(s).

OSHA PEL (United States, 1993).

TWA: 5000 ppm 8 hour(s).
TWA: 9000 mg/m³ 8 hour(s).
TWA: 9000 mg/m³ 8 hour(s).
TWA: 5000 ppm 8 hour(s).

Control Measures Handle the material in a fume hood/cupboard or under local exhaust ventilation. Ensure that eyewash stations and safety showers are proximal to the work-station location.

Hygiene measures Wash hands after handling compounds and before eating, smoking, using lavatory, and at the end of day. Approved air-supplied breathing apparatus must be worn where there is a risk of oxygen deficiency (i.e. low oxygen concentration). Ensure that eyewash stations and safety showers are close to the work-station location.

Personal protection

Eyes Wear chemical goggles and a full face shield

Skin and body Avoid contact with skin and clothing. Wear clothing and footwear that cannot be penetrated by chemicals or oil.

Respiratory Use only with adequate ventilation. Do not breathe vapor or mist. If operating conditions cause high vapor concentrations or TLV is exceeded, use NIOSH certified supplied-air respiratory.

Hands Wear suitable gloves. (Insulated gloves suitable for low temperatures)

Consult your supervisor or S.O.P. for special handling directions

Consult local authorities for acceptable exposure limits.

9. Physical and chemical properties

Physical state Liquefied gas (Natural gas refrigerated liquid)

Odor Odorless, unless odorized with ethyl mercaptan (skunky odor).

Color Colorless.

Boiling point / Range -160 °C (-256 °F)

Melting point / Range -182 °C (-295 °F)

Critical temperature -82°C (-115 °F)

Vapor Density (Air = 1) 0.55 to 0.6 (after vapor has warmed to ambient temperature)

Solubility Insoluble in cold water.

10. Stability and reactivity

Stability and reactivity The product is stable.

Conditions to avoid Keep away from sources of ignition. Keep away from heat and direct sunlight. In extreme heat containers may rupture.

Incompatibility with various substances Reactive with halogenated compounds, oxidizing agents.

Hazardous decomposition products Products of combustion: carbon oxides (CO, CO_2)

Hazardous polymerization Will not occur.

11. Toxicological information

Acute toxicity

High vapor concentrations can cause headaches, dizziness, drowsiness, and nausea, and may lead to unconsciousness. Exposure to vapor at high concentrations may have the following effects: heart beat irregularity (arrythmia).

Chronic toxicity

Carcinogenic effects

No component of this product at levels greater than 0.1% is identified as a carcinogen by ACGIH or the International Agency for Research on Cancer (IARC). No component of this product present at levels greater than 0.1% is identified as a carcinogen by the U.S. National Toxicology Program (NTP) or the U.S. Occupational Safety and Health Act (OSHA).

Mutagenic effects

No component of this product at levels greater than 0.1% is classified by established regulatory criteria as a mutagen.

Reproductive effects

No component of this product at levels greater than 0.1% is classified by established regulatory criteria as a reproductive toxin.

Teratogenic effects

No component of this product at levels greater than 0.1% is classified by established regulatory criteria as teratogenic or embryotoxic.

Other information

This material is an asphyxiant. Asphyxiants may reduce the oxygen concentration in the air to dangerous levels. Symptoms of lack of oxygen include increased depth and frequency of breathing, air hunger, dizziness, headache, nausea or loss of consciousness.

12. Ecological information

Ecotoxicity

No testing has been performed by the manufacturer.

Mobility

This product is likely to volatize rapidly into the air because of its high vapor pressure. This product is not likely to move rapidly with surface or groundwater flows because of its low water solubility of: <0.1%.

13. Disposal considerations

Waste information

Avoid contact of spilled material and runoff with soil and surface waterways. Consult an environmental professional to determine if state or federal regulations would classify spilled or contaminated materials as hazardous waste. Use only approved transporters, recyclers, treatment, storage or disposal facilities. Dispose of in accordance with all applicable local and national regulations.

Consult your local or regional authorities.

14. Transport information

International transport regulations

Regulatory information	UN number	Proper shipping name	Class	Packing group	Label	Additional information
DOT Classification	UN1972	Methane, refrigerated liquid or Natural gas, refrigerated liquid (with high methane content) (ETHANE)	2.1	Not applicable	Not determined.	-----
					Not determined.	

TDG Classification	UN1972	Methane, refrigerated liquid or Natural gas, refrigerated liquid (with high methane content) (ETHANE)	2.1	Not applicable		-----
IMDG Classification	UN1972	Methane, refrigerated liquid or Natural gas, refrigerated liquid (with high methane content) (ETHANE)	2.1	Not applicable	Not determined.	-----
IATA Classification	Not determined.	-----	Not determined.	Not determined.	Not determined.	-----

15. Regulatory information

U.S. Federal regulations US INVENTORY (TSCA): In compliance.

This product is not regulated under Section 302 of SARA and 40 CFR Part 355.

SARA 311/312 MSDS distribution - chemical inventory - hazard identification: NATURAL GAS, REFRIGERATED LIQUID (CRYOGENIC LIQUID): Fire hazard, Immediate (Acute) Health Hazard

SARA 313

Form R - Reporting requirements This product does not contain any hazardous ingredients at or above regulated thresholds.

Supplier notification This product does not contain any hazardous ingredients at or above regulated thresholds.

CERCLA Sections 102a/103 Hazardous Substances (40 CFR Part 302.4):: This material is not regulated under CERCLA Sections 103 and 107.

State regulations Massachusetts RTK:METHANE; ETHANE; Propane; Butane; n-Pentane; Nitrogen
New Jersey:METHANE; ETHANE; Propane; Butane; n-Pentane; Nitrogen
Pennsylvania RTK:METHANE (generic environmental hazard); ETHANE (generic environmental hazard); Propane (generic environmental hazard); Butane (generic environmental hazard); n-Pentane (generic environmental hazard); Nitrogen (generic environmental hazard)

Inventories AUSTRALIAN INVENTORY (AICS): In compliance.

CANADA INVENTORY (DSL): In compliance.

CHINA INVENTORY (IECS): Not determined.

EC INVENTORY (EINECS): In compliance.

JAPAN INVENTORY (ENCS): Not determined.

KOREA INVENTORY (ECL): In compliance.

PHILIPPINE INVENTORY (PICCS): Not determined.

16. Other information

Label requirements DANGER!

Extremely flammable liquefied gas. Vapors may form explosive mixtures with air in confined spaces. Vapor may cause flash fire.
Inhalation causes headaches, dizziness, drowsiness, and nausea, and may lead to unconsciousness.
At very high concentrations, can displace the normal air and cause suffocation from lack of oxygen.
Extremely cold material; can cause burns similar to frostbite.

HMIS® Rating :

Health	**2**
Flammability	**4**
Physical Hazard	**0**
Personal protection	**X**

National Fire Protection Association (U.S.A.)

History

Date of issue 05/13/2005.

Date of previous issue 05/11/2005.

Prepared by Product Stewardship

Notice to reader

NOTICE : This Material Safety Data Sheet is based upon data considered to be accurate at the time of its preparation. Despite our efforts, it may not be up to date or applicable to the circumstances of any particular case. We are not responsible for any damage or injury resulting from abnormal use, from any failure to follow appropriate practices or from hazards inherent in the nature of the product.

ANNEX V

El Musel Regasification
Hazardous Area Classification Data Sheet

Plant:	**El Musel Regasification (Enagás)**		**Flammable material list and characteristics**									
1	2	3	4	5	6	7	8	9	10	11	12	13
Flammable material				LEL		Volatility						
N°	Name	Composition	Flashpoint [°C]	kg/m^3	Vol%	Vapour pressure at 20°C [bar]	Boiling-point [°C]	Relative density of gas or vapour to air	Ignition temperature [°C]	Group and temperature class	M [kg/kmol]	Any other relevant information
1	Natural Gas (NG)	*Note 1*	<0	0.02563 - 0.04305	3.93 - 6.60	-	-163	0.587 - 0.707	482	IIAT1	13.734 - 17.850	
2	Boil-off Gas (BOG)	Assumed equal to 100% CH_4	<0	0.02936	4.40	-	-161.4	0.554	537	IIAT1	16.04	
3	Tetrahydrothiophene (THT)	$CH_2(CH_2)_2CH_2S$	12	0.04034	1.10	0.0186	118	3.04	202	IIAT3	88.17	

Note 1 :
Values of reference of hydrocarbons percentages for the considered NG are listed below:

CH_4 %	C_2H_6 %	C_3H_8 %	C_4H_{10} %	C_5H_{12} %	C_6H_{14} %
79 - 99.6	0.01 - 10	traces - 2.35	traces - 1.35	traces - 0.4	traces - 0.15

Plant:	El Musel Regasification (Enagás)				Area:	LNG unloading dock		List of sources of release							
1	2	3	4	5	6	7		8	9			10	11	12	13
Source of relese					Flammable material				Ventilation			Hazardous area			
N°	Description	Position	Operation	Grade of release [1]	Reference [2]	Operating temperature and pressure [3]		State[4]	Type[5]	Degree[6]	Availability [7]	Zone type 0-1-2	Zone extent (m)		Any other relevant information and remarks
						°C	kPa						Vertical	Horizontal	
1	QCDC coupling - 20" LNG unloading arms[8]	LNG carrier mainfold	Clamping / Unclamping	P	1	≈ -163	Rate ≃ 6 000 m^3/h ρ_{liq} ≃ 432 kg/m^3	L[9]	N	Medium	Good	1	3	3	Zone 1 : 3 m in all directions from LNG unloading arm maximum allowable working envelope.
2	QCDC coupling - 20" vapour devolution arm	LNG carrier mainfold	Clamping / Unclamping	P	2			G	N	Medium	Good	1	3	3	Zone 1 : 3 m in all directions from vapour devolution arm maximum allowable working envelope.
3	Pool at floor level below 20" LNGunloading arms	LNG carrier mainfold	Clamping / Unclamping	P	1	≈ -163	Ambient	L	N	Medium	Good	1	3	1.5	Values calculated for a pool having an area of 10 times the section of the corresponding unloading arm source of leakage. [10]
4	Rotating joints 20" unloading arms	LNG carrier mainfold	LNG transfer	S	1	≈ -163	Rate ≃ 6 000 m^3/h ρ_{liq} ≃ 432 kg/m^3	L[11]	N	Medium	Good	2	1.5	1.5	Zone 2: 1.5 m in all directions from source of release.
5	Rotating joints 20" vapour devolution arm	LNG carrier mainfold	Vapour devolution to mainfold	S	2			G	N	Medium	Good	2	1.5	1.5	Zone 2: 1.5 m in all directions from source of release.
6	ERS emergency system isolating ball valves	LNG carrier mainfold	LNG transfer	S	1	≈ -163	Rate ≃ 6 000 m^3/h ρ_{liq} ≃ 432 kg/m^3	L[11]	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
7	ERS emergency system isolating ball valves	LNG carrier mainfold	Vapour devolution to mainfold	S	2			G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
8	Check valves downstream from 20" unloading arms	LNG carrier mainfold	LNG transfer	S	1	≈ -163	Rate ≃ 6 000 m^3/h ρ_{liq} ≃ 432 kg/m^3	L[11]	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
9	Check valves downstream from 20" vapour devolution arm	LNG carrier mainfold	Vapour devolution to mainfold	S	2			G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
10	Leakages collecting channels	Docking port	LNG transfer	P	1		Ambient	L	N	Medium	Good	1	3	1.5	Horizontal distance starts from channel boundaries. Vertical distance is from liquid surface (ref. to n° 3).
11	Leakages collecting basin	Docking port	LNG transfer	C	1			L	N	Low	Poor	0	-	-	Zone 0 in the whole interior of the tank.

Plant:	El Musel Regasification (Enagás)				Area:	LNG unloading dock		List of sources of release							
1	2	3	4	5	6	7		8	9			10	11	12	13
Source of relese					Flammable material				Ventilation			Hazardous area			
N°	Description	Position	Operation	Grade of release [1]	Reference [2]	Operating temperature and pressure [3]		State[4]	Type[5]	Degree[6]	Availability [7]	Zone type	Zone extent (m)		Any other relevant
						°C	kPa					0-1-2	Vertical	Horizontal	information and remarks
12	Hand control gate valves	Docking port	LNG transfer	S	1	≈ -163	Rate ≃ 6 000 m^3/h ρ_{liq} ≃ 432 kg/m^3	L[11]	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
13	Hand control gate valves	Docking port	Vapour devolution to mainfold	S	2			G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
14	Flanges	Docking port	LNG transfer	S	1	≈ -163	Rate ≃ 6 000 m^3/h ρ_{liq} ≃ 432 kg/m^3	L[11]	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
15	Flanges	Docking port	Vapour devolution to mainfold	S	2			G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
16	Tubing measurement accessories	Docking port	LNG transfer	S	1	≈ -163	Rate ≃ 6 000 m^3/h ρ_{liq} ≃ 432 kg/m^3	L[11]	N	Medium	Good	2	Negligible	Negligible	Zone 2 limited to the immediate vicinity of the source of release.
17	Tubing measurement accessories	Docking port	Vapour devolution to mainfold	S	2			G	N	Medium	Good	2	Negligible	Negligible	Zone 2 limited to the immediate vicinity of the source of release.
18	Vapour inlet control valve	Flash drum - docking port	Vapour devolution to mainfold	S	2			G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
19	Vapour flow / LNG drops	Interior of flash drum	Vapour cooling	C	1 + 2	≈ -163		G + L	N	Low	Poor	0	-	-	Zone 0 in the whole interior of the tank.
20	Leakages collecting channels	Flash drum - docking port	Vapour devolution to mainfold	P	1		Ambient	L	N	Medium	Good	1	3	1.5	Horizontal distance starts from channel boundaries. Vertical distance is from liquid surface (ref. to n° 3).
21	Leakages collecting basin	Flash drum - docking port	Vapour devolution to mainfold	C	1			L	N	Low	Poor	0	-	-	Zone 0 in the whole interior of the tank.
22	Vapour outlet control valve	Flash drum - docking port	Vapour devolution to mainfold	S	2	≈ -163		G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
23	Tubing measurement accessories	Flash drum - docking port	Vapour devolution to mainfold	S	2			G	N	Medium	Good	2	Negligible	Negligible	Zone 2 limited to the immediate vicinity of the source of release
24	GNL inlet control valve	Flash drum - docking port	Vapour cooling	S	1	≈ -163		L[11]	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
25	GNL outlet ball valve	Flash drum - docking port	Vapour cooling	S	1	≈ -163		L[11]	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.

Plant:	El Musel Regasification (Enagás)				Area:	LNG unloading dock		List of sources of release							
1	2	3	4	5	6	7		8	9			10	11	12	13
Source of relese					Flammable material				Ventilation			Hazardous area			
N°	Description	Position	Operation	Grade of release [1]	Reference [2]	Operating temperature and pressure [3]		State[4]	Type[5]	Degree[6]	Availability [7]	Zone type 0-1-2	Zone extent (m)		Any other relevant information and remarks
						°C	kPa						Vertical	Horizontal	
26	Pressure safety valve	Flash drum - docking port	Vapour cooling - drum overpressure protection	S	2			G	N	Medium	Good	2	3	3	Zone 2: 3 m in all directions from source of release.

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[5]N - Natural; A- Artificial.
[6]High; Medium; Low.
[7]Good; Fair; Poor.

[8] 3 liquid unloading arms present.
[9]At moment of leakage a part of liquid vapourizes forming clouds or mists before complete evaporation and ascension.
[10]The whole floor surface of the LNG unloading area mainfold should be classified as Zone 1.
[11] It is assumed that for slight releases the liquid istantaneously evapourates in contact with atmosphere.

Plant:	El Musel Regasification (Enagás)				Area:	Transfer liners from dock to storage tanks		List of sources of release							
1	2	3	4	5	6	7		8	9			10	11	12	13
Source of relese					Flammable material				Ventilation			Hazardous area			
N°	Description	Position	Operation	Grade of release (1)	Reference (2)	Operating temperature and pressure(3) °C	kPa	State(4)	Type(5)	Degree(6)	Availability (7)	Zone type 0-1-2	Zone extent (m) Vertical	Horizontal	Any other relevant information and
1	Shutdown / Control valves	Primary LNG transfer line	LNG transfer	S	1	≈ -163	Rate ≃ 18 000 m^3/h $\rho_{liq} \simeq 432$ kg/m^3	L(8)	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
2	Shutdown / Control valves	Secondary LNG transfer line	Cooling	S	1	≈ -163	$\rho_{liq} \simeq 432$ kg/m^4	L(8)	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
3	Shutdown / Control valves	Vapour line	Vapour devolution to mainfold	S	2			G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
4	Tubing measurement accessories	Primary LNG transfer line	LNG transfer	S	1	≈ -163	Rate ≃ 18 000 m^3/h $\rho_{liq} \simeq 432$ kg/m^3	L(8)	N	Medium	Good	2	Negligible	Negligible	Zone 2 limited to the immediate vicinity of the source of release.
5	Tubing measurement accessories	Secondary LNG transfer line	Cooling	S	1	≈ -163	$\rho_{liq} \simeq 432$ kg/m^4	L(8)	N	Medium	Good	2	Negligible	Negligible	Zone 2 limited to the immediate vicinity of the source of release.
6	Tubing measurement accessories	Vapour line	Vapour devolution to mainfold	S	2			G	N	Medium	Good	2	Negligible	Negligible	Zone 2 limited to the immediate vicinity of the source of release.

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(5) N - Natural; A- Artificial.
(6) High; Medium; Low.
(7) Good; Fair; Poor.

(8) It is assumed that for slight releases the liquid istantaneously evapourates in contact with atmosphere.

Plant:	El Musel Regasification (Enagás)				Area:	LNG storage tanks area				List of sources of release					
1	2	3	4	5	6	7		8	9			10	11	12	13
Source of relese					Flammable material				Ventilation			Hazardous area			
N°	Description	Position	Operation	Grade of release (1)	Reference (2)	Operating temperature and pressure (3)		State(4)	Type(5)	Degree(6)	Availability (7)	Zone type 0-1-2	Zone extent (m)		Any other relevant information and remarks
						°C	kPa						Vertical	Horizontal	
1	MOV valves	Tank dome roof - LNG inlet lines	LNG filling	S	1	≈ -163		L(8)	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
2	Check valves	Tank dome roof - LNG inlet lines	LNG filling	S	1	≈ -163		L(8)	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
3	Tubing measurement accessories	Tank dome roof - LNG inlet lines	LNG filling	S	1	≈ -163		L(8)	N	Medium	Good	2	Negligible	Negligible	Zone 2 limited to the immediate vicinity of the source of release.
4	MOV valves	Tank dome roof - vapour displacing lines	Vapour displacing	S	2			G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
5	Check valves	Tank dome roof - vapour displacing lines	Vapour displacing	S	2			G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
6	Tubing measurement accessories	Tank dome roof - vapour displacing lines	Vapour displacing	S	2			G	N	Medium	Good	2	Negligible	Negligible	Zone 2 limited to the immediate vicinity of the source of release.
7	Pressure Safety Valves	Tank dome roof	To vapour displacing line	S	2			G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
8	Pressure Safety Valves	Tank dome roof	To open air	S	2			G	N	Medium	Good	2	3	3	Zone 2: 3 m in all directions from source of release.
9	Pump well accesses	Tank dome roof	Pumps maintenance	S	1 /2	≈ -162	max 25	G / L	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
10	Manholes	Tank dome roof	Maintenance	S	2	≈ -162	max 25	G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
11	Bursting discs	Tank dome roof	Overpressure protection	S	2	≈ -162		G	N	Medium	Good	2	3	3	Zone 2: 3 m in all directions from source of release.
12	Vacuum breaker valves	Tank dome roof	Anti Vacuum Protection	S	2	≈ -162		G	N	Medium	Good	2	3	3	Zone 2: 3 m in all directions from source of release.
13	Level measuring floaters channelling	LNG tank coating	LNG storage	S	2	≈ -162	max 25	G	N	Medium	Good	2	Negligible	Negligible	Zone 2 limited to the immediate vicinity of the source of release.
14	Temperature / pressure measuring accessories	LNG tank coating	LNG storage	S	2	≈ -162	max 25	G	N	Medium	Good	2	Negligible	Negligible	Zone 2 limited to the immediate vicinity of the source of release.

Plant:	**El Musel Regasification (Enagás)**				**Area:**	**LNG storage tanks area**				**List of sources of release**					
1	2	3	4	5	6	7		8	9			10	11	12	13
Source of relese					Flammable material				Ventilation			Hazardous area			
N°	Description	Position	Operation	Grade of release [1]	Reference [2]	Operating temperature and pressure [3]		State[4]	Type[5]	Degree[6]	Availability [7]	Zone type 0-1-2	Zone extent (m)		Any other relevant information and remarks
						°C	kPa						Vertical	Horizontal	
15	Leakages collecting channels	Area between the two tanks - floor level	LNG storage	P	1		Ambient	L	N	Medium	Good	1	3	1.5	Horizontal distance starts from channel boundaries. Vertical distance is from liquid surface.
16	Leakages collecting basin	Area between the two tanks - floor level	LNG storage	C	1			L	N	Low	Poor	0	-	-	Zone 0 in the whole interior of the tank.
17	Liquid surface	Inner tank 9% nickel steel	LNG storage	C	1	≈ -162	max 25	L	N	Low	Poor	0	-	-	Zone 0 in the whole space between internal and external tank.
18	Tubing measurement accessories	LNG outlet	Primary pumping lines	S	1		Rate $\simeq$ 300 m^3/h $\rho_{liq} \simeq$ 432 kg/m^3	L[8]	N	Medium	Good	2	Negligible	Negligible	Zone 2 limited to the immediate vicinity of the source of release.
19	Flanges	LNG outlet	Primary pumping lines	S	1		Rate $\simeq$ 300 m^3/h $\rho_{liq} \simeq$ 432 kg/m^2	L[8]	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
20	Pressure Safety Valves	LNG outlet	Primary pumping lines	S	1		Rate $\simeq$ 300 m^3/h $\rho_{liq} \simeq$ 432 kg/m^2	L[8]	N	Medium	Good	2	3	3	Zone 2: 3 m in all directions from source of release.
21	Cut-off valves	LNG outlet	Primary pumping lines	S	1		Rate $\simeq$ 300 m^3/h $\rho_{liq} \simeq$ 432 kg/m^2	L[8]	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
22	Check valves	LNG outlet	Primary pumping lines	S	1		Rate $\simeq$ 300 m^3/h $\rho_{liq} \simeq$ 432 kg/m^2	L[8]	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.

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[5] N - Natural; A- Artificial.
[6] High; Medium; Low.
[7] Good; Fair; Poor.

[8] It is assumed that for slight releases the liquid istantaneously evapourates in contact with atmosphere.

Plant:	El Musel Regasification (Enagás)				Area:	BOG compression unit			List of sources of release						
1	2	3	4	5	6	7		8	9			10	11	12	13
Source of relese					Flammable material				Ventilation			Hazardous area			
N°	Description	Position	Operation	Grade of release (1)	Reference (2)	Operating temperature and pressure (3)		State(4)	Type(5)	Degree(6)	Availability (7)	Zone type 0-1-2	Zone extent (m)		Any other relevant information and remarks
						°C	kPa						Vertical	Horizontal	
1	Control valve	Ejector inlet	BOG cooling with LNG before entering in the sepatator	S	2	> 80	10 - 23	G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
2	Control valve	Ejector inlet	BOG cooling with LNG before entering in the sepatator	S	1	≈ -163		L(8)	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
3	BOG cooling ejector	Drop separator inlet	BOG cooling with LNG before entering in the sepatator	S	1 / 2	< 80		G / L	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
4	Tubing measurement accessories	Drop separator inlet	BOG entering in the separator	S	2	< 80		G	N	Medium	Good	2	Negligible	Negligible	Zone 2 limited to the immediate vicinity of the source of release.
5	Flow inside the separator	Interior of drop separator	Liquid separation	C	1 / 2	< 80		G / L	N	Low	Poor	0	-	-	Zone 0 in the whole interior of the tank.
6	Cut-off ball valve	Drop separator liquid outlet	Liquid discharging	S	1			L(8)	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
7	Leakages collecting channels	Drop separator liquid outlet	Liquid discharging	P	1		Ambient	L	N	Medium	Good	1	3	1.5	Horizontal distance starts from channel boundaries. Vertical distance is from liquid surface.
8	Leakages collecting basin	Drop separator liquid outlet	Liquid discharging	C	1			L	N	Low	Poor	0	-	-	Zone 0 in the whole interior of the tank.
9	Tubing measurement accessories	BOG compressors inlet lines	BOG compressors feeding	S	2	< 80		G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
10	Suction valves	BOG compressors inlet lines	BOG compressors feeding	S	2	< 80		G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
11	Cut-off valves	BOG compressors inlet lines	BOG compressors feeding	S	2	< 80		G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
12	Control valves	BOG compressors outlet lines	BOG discharging	S	2		Compressors nominal capacity = 10 000 kg/h	G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
13	Cut-off valves	BOG compressors outlet lines	BOG discharging	S	2		Compressors nominal capacity = 10 000 kg/h	G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.

Plant:	El Musel Regasification (Enagás)				Area:	BOG compression unit			List of sources of release						
1	2	3	4	5	6	7		8	9			10	11	12	13
Source of relese					Flammable material				Ventilation			Hazardous area			
N°	Description	Position	Operation	Grade of release (1)	Reference (2)	Operating temperature and pressure (3)		State(4)	Type(5)	Degree(6)	Availability (7)	Zone type 0-1-2	Zone extent (m)		Any other relevant information and remarks
						°C	kPa						Vertical	Horizontal	
14	Control valves	BOG compressors recirculation line	BOG recirculation to drop separator inlet	S	2			G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
15	Pressure Safety Valves	BOG compressors	BOG compression	S	2			G	N	Medium	Good	2	3	3	Zone 2: 3 m in all directions from source of release.
16	Compressors seals	BOG compressors	BOG compression	S	2			G	N	Medium	Good	2	3	3	Zone 2: 3 m in all directions from source of release.

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(5)N - Natural; A- Artificial.
(6)High; Medium; Low.
(7)Good; Fair; Poor.

(8)It is assumed that for slight releases the liquid istantaneously evapourates in contact with atmosphere.

Plant:	El Musel Regasification (Enagás)				Area:	Reliquefier			List of sources of release						
1	2	3	4	5	6	7		8	9			10	11	12	13
Source of relese					Flammable material				Ventilation			Hazardous area			
N°	Description	Position	Operation	Grade of release (1)	Reference (2)	Operating temperature and pressure (3)		State(4)	Type(5)	Degree(6)	Availability (7)	Zone type 0-1-2	Zone extent (m)		Any other relevant information and remarks
						°C	kPa						Vertical	Horizontal	
1	Control valve	Reliquefier LNG inlet	Reliquefier LNG inflow	S	1			L(8)	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
2	Cut-off valve	Reliquefier LNG inlet	Reliquefier LNG inflow	S	1			L(8)	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
3	Flanges	Reliquefier LNG inlet	Reliquefier LNG inflow	S	1			L(8)	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
4	Tubing measurement accessories	Reliquefier LNG inlet	Reliquefier LNG inflow	S	1			L(8)	N	Medium	Good	2	Negligible	Negligible	Zone 2 limited to the immediate vicinity of the source of release.
5	Control valve	Reliquefier BOG inlet	Reliquefier BOG inflow	S	2			G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
6	Cut-off valve	Reliquefier BOG inlet	Reliquefier BOG inflow	S	2			G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
7	Flanges	Reliquefier BOG inlet	Reliquefier BOG inflow	S	2			G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
8	Tubing measurement accessories	Reliquefier BOG inlet	Reliquefier BOG inflow	S	2			G	N	Medium	Good	2	Negligible	Negligible	Zone 2 limited to the immediate vicinity of the source of release.
9	Natural gas processed	Reliquefier interior	BOG reliquefaction	C	1 / 2	-135 / -126	600 - 900	G/L	N	Low	Poor	0	-	-	Zone 0 in the whole interior of the tank.
10	Leakages collecting channels	Reliquefier	BOG reliquefaction	P	1		Ambient	L	N	Medium	Good	1	3	1.5	Horizontal distance starts from channel boundaries. Vertical distance is from liquid surface.
11	Leakages collecting basin	Reliquefier	BOG reliquefaction	C	1			L	N	Low	Poor	0	-	-	Zone 0 in the whole interior of the tank.
12	Cut-off ball valve	Reliquefier LNG outlet	Reliquefier LNG outflow	S	1	< -126		L(8)	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
13	Flanges	Reliquefier LNG outlet	Reliquefier LNG outflow	S	1	< -126		L(8)	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
14	Tubing measurement accessories	Reliquefier LNG outlet	Reliquefier LNG outflow	S	1	< -126		L(8)	N	Medium	Good	2	Negligible	Negligible	Zone 2 limited to the immediate vicinity of the source of release.

Plant:	El Musel Regasification (Enagás)				Area:	Reliquefier			List of sources of release						
1	2	3	4	5	6	7		8	9			10	11	12	13
Source of relese					Flammable material				Ventilation			Hazardous area			
N°	Description	Position	Operation	Grade of release (1)	Reference (2)	Operating temperature and pressure (3)		State(4)	Type(5)	Degree(6)	Availability (7)	Zone type 0-1-2	Zone extent (m)		Any other relevant information and remarks
						°C	kPa						Vertical	Horizontal	
15	By-pass control valve	LNG main line	LNG by-passing reliquefier	S	1			L(8)	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
16	Control valve	Reliquefier	To BOG collector	S	2			G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
17	Pressure safety valve	Reliquefier	To BOG collector	S	2			G	N	Medium	Good	2	3	3	Zone 2: 3 m in all directions from source of release.

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(7) Good; Fair; Poor.

(8) It is assumed that for slight releases the liquid istantaneously evapourates in contact with atmosphere.

Plant:	El Musel Regasification (Enagás)				Area:	Secondary Pumping System			List of sources of release						
1	2	3	4	5	6	7		8	9			10	11	12	13
Source of relese					Flammable material				Ventilation			Hazardous area			
N°	Description	Position	Operation	Grade of release (1)	Reference (2)	Operating temperature and pressure (3)		State(4)	Type(5)	Degree(6)	Availability (7)	Zone type	Zone extent (m)		Any other relevant information and remarks
						°C	kPa					0-1-2	Vertical	Horizontal	
1	Control valves	Secondary pumps LNG inlet lines	Secondary pumps LNG inflow	S	1		≈900	L(8)	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
2	Cut-off valves	Secondary pumps LNG inlet lines	Secondary pumps LNG inflow	S	1		≈900	L(8)	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
3	Flanges	Secondary pumps LNG inlet lines	Secondary pumps LNG inflow	S	1		≈900	L(8)	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
4	Tubing measurement accessories	Secondary pumps LNG inlet lines	Secondary pumps LNG inflow	S	1		≈900	L(8)	N	Medium	Good	2	Negligible	Negligible	Zone 2 limited to the immediate vicinity of the source of release
5	Vent	Secondary pumps BOG outlet lines	BOG discharging to reliquefier	S	2	≈-196		G	N	Medium	Good	2	3	3	Zone 2: 3 m in all directions from source of release.
6	Flanges	Secondary pumps BOG outlet lines	BOG discharging to reliquefier	S	2	≈-196		G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
7	Flanges	Secondary pumps LNG outlet lines	LNG pumped to vaporizers	S	1		5000 - 8000	L(8)	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
8	Check valves	Secondary pumps LNG outlet lines	LNG pumped to vaporizers	S	1		5000 - 8000	L(8)	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
9	Pressure Safety Valves	Secondary pumps LNG outlet lines	LNG pumped to vaporizers	S	1		5000 - 8000	L(8)	N	Medium	Good	2	3	3	Zone 2: 3 m in all directions from source of release.
10	Tubing measurement accessories	Secondary pumps LNG outlet lines	LNG pumped to vaporizers	S	1		5000 - 8000	L(8)	N	Medium	Good	2	Negligible	Negligible	Zone 2 limited to the immediate vicinity of the source of release
11	Cut-off valves	Secondary pumps LNG outlet lines	LNG pumped to vaporizers	S	1		5000 - 8000	L(8)	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
12	Control valves	Recirculation line to reliquefier	Minimum flow to reliquefier	S	1			L(8)	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
13	Leakages collecting channels	Secondary Pumps	LNG pumped to vaporizers	P	1		Ambient	L	N	Medium	Good	1	3	1.5	Horizontal distance starts from channel boundaries. Vertical distance is from liquid surface.
14	Leakages collecting basin	Secondary Pumps	LNG pumped to vaporizers	C	1			L	N	Low	Poor	0	-	-	Zone 0 in the whole interior of the tank.

Plant:	El Musel Regasification (Enagás)				Area:	Secondary Pumping System			List of sources of release						
1	2	3	4	5	6	7		8	9			10	11	12	13
Source of relese					Flammable material				Ventilation			Hazardous area			
N°	Description	Position	Operation	Grade of release [1]	Reference [2]	Operating temperature and pressure [3]		State[4]	Type[5]	Degree[6]	Availability [7]	Zone type 0-1-2	Zone extent (m)		Any other relevant information and remarks
						°C	kPa						Vertical	Horizontal	
15	Pumps seals	Secondary pumps	LNG pumping	S	1	≈-196		L[8]	N	Medium	Good	2	3	3	Zone 2: 3 m in all directions from source of release.

[1]C - Continuos; S - Secondary; P - Primary.

[2]Quote the number of list in Part I.

[3] Avaliable data are given regarding the operating temperature and pressure or useful to their estimation.

[4]G - Gas; L - Liquefied gas; S - solid.

[5]N - Natural; A- Artificial.

[6]High; Medium; Low.

[7]Good; Fair; Poor.

[8]It is assumed that for slight releases the liquid istantaneously evapourates in contact with atmosphere.

Plant:	**El Musel Regasification (Enagás)**				**Area:**	**Vaporization area (ORV/SCV)**			**List of sources of release**						
1	2	3	4	5	6	7		8	9			10	11	12	13
Source of relese					Flammable material				Ventilation			Hazardous area			
N°	Description	Position	Operation	Grade of release (1)	Reference (2)	Operating temperature and pressure (3)		State(4)	Type(5)	Degree(6)	Availability (7)	Zone type 0-1-2	Zone extent (m)		Any other relevant information and remarks
						°C	kPa						Vertical	Horizontal	
1	Cut-off valves	ORV vaporizers inlet lines (8)	vaporizers LNG inflow	S	1	≈ -155	5000 - 8000	L (9)	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
2	Control valves	ORV vaporizers inlet lines (8)	vaporizers LNG inflow	S	1	≈ -155	5000 - 8000	L (9)	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
3	Check valves	ORV vaporizers inlet lines (8)	vaporizers LNG inflow	S	1	≈ -155	5000 - 8000	L (9)	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
4	Tubing measurement accessories	ORV vaporizers inlet lines (8)	vaporizers LNG inflow	S	1	≈ -155	5000 - 8000	L (9)	N	Medium	Good	2	Negligible	Negligible	Zone 2 limited to the immediate vicinity of the source of release.
5	Cut-off valves	ORV vaporizers outlet lines (8)	vaporizers NG outflow	S	1	≈ 1	5000 - 8000	G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
6	Control valves	ORV vaporizers outlet lines (8)	vaporizers NG outflow	S	1	≈ 1	5000 - 8000	G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
7	Check valves	ORV vaporizers outlet lines (8)	vaporizers NG outflow	S	1	≈ 1	5000 - 8000	G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
8	Tubing measurement accessories	ORV vaporizers outlet lines (8)	vaporizers NG outflow	S	1	≈ 1	5000 - 8000	G	N	Medium	Good	2	Negligible	Negligible	Zone 2 limited to the immediate vicinity of the source of release.
9	Pressure Safety Valves	ORV vaporizers outlet lines (8)	vaporizers NG outflow	S	1	≈ 1		G	N	Medium	Good	2	3	3	Zone 2: 3 m in all directions from source of release.
10	Leakages collecting channels	ORV vaporizers (8)	NG vaporization	P	1		Ambient	L	N	Medium	Good	1	3	1.5	Horizontal distance starts from channel boundaries. Vertical distance is from liquid surface.
11	Leakages collecting basin	ORV vaporizers (8)	NG vaporization	C	1			L	N	Low	Poor	0	-	-	Zone 0 in the whole interior of the tank.
12	Cut-off valves	SCV vaporizers inlet lines (10)	vaporizers LNG inflow	S	1		5000 - 8000	L (9)	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
13	Control valves	SCV vaporizers inlet lines (10)	vaporizers LNG inflow	S	1		5000 - 8000	L (9)	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
14	Check valves	SCV vaporizers inlet lines (10)	vaporizers LNG inflow	S	1		5000 - 8000	L (9)	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.

Plant:	El Musel Regasification (Enagás)				Area:	Vaporization area (ORV/SCV)			List of sources of release						
1	2	3	4	5	6	7		8	9			10	11	12	13
Source of relese					Flammable material				Ventilation			Hazardous area			
N°	Description	Position	Operation	Grade of release [1]	Reference [2]	Operating temperature and pressure [3]		State[4]	Type[5]	Degree[6]	Availability [7]	Zone type 0-1-2	Zone extent (m)		Any other relevant information and remarks
						°C	kPa						Vertical	Horizontal	
15	Tubing measurement accessories	SCV vaporizers inlet lines (10)	vaporizers LNG inflow	S	1		5000 - 8000	L [9]	N	Medium	Good	2	Negligible	Negligible	Zone 2 limited to the immediate vicinity of the source of release.
16	Cut-off valves	SCV vaporizers outlet lines (10)	vaporizers NG outflow	S	1		5000 - 8000	G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
17	Control valves	SCV vaporizers outlet lines (10)	vaporizers NG outflow	S	1		5000 - 8000	G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
18	Check valves	SCV vaporizers outlet lines (10)	vaporizers NG outflow	S	1		5000 - 8000	G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
19	Tubing measurement accessories	SCV vaporizers outlet lines (10)	vaporizers NG outflow	S	1		5000 - 8000	G	N	Medium	Good	2	Negligible	Negligible	Zone 2 limited to the immediate vicinity of the source of release.
20	Pressure Safety Valves	SCV vaporizers outlet lines (10)	vaporizers NG outflow	S	1			G	N	Medium	Good	2	3	3	Zone 2: 3 m in all directions from source of release.
21	Cut-off valves	Pilot flame BOG inle	BOG combustion	S	2			G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
22	Control valves	Pilot flame BOG inle	BOG combustion	S	2			G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
23	Check valves	Pilot flame BOG inle	BOG combustion	S	2			G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
24	Tubing measurement accessories	Pilot flame BOG inle	BOG combustion	S	2			G	N	Medium	Good	2	Negligible	Negligible	Zone 2 limited to the immediate vicinity of the source of release.
25	Cut-off valves	Burners BOG inlet	BOG combustion	S	2			G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
26	Control valves	Burners BOG inlet	BOG combustion	S	2			G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
27	Check valves	Burners BOG inlet	BOG combustion	S	2			G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
28	Tubing measurement accessories	Burners BOG inlet	BOG combustion	S	2			G	N	Medium	Good	2	Negligible	Negligible	Zone 2 limited to the immediate vicinity of the source of release.

Plant:	El Musel Regasification (Enagás)				Area:	Vaporization area (ORV/SCV)			List of sources of release						
1	2	3	4	5	6	7		8	9			10	11	12	13
Source of relese					Flammable material				Ventilation			Hazardous area			
N°	Description	Position	Operation	Grade of release (1)	Reference (2)	Operating temperature and pressure (3)		State(4)	Type(5)	Degree(6)	Availability (7)	Zone type	Zone extent (m)		Any other relevant information and remarks
						°C	kPa					0-1-2	Vertical	Horizontal	
29	Leakages collecting channels	SCV vaporizers (10)	NG vaporization	P	1		Ambient	L	N	Medium	Good	1	3	1.5	Horizontal distance starts from channel boundaries. Vertical distance is from liquid surface.
30	Leakages collecting basin	SCV vaporizers (10)	NG vaporization	C	1			L	N	Low	Poor	0	-	-	Zone 0 in the whole interior of the tank.

(1)C - Continuos; S - Secondary; P - Primary.

(2)Quote the number of list in Part I.

(3) Avaliable data are given regarding the operating temperature and pressure or useful to their estimation.

(4)G - Gas; L - Liquefied gas; S - solid.

(5)N - Natural; A- Artificial.

(6)High; Medium; Low.

(7)Good; Fair; Poor.

(8)Open rack vaporizers.

(9)It is assumed that for slight releases the liquid istantaneously evapourates in contact with atmosphere.

(10) Submerged combustion vaporizers.

Plant:	El Musel Regasification (Enagás)				Area:	Measuring and odorizing station			List of sources of release						
1	2	3	4	5	6	7		8	9			10	11	12	13
Source of relese					Flammable material				Ventilation			Hazardous area			
N°	Description	Position	Operation	Grade of release [1]	Reference [2]	Operating temperature and pressure [3]		State[4]	Type[5]	Degree[6]	Availability [7]	Zone type 0-1-2	Zone extent (m)		Any other relevant information and remarks
						°C	kPa						Vertical	Horizontal	
1	Cut-off valves	Measuring station	NG measurement	S	1		5000 - 8000	G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
2	Control valves	Measuring station	NG measurement	S	1		5000 - 8000	G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
3	Check valves	Measuring station	NG measurement	S	1		5000 - 8000	G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
4	Tubing measurement accessories	Measuring station	NG measurement	S	1		5000 - 8000	G	N	Medium	Good	2	Negligible	Negligible	Zone 2 limited to the immediate vicinity of the source of release.
5	THT tank liquid surface	Odorizing station	THT storage	C	3	<30		L	N	Low	Poor	0	-	-	Zone 0 in the whole interior of the tank.
6	Leakages collecting channels	Odorizing station	THT storage	P	3			L	N	Medium	Good	1	3	1.5	Horizontal distance starts from channel boundaries. Vertical distance is from liquid surface.
7	Leakages collecting basin	Odorizing station	THT storage	C	3			L	N	Low	Poor	0	-	-	Zone 0 in the whole interior of the tank.
8	Cut-off valves	Odorizing station	NG odorization	S	3			L	N	Medium	Good	2	Negligible	Negligible	Zone 2 limited to the immediate vicinity of the source of release.
9	Control valves	Odorizing station	NG odorization	S	3			L	N	Medium	Good	3	Negligible	Negligible	Zone 2 limited to the immediate vicinity of the source of release.
10	Check valves	Odorizing station	NG odorization	S	3			L	N	Medium	Good	4	Negligible	Negligible	Zone 2 limited to the immediate vicinity of the source of release.
11	Tubing measurement accessories	Odorizing station	NG odorization	S	3			L	N	Medium	Good	5	Negligible	Negligible	Zone 2 limited to the immediate vicinity of the source of release.

[1] C - Continuos; S - Secondary; P - Primary.

[2] Quote the number of list in Part I.

[3] Avaliable data are given regarding the operating temperature and pressure or useful to their estimation.

[4] G - Gas; L - Liquefied gas; S - solid.

[5] N - Natural; A- Artificial.

[6] High; Medium; Low.

[7] Good; Fair; Poor.

Plant:	El Musel Regasification (Enagás)				Area:	LNG truck loading area			List of sources of release						
1	2	3	4	5	6	7		8	9			10	11	12	13
Source of relese					Flammable material				Ventilation			Hazardous area			
N°	Description	Position	Operation	Grade of release [1]	Reference [2]	Operating temperature and pressure [3]		State[4]	Type[5]	Degree[6]	Availability [7]	Zone type 0-1-2	Zone extent (m)		Any other relevant information and remarks
						°C	kPa						Vertical	Horizontal	
1	Cut off valves	LNG loading lines	LNG truck loading	S	1		max 60 m^3/h	L[8]	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
2	Control valves	LNG loading lines	LNG truck loading	S	1		max 60 m^3/h	L[8]	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
3	Check valves	LNG loading lines	LNG truck loading	S	1		max 60 m^3/h	L[8]	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
4	Tubing measurement accessories	LNG loading lines	LNG truck loading	S	1		max 60 m^3/h	L[8]	N	Medium	Good	2	Negligible	Negligible	Zone 2 limited to the immediate vicinity of the source of release.
5	LNG fillers couplings	LNG loading arms	Clamping / Unclamping	P	1		20 - 50	L[9]	N	Medium	Good	1	1.5	1.5	Zone 1: 1.5 m in all directions from source of release.
6	Pool at floor level below LNG filler	LNG loading arms	Clamping / Unclamping	P	1		Ambient	L	N	Medium	Good	1	3	-	Zone 1: 3 m above loading area ground level.
7	Leakages collecting channels	LNG loading arms area	LNG truck loading	P	1		Ambient	L	N	Medium	Good	1	3	1.5	Horizontal distance starts from channel boundaries. Vertical distance is from liquid surface.
8	Leakages collecting basin	LNG loading arms area	LNG truck loading	C	1			L	N	Low	Poor	0	-	-	Zone 0 in the whole interior of the tank.
9	Vapour arms couplings	BOG devolution arms	Clamping / Unclamping	P	2			G	N	Medium	Good	1	1.5	1.5	Zone 1: 1.5 m in all directions from source of release.
10	Cut off valves	BOG devolution lines	BOG devolution to the plant	S	1			G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
11	Control valves	BOG devolution lines	BOG devolution to the plant	S	2			G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
12	Check valves	BOG devolution lines	BOG devolution to the plant	S	2			G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
13	Tubing measurement accessories	BOG devolution lines	BOG devolution to the plant	S	2			G	N	Medium	Good	2	Negligible	Negligible	Zone 2 limited to the immediate vicinity of the source of release.

[1] C - Continuos; S - Secondary; P - Primary.
[2] Quote the number of list in Part I.
[3] Avaliable data are given regarding the operating temperature and pressure or useful to their estimation.

[4] G - Gas; L - Liquefied gas; S - solid.
[5] N - Natural; A- Artificial.
[6] High; Medium; Low.
[7] Good; Fair; Poor.

[8] It is assumed that for slight releases the liquid istantaneously evapourates in contact with atmosphere.

[9] At moment of leakage a part of liquid vapourizes forming clouds or mists before complete evaporation and ascension.

Plant:	**El Musel Regasification (Enagás)**				**Area:**	**Venting system to torch**			**List of sources of release**						
1	2	3	4	5	6	7		8	9			10	11	12	13
Source of relese					Flammable material				Ventilation			Hazardous area			
N°	Description	Position	Operation	Grade of release [1]	Reference [2]	Operating temperature and pressure[3]		State[4]	Type[5]	Degree[6]	Availability [7]	Zone type 0-1-2	Zone extent (m)		Any other relevant information and remarks
						°C	kPa						Vertical	Horizontal	
1	Cut-off valves	Torch drop separator inlet line	BOG entering in the separator	S	2			G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
2	Control valves	Torch drop separator inlet line	BOG entering in the separator	S	3			G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
3	Check valve	Torch drop separator inlet line	BOG entering in the separator	S	4			G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
4	Tubing measurement accessories	Torch drop separator inlet line	BOG entering in the separator	S	2			G	N	Medium	Good	2	Negligible	Negligible	Zone 2 limited to the immediate vicinity of the source of release.
5	Flow inside the separator	Interior of torch drop separator	Liquid separation	C	1 / 2			G / L	N	Low	Poor	0	-	-	Zone 0 in the whole interior of the tank.
6	Cut-off ball valve	Drop separator liquid outlet	Liquid discharging	S	1			L[8]	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
7	Leakages collecting channels	Drop separator liquid outlet	Liquid discharging	P	1		Ambient	L	N	Medium	Good	1	3	1.5	Horizontal distance starts from channel boundaries. Vertical distance is from liquid surface.
8	Leakages collecting basin	Drop separator liquid outlet	Liquid discharging	C	1			L	N	Low	Poor	0	-	-	Zone 0 in the whole interior of the tank.
9	Cut-off valves	BOG outlet line from separator	BOG to torch	S	2		Rate ≃ 150 000 kg/h	G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
10	Control valves	BOG outlet line from separator	BOG to torch	S	2		Rate ≃ 150 000 kg/h	G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
11	Check valve	BOG outlet line from separator	BOG to torch	S	2		Rate ≃ 150 000 kg/h	G	N	Medium	Good	2	1	1	Zone 2: 1 m in all directions from source of release.
12	Tubing measurement accessories	BOG outlet line from separator	BOG to torch	S	2		Rate ≃ 150 000 kg/h	G	N	Medium	Good	2	Negligible	Negligible	Zone 2 limited to the immediate vicinity of the source of release.

[1] C - Continuos; S - Secondary; P - Primary.

[2] Quote the number of list in Part I.

[3] Avaliable data are given regarding the operating temperature and pressure or useful to their estimation.

[4] G - Gas; L - Liquefied gas; S - solid.

[5] N - Natural; A- Artificial.

[6] High; Medium; Low.

[7] Good; Fair; Poor.

[8] It is assumed that for slight releases the liquid istantaneously evapourates in contact with atmosphere.

ANNEX VI

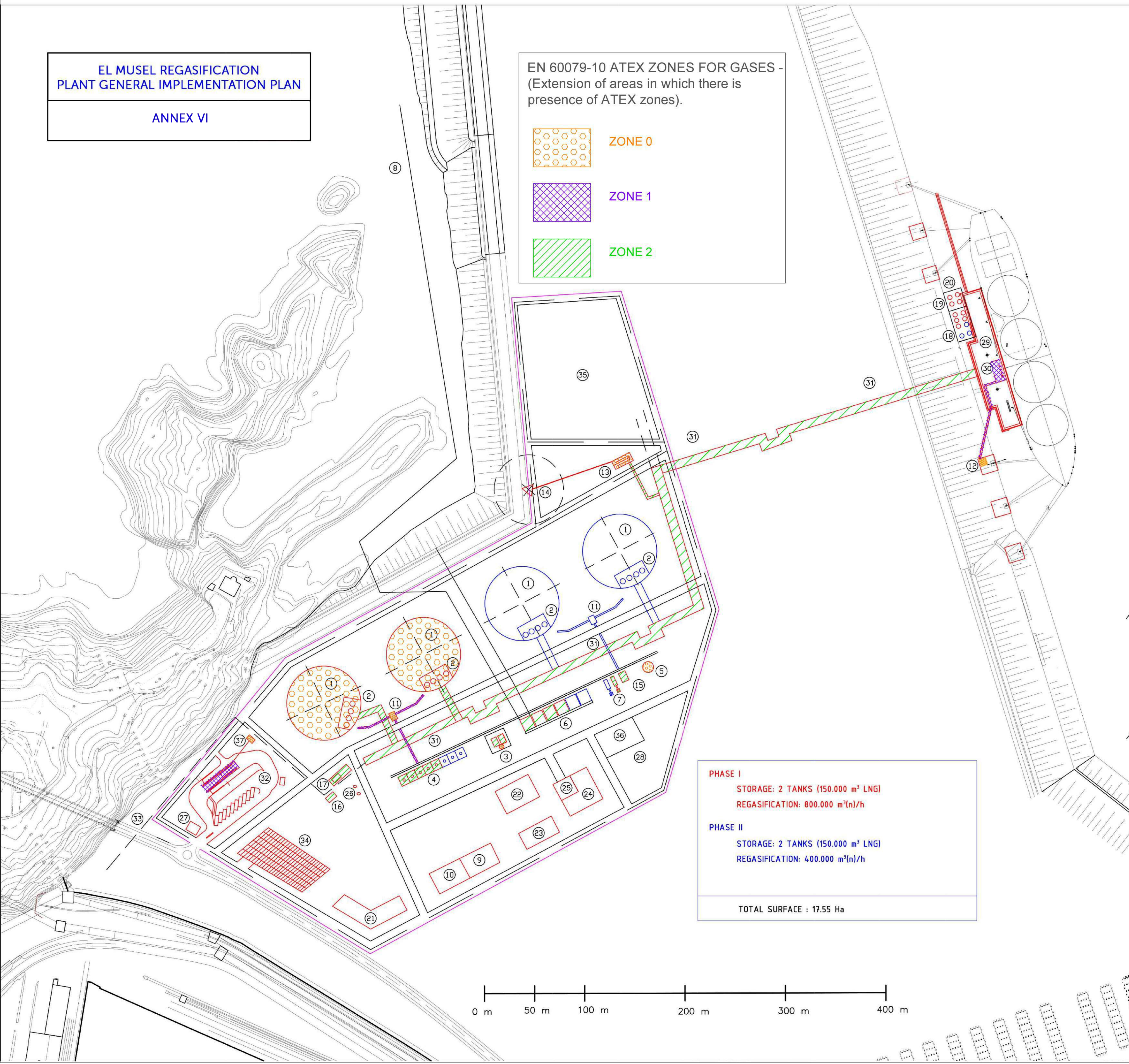
El Musel Regasification ATEX zones extension

EL MUSEL REGASIFICATION PLANT GENERAL IMPLEMENTATION PLAN

ANNEX VI

EN 60079-10 ATEX ZONES FOR GASES - (Extension of areas in which there is presence of ATEX zones).

- ZONE 0
- ZONE 1
- ZONE 2



PHASE I

STORAGE: 2 TANKS (150.000 m³ LNG)

REGASIFICATION: 800.000 m³(n)/h

PHASE II

STORAGE: 2 TANKS (150.000 m³ LNG)

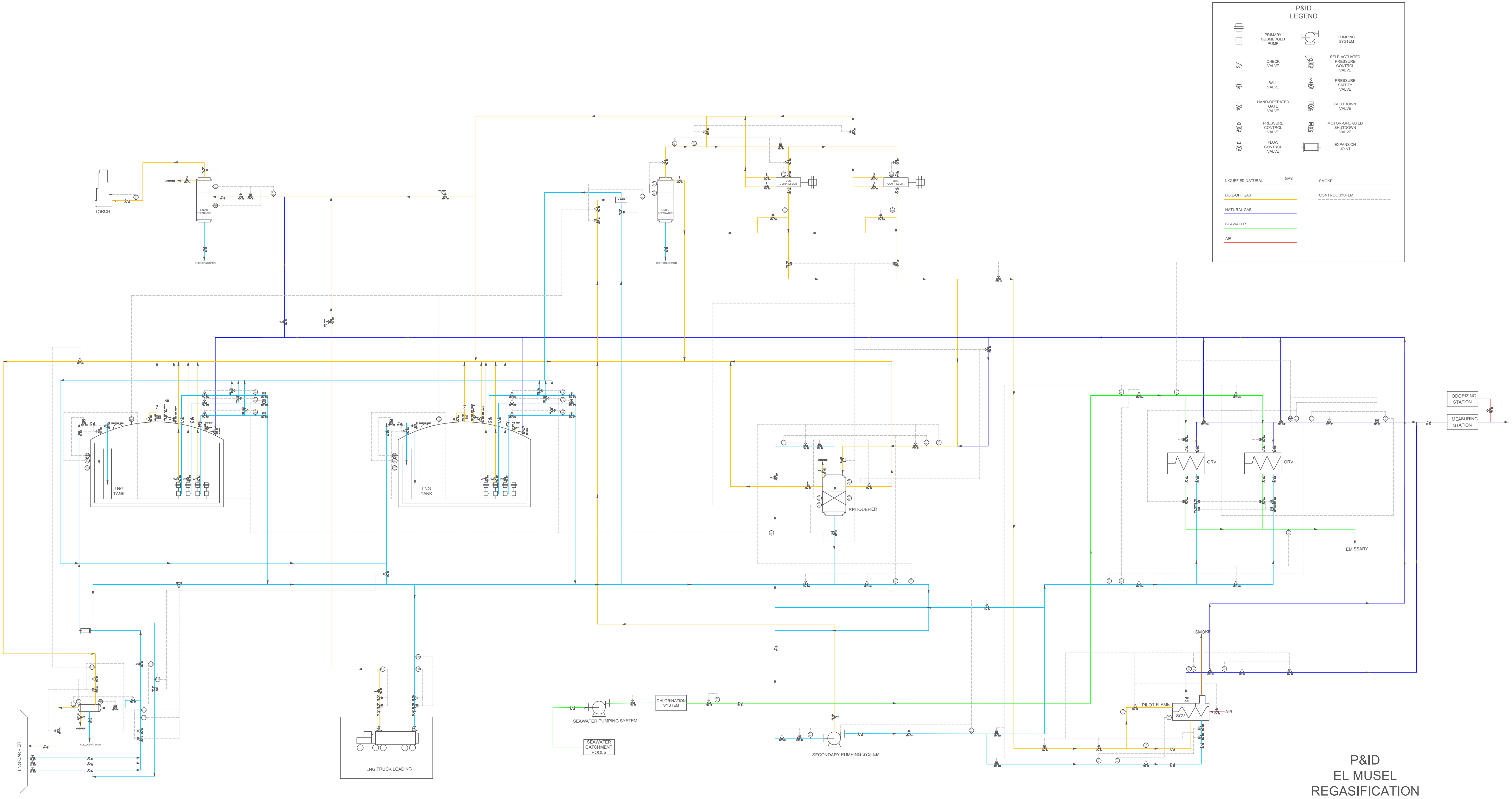
REGASIFICATION: 400.000 m³(n)/h

TOTAL SURFACE : 17.55 Ha

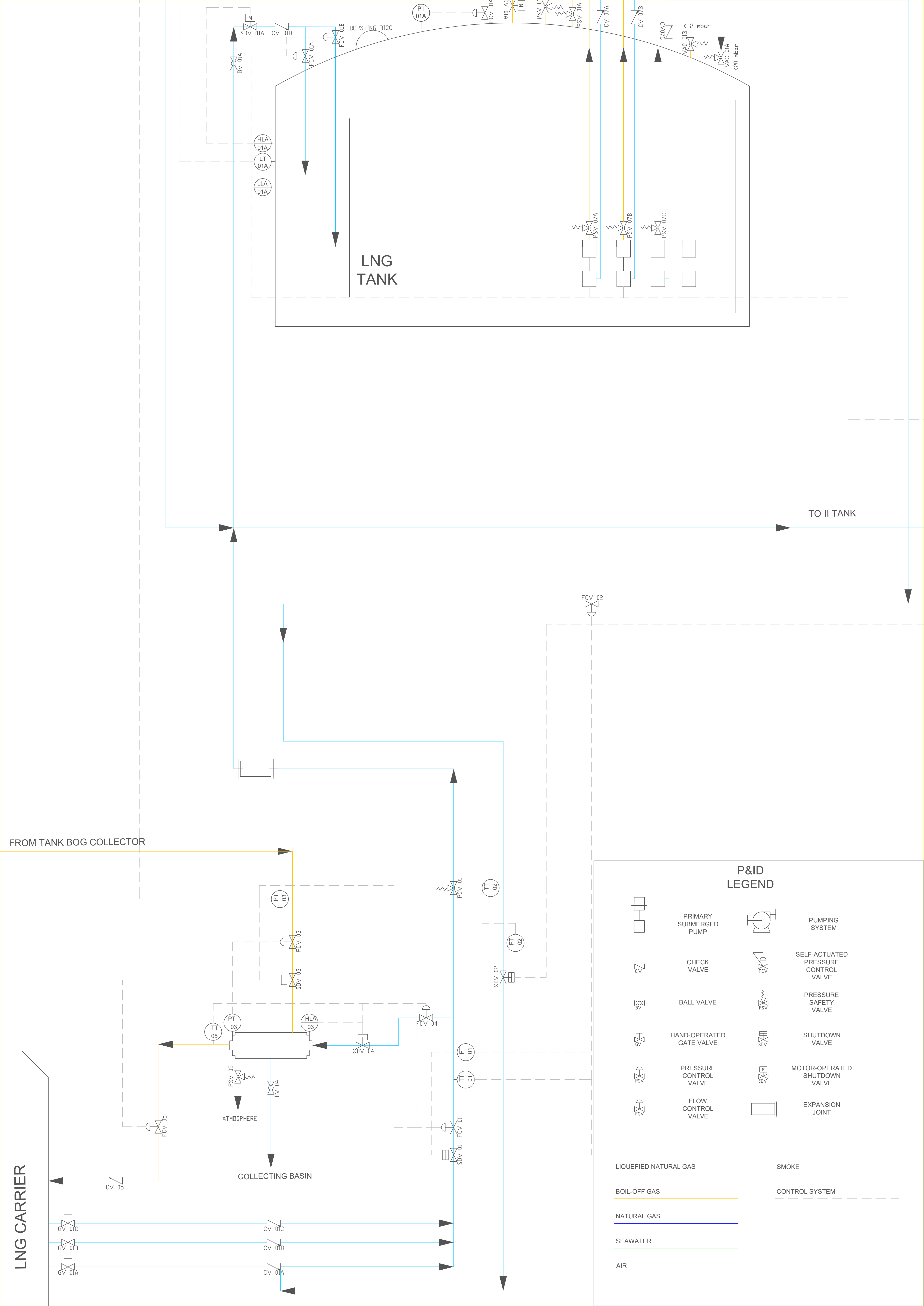
1	LNG TANKS (3 PUMP WELLS)	Approx. volume 150 000 m³ of LNG
2	PRIMARY PUMPS	Q = 300 m³/h LNG
3	BOIL-OFF COMPRESSORS	Q = 10 000 kg/h
4	SECONDARY PUMPS	Q = 350 m³/h LNG
5	RELIQUEFIER	
6	OPEN RACK LNG VAPORISERS	Approx. Q 200 00 m³(n)/h
7	SUBMERGED COMBUSTION LNG VAPORIZERS	Approx. Q 200 00 m³(n)/h
8	EMISSARY	Capacity = 30 000 m³/h
9	ELECTRIC SUBSTATION	
10	CONTROL ROOM	
11	LEAKAGES COLLECTING BASIN OF TANK AND PROCESS AREA	
12	LEAKAGES COLLECTING BASIN OF DOCKING AREA	
13	TORCH LIQUID SEPARATOR	
14	TORCH	Q = 150 000 kg/h
15	FUEL GAS SYSTEM	
16	ODORIZATION	
17	REGULATION AND MEASURING STATION	3 + 1 lines 400 000 m³(n)/h
18	SEAWATER CATCHMENT PUMPS	Q = 5 500 m³/h
19	DCI PUMPS	
20	PLANT WATER AND DCI BASIN	
21	OFFICES	
22	DEPOSITS	
23	STORAGE FACILITIES	
24	WEATHER PROTECTION STORAGE FACILITIES	
25	FIREHOUSE	
26	UTILITIES (WATER, AIR, NITROGEN)	
27	ACCESS	
28	ZONE FOR CONTRACTORS AND MAINTENANCE	
29	LNG UNLOADING PLATFORM / DOCKING	LNG carriers to 250 000 m³ LNG
30	UNLOADING ARMS	3 x 20" + 1 x 20"
31	LNG TRANSFER LINES	
32	LNG TRUCK LOADING AREA	
33	HIGH-PRESSURE PIPELINE NETWORK	
34	PARKING	
35	TEMPORARY INSTALLATIONS	
36	FUTURE COLD SYSTEM AREA	
37	LEAKAGES COLLECTING BASIN OF LNG TRUCK LOADING AREA	

ANNEX VII

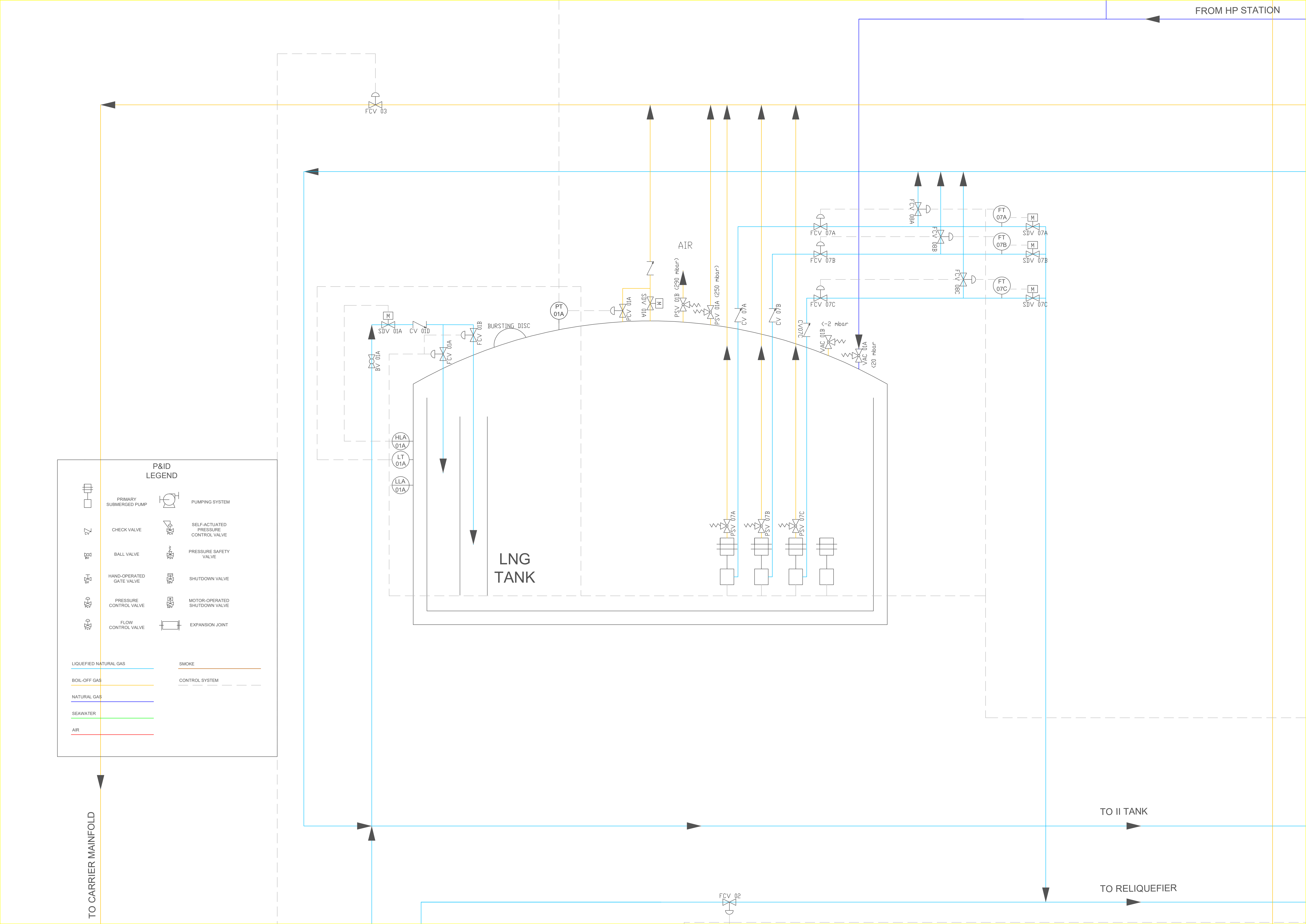
El Musel Regasification P&ID



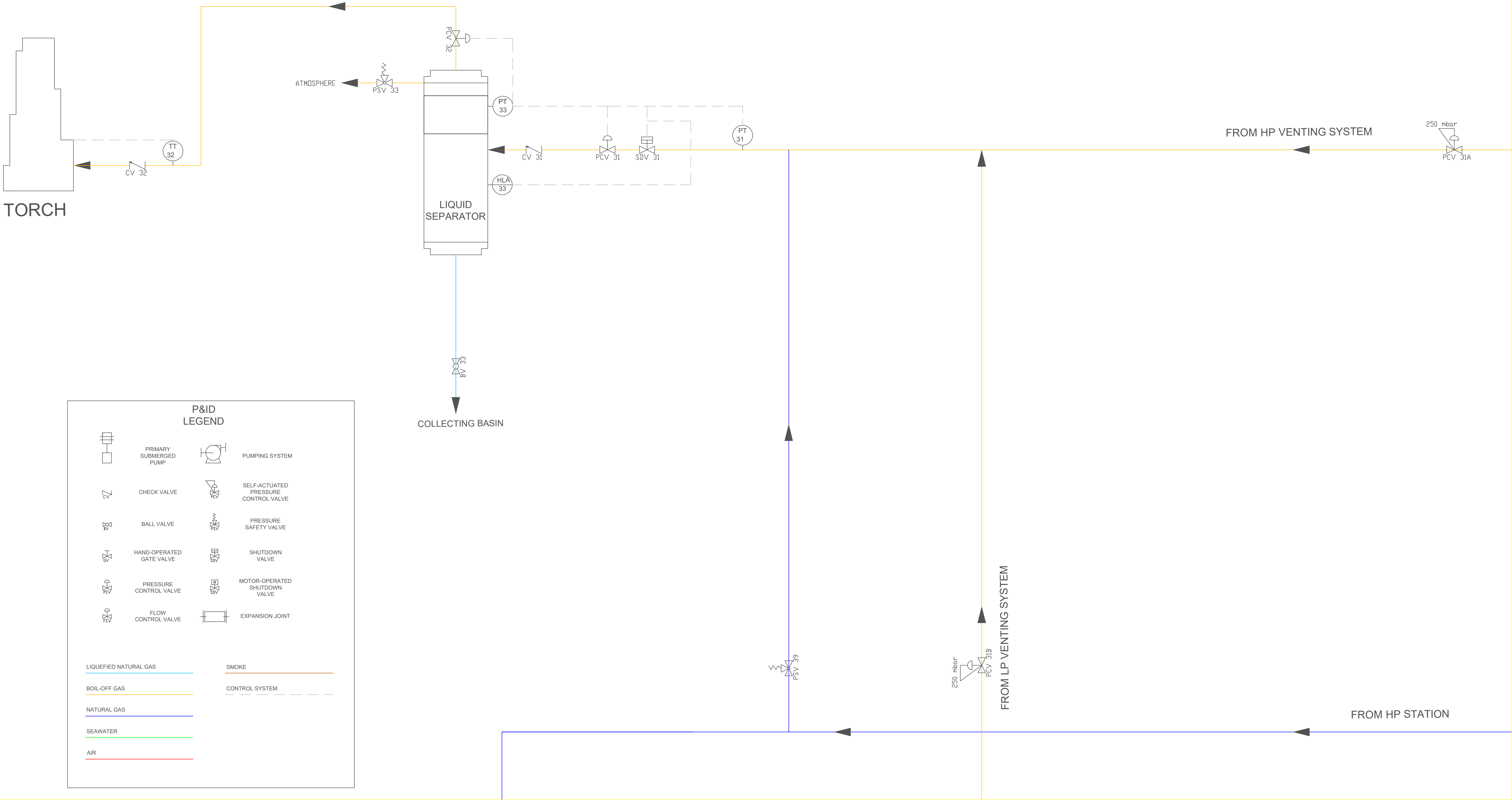
P&ID
EL MUSEL
REGASIFICATION
PLANT



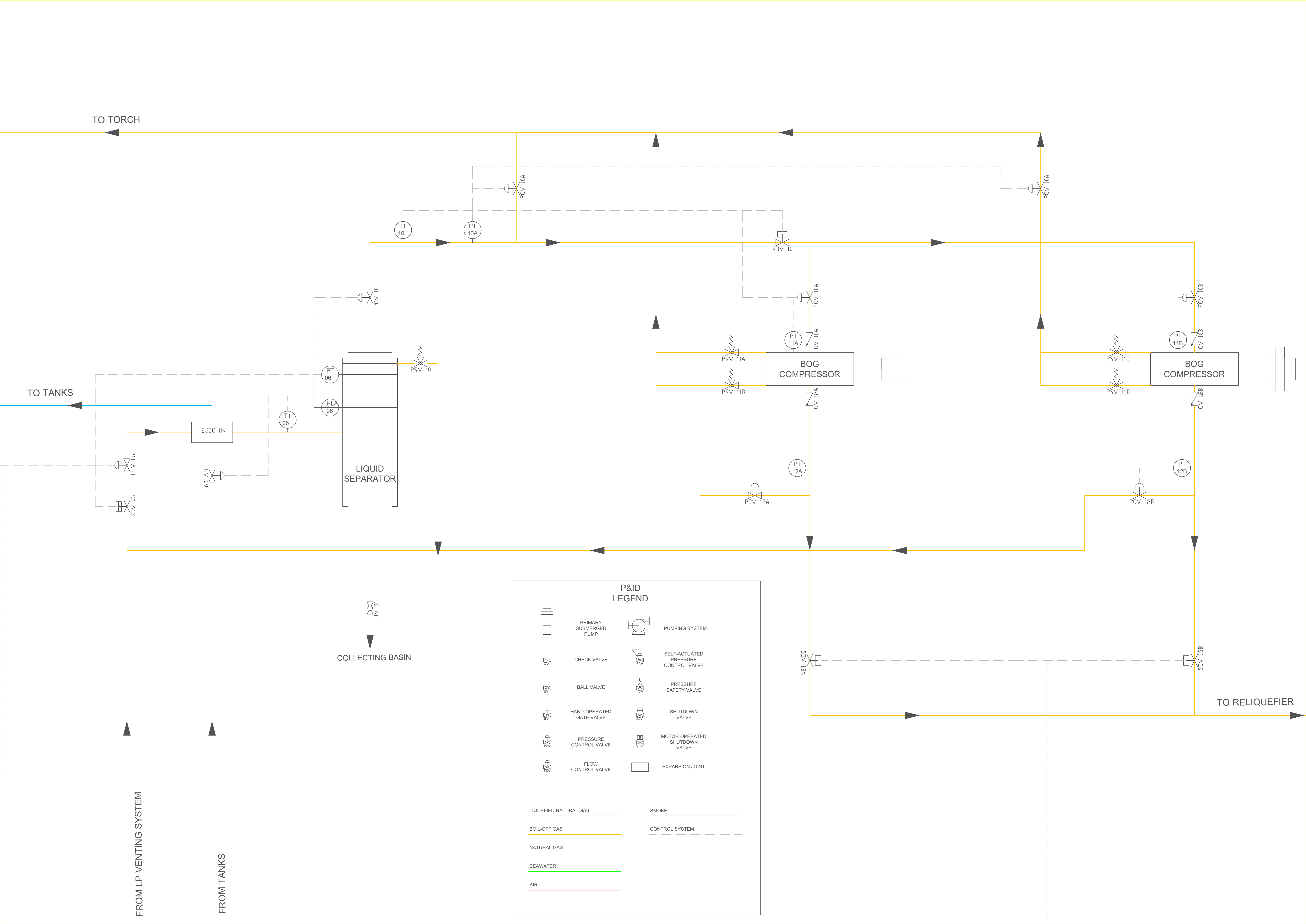
SDV 01A
CV 01D
FCV 01B
BURSTING DISC
BV 01A
FCV 01A
PT 01A
PCV 01A
PSV 01A
CV 07A
CV 07B
CV 07C
VAC 01B
<-2 mbar
VAC 01A
<20 mbar
HLA 01A
LT 01A
LLA 01A
PSV 07A
PSV 07B
PSV 07C
LNG TANK
TO II TANK
FCV 02
FROM TANK BOG COLLECTOR
PSV 01
TT 02
FT 02
SDV 02
PT 03
PCV 03
SDV 03
TT 05
PT 03
HLA 03
SDV 04
FCV 04
FT 01
TT 01
PSV 05
BV 04
ATMOSPHERE
FCV 05
FCV 01
SDV 01
COLLECTING BASIN
CV 05
LNG CARRIER
GV 01C
CV 01C
GV 01B
CV 01B
GV 01A
CV 01A
P&ID LEGEND
PRIMARY SUBMERGED PUMP
PUMPING SYSTEM
CHECK VALVE
SELF-ACTUATED PRESSURE CONTROL VALVE
BALL VALVE
PRESSURE SAFETY VALVE
HAND-OPERATED GATE VALVE
SHUTDOWN VALVE
PRESSURE CONTROL VALVE
MOTOR-OPERATED SHUTDOWN VALVE
FLOW CONTROL VALVE
EXPANSION JOINT
LIQUEFIED NATURAL GAS
SMOKE
BOIL-OFF GAS
CONTROL SYSTEM
NATURAL GAS
SEAWATER
AIR

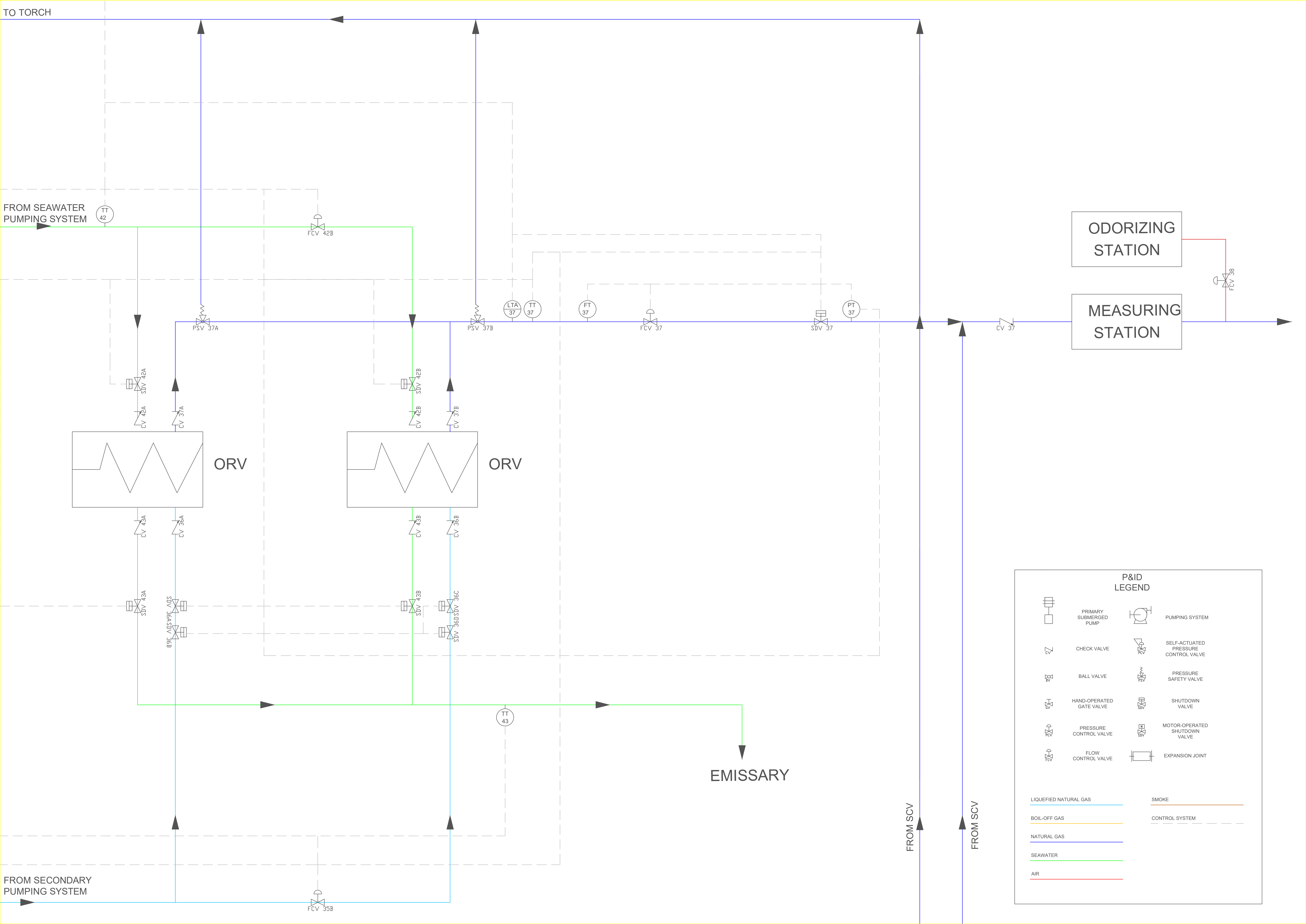


FROM HP STATION
FCV 03
AIR
PT 01A
BURSTING DISC
SDV 01A
CV 01D
FCV 01B
FCV 01A
BV 01A
PCV 01A
SDV 01A
PSV 01B (290 mbar)
PSV 01A (250 mbar)
CV 07A
CV 07B
CV 07C
VAC 01B
<-2 mbar
VAC 01A
<20 mbar
FCV 07A
FCV 07B
FCV 07C
FCV 08A
FCV 08B
FCV 08C
FT 07A
FT 07B
FT 07C
SDV 07A
SDV 07B
SDV 07C
HLA 01A
LT 01A
LLA 01A
PSV 07A
PSV 07B
PSV 07C
LNG TANK
P&ID LEGEND
PRIMARY SUBMERGED PUMP
PUMPING SYSTEM
CHECK VALVE
SELF-ACTUATED PRESSURE CONTROL VALVE
BALL VALVE
PRESSURE SAFETY VALVE
HAND-OPERATED GATE VALVE
SHUTDOWN VALVE
PRESSURE CONTROL VALVE
MOTOR-OPERATED SHUTDOWN VALVE
FLOW CONTROL VALVE
EXPANSION JOINT
LIQUEFIED NATURAL GAS
SMOKE
BOIL-OFF GAS
CONTROL SYSTEM
NATURAL GAS
SEAWATER
AIR
TO CARRIER MANIFOLD
TO II TANK
TO RELIQUEFIER
FCV 02

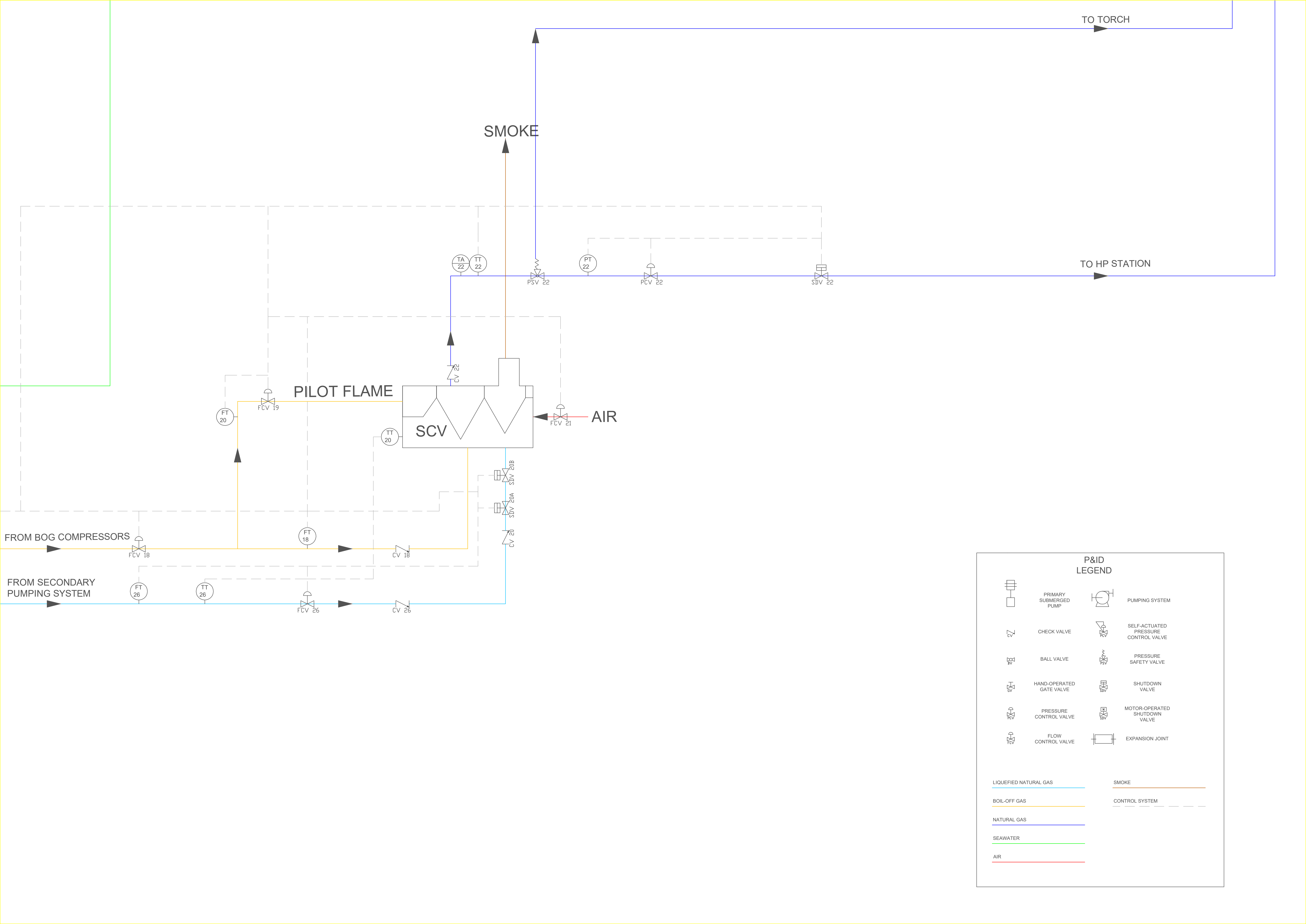


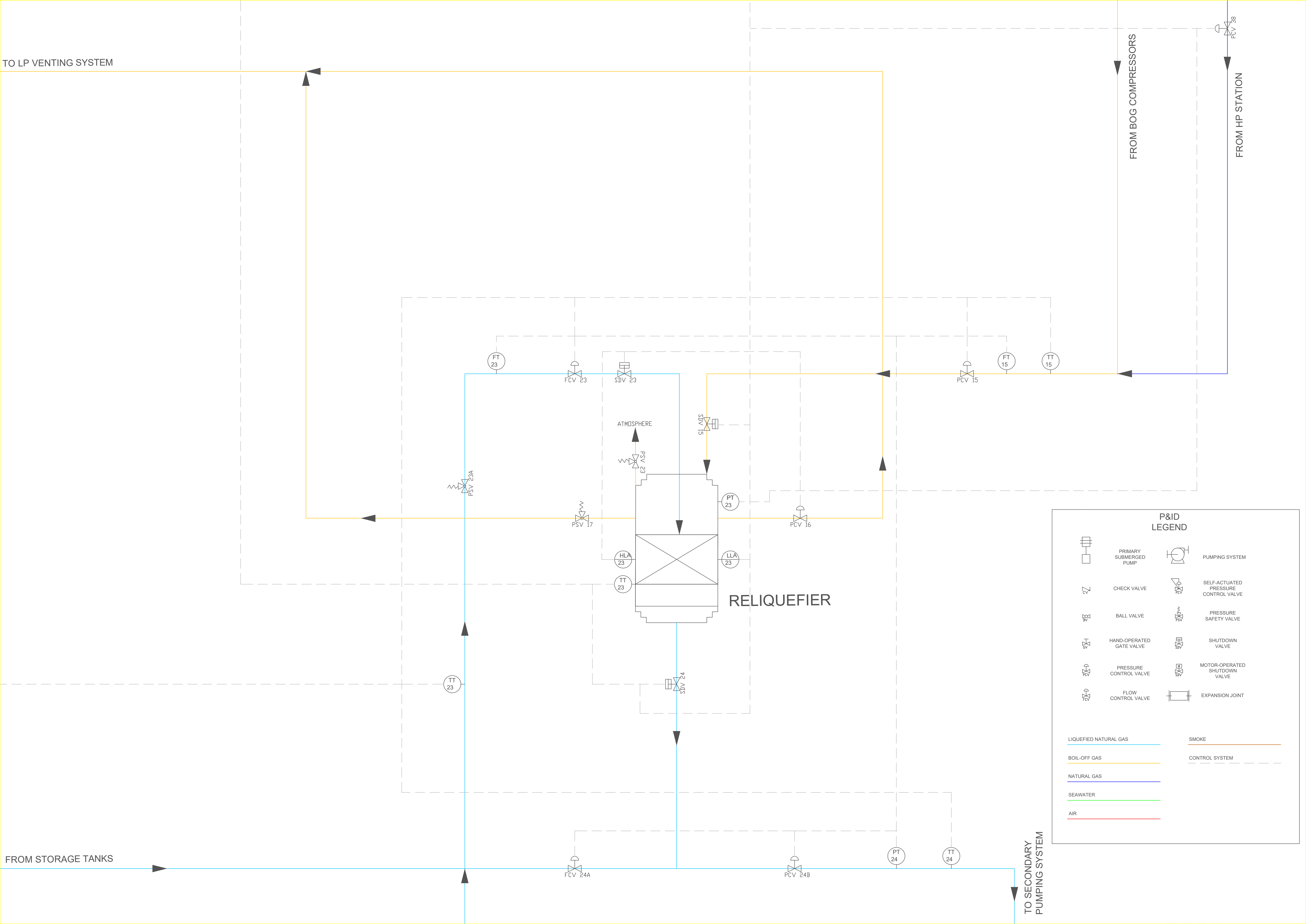
TORCH
TT 32
CV 32
PCV 32
ATMOSPHERE
PSV 33
PT 33
HLA 33
LIQUID SEPARATOR
CV 31
PCV 31
SDV 31
PT 31
FROM HP VENTING SYSTEM
250 mbar
PCV 31A
BV 33
COLLECTING BASIN
PSV 39
250 mbar
PCV 31B
FROM LP VENTING SYSTEM
FROM HP STATION
P&ID LEGEND
PRIMARY SUBMERGED PUMP
PUMPING SYSTEM
CHECK VALVE
SELF-ACTUATED PRESSURE CONTROL VALVE
BALL VALVE
PRESSURE SAFETY VALVE
HAND-OPERATED GATE VALVE
SHUTDOWN VALVE
PRESSURE CONTROL VALVE
MOTOR-OPERATED SHUTDOWN VALVE
FLOW CONTROL VALVE
EXPANSION JOINT
LIQUEFIED NATURAL GAS
SMOKE
BOIL-OFF GAS
CONTROL SYSTEM
NATURAL GAS
SEAWATER
AIR


TO TORCH
PCV 10A
PCV 10A
TT 10
PT 10A
SDV 10
PCV 10
FCV 10A
FCV 10B
PT 11A
CV 10A
PT 11B
CV 10B
PSV 11A
PSV 11B
PSV 11C
PSV 11D
BOG COMPRESSOR
BOG COMPRESSOR
CV 12A
CV 12B
PSV 10
PT 06
HLA 06
TO TANKS
TT 06
EJECTOR
FCV 06
FCV 09
SDV 06
LIQUID SEPARATOR
PT 12A
PCV 12A
PT 12B
PCV 12B
BV 06
COLLECTING BASIN
SDV 13A
SDV 13B
TO RELIQUEFIER
FROM LP VENTING SYSTEM
FROM TANKS
P&ID LEGEND
PRIMARY SUBMERGED PUMP
PUMPING SYSTEM
CHECK VALVE
SELF-ACTUATED PRESSURE CONTROL VALVE
BALL VALVE
PRESSURE SAFETY VALVE
HAND-OPERATED GATE VALVE
SHUTDOWN VALVE
PRESSURE CONTROL VALVE
MOTOR-OPERATED SHUTDOWN VALVE
FLOW CONTROL VALVE
EXPANSION JOINT
LIQUEFIED NATURAL GAS
SMOKE
BOIL-OFF GAS
CONTROL SYSTEM
NATURAL GAS
SEAWATER
AIR

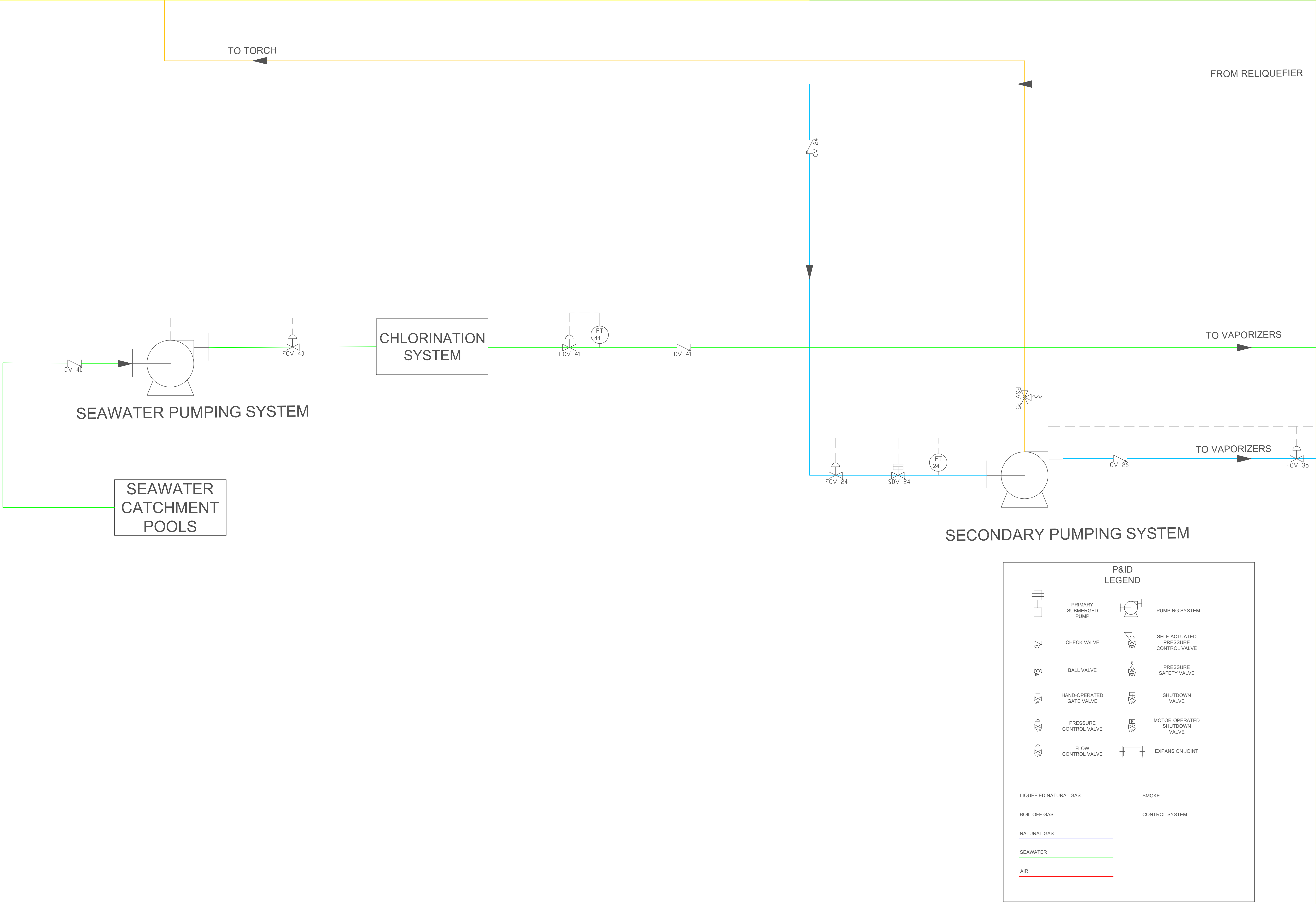


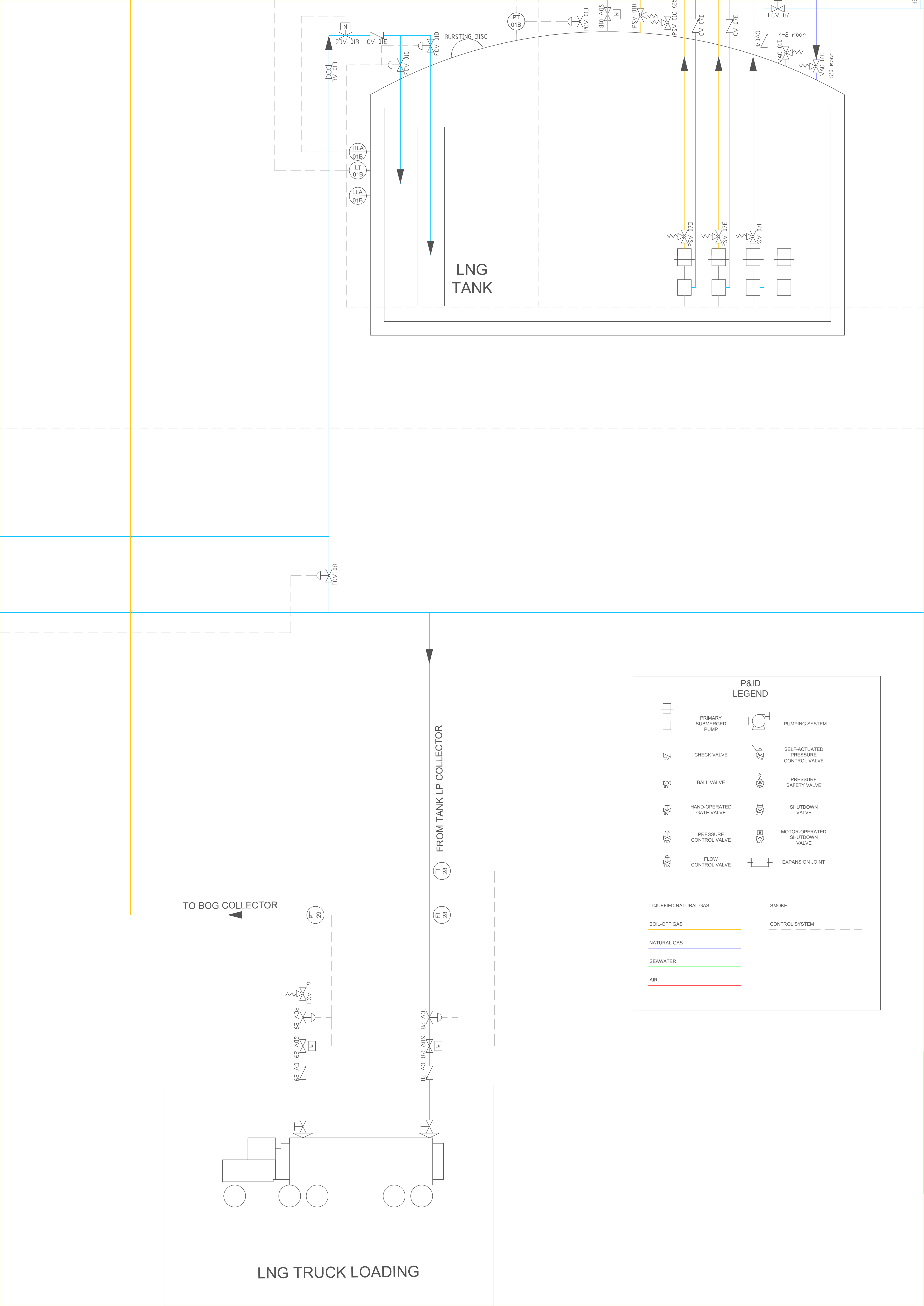
TO TORCH
FROM SEAWATER PUMPING SYSTEM
TT 42
FCV 42B
PSV 37A
PSV 37B
LTA 37
TT 37
FT 37
FCV 37
SDV 37
PT 37
CV 37
ODORIZING STATION
MEASURING STATION
FCV 38
SDV 42A
SDV 42B
CV 42A
CV 37A
CV 42B
CV 37B
ORV
ORV
CV 43A
CV 36A
CV 43B
CV 36B
SDV 43A
SDV 36A
SDV 36B
SDV 43B
SDV 36C
SDV 36D
TT 43
EMISSARY
FROM SECONDARY PUMPING SYSTEM
FCV 35B
FROM SCV
FROM SCV
P&ID LEGEND
PRIMARY SUBMERGED PUMP
PUMPING SYSTEM
CHECK VALVE
SELF-ACTUATED PRESSURE CONTROL VALVE
BALL VALVE
PRESSURE SAFETY VALVE
HAND-OPERATED GATE VALVE
SHUTDOWN VALVE
PRESSURE CONTROL VALVE
MOTOR-OPERATED SHUTDOWN VALVE
FLOW CONTROL VALVE
EXPANSION JOINT
LIQUEFIED NATURAL GAS
SMOKE
BOIL-OFF GAS
CONTROL SYSTEM
NATURAL GAS
SEAWATER
AIR


TO TORCH
SMOKE
TO HP STATION
TA 22
TT 22
PSV 22
PT 22
PCV 22
SDV 22
CV 22
PILOT FLAME
FT 20
FCV 19
TT 20
SCV
FCV 21
AIR
SDV 20B
SDV 20A
CV 20
FROM BOG COMPRESSORS
FCV 18
FT 18
CV 18
FROM SECONDARY PUMPING SYSTEM
FT 26
TT 26
FCV 26
CV 26
P&ID LEGEND
PRIMARY SUBMERGED PUMP
PUMPING SYSTEM
CHECK VALVE
SELF-ACTUATED PRESSURE CONTROL VALVE
BALL VALVE
PRESSURE SAFETY VALVE
HAND-OPERATED GATE VALVE
SHUTDOWN VALVE
PRESSURE CONTROL VALVE
MOTOR-OPERATED SHUTDOWN VALVE
FLOW CONTROL VALVE
EXPANSION JOINT
LIQUEFIED NATURAL GAS
SMOKE
BOIL-OFF GAS
CONTROL SYSTEM
NATURAL GAS
SEAWATER
AIR



TO LP VENTING SYSTEM
FROM BOG COMPRESSORS
FROM HP STATION
PCV 38
FT 23
FCV 23
SDV 23
PCV 15
FT 15
TT 15
SDV 15
ATMOSPHERE
PSV 23
PSV 23A
PSV 17
PT 23
PCV 16
HLA 23
LLA 23
TT 23
RELIQUEFIER
SDV 24
TT 23
FROM STORAGE TANKS
FCV 24A
PCV 24B
PT 24
TT 24
TO SECONDARY PUMPING SYSTEM
P&ID LEGEND
PRIMARY SUBMERGED PUMP
PUMPING SYSTEM
CHECK VALVE
SELF-ACTUATED PRESSURE CONTROL VALVE
BALL VALVE
PRESSURE SAFETY VALVE
HAND-OPERATED GATE VALVE
SHUTDOWN VALVE
PRESSURE CONTROL VALVE
MOTOR-OPERATED SHUTDOWN VALVE
FLOW CONTROL VALVE
EXPANSION JOINT
LIQUEFIED NATURAL GAS
SMOKE
BOIL-OFF GAS
CONTROL SYSTEM
NATURAL GAS
SEAWATER
AIR

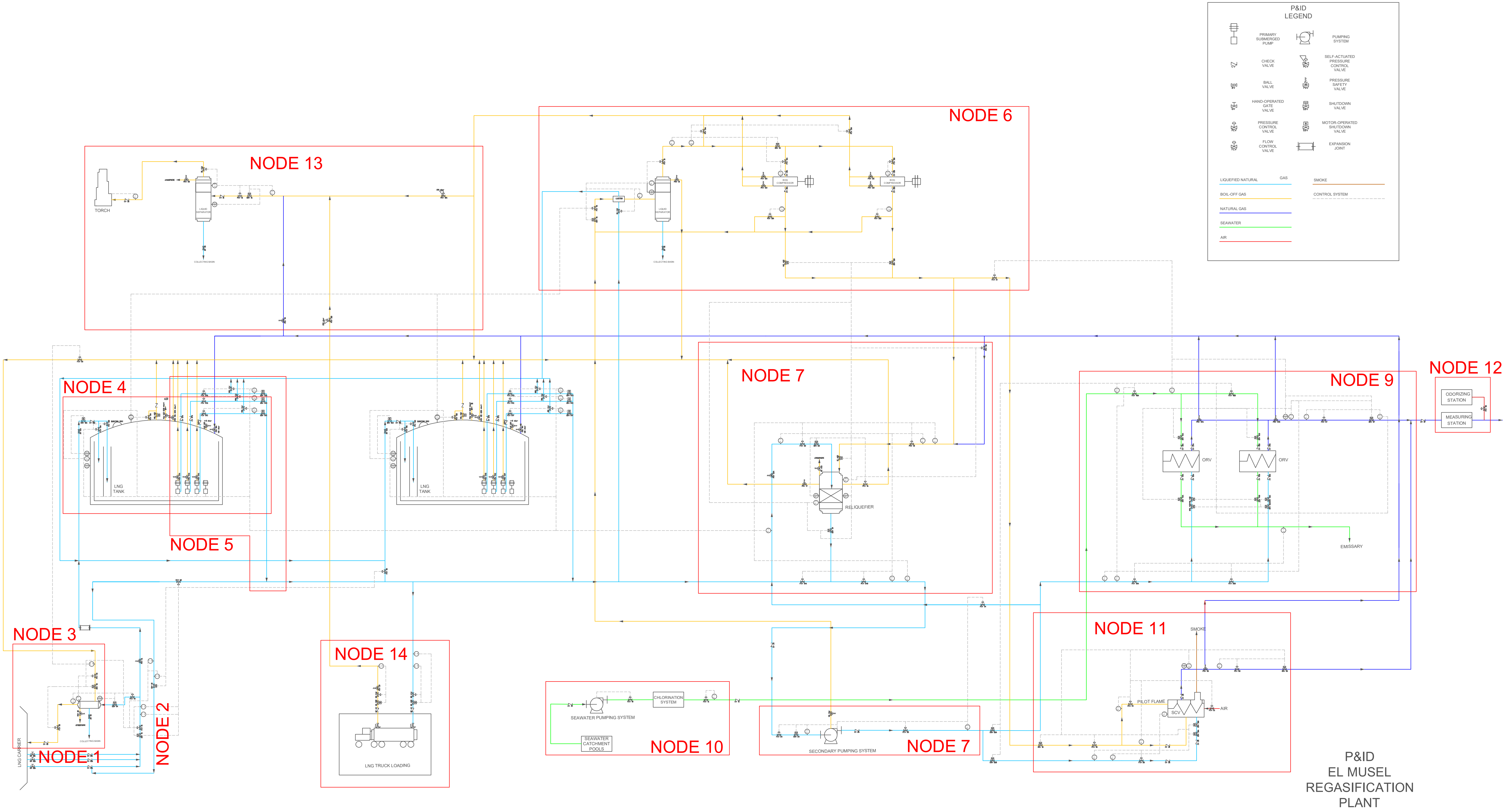

TO TORCH
FROM RELIQUEFIER
CV 24
TO VAPORIZERS
FCV 40
CHLORINATION SYSTEM
FCV 41
FT 41
CV 41
CV 40
SEAWATER PUMPING SYSTEM
PSV 25
TO VAPORIZERS
FT 24
FCV 24
SDV 24
CV 26
FCV 35
SEAWATER CATCHMENT POOLS
SECONDARY PUMPING SYSTEM
P&ID LEGEND
PRIMARY SUBMERGED PUMP
PUMPING SYSTEM
CHECK VALVE
SELF-ACTUATED PRESSURE CONTROL VALVE
BALL VALVE
PRESSURE SAFETY VALVE
HAND-OPERATED GATE VALVE
SHUTDOWN VALVE
PRESSURE CONTROL VALVE
MOTOR-OPERATED SHUTDOWN VALVE
FLOW CONTROL VALVE
EXPANSION JOINT
LIQUEFIED NATURAL GAS
SMOKE
BOIL-OFF GAS
CONTROL SYSTEM
NATURAL GAS
SEAWATER
AIR



SDV 01B
CV 01E
FCV 01D
BURSTING DISC
PT 01B
PCV 01B
SDV 01B
PSV 01D
PSV 01C
CV 07D
CV 07E
CV07F
FCV 07F
<-2 mbar
VAC 01D
VAC 01C
<20 mbar
BV 01B
FCV 01C
HLA 01B
LT 01B
LLA 01B
LNG TANK
PSV 07D
PSV 07E
PSV 07F
FCV 08
FROM TANK LP COLLECTOR
TT 28
FT 28
TO BOG COLLECTOR
PT 29
PSV 29
PCV 29
SDV 29
CV 29
FCV 28
SDV 28
CV 28
LNG TRUCK LOADING
P&ID LEGEND
PRIMARY SUBMERGED PUMP
PUMPING SYSTEM
CHECK VALVE
SELF-ACTUATED PRESSURE CONTROL VALVE
BALL VALVE
PRESSURE SAFETY VALVE
HAND-OPERATED GATE VALVE
SHUTDOWN VALVE
PRESSURE CONTROL VALVE
MOTOR-OPERATED SHUTDOWN VALVE
FLOW CONTROL VALVE
EXPANSION JOINT
LIQUEFIED NATURAL GAS
SMOKE
BOIL-OFF GAS
CONTROL SYSTEM
NATURAL GAS
SEAWATER
AIR

ANNEX VIII

Hazard and Operability Analysis (HAZOP)


P&ID
LEGEND
PRIMARY SUBMERGED PUMP
PUMPING SYSTEM
CHECK VALVE
SELF-ACTUATED PRESSURE CONTROL VALVE
BALL VALVE
PRESSURE SAFETY VALVE
HAND-OPERATED GATE VALVE
SHUTDOWN VALVE
PRESSURE CONTROL VALVE
MOTOR-OPERATED SHUTDOWN VALVE
FLOW CONTROL VALVE
EXPANSION JOINT
LIQUEFIED NATURAL GAS
SMOKE
BOIL-OFF GAS
CONTROL SYSTEM
NATURAL GAS
SEAWATER
AIR
NODE 1
NODE 2
NODE 3
NODE 4
NODE 5
NODE 6
NODE 7
NODE 9
NODE 10
NODE 11
NODE 12
NODE 13
NODE 14
TORCH
LNG TANK
LNG CARRIER
LNG TRUCK LOADING
RELIQUEFIER
ORV
EMISSARY
ODORIZING STATION
MEASURING STATION
SMOKE
PILOT FLAME
SCV
AIR
SEAWATER PUMPING SYSTEM
CHLORINATION SYSTEM
SEAWATER CATCHMENT POOLS
SECONDARY PUMPING SYSTEM
P&ID
EL MUSEL
REGASIFICATION
PLANT

List of abbreviations	
BV	Ball Valve
DCS	Distributed Control System
EDS	Emergency Shut Down
ERS	Emergency Release System
FCV	Flow Control Valve
FT	Flow Transmitter to DCS
HP	High Pressure Pump
LA	Level Alarm
LNG	Liquefied Natural Gas
LP	Low Pressure Pump
LT	Level Transmitter to DCS
PCV	Pressure Control Valve
PPS	Primary Pumping System
PSV	Pressure Safety Valve
PT	Pressure Transmitter to DCS
SDV	Shut Down Valve
SPS	Secondary Pumping System
TT	Temperature Transmitter to DCS
VAC	Anti-Vacuum Valve

PLANT: El Musel Regasification (Enagás).
NODE: 1.1: LNG transfer line from unloading dock to storage tanks (3 arm lines + 1 common line + 2 tank filling lines).
DESIGN INTENT: Inputs: LNG from secondary recirculation line.
Activities: Cooling of transfer line before LNG transfer.

N°	Guide word	Parameter	Parameter intention	Deviation	Cause	Consequence	Safeguards	RASE Record of Hazard Identification	
								Explosive atmosphere	Ignition source
1	MORE	Temperature	Gradual line cooling to op. T: ≈ -163°C	Too slow line temperature decrease	-Reduction of LNG flow from secondary cooling line (regulation fault of FCV 02)	-Time loss in line cooling before LNG transfer	- TT 01 temperature transmitter to control panel for LNG unloading not starting		
2	LESS	Temperature	Gradual line cooling to op. T: ≈ -163°C	Too fast line temperature decrease	-Increse of LNG flow from secondary cooling line (regulation fault of FCV 02)	-Excessive thermal contractions	- TT 01 temperature transmitter to SDV 02 for flow shut down - Expansion joints	-Damages to pipeline with possible LNG releases	
3	NO	Flow	Gradual line cooling to op. T: ≈ -163°C	No cooling of the line	-No LNG flow from secondary cooling line (FCV 02 fails closed, spurius closing of SDV 02)	-Impossible to start LNG transfer operation	- FT 01, FT 02 flow transmitters to control panel for LNG unloading not starting		

PLANT: El Musel Regasification (Enagás).
NODE: 1.2: LNG transfer line from unloading dock to storage tanks (3 arm lines + 1 common line + 2 tank filling lines).
DESIGN INTENT: Inputs: LNG from carrier pumping system.
Activities: LNG transfer from carrier to storage tanks.

N°	Guide word	Parameter	Parameter intention	Deviation	Cause	Consequence	Safeguards	RASE Record of Hazard Identification	
								Explosive atmosphere	Ignition source
1	MORE	Flow	≈ 18 000 m^3/h	High LNG flow	- LNG at higher pressure from carrier pumping system - FCV 01 fails regulation	-Pipeline overloading -High LNG level inside tanks (ref. to Node 4)	- FT 01 flow transmitter to FCV 01 for flow reduction - FT 01 to SDV 01 for flow shut down - Liquid unloading arm ERS	-Ref. to Node 4 point 2 -Emergency disconnection of liquid arm at mainfold with LNG releases above unloading area floor	
2	LESS	Flow	≈ 18 000 m^3/h	Low LNG flow	-LNG at lower pressure from carrier pumping system - Failure of FCV 01	-More transfer time for tank filling -Low LNG level inside the tank	- FT 01 flow transmitter to FCV 01 for flow increase	-Ref. to Node 4 point 3	
3	NO	Flow	≈ 18 000 m^3/h	Sudden arrest of LNG flow	- Spurius closing of SDV 01	-Possible water hammer		-Damages to pipeline with possible LNG releases	
4	REVERSE	Flow		Back flow detected	- Spurius closing of SDV 01	-LNG flowing back to mainfold	- CV 01A, CV 01B, CV 01D		
5	MORE	Temperature	≈ -163°C	High LNG temperature inside pipeline	- LNG overwarmed after discharge pumping	-Possible presence of vapour phase inside transfer flow if T>Teb at operation pressure	- TT 01 temperature transmitter to SDV 01 for flow shut down - PSV 01	-Possible releases of natural gas to atmosphere (PSVs) along transfer path -Increase of BOG rate inside storage tanks (ref. to Node 4)	

PLANT: El Musel Regasification (Enagás).
NODE: 2: LNG secondary recirculation line.
DESIGN INTENT: Inputs: LNG from low pressure collector (downstream PPS).
Activities: LNG recirculation for transfer line cooling during normal operation.

N°	Guide word	Parameter	Parameter intention	Deviation	Cause	Consequence	Safeguards	RASE Record of Hazard Identification	
								Explosive atmosphere	Ignition source
1	MORE	Flow	≈ 80 m^3/h	High LNG recirculation flow	-Failure of FCV 02	-LNG flow wasted in recirculation	- FT 02 flow transmitter to SDV 02 for flow shut down		
2	LESS	Flow	≈ 80 m^3/h	Low LNG recirculation flow	-Failure of FCV 02 -Low flow from PPS	-Transfer line not cooled enaugh for LNG transfer starting	- FT 02 flow transmitter to control panel		
3	NO	Flow	≈ 80 m^3/h	No LNG recirculation flow	-Failure of FCV 02 -No flow from PPS	-Impossible to start LNG transfer	- FT 02 flow transmitter to control panel		
4	MORE	Temperature	< -163 °C	LNG temperature too high	-LNG overwarmed after primary pumping	-Transfer line not cooled enaugh for LNG transfer starting	- TT 02 temperature transmitter to FCV 01 for flow regulation		

PLANT: El Musel Regasification (Enagás).
NODE: 3: Vapour devolution line to mainfold (vapour line + liquid separator).
DESIGN INTENT: Inputs: BOG from storage tanks.
Activities: BOG cooling, liquid separation and devolution to carrier mainfold.

N°	Guide word	Parameter	Parameter intention	Deviation	Cause	Consequence	Safeguards	RASE Record of Hazard Identification	
								Explosive atmosphere	**Ignition source**
1	MORE	Flow	Pressure balance during LNG transfer	High BOG flow from tanks	-Failure of FCV 03, PCV 03	-Overpressure inside carrier tanks	- PT 03 pressure transmitter to SDV 03 -Vapour devolution arm ERS	-Emergency disconnection of vapour arm at mainfold with natural gas releases to atmosphere	
2	LESS	Flow	Pressure balance during LNG transfer	Low BOG flow from tanks	-Failure of FCV 03, PCV 03 -Less BOG from tanks	-Lack of pressure maintenance during LNG transfer phase	- PT 03 pressure transmitter to FCV 01 for flow reduction		
3	NO	Flow	Pressure balance during LNG transfer	Absence of BOG flow from tanks	-Failure of FCV 03, PCV 03 -Spurius closing of SDV03	-Impossible to continue LNG transfer	- PT 03 pressure transmitter to FCV 01 for flow stopping		
4	MORE	Temperature	BOG cooled to -163°C before devolution to mainfold	BOG not cooled enaught inside Flash Tank	-LNG flow to Flash Tank not sufficient for cooling -Failure of LNG inlet line FCV 04	-BOG flow to mainfold arrested	- TT 05 temperature transmitter to FCV 05 for flow reduction		
5	MORE	Pressure	Lower than maximum operation pressure	High Pressure inside Flash Tank	-Ref. to previous point -Failure of BOG inlet line PCV 03	-Flash Tank overpressure	- PT 05 pressure transmitter closing SDV 03 - PSV 05	-Possible natural releases to atmosphere	
6	LESS	Pressure	Pressure balance during LNG transfer	Low Pressure inside Flash Tank	-Failure of PCV 03 -Less BOG from tanks	-Lack of pressure maintenance during LNG transfer phase	-PT 03 pressure transmitter to FCV04 for pressure mantaining through LNG inlet		
7	MORE	Level	Lower than maximum operation level	High LNG level	-Failure of LNG inlet line FCV 04	-High LNG level inside Flash Tank	-HLA 03 to SDV 04 -Drainage BV 04	-LNG expelled to drainage collecting basin	

PLANT: El Musel Regasification (Enagás).
NODE: 4: LNG total containment storage tank (x2).
DESIGN INTENT:
Inputs: LNG from carrier mainfold; high pressure NG from emission station.
Activities: LNG storage; BOG devolution to mainfold or compressors.

N°	Guide word	Parameter	Parameter intention	Deviation	Cause	Consequence	Safeguards	RASE Record of Hazard Identification	
								Explosive atmosphere	**Ignition source**
1	MORE	Density difference	Constant LNG density along the whole internal tank height	Density difference between two adiacent levels of measurement by LTD continous measuring system (200 mm) higher than a set value	-LNG stored in tanks for too long time -High density difference between unloaded LNG and LNG alredy present inside the tank -LNG from carriers stored for too long time -Carrier tank pressure higher than storage tank pressure (*Flash*)	-LNG stratification, risk of roll-over	-LNG recirculation system	-Important additional evaporation: values of pressure may exceed gas venting lines and PSVs capacity causing damages to equipment and natural gas releases to atmosphere	
2	MORE	Level	Lower than maximum operation level	High LNG level inside the tank	-Improper LNG flow distribution among the tanks -Low suction or fault of PPS -Excessive LNG flow from mainfold (failure of FCV 01, FCV 01A, FCV, 01B)	-Risk of fault of internal metallic tank -Risk of LNG overflow spillages to perimeter isolation	- LT 01A level transmitter to FCV 01A, FCV 01B for LNG inlet flow reduction - LT 01A level transmitter to PPS - HLA 01A alarm to SDV 01A for inlet flow stopping -Level interruptor -Overflow fitting -Thermocouple between internal and external tank and on liquid collecting channels	-LNG evacuation to collecting basin -Cold spot zones formation	
3	LESS	Level	Higher than minimum operation level	Low LNG level inside the tank	-Lack of flow from mainfold (failure of FCV 01, FCV 01A, FCV, 01B) -High suction of PPS	-Rapid rewarming of tank interior	- LT 01A level transmitter to FCV 01A, FCV 01B for LNG inlet flow regulation - LT 01A level transmitter to PPS		

PLANT: El Musel Regasification (Enagás).
NODE: 4: LNG total containment storage tank (x2).
DESIGN INTENT:
Inputs: LNG from carrier mainfold; high pressure NG from emission station.
Activities: LNG storage; BOG devolution to mainfold or compressors.

N°	Guide word	Parameter	Parameter intention	Deviation	Cause	Consequence	Safeguards	RASE Record of Hazard Identification	
								Explosive atmosphere	Ignition source
4	MORE	Pressure	≈160 mbarg during normal operation 170-200 mbarg during LNG unloading from mainfold	P > 250 mbarg	-LNG vaporization due to instrumentation heat dissipation -High temperature of LNG from mainfold -Emergency shut down of PPS -Emergency shut down or flow reduction to compressors -Liquid movements due to density differencies (ref. point 1) -Flash phenomena	-LNG vapour phase overpressure danger	- PT 01A to FCV 01A, FCV 01B for LNG inlet flow regulation, to PPS and to FCV 06 to compressors -PSV 01A to BOG venting system	-Overpressure: releases to atmposphere; values of pressure may exceed gas venting lines and PSVs capacity; damages to tank dome and instrumentation	
				P > 290 mbarg	-Failure of PSVs to torch		-PSV 01B (n+1) to air -Bursting discs		
5	LESS	Pressure	≈160 mbarg during normal operation 170-200 mbarg during LNG unloading from mainfold	P < 20 mbarg	-Too fast cooling of vapour zone after initial LNG irrigation -Start of PPS -Flow increase to compressors (fault of PCV 01A)	- Vacuum danger inside the tank	-PT 01A to FCV 01A, FCV 01B for LNG inlet flow increase, to PPS for stopping -Anti-vacuum valve (VAC 01A) allowing entrance of NG from emission station inside the tank		
				P < -2 mbarg	-Failure of NG supply from emission station (VAC 01A)		-Anti-vacuum valve (VAC 01B) allowing entrance of air inside the tank	-High probability of apparence of explosive atmosphere inside the tank and around safety equipment	
6	MORE	Temperature difference	Constant LNG temperature along the whole internal tank height	Temperature difference between two adiacent levels of measurement by LTD continous measuring system (200 mm) higher than a set value	-LNG stored for too long time -High density difference between unloaded LNG and LNG alredy present inside the tank -LNG from carriers stored for too long time -Carrier tank pressure higher than storage tank pressure (*Flash*)	-LNG stratification, risk of roll-over	-2 x 10 fixed temperature sensors installed at differet levels connected to DCS -LNG recirculation system	-Ref. to point 1	

PLANT: El Musel Regasification (Enagás).
NODE: 4: LNG total containment storage tank (x2).
DESIGN INTENT: Inputs: LNG from carrier mainfold; high pressure NG from emission station.
Activities: LNG storage; BOG devolution to mainfold or compressors.

N°	Guide word	Parameter	Parameter intention	Deviation	Cause	Consequence	Safeguards	RASE Record of Hazard Identification	
								Explosive atmosphere	Ignition source
7	MORE	Temperature	Vapour phase temperature < -80°C	High temperature of vapour zone	-*Flash* phenomena -Excessive recirculation flow from PPS (failure of FCV 08A, FCV 08B, FCV 08C) -Fire arising	-Dangerous heating of tank interior above liquid surface	-Independent temperature sensors installed immedialtely below the suspended ceiling connected to DCS	-Risk of fire and explosion in the vapour zone of the tank	

PLANT: El Musel Regasification (Enagás).

NODE: 5: PPS: low pressure pumps (LPs), primary pumping lines until low pressure LNG principal collector, LNG recirculation line to storage tank. (3+1 LPs per tank).

DESIGN INTENT: Inputs: LNG present in storage tanks

Activities: LNG low pressure pumping to plant.

N°	**Guide word**	**Parameter**	**Parameter intention**	**Deviation**	**Cause**	**Consequence**	**Safeguards**	**RASE Record of Hazard Identification**	
								Explosive atmosphere	**Ignition source**
1	MORE	Pressure	No gas phase inside pump well	Abnormal values of pressure detected in LP container	-Heat entrances after pump arrest procedure increasing LNG evaporation	-Appearance of gas pockets inside pump well and primary pumping line	- LPs vent systems with PSVs connected to boil-off system (PSV 07A, PSV 07B, PSV 07C)	-Presence of gas phase in pump well, particularly dangerous during pump maintenance	-Electrical connection box located in the upper part of the well
2	MORE	Flow	300 m^3/h	Flow delivered to primary pumping line higher than maximum value	-LP overworking -Failure of control instrumentation on primary pumping line (FCV 07A, FCV 07B, FCV 07C)	-Excessive LNG flow delivered to tank PPS collector	- FT 07A, FT 07B, FT 07C flow transmitters to PPS for pumps arrest - FT 07A, FT 07B, FT 07C flow transmitters to SDV 07A, SDV 07B, SDV 07C for closing of primary pumping lines - FT 07A, FT 07B, FT 07C flow transmitters to FCV 08A, FCV 08B, FCV 08C for LNG recirculation to tank		
3	LESS	Flow	Minimum pump recirculation flow (30-50% of nominal flow)	Flow less than minimum measured at pump inlet	-Obstruction at pump suction inlet -Low LNG level inside storage tank (ref. to Node 4 point 3) -Fault in recirculation system control instrumentation (FCV 08A, FCV 08B, FCV 08C)	-Minimum working flow not delivered to pump: impossible to continue primary pumping operation	- Flow transmitters at pumps inlets to control panel - FT 07A, FT 07B, FT 07C to PPS for pumps arrest		
4	REVERSE	Flow	LNG flowing to primary pumping line	Back flow detected	-ESD of the primary pumping outlet line	-LNG flowing back to LP	-Check valves installed downstream LPs containers (CV 07A, CV 07B, CV 07C)		
5	MORE	Vibrations	Safety level of vibrations	Pump vibrations higher than acceptable level	LP overworking	-ESD of LP	-High vibrations alarm to operator		-Hot surfaces during malfunctionings

PLANT: El Musel Regasification (Enagás).
NODE: 6.1: BOG compressors feeding: gas line from BOG collector to liquid separator inlet, BOG vertical liquid separator with gas cooling system, separator o
DESIGN INTENT: Inputs: Gas from BOG collector.
Activities: BOG sent to compression.

N°	Guide word	Parameter	Parameter intention	Deviation	Cause	Consequence	Safeguards	RASE Record of Hazard Identification	
								Explosive atmosphere	Ignition source
1	MORE	Temperature	Compressors maximum suction temperature: -80°C	Temperature of BOG gas entering in the separator too high	-Gas present in BOG collector having a temperature higher than normal operation for excessive LNG evaporation (ref. to Node 4)	-BOG sent to compression at temperature too high (> -80°C)	-TT 06 temperature transmitter to FCV 06, FCV 09 for BOG cooling -Tempering ejector with control instrumentation above: BOG is cooled by a flux of LNG from PPS before entering in the separator		
2	MORE	Pressure	Lower than separator maximum operation pressure	Pressure too high measured inside the separator	-Excessive BOG flow coming from separator feeding line (ref. to Node 4) -Fault in control instrumentation of BOG separator feeding line (FCV 06)	-Overpressure danger inside the separator	- PT 06 pressure transmitter to PCV 10 for pressure balance inside BOG liquid separator - PT 06 pressure transmitter to SDV 10 for BOG inlet flow stopping	-Overpressure may damage venting instrumentation with possible natural gas releases to atmosphere	
3	MORE	Level	Lower than separator maximum operation liquid level	Liquid level inside the separator too high	-No complete LNG vaporization inside tempering ejector	-Inadequate liquid separation -Drops of liquid in BOG coming out from separator can perilously damage compressors (ref. Node 6.2) -Too high liquid level can damage separator components	- HLA 06 alarm to SDV 06 for BOG inlet flow stopping -Separator drainage line to collecting basin	-LNG expelled to drainage collecting basin	

PLANT: El Musel Regasification (Enagás).
NODE: 6.2: BOG compressor inlet line, BOG compressor, compressed gas line to reliquefier and SCVs (x2 each).
DESIGN INTENT: Inputs: BOG cooled and free of liquid particles from BOG vertical liquid separator.
Activities: BOG compression for reliquefaction or combustion in SCVs.

N°	Guide word	Parameter	Parameter intention	Deviation	Cause	Consequence	Safeguards	RASE Record of Hazard Identification	
								Explosive atmosphere	Ignition source
1	MORE	Temperature	Compressor maximum suction temperature: -80°C	Temperature of BOG entering in the compressor too high	-Fault in BOG cooling at separator inlet (ref. to Node 7.1)	-Temperature of compressed gas at compressor outlet too high -Possible lack of refrigerating action on compressor components	- TT 10 to SDV 10 for BOG flow stopping		-Hot surfaces during malfunctionings can act as ignition sources
2	MORE	Pressure	Lower than maximum operation pressure	High pressure in compressors drums	-Compressor overworking (human error, fault in imput transmission) -Fault in compressor feeding line control instrumentation (FCV 10A, FCV 10B)	-Overpressure inside compressor drums	-PSVs (PSV 10A, PSV 11A)to venting system installed for each drum (suction/discharge for each step)	-Possible natural gas releases to atmosphere from safety valves, compressor seals.	
3	MORE	Pressure	6 - 9 bar (reliquefier pressure)	High pressure in compressor discharge line	-Ref. to point 2 -Fault in control valve downstream of compressor (PCV 15)	-Gas delivered at too high pressure to reliquefier	-PT 12A, PT 12B pressure transmitters to PCV 12A, PCV 12B on the discharge line allowing compressed gas recirculation to liquid separator inlet.	-Possible damages to pipeline and equipment located downstream the compressors with natural gas releases	
4	LESS	Pressure	6 - 9 bar (reliquefier pressure)	Low pressure in compressor discharge line	-Fault in compression system, compressor mechanical damage -Fault in delivery pressure transmission from control system -Fault in compressor feeding line control instrumentation (FCV 10A, FCV 10B)	-Gas delivered at too low pressure to reliquefier	-PT 12A, PT 12B to control system		
5	MORE	Vibrations	Compressor reference vibration levels	Compressor subjected to abnormal vibration intensity	-Anomalies present in kinematic chain	-Compressor ESD -Compressor damage			-Hot surfaces during malfunctionings can act as ignition sources

PLANT: El Musel Regasification (Enagás).
NODE: 7.1: Reliquefier LNG inlet line.
DESIGN INTENT: Inputs: LNG from low pressure LNG principal collector.
Activities: LNG flow to reliquefier.

N°	Guide word	Parameter	Parameter intention	Deviation	Cause	Consequence	Safeguards	RASE Record of Hazard Identification	
								Explosive atmosphere	Ignition source
1	LESS	Flow	LNG flow for produced BOG reliquefaction. Reliquefier operation pressure: ≈ 6 bar (normal operation) ≈ 9 bar (during LNG unloading from carrier mainfold)	Low LNG level inside reliquefier	-LNG flow from PPS less than required for reliquefaction (ref. to Node 5). -Fault in LNG inlet line control instrumentation (fault of FCV 23, spurius closing of SDV 23) -Fault in recirculation line from SPS (ref. to Node 8)				
2	MORE	Flow	LNG flow for produced BOG reliquefaction. Reliquefier operation pressure: ≈ 6 bar (normal operation) ≈ 9 bar (during LNG unloading from carrier mainfold)	High LNG level inside reliquefier	-LNG flow from PPS more than required (ref. to Node 5). -Fault in LNG inlet line FCV 23 -Fault in recirculation line from SPS (ref. to Node 8)	-Ref. to Node 8.2 point 3	-Ref. to Node 8.2 point 3	-Ref. to Node 8.2 point 3	
3	MORE	Temperature	T<Teb at current operation pressure	High LNG temperature inside pipeline	-LNG overwarmed after primary pumping (ref. to Node 5)	Presence of gas phase inside pipeline can produce alterations in reliquefier operation: pressure / temperature (ref. to Node 7.2)	- TT 23 temperature transmitter to FCV 23 and PPS for flow regulation - TT 23 temperature transmitter to PPS	-Possible natural gas releases to atmosphere (PSV 23A) -Ref. to Node 7.2	

PLANT: El Musel Regasification (Enagás).
NODE: 7.2: BOG reliquefier.
DESIGN INTENT: Inputs: LNG from low pressure LNG principal collector, BOG from compressors.
Activities: BOG reliquefaction and reincorporation to process.

N°	Guide word	Parameter	Parameter intention	Deviation	Cause	Consequence	Safeguards	RASE Record of Hazard Identification	
								Explosive atmosphere	Ignition source
1	MORE	Temperature	Temperature inside reliquefier must be lower than LNG boiling temperature at current reliquefier operating pressure	High temperature inside reliquefier	- Low LNG level inside reliquefier - LNG flow from PPS less than required for reliquefaction (ref. to Node 5). - Fault in LNG inlet line control instrumentation (fault of FCV 23, spurius closing of SDV 23)	-LNG evaporation inside reliquefier -Gas phase present inside flow delivered to SPS	-TT 23 temperature transmitter to PPS - TT 15 temperature transmitter to FCV 15 for flow regulation -TT 23 temperature transmitter to SDV 24 to arrest LNG outflow -ESD of compressors		-Biphasic flow may induce cavitation damages in HPs suction
2	LOW	Level	Liquid level must ensure intention of point 1	Low LNG level inside reliquefier	- LNG flow from PPS less than required for reliquefaction (ref. to Node 5). - Fault in LNG inlet line control instrumentation (fault of FCV 23, spurius closing of SDV 23) - Fault in outlet line control instrumentation (PCV 24B) - Fault in recirculation line from SPS (ref. to Node 8)	-LNG evaporation inside reliquefier -Gas phase present inside flow delivered to SPS -High contact surface between gas phase and liquid phase	-LLA 23 to SDV 24 to shut down of LNG outlet line -ESD of compressors		-Same as point 1.
3	MORE	Level	Lower than reliquefier maximum operation level	High LNG level inside reliquefier	-LNG flow from PPS more than required (ref. to Node 5). -Fault in LNG inlet line control instrumentation (FCV 23) -Fault in recirculation line from SPS (ref. to Node 8)	-Low contact surface between gas phase and liquid phase -High level LNG danger	- HLA 23 to SDV 23 for LNG flow stopping - HLA 23 to PCV 24B for complete opening - HLA 23 to SDV 13A, SDV 13B for flow stopping from compressors	-LNG leakages to collecting basin	-Possible damages to reliquefier components

PLANT: El Musel Regasification (Enagás).
NODE: 7.2: BOG reliquefier.
DESIGN INTENT: Inputs: LNG from low pressure LNG principal collector, BOG from compressors.
Activities: BOG reliquefaction and reincorporation to process.

N°	Guide word	Parameter	Parameter intention	Deviation	Cause	Consequence	Safeguards	RASE Record of Hazard Identification	
								Explosive atmosphere	Ignition source
4	LOW	Pressure	≈ 6 bar (normal operation) ≈ 9 bar (during LNG unloading from carrier mainfold)	Low pressure inside reliquefier	-Low BOG flow from compressors (ref. to Node 7). -Fault in reliquefier BOG inlet line control instrumentation (fault of FCV 23, PCV 15, spurius closing of SDV 23)	-Decrease of LNG Teb inside reliquefier -Risk of LNG evaporation inside reliquefier -Risk of biphasic flow at reliquefier outlet	-PT 23 pressure transmitter to PCV 38 on NG inlet line from high pressure emission station -PT 23 pressure transmitter to ESD isolating reliquefier (SDV 23, SDV 24) - PT 23 pressure transmitter to FCV 24A for bypassing reliquefier		-Same as point 1.
5	MORE	Pressure	≈ 6 bar (normal operation) ≈ 9 bar (during LNG unloading from carrier mainfold)	High pressure inside reliquefier	-High BOG flow from compressors (ref. to Node 7). -Fault in reliquefier BOG inlet line control instrumentation (FCV 23, PCV 15)	-Overpressure inside reliquefier -Increase of LNG Teb inside reliquefier	-PSV 17 to BOG venting system -ESD: SDVs isolating reliquefier -PT 23 pressure transmitter to ESD isolating reliquefier (SDV 23, SDV 24) - PT 23 pressure transmitter to FCV 24A for bypassing reliquefier	-Possible natural gas releases to atmosphere	
6	MORE	Temperature	T < Teb at operation pressure for LNG coming out from reliquefier (≈ -140°C)	High temperature of LNG in reliquefier outlet line	-Overwarming of LNG during reliquefaction operation -Ref. points 1,2.	-Gas phase present inside flow delivered to SPS	- TT 23 temperature transmitter to FCV 23 for reliquefier LNG inlet flow regulation - TT 23 temperature transmitter to vaporizers LNG inlet flow regulation FCV 35A, FCV 36A, FCV 26		-Same as point 1.
7	LESS	Flow	SPS working flow	Low LNG flow sent to SPS	-Flow required for level increase, ref. to point 1,2.	-Low quantity of LNG sent to vaporization	-PT 24 pressure transmitter on reliquefier LNG outlet line to control panel		
8	MORE	Flow	Maximum BOG mass flow that can be vaporized: 15% of LNG mass flow	Hig BOG flow from reliquefier inlet line	-Same as point 5.	-Same as point 5.	-Same as point 5.	-Same as point 5.	

PLANT: El Musel Regasification (Enagás).
NODE: 7.3: Reliquefier LNG outlet line.
DESIGN INTENT: Inputs: LNG from BOG reliquefier.
Activities: LNG flow to SPS.

N°	Guide word	Parameter	Parameter intention	Deviation	Cause	Consequence	Safeguards	RASE Record of Hazard Identification	
								Explosive atmosphere	Ignition source
1	LESS	Flow		High LNG flow at reliquefier outlet	-Low LNG level inside reliquefier (ref. to Node 7.2 point 2) -Fault in outlet line control instrumentation (PCV 24B fails closed, spurius closing of SDV 24)		- PT 24 pressure transmitter to SPS for emergency shutdown		
2	MORE	Flow		Low LNG flow at reliquefier outlet	-High LNG level inside reliquefier (ref. to Node 7.2 point 3) -Fault in outlet line control instrumentation (PCV 24B)	-Ref. to Node 8.2 point 3	-Ref. to Node 8.2 point 3	-Ref. to Node 8.2 point 3	
4	REVERSE	Flow		Back flow detected	- Fault in SPS (ref. to Node 8)	-LNG flowing back to reliquefier	-Check valve CV 24		
3	MORE	Temperature	T<Teb at current operation pressure	High LNG temperature inside pipeline	-LNG overwarmed after reliquefaction process	-Ref. to Node 8.2 point 1	-Ref. to Node 8.2 point 1	-Ref. to Node 8.2 point 1	

PLANT: El Musel Regasification (Enagás).
NODE: 8: SPS (high pressure pumps (HPs),secondary pumping lines until high pressure LNG principal collector, LNG recirculation line to reliquefier). (5 HPs).
DESIGN INTENT: Inputs: LNG from reliquefier.
Activities: LNG high pressure pumping to vaporization.

N°	Guide word	Parameter	Parameter intention	Deviation	Cause	Consequence	Safeguards	RASE Record of Hazard Identification	
								Explosive atmosphere	Ignition source
1	MORE	Pressure	No gas phase inside pump well	Abnormal values of pressure detected in HP container	-Heat entrances after pump arrest procedure increasing LNG evaporation	-Appearance of gas pockets inside pump well and secondary pumping line	-HP vent system with PSVs connected to boil-off system (PSV 25)	-Presence of gas phase in pump well, particularly dangerous during pump maintenance operations	-Electrical connection box located in the upper part of the well -Maintenance instrumentation
2	MORE	Flow	350 m^3/h	Flow delivered to secondary pumping line higher than maximum value	-HP overworking -Failure of control instrumentation on secondary pumping line (FCV 35 fails completely open)	-Excessive LNG flow delivered to SPS high pressure collector	- FT 26 flow transmitter to FCV 34 for LNG recirculation to reliqiefier - FT 26 flow transmitter to SPS for emergency shutdown		
3	LESS	Flow	Minimum pump recirculation flow (30-50% of nominal flow)	-Flow less than minimum measured at pump inlet -Low LNG level inside pump vessel	-Obstruction at pump suction inlet -Low LNG flow coming from Reliquefier (ref. to Node 8), FCV 24 fails closed -Fault in recirculation system control instrumentation (FCV 34 fails closed)	-Minimum working flow not delivered to pump: impossible to continue secondary pumping operation	-Flow transmitter at pump inlet (FT 24) to SPS for emergency shutdown		
4	REVERSE	Flow	LNG flowing to secondary pumping line	Back flow detected	-ESD of the line	-LNG flowing back to HP	-Check valve installed immediately downstream after HP container (CV 26)		
5	MORE	Vibrations	Safety level of vibrations	Pump vibrations higher than acceptable level	HP overworking	-ESD of HP	-High vibrations alarm to operator		-Hot surfaces during malfunctionings can act as ignition sources

PLANT: El Musel Regasification (Enagás).
NODE: 9.1: ORV LNG inlet line.
DESIGN INTENT: Inputs: LNG from high pressure LNG principal collector.
Activities: LNG delivered to ORV collector for vaporization.

N°	Guide word	Parameter	Parameter intention	Deviation	Cause	Consequence	Safeguards	RASE Record of Hazard Identification	
								Explosive atmosphere	Ignition source
1	NO	Flow	≈ 160 kg/h	No LNG flow to vaporizers	- Fault in SPS (ref. to Node 8) - ESD of SPS - Fault in line control instrumentation (FCV 35A fails closed, SDV 36A, SDV 36B spurius closing)	-Impossible to continue vaporization -Shut down of ORV	- FT 35 to control panel for ORV shut down - FT 35 to FCV 42 for seawater flow stopping		
2	LESS	Flow	≈ 160 kg/h	Low LNG flow to vaporizers	-Fault in SPS (ref. to Node 8) -Fault in line control instrumentation (FCV 35 fails in regulation)	-Reduced NG flow to high pressure network	- FT 35 to control panel for ORV shut down - FT 35 to FCV 42 for seawater flow reduction		
3	MORE	Flow	≈ 160 kg/h	High LNG flow to vaporizers	- High LNG flow coming from SPS - failure in control instrumentation (FCV 35 fails open)	-High LNG flow to vaporizer LNG collector -Low temperature of NG at outlet (ref. to Node 9.3 point 1) -Possible overpressure inside vaporizer panelling	-FI, FT, FCV to reliquefier recirculation -Ref. to Node 9.2 - 9.3	-Ref. to Node 9.2 - 9.3	
4	REVERSE	Flow		Back flow detected	-ESD of the line	-LNG flowing back to SPS	-Check valve CV 36A		
5	MORE	Temperature	≈ -155°C	High temperature of LNG flow to vaporizers	- LNG overwarmed after SPS	-Low temperature of NG at outlet (ref. to Node 9.3 point 1) -Ref. to Node 9.2 point 3	- TT 35, TT 37 temperature transmitters to FCV 35A for flow regulation	- Ref. to Node 9.2 - 9.3	

PLANT: El Musel Regasification (Enagás).
NODE: 9.2: Open Rack Vaporizer (x 4).
DESIGN INTENT: Inputs: LNG from high pressure LNG principal collector, seawater from water pumping system.
Activities: LNG vaporization.

N°	Guide word	Parameter	Parameter intention	Deviation	Cause	Consequence	Safeguards	RASE Record of Hazard Identification	
								Explosive atmosphere	Ignition source
1	NO	Flow	Minimum water working flow	No water flow for LNG vaporization	-Ref. to Node 10	-Water flow less than minimum required by manufacturer -Necessary arrest of vaporization process by ORVs -Activation of SCVs	-ESD of ORV (SDV 36A, SDV 36B, SDV 37)		
2	LESS	Flow	≈ 5 500 m^3/h	Low water flow for LNG vaporization	-Ref. to Node 10	-Non-uniform water distribution along panelling pipes: ice accumulations in the lower parts (vaporization zones) -Ref. to Node 9.3 point 1	-FT 42 flow transmitter to SDV 36A, SDV 36B for LNG flow stopping -Regular visual inspection of panelling state by operator -Leakages collecting basin	-Torsions may lead to pipes rupture and LNG spillages	
3	MORE	Pressure	50 - 80 bar	High pressure in vaporizer panelling	-SDV 37 spurius colsing on vaporizer NG outlet line	-Vaporization of LNG remained in vaporizer causes overpressure inside paneling	-PSV 37A to high pressure venting system	-Possible natural gas releases to atmosphere	

PLANT: El Musel Regasification (Enagás).
NODE: 9.3: ORV NG collector and outlet line.
DESIGN INTENT: Inputs: NG from ORV vaporization.
Activities: NG sent to high pressure station.

N°	Guide word	Parameter	Parameter intention	Deviation	Cause	Consequence	Safeguards	RASE Record of Hazard Identification	
								Explosive atmosphere	Ignition source
1	LESS	Temperature	> 0°C	Low temperature of NG from vaporization: < 0°C	-NG not warmed enaugh in ORV by seawater vaporization process -Low water flow to vaporizer (ref. to Node 10) -High LNG flow to vaporizer (refer. to Node 9.1)	-NG not deliverable to high pressure network -Possible condensation and hydrates formation inside pipeline	- TT 37 temperature transmitter to FCV 35A for LNG inlet flow reduction - TT 37 temperature transmitter to FCV 42A for seawater flow increase - LTA 37 alarm to control panel for operator intervention		
				Low temperature of NG from vaporization: < -5°C	- NG not warmed enaugh in ORV by seawater vaporization process - Low water flow to vaporizer (ref. to Node 10) - High LNG flow to vaporizer (refer. to Node 9.1) - Lack of response by operator to temperature alarm and manual flow regulation actions	- Cold NG (with possible LNG drops) coming out from vaporizers (< 20°C) may reach pipelines downstream - Possible condensation and hydrates formation inside pipeline	- TT 37 temperature transmitter to SDV 37 for NG outflow stopping - TT 37 temperature transmitter to SDV 36A, SDV 36B for LNG inlet flow stopping	-Damages to pipelines and equipment downstream vaporizers due to change in pipeline material (from stainless steal to carbon steel) may lead to natural gas releases	
2	LESS	Flow	2 000 m^3(n)/h (4x)	Low pressure of NG at vaporizer outlet	-Fault in outlet line pressure regulation instrumentation FCV 37	-Reduced NG flow to high pressure network			
3	MORE	Pressure	50 - 70 bar	High pressure of NG at vaporizer outlet	-NG overpressure in regasification process	-NG pressure at outlet exceeding safety limits	- PT 37 pressure transmitter to SDV 36A, SDV 36B for LNG inlet to vaporizer shut down - PSVs (PSV 37A)	-Possible natural gas releases to atmosphere	

PLANT: El Musel Regasification (Enagás).
NODE: 10: Seawater circulation system (catchment pools, 5 water pumps, vaporizer inlet and outlet lines).
DESIGN INTENT: Inputs: Seawater from catchment pools.
Activities: Seawater sent for LNG vaporization.

N°	Guide word	Parameter	Parameter intention	Deviation	Cause	Consequence	Safeguards	RASE Record of Hazard Identification	
								Explosive atmosphere	**Ignition source**
1	LESS	Flow	≈ 5 500 m^3/h	No water flow to vaporizers	- Mechanical fault in water pump - ESD of water pumping system - Fault in vaporizer water inlet line control instrumentation (FCV 40, FCV 41, FCV 42A, FCV 42BAHTTESTO fail close)	-Ref. to Node 9.2 point 1	-Ref. to Node 9.2 point 1	-Ref. to Node 9.2 point 1	
2	NO	Flow	Minimum pump working flow	Low water flow to vaporizers	- Mechanical fault in water pump - Fault in vaporizer water inlet line control instrumentation (FCV 40, FCV 41, FCV 42A, FCV 42 fail seawater flow contrl)	-Ref. to Node 9.2 point 2	-Ref. to Node 9.2 point 2	-Ref. to Node 9.2 point 2	
3	LESS	Temperature	T > 12°C	Low temperature of water entering in vaporizers	-Seawater natural temperature less than required for vaporization	-Impossible to continue vaporization in ORV -Activation of SCV	- TT 42 temperature transmitter to control panel for SCV activation - TT 42 temperature transmitter to SDV 42A for water flow to ORV stopping		
4	LESS	Temperature	T > 7°C	Low temperature of water coming out from vaporizers	-Overcooling of water in vaporization process -Ref. to Node 9.1 point 3	-Water devolution to sea at a temperature lower than allowed -Shut down of ORV -Activation of SCV	- TT 43 to FCV 35A, FCV 35B for LNG inlet flow to ORV closing - TT 43 to control panel for SCV activation		

PLANT: El Musel Regasification (Enagás).
NODE: 11.1: SCV LNG inlet line.
DESIGN INTENT: Inputs: LNG from high pressure LNG principal collector.
Activities: LNG delivered to SCV collector for vaporization.

N°	Guide word	Parameter	Parameter intention	Deviation	Cause	Consequence	Safeguards	RASE Record of Hazard Identification	
								Explosive atmosphere	Ignition source
1	NO	Flow	≈ 160 kg/h	No LNG flow to vaporizers	- Fault in SPS (ref. to Node 8) - ESD of SPS - Fault in inlet line control instrumentation (FCV 26 fails closed) - Spurius closing of SDV 26B, SDV 20A, SDV 20B	-Impossible to continue vaporization -Shut down of SCV	- FT 26 flow transmitter to control panel for SCV shut down		
2	LESS	Flow	≈ 160 kg/h	Low LNG flow to vaporizers	- Fault in SPS (ref. to Node 8) - ESD of SPS - Fault in inlet line control instrumentation (FCV 26 fails regulation)	-Reduced NG flow to high pressure network	- FT 26 flow transmitter to control panel		
3	MORE	Flow	≈ 160 kg/h	High LNG flow to vaporizers	- Overworking of SPS - Failure in inlet control instrumentation (FCV 26 fails regulation)	-High LNG flow to vaporizer LNG collector -Low temperature of NG at outlet (ref. to Node 11.3 point 1) -Possible overpressure inside vaporizer serpentines	- FT 26 flow transmitter to FCV 34 for LNG recirculation to Reliquefier - FT 26 flow transmitter to SDV 20A, SDV 20B for LNG inlet flow to SCV stopping - Ref. to Node 11.2 - 11.3	- Ref. to Node 11.2 - 11.3	
4	REVERSE	Flow		Back flow detected	- ESD of the line	-LNG flowing back to SPS	- Check valve 26		
5	LESS	Temperature	≈ -155°C	Low temperature of LNG flow to vaporizers	- Abnormal LNG low temperature after SPS	-Low temperature of NG at outlet (ref. to Node 11.3 point 1)	-TI 26 temperature transmitter to FCV 26 for LNG inlet flow regulation -Ref. to Node 11.2 - 11.3	-Ref. to Node 11.2 - 11.3	

PLANT: El Musel Regasification (Enagás).
NODE: 11.2: Submerged Combustion Vaporizer (x1).
DESIGN INTENT: Inputs: LNG from high pressure LNG principal collector, BOG from compressors, air for combustion.
Activities: LNG vaporization.

N°	Guide word	Parameter	Parameter intention	Deviation	Cause	Consequence	Safeguards	RASE Record of Hazard Identification	
								Explosive atmosphere	Ignition source
1	NO	Flow	Minimum combustible gas flow to pilot flame	Combustible gas not reaching SCVs	-Fault in BOG compressors (ref. to Node 6.2) -Fault in combustible gas inlet line control instrumentation(FCV 18, FCV 19 fail close, spurius closing of SDV 18)	-Impossible to start combustion vaporization process	- FT 20 flow transmitter to control panel for SCV shut down. - Flame detection sensors		
2	LESS	Flow	Required gas flow for combustion	Low BOG flow from compressors	-Fault in BOG compressors (ref. to Node 6.2) -Fault in combustible gas inlet line control instrumentation (FCV 18, FCV 19 fail regulation)	-Ref. to Node 11.3 point 1	- FT 18 flow transmitter to SDV 20A, SDV 20B for LNG inlet flow stopping.	-Ref. to Node 11.3 point 1	
3	MORE	Flow	Required gas flow for combustion	High BOG flow from compressors	-Fault in BOG compressors (ref. to Node 6.2) -Fault in combustible gas inlet line control instrumentation (FCV 18, FCV 19 fail regulation)	-Greater gas quantity burned during vaporization	- FT 18 flow transmitter to SDV 18 for gas inlet flow stopping		
4	MORE	Pressure	50 - 80 bar	High pressure in vaporizer serpentines	-SDV 22 colsing on vaporizer NG outlet line -High heat transfer coefficient due to fault in combustion process	-Vaporization of LNG remained in vaporizer causes overpressure in serpentines	-PSV 22 to high pressure venting system	-Possible natural gas releases to atmosphere	-Hot gases and hot particles arising from combustion
5	LESS	Flow	Required air flow for combustion	Low air flow from combustion air fan	-Fault in combustion air fan -Fault in combustible air inlet control instrumentation	-Impossible to start combustion vaporization process			
6	LESS	Temperature	Required water temperature for LNG heating	Low temperature of water bath	-Fault in combustion process -Low temperature of water used for bath filling	-Ref. to Node 11.3 point 1	- TT 20 temperature transmitter to control panel ant to FCV 26 for LNG inlet flow regulation	-Ref. to Node 11.3 point 1	
7	LESS	Level	Required water level for serpentines heating	Low water bath level	-Fault in water filling process -Fault in water bath containment	-Ref. to Node 11.3 point 1	- Level transmitter in water bath to control panel	-Ref. to Node 11.3 point 1	

PLANT: El Musel Regasification (Enagás).
NODE: 11.3: SCV NG outlet line and collector.
DESIGN INTENT: Inputs: NG from SCV vaporization.
Activities: NG sent to high pressure station.

N°	Guide word	Parameter	Parameter intention	Deviation	Cause	Consequence	Safeguards	RASE Record of Hazard Identification	
								Explosive atmosphere	Ignition source
1	LESS	Temperature	> 0°C	Low temperature of NG from vaporization: < 0°C	-NG not warmed enaugh in SCV by combustion vaporization process -Low fuel gas flow to vaporizer burner (ref. to Node 11.2 point 2) -High LNG flow to vaporizer (ref. to Node 11.1 point 3) -Ref. to Node 11.2	-NG not deliverable to high pressure network -Possible condensation and hydrates formation inside pipeline	- TA 22 temperature alarm, TT 22 temperature transmitter to FCV 26 for LNG inlet flow decreasing		
				Low temperature of NG from vaporization: < -5°C	-NG not warmed enaugh in SCV by combustion vaporization process -Low fuel gas flow to vaporizer burner (ref. to Node 11.2 point 2) -High LNG flow to vaporizer (ref. to Node 11.1 point 3) -Ref. to Node 11.2 - Lack of response by operator to temperature alarm and manual flow regulation	- Cold NG or LNG coming out from vaporizers (< 20°C) may reach pipelines downstream -Possible condensation and hydrates formation inside pipeline	- TT 22 temperature transmitter to SDV 20A, SDV 20B, SDV 22 for SCV isolation and shut down	-Damages to pipelines and equipment downstream vaporizers due to change in pipeline material (from stainless steal to carbon steel) may lead to natural gas releases	
2	LESS	Pressure	50 - 70 bar	Low pressure of NG at vaporizer outlet	-ESD of NG outlet line due to low temperature (ref. previous point) -Fault in outlet line pressure regulation instrumentation (PCV 22)	-Reduced NG flow to high pressure network			
3	MORE	Pressure	50 - 70 bar	High pressure of NG at vaporizer outlet	-NG overpressure in regasification process	-NG pressure at outlet exceeding safety limits	-PI, PT to LNG inlet line -PSVs	-Possible natural gas releases to atmosphere	
4	NO	Flow	400 000 m^3(n)/h	No NG flow at vaporizer outlet	- Spurius closing of SDV 22	- No NG flow to high pressure network			

PLANT: El Musel Regasification (Enagás).
NODE: 12.1: Measuring station.
DESIGN INTENT: Inputs: NG from high pressure collector.
Activities: NG flow and composition measuring before immission to high pressure network.

N°	Guide word	Parameter	Parameter intention	Deviation	Cause	Consequence	Safeguards	RASE Record of Hazard Identification	
								Explosive atmosphere	Ignition source
1	LESS	Flow	400 000 m^3(n)/h	Low NG flow to measuring station	-Less NG flow from vaporizers high pressure collector -Fault in control line instrumentation (FCV 37)	-NG flow sent to network at lower pressure			
2	MORE	Pressure	50 - 70 bar	High NG pressure reaching measuring station	-Overpressure in vaporizers high pressure collector due to fault in vaporization process	-NG delivered to network at too high pressure -Instability in flow measuring working pressure	- PT 37 pressure transmitter to SDV 36A, SDV 36B for LNG inlet flow to vaporizers stopping.	-Ref. to Node 9.2 point 2	
3	LESS	Temperature	> 0°C	Low temperature of NG reaching measuring station	-Ref. to Nodes 9.3 / 11.3	-Possible condensation and hydrates formation inside pipeline -Ref. to Nodes 9.3 / 11.3	-Temperature transmitters inside measuring station to control panel -Ref. to Nodes 9.3 / 11.3	-Ref. to Nodes 9.3 / 11.3	

PLANT: El Musel Regasification (Enagás).
NODE: 12.2: Odorizing station.
DESIGN INTENT: Inputs: NG from measuring station.
Activities: NG odorization with injection of tetrahydrothiophene THT.

N°	Guide word	Parameter	Parameter intention	Deviation	Cause	Consequence	Safeguards	RASE Record of Hazard Identification	
								Explosive atmosphere	Ignition source
1	LESS	Flow	Required quantity of THT according to current NG flow	Low THT flow to natural gas high pressure pipeline	-Fault in NG flow measuring and transmission at measuring station -Fault in THT injection line control instrumentation -Fault in THT injection pumps	-NG flow coming out from measuring station not sufficently odorized.	- Flow transmitter on THT injection line to control panel	-Possible faults in leakages detection downstream odorizing station (not considered in Hazard Identification)	

PLANT: El Musel Regasification (Enagás).
NODE: 13.1: From BOG collector (low pressure) to torch liquid separator inlet.
DESIGN INTENT: Inputs: Gas from low pressure collector.
Activities: Safety gas discharge to torch system.

N°	Guide word	Parameter	Parameter intention	Deviation	Cause	Consequence	Safeguards	RASE Record of Hazard Identification	
								Explosive atmosphere	Ignition source
1	MORE	Pressure	Set pressure value: 250 mbarg	BOG in low pressure collector exceeds maximum set value	-Overpressure in low pressure venting system	-BOG sent to torch system	- PCV 31B self-actuated at 250 mbar		

PLANT: El Musel Regasification (Enagás).
NODE: 13.2: From high pressure gas collector to torch liquid separator inlet.
DESIGN INTENT: Inputs: Gas from high pressure collector.
Activities: Safety gas discharge to torch system.

N°	Guide word	Parameter	Parameter intention	Deviation	Cause	Consequence	Safeguards	RASE Record of Hazard Identification	
								Explosive atmosphere	Ignition source
1	MORE	Pressure	Set pressure value: 250 mbarg	Gas in high pressure collector exceeds maximum set value	-Overpressure in high pressure system	- Natural gas sent to torch system	- PCV 31A self-actuated at 250 mbar		

PLANT: El Musel Regasification (Enagás).
NODE: 13.3: Torch liquid separator, outlet line to torch.
DESIGN INTENT: Inputs: Natural gas from low and high pressure collectors.
Activities: Excess natural gas liquid separation and sending to torch.

N°	Guide word	Parameter	Parameter intention	Deviation	Cause	Consequence	Safeguards	RASE Record of Hazard Identification	
								Explosive atmosphere	Ignition source
1	MORE	Pressure	Less than separator maximum operation pressure	High pressure inside separator	-Fault in gas inlet line control instrumentation (PCV 31) -Fault in gas outlet line control instrumentation (PCV 32)	-Overpressure inside torch liquid separator	-PSV 33 to atmosphere - PT 33 pressure transmitter to control panel	-Possible natural gas releases to atmosphere	
2	MORE	Level	Less than separator maximum operation liquid level	Liquid level inside the separator too high	-Fault in gas outlet line control instrumentation (PCV 32) -Undesired condensation of natural gas inside separator	-Inadequate liquid separation -Drops of liquid in gas coming out from separator may cause improper combustion to torch -Too high liquid level may damage separator components	- HLA to control panel and SDV 31 for natural gas inlet flow stopping - Separator drainage line to collecting basin	-LNG expelled to drainage collecting basin	
3	LESS	Temperature		Low temperature of gas sent to torch	-Fault in liquid separation (ref. to previous point)	-Drops of liquid in gas coming out from separator may cause improper combustion to torch	- TT 32 temperature transmitter to control panel for combustion at torch stopping		

PLANT: El Musel Regasification (Enagás).
NODE: 14.1: LNG filling line from LNG low pressure collector to truck loading arm.
(Two loading/unloading platform for LNG trucks).
DESIGN INTENT: Inputs: LNG from low pressure collector.
Activities: LNG truck loading.

N°	Guide word	Parameter	Parameter intention	Deviation	Cause	Consequence	Safeguards	RASE Record of Hazard Identification	
								Explosive atmosphere	Ignition source
1	LESS	Flow	50 - 60 m^3/h	Low LNG filling flow	-Fault in PPS (ref. to Node 5) -Fault in line control instrumentation (FCV 28 fails closed)	-Flow less than required in truck filling	- FT 28 to control panel		
2	MORE	Flow	50 - 60 m^3/h	High LNG filling flow	-Fault in PPS (ref. to Node 5) -Fault in line control instrumentation (FCV 28 fails open)	-Flow more than required in truck filling	- FT 28 to control panel and SDV 28 for LNG filling flow stopping -Drainage collecting channels, collecting basin -Emergency unclamping of truck liquid filling arm	-Possible LNG releases above loading area floor	
3	MORE	Temperature	≈ -163°C	High temperature of LNG filling truck	-Fault in PPS (ref. to Node 5): LNG overwarming	-Risk of boil-off generation inside truck LNG tank	- TT 28 to control panel and SDV 28 for LNG filling flow stopping	-Ref. to Node 14.2 point 1	

PLANT: El Musel Regasification (Enagás).
NODE: 14.2: Vapour devolution line from truck vapour arm to plant BOG collector.
(Two loading/unloading platform for LNG trucks).
DESIGN INTENT: Inputs: BOG gas inside truck tank.
Activities: Vapour devolution to plant, pressure balance during filling operation.

N°	Guide word	Parameter	Parameter intention	Deviation	Cause	Consequence	Safeguards	RASE Record of Hazard Identification	
								Explosive atmosphere	Ignition source
1	MORE	Pressure	200 - 500 mbarg	High pressure truk tank released to vapour devolution line	-Boil-off generation inside truck LNG tank due to low LNG temperature (ref. to Node 14.1 point 3) -Truck LNG tank not properly cooled before filling operation	-Overpressure inside vapour devolution line / truck tank	- PT 29 pressure transmitter to control panel -Pipeline PSV 29 to atmosphere -Truck tank PSVs -Emergency unclamping of truck vapour devolution arm	-Important natural gas releases to atmosphere on truck filling area: truck tank PSVs/vapour arm disconnection	

ANNEX IX

Record of Hazard Identification – Risk Estimation

	Hazard Identification								Risk Estimation				
Ref.	Type	Reference to HAZOP	Frequency of occurrence or release	Location	Type	Cause	Likelihood	Effectiveness of ignition sources	Frequency of Occurrence	Quantity and characteristics of product and installation	Confinement and capacity of propagation	Severity	Risk level
1	LNG spillages due to damage to sealing in pipeline components.	Node 1.1 point 2	ATEX level 3	Along LNG transfer pipeline path from unloading dock to storage tanks (32"-36" pipeline).	Electrical apparatus	During malfunction or short-circuit of measuring and control equipment	FAULT	HIGH	Remote	LOW	LOW	Negligible	D
2	LNG spillages due to damage to sealing in pipeline components.	Node 1.1 point 2	ATEX level 3	Along LNG transfer pipeline path from unloading dock to storage tanks (32"-36" pipeline).	Static electricity spark discharges	Deterioration and/or lack of continuity of earthing and equipotential union of conductive parts (loose connections)	FAULT	HIGH	Remote	LOW	LOW	Negligible	D
3	LNG spillages due to damage to sealing in pipeline components.	Node 1.1 point 2	ATEX level 3	Along LNG transfer pipeline path from unloading dock to storage tanks (32"-36" pipeline).	Static electricity spark discharges	Use of improper shoes, clothing, instrumentation during repair, maintenance, cleaning operations	FAULT	HIGH	Remote	LOW	LOW	Negligible	D
4	LNG spillages due to damage to sealing in pipeline components.	Node 1.1 point 2	ATEX level 3	Along LNG transfer pipeline path from unloading dock to storage tanks (32"-36" pipeline).	Mechanically generated sparks	Carrying out of repair, maintenance, cleaning operations with improper instrumentation	FAULT	HIGH	Remote	LOW	LOW	Negligible	D
5	LNG releases due to ERS of liquid unloading arms	Node 1.1 point 1	ATEX level 3	LNG unloading dock - arms connection zone	Electrical apparatus	During malfunction or short-circuit of measuring and control equipment	FAULT	HIGH	Remote	MEDIUM	LOW	Negligible	D
6	LNG releases due to ERS of liquid unloading arms	Node 1.1 point 1	ATEX level 3	LNG unloading dock - arms connection zone	Static electricity spark discharges	Deterioration and/or lack of continuity of earthing and equipotential union of conductive parts (loose connections)	FAULT	HIGH	Remote	MEDIUM	LOW	Negligible	D
7	LNG spillages due to water hammer causing pipe rupture	Node 1.2 point 3	ATEX level 3	Along LNG transfer pipeline path from unloading dock to storage tanks (32"-36" pipeline).	Electrical apparatus	During malfunction or short-circuit of measuring and control equipment	FAULT	HIGH	Remote	HIGH	LOW	Minor	C
8	LNG spillages due to water hammer causing pipe rupture	Node 1.2 point 3	ATEX level 3	Along LNG transfer pipeline path from unloading dock to storage tanks (32"-36" pipeline).	Static electricity spark discharges	Deterioration and/or lack of continuity of earthing and equipotential union of conductive parts (loose connections)	FAULT	HIGH	Remote	HIGH	LOW	Minor	C
9	LNG spillages due to water hammer causing pipe rupture	Node 1.2 point 3	ATEX level 3	Along LNG transfer pipeline path from unloading dock to storage tanks (32"-36" pipeline).	Static electricity spark discharges	Use of improper shoes, clothing, instrumentation during repair, maintenance, cleaning operations	FAULT	HIGH	Remote	HIGH	LOW	Minor	C
10	LNG spillages due to water hammer causing pipe rupture	Node 1.2 point 3	ATEX level 3	Along LNG transfer pipeline path from unloading dock to storage tanks (32"-36" pipeline).	Mechanically generated sparks	Carrying out of repair, maintenance, cleaning operations with improper instrumentation	FAULT	HIGH	Remote	HIGH	LOW	Minor	C

	Hazard Identification						Risk Estimation						
Ref.	Type	Reference to HAZOP	Frequency of occurrence or release	Location	Type	Cause	Likelihood	Effectiveness of ignition sources	Frequency of Occurrence	Quantity and characteristics of product and installation	Confinement and capacity of propagation	Severity	Risk level
11	LNG spillages due to water hammer causing pipe rupture	Node 1.2 point 3	ATEX level 3	Along LNG transfer pipeline path from unloading dock to storage tanks (32"-36" pipeline).	Mechanically generated sparks	Rubbing of pipe metallic parts	RARE FAULT	HIGH	Remote	HIGH	LOW	Minor	C
12	Releases of natural gas to atmosphere through pipeline PSVs	Node 1.2 point 5	ATEX level 2	Along LNG transfer pipeline path from unloading dock to storage tanks (32"-36" pipeline).	Electrical apparatus	During malfunction or short-circuit of measuring and control equipment	FAULT	HIGH	Occasional	MEDIUM	LOW	Negligible	D
13	Releases of natural gas to atmosphere through pipeline PSVs	Node 1.2 point 5	ATEX level 2	Along LNG transfer pipeline path from unloading dock to storage tanks (32"-36" pipeline).	Static electricity spark discharges	Deterioration and/or lack of continuity of earthing and equipotential union of conductive parts (loose connections)	FAULT	HIGH	Occasional	MEDIUM	LOW	Negligible	D
14	Natural gas releases to atmosphere due to ERS of vapour devolution arm	Node 3 point 1	ATEX level 3	LNG unloading dock - arms connection zone	Electrical apparatus	During malfunction or short-circuit of measuring and control equipment	FAULT	HIGH	Remote	MEDIUM	LOW	Negligible	D
15	Natural gas releases to atmosphere due to ERS of vapour devolution arm	Node 3 point 1	ATEX level 3	LNG unloading dock - arms connection zone	Electrical apparatus	Deterioration and/or lack of continuity of earthing and equipotential union of conductive parts (loose connections)	FAULT	HIGH	Remote	MEDIUM	LOW	Negligible	D
16	Natural gas releases to atmosphere through flash tank PSVs	Node 3 point 5	ATEX level 2	Flash drum - docking port	Electrical apparatus	During malfunction or short-circuit of measuring and control equipment	FAULT	HIGH	Occasional	MEDIUM	LOW	Negligible	D
17	Natural gas releases to atmosphere through flash tank PSVs	Node 3 point 5	ATEX level 2	Flash drum - docking port	Static electricity spark discharges	Deterioration and/or lack of continuity of earthing and equipotential union of conductive parts (loose connections)	FAULT	HIGH	Occasional	MEDIUM	LOW	Negligible	D
18	LNG leakages in collecting channels	Node 3 point 7	ATEX level 3	Flash drum - docking port	Static electricity spark discharges	Use of improper shoes, clothing, instrumentation during repair, maintenance, cleaning operations	FAULT	HIGH	Remote	MEDIUM	LOW	Negligible	D
19	Natural gas vapours from collecting basin	Node 3 point 7	ATEX level 2	Flash drum - docking port	Electrical apparatus	During malfunction or short-circuit of measuring and control equipment	FAULT	HIGH	Occasional	MEDIUM	MEDIUM	Minor	B
20	Natural gas vapours from collecting basin	Node 3 point 7	ATEX level 2	Flash drum - docking port	Static electricity spark discharges	Deterioration and/or lack of continuity of earthing and equipotential union of conductive parts (loose connections)	FAULT	HIGH	Occasional	MEDIUM	MEDIUM	Minor	B
21	Natural gas vapours from collecting basin	Node 3 point 7	ATEX level 2	Flash drum - docking port	Static electricity spark discharges	Use of improper shoes, clothing, instrumentation during repair, maintenance, cleaning operations	FAULT	HIGH	Occasional	MEDIUM	MEDIUM	Minor	B

	Hazard Identification								Risk Estimation				
Ref.	**Type**	**Reference to HAZOP**	**Frequency of occurrence or release**	**Location**	**Type**	**Cause**	**Likelihood**	**Effectiveness of ignition sources**	**Frequency of Occurrence**	**Quantity and characteristics of product and installation**	**Confinement and capacity of propagation**	**Severity**	**Risk level**
22	Natural gas vapours from collecting basin	Node 3 point 7	ATEX level 2	Flash drum - docking port	Mechanically generated sparks	Carrying out of repair, maintenance, cleaning operations with improper instrumentation	FAULT	HIGH	Occasional	MEDIUM	MEDIUM	Minor	B
23	Important natural gas releases to atmosphere	Node 4 point 1, 4	ATEX level 3	LNG storage tanks - dome venting lines and PSVs	Electrical apparatus	During malfunction or short-circuit of measuring and control equipment	FAULT	HIGH	Remote	HIGH	LOW	Minor	C
24	Important natural gas releases to atmosphere	Node 4 point 1, 4	ATEX level 3	LNG storage tanks - dome venting lines and PSVs	Static electricity spark discharges	Deterioration and/or lack of continuity of earthing and equipotential union of conductive parts (loose connections)	FAULT	HIGH	Remote	HIGH	LOW	Minor	C
25	LNG leakages in collecting channels	Node 4 point 2	ATEX level 3	LNG storage tanks leakages collecting channels to collecting basin	Static electricity spark discharges	Use of improper shoes, clothing, instrumentation during repair, maintenance, cleaning operations	FAULT	HIGH	Remote	MEDIUM	LOW	Negligible	D
26	Natural gas vapours from collecting basin	Node 4 point 2	ATEX level 2	LNG storage tanks leakages collecting basin	Electrical apparatus	During malfunction or short-circuit of measuring and control equipment	FAULT	HIGH	Occasional	MEDIUM	MEDIUM	Minor	B
27	Natural gas vapours from collecting basin	Node 4 point 2	ATEX level 2	LNG storage tanks leakages collecting basin	Static electricity spark discharges	Deterioration and/or lack of continuity of earthing and equipotential union of conductive parts (loose connections)	FAULT	HIGH	Occasional	MEDIUM	MEDIUM	Minor	B
28	Natural gas vapours from collecting basin	Node 4 point 2	ATEX level 2	LNG storage tanks leakages collecting basin	Static electricity spark discharges	Use of improper shoes, clothing, instrumentation during repair, maintenance, cleaning operations	FAULT	HIGH	Occasional	MEDIUM	MEDIUM	Minor	B
29	Natural gas vapours from collecting basin	Node 4 point 2	ATEX level 2	LNG storage tanks leakages collecting basin	Mechanically generated sparks	Carrying out of repair, maintenance, cleaning operations with improper instrumentation	FAULT	HIGH	Occasional	MEDIUM	MEDIUM	Minor	B
30	Natural gas vapours from cold spots	Node 4 point 2	ATEX level 3	LNG storage tanks - external concrete tank base	Electrical apparatus	During malfunction or short-circuit of measuring and control equipment	FAULT	HIGH	Remote	LOW	LOW	Negligible	D
31	Natural gas vapours from cold spots	Node 4 point 2	ATEX level 3	LNG storage tanks - external concrete tank base	Static electricity spark discharges	Use of improper shoes, clothing, instrumentation during repair, maintenance, cleaning operations	FAULT	HIGH	Remote	LOW	LOW	Negligible	D
32	Natural gas vapours from cold spots	Node 4 point 2	ATEX level 3	LNG storage tanks - external concrete tank base	Mechanically generated sparks	Carrying out of repair, maintenance, cleaning operations with improper instrumentation	FAULT	HIGH	Remote	LOW	LOW	Negligible	D

	Hazard Identification							Risk Estimation					
Ref.	Type	Reference to HAZOP	Frequency of occurrence or release	Location	Type	Cause	Likelihood	Effectiveness of ignition sources	Frequency of Occurrence	Quantity and characteristics of product and installation	Confinement and capacity of propagation	Severity	Risk level
33	Explosive natural gas/air mixture	Node 4 point 5	ATEX level 3	LNG storage tanks - space between suspended roof and external tank in proximity to the highest part of the dome	Electrical apparatus	During malfunction or short-circuit of measuring and control equipment	RARE FAULT	HIGH	Improbable	HIGH	HIGH	Catastrophic	B
34	Natural gas in vapour form	Node 5 point 1	ATEX level 2	Primary pump wells - LP containers	Hot surface	Anomalies in pumps components - cavitation causing overheating	FAULT	MEDIUM	Remote	MEDIUM	HIGH	Major	B
35	Natural gas in vapour form	Node 5 point 1	ATEX level 2	Primary pump wells - LP containers	Mechanically generated sparks	Rubbing of metalling parts due to malfunctions or cavitation	FAULT	HIGH	Occasional	MEDIUM	HIGH	Major	B
36	Natural gas in vapour form	Node 5 point 1	ATEX level 2	Primary pump wells - LP containers	Electrical apparatus	During malfunction or short-circuit of measuring and control equipment - electrical connection box located in the upper part of the well	FAULT	HIGH	Occasional	MEDIUM	HIGH	Major	B
37	Natural gas in vapour form	Node 5 point 1	ATEX level 2	Primary pump wells - LP containers	Static electricity spark discharges	Deterioration and/or lack of continuity of earthing and equipotential union of conductive parts (loose connections)	FAULT	HIGH	Occasional	MEDIUM	HIGH	Major	B
38	Releases of natural gas to atmosphere through venting line PSVs	Node 6.1 point 2	ATEX level 2	BOG vertical liquid separator	Electrical apparatus	During malfunction or short-circuit of measuring and control equipment	FAULT	HIGH	Occasional	MEDIUM	LOW	Negligible	D
39	Releases of natural gas to atmosphere through venting line PSVs	Node 6.1 point 2	ATEX level 2	BOG vertical liquid separator	Static electricity spark discharges	Deterioration and/or lack of continuity of earthing and equipotential union of conductive parts (loose connections)	FAULT	HIGH	Occasional	MEDIUM	LOW	Negligible	D
40	LNG leakages in collecting channels	Node 6.1 point 3	ATEX level 3	BOG vertical liquid separator	Static electricity spark discharges	Use of improper shoes, clothing, instrumentation during repair, maintenance, cleaning operations	FAULT	HIGH	Remote	MEDIUM	LOW	Negligible	D
41	Natural gas vapours from collecting basin	Node 6.1 point 3	ATEX level 2	BOG vertical liquid separator	Electrical apparatus	During malfunction or short-circuit of measuring and control equipment	FAULT	HIGH	Occasional	MEDIUM	MEDIUM	Minor	B
42	Natural gas vapours from collecting basin	Node 6.1 point 3	ATEX level 2	BOG vertical liquid separator	Static electricity spark discharges	Deterioration and/or lack of continuity of earthing and equipotential union of conductive parts (loose connections)	FAULT	HIGH	Occasional	MEDIUM	MEDIUM	Minor	B
43	Natural gas vapours from collecting basin	Node 6.1 point 3	ATEX level 2	BOG vertical liquid separator	Static electricity spark discharges	Use of improper shoes, clothing, instrumentation during repair, maintenance, cleaning operations	FAULT	HIGH	Occasional	MEDIUM	MEDIUM	Minor	B

	Hazard Identification								Risk Estimation				
Ref.	**Type**	**Reference to HAZOP**	**Frequency of occurrence or release**	**Location**	**Type**	**Cause**	**Likelihood**	**Effectiveness of ignition sources**	**Frequency of Occurrence**	**Quantity and characteristics of product and installation**	**Confinement and capacity of propagation**	**Severity**	**Risk level**
44	Natural gas vapours from collecting basin	Node 6.1 point 3	ATEX level 2	BOG vertical liquid separator	Mechanically generated sparks	Carrying out of repair, maintenance, cleaning operations with improper instrumentation	FAULT	HIGH	Occasional	MEDIUM	MEDIUM	Minor	B
45	Natural gas releases to atmosphere from safety valves, compressor seals.	Node 6.2 point 2	ATEX level 2	BOG compressor stations	Hot surface	Anomalies in compressors componentes causing overheating - kinematic chain, cylinders, glands	FAULT	MEDIUM	Remote	MEDIUM	MEDIUM	Minor	C
46	Natural gas releases to atmosphere from safety valves, compressor seals.	Node 6.2 point 2	ATEX level 2	BOG compressor stations	Mechanically generated sparks	Carrying out of repair, maintenance, cleaning operations with improper instrumentation	FAULT	HIGH	Occasional	MEDIUM	MEDIUM	Minor	B
47	Natural gas releases to atmosphere from safety valves, compressor seals.	Node 6.2 point 2	ATEX level 2	BOG compressor stations	Mechanically generated sparks	Rubbing of metalling parts	RARE FAULT	HIGH	Remote	MEDIUM	MEDIUM	Minor	C
48	Natural gas releases to atmosphere from safety valves, compressor seals.	Node 6.2 point 2	ATEX level 2	BOG compressor stations	Electrical apparatus	During malfunction or short-circuit of measuring and control equipment	FAULT	HIGH	Occasional	MEDIUM	MEDIUM	Minor	B
49	Natural gas releases to atmosphere from safety valves, compressor seals.	Node 6.2 point 2	ATEX level 2	BOG compressor stations	Static electricity spark discharges	Deterioration and/or lack of continuity of earthing and equipotential union of conductive parts (loose connections)	FAULT	HIGH	Occasional	MEDIUM	MEDIUM	Minor	B
50	Natural gas releases to atmosphere from safety valves, compressor seals.	Node 6.2 point 2	ATEX level 2	BOG compressor stations	Static electricity spark discharges	Use of improper shoes, clothing, instrumentation during repair, maintenance, cleaning operations	FAULT	HIGH	Occasional	MEDIUM	MEDIUM	Minor	B
51	Releases of natural gas to atmosphere through pipeline PSVs	Node 6.2 point 3	ATEX level 2	BOG compressor discharge line	Electrical apparatus	During malfunction or short-circuit of measuring and control equipment	FAULT	HIGH	Occasional	MEDIUM	LOW	Negligible	D
52	Releases of natural gas to atmosphere through pipeline PSVs	Node 6.2 point 3	ATEX level 2	BOG compressor discharge line	Static electricity spark discharges	Deterioration and/or lack of continuity of earthing and equipotential union of conductive parts (loose connections)	FAULT	HIGH	Occasional	MEDIUM	LOW	Negligible	D
53	LNG leakages in collecting channels	Node 7.2 point 3	ATEX level 3	BOG reliquefier	Static electricity spark discharges	Use of improper shoes, clothing, instrumentation during repair, maintenance, cleaning operations	FAULT	HIGH	Remote	MEDIUM	LOW	Negligible	D
54	Natural gas vapours from collecting basin	Node 7.2 point 3	ATEX level 2	BOG reliquefier	Electrical apparatus	During malfunction or short-circuit of measuring and control equipment	FAULT	HIGH	Occasional	MEDIUM	MEDIUM	Minor	B

	Hazard Identification								Risk Estimation				
Ref.	Type	Reference to HAZOP	Frequency of occurrence or release	Location	Type	Cause	Likelihood	Effectiveness of ignition sources	Frequency of Occurrence	Quantity and characteristics of product and installation	Confinement and capacity of propagation	Severity	Risk level
55	Natural gas vapours from collecting basin	Node 7.2 point 3	ATEX level 2	BOG reliquefier	Static electricity spark discharges	Deterioration and/or lack of continuity of earthing and equipotential union of conductive parts (loose connections)	FAULT	HIGH	Occasional	MEDIUM	MEDIUM	Minor	B
56	Natural gas vapours from collecting basin	Node 7.2 point 3	ATEX level 2	BOG reliquefier	Static electricity spark discharges	Use of improper shoes, clothing, instrumentation during repair, maintenance, cleaning operations	FAULT	HIGH	Occasional	MEDIUM	MEDIUM	Minor	B
57	Natural gas vapours from collecting basin	Node 7.2 point 3	ATEX level 2	BOG reliquefier	Mechanically generated sparks	Carrying out of repair, maintenance, cleaning operations with improper instrumentation	FAULT	HIGH	Occasional	MEDIUM	MEDIUM	Minor	B
58	Releases of natural gas to atmosphere through venting line PSVs	Node 7.2 point 5	ATEX level 2	BOG reliquefier	Electrical apparatus	During malfunction or short-circuit of measuring and control equipment	FAULT	HIGH	Occasional	MEDIUM	LOW	Negligible	D
59	Releases of natural gas to atmosphere through venting line PSVs	Node 7.2 point 5	ATEX level 2	BOG reliquefier	Static electricity spark discharges	Deterioration and/or lack of continuity of earthing and equipotential union of conductive parts (loose connections)	FAULT	HIGH	Occasional	MEDIUM	LOW	Negligible	D
60	Natural gas in vapour form	Node 8 point 1	ATEX level 2	Secondary pump wells - HP containers	Hot surface	Anomalies in pumps components / cavitation causing overheating	FAULT	MEDIUM	Remote	MEDIUM	HIGH	Major	B
61	Natural gas in vapour form	Node 8 point 1	ATEX level 2	Secondary pump wells - HP containers	Mechanically generated sparks	Rubbing of metalling parts due to malfunctions or cavitation	FAULT	HIGH	Occasional	MEDIUM	HIGH	Major	B
62	Natural gas in vapour form	Node 8 point 1	ATEX level 2	Secondary pump wells - HP containers	Electrical apparatus	During malfunction or short-circuit of measuring and control equipment - electrical connection box located in the upper part of the well	FAULT	HIGH	Occasional	MEDIUM	HIGH	Major	B
63	Natural gas in vapour form	Node 8 point 1	ATEX level 2	Secondary pump wells - HP containers	Static electricity spark discharges	Deterioration and/or lack of continuity of earthing and equipotential union of conductive parts (loose connections)	FAULT	HIGH	Occasional	MEDIUM	HIGH	Major	B
64	Important LNG spillages	Node 9.2 point 2	ATEX level 3	Open Rack Vaporizers	Mechanically generated sparks	Rubbing of pipe metallic parts and components due to panelling rupture	RARE FAULT	HIGH	Improbable	HIGH	MEDIUM	Major	C
65	Important LNG spillages	Node 9.2 point 2	ATEX level 3	Open Rack Vaporizers	Static electricity spark discharges	Use of improper shoes, clothing, instrumentation during repair, maintenance, cleaning operations	FAULT	HIGH	Remote	HIGH	MEDIUM	Major	B

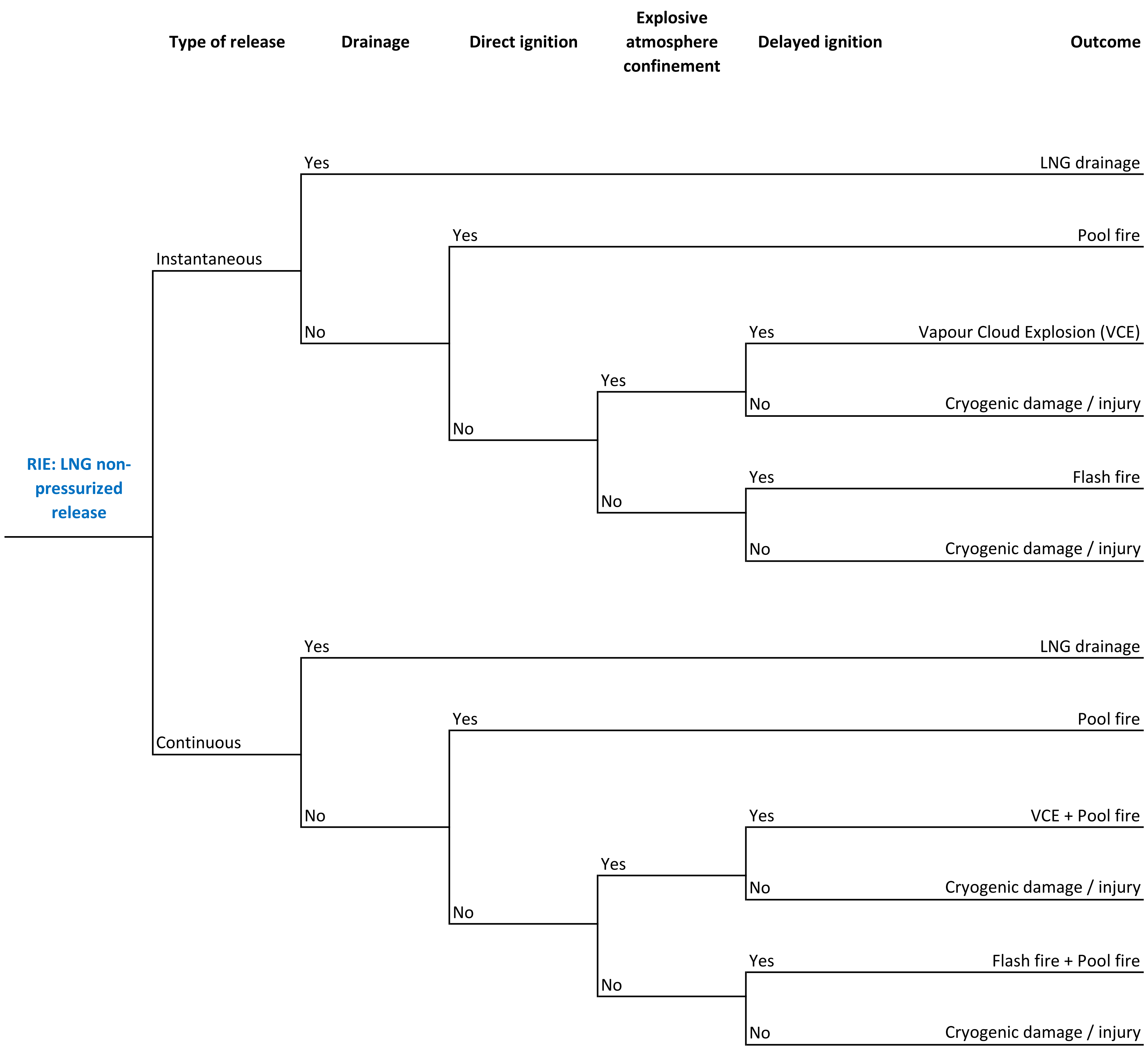
	Hazard Identification								Risk Estimation				
Ref.	Type	Reference to HAZOP	Frequency of occurrence or release	Location	Type	Cause	Likelihood	Effectiveness of ignition sources	Frequency of Occurrence	Quantity and characteristics of product and installation	Confinement and capacity of propagation	Severity	Risk level
66	Important natural gas releases to atmosphere through vaporizers PSVs	Node 9.2 point 3	ATEX level 2	Open Rack Vaporizers (ORV)	Electrical apparatus	During malfunction or short-circuit of measuring and control equipment	FAULT	HIGH	Occasional	MEDIUM	LOW	Negligible	D
67	Important natural gas releases to atmosphere through vaporizers PSVs	Node 9.2 point 3	ATEX level 2	Open Rack Vaporizers (ORV)	Static electricity spark discharges	Deterioration and/or lack of continuity of earthing and equipotential union of conductive parts (loose connections)	FAULT	HIGH	Occasional	MEDIUM	LOW	Negligible	D
68	Naural gas releases due to damage to sealing in pipeline components	Node 9.3 point 1	ATEX level 3	Natural gas ORV outlet line	Electrical apparatus	During malfunction or short-circuit of measuring and control equipment	FAULT	HIGH	Remote	LOW	LOW	Negligible	D
69	Naural gas releases due to damage to sealing in pipeline components	Node 9.3 point 1	ATEX level 3	Natural gas ORV outlet line	Static electricity spark discharges	Deterioration and/or lack of continuity of earthing and equipotential union of conductive parts (loose connections)	FAULT	HIGH	Remote	LOW	LOW	Negligible	D
70	Naural gas releases due to damage to sealing in pipeline components	Node 9.3 point 1	ATEX level 3	Natural gas ORV outlet line	Static electricity spark discharges	Use of improper shoes, clothing, instrumentation during repair, maintenance, cleaning operations	FAULT	HIGH	Remote	LOW	LOW	Negligible	D
71	Naural gas releases due to damage to sealing in pipeline components	Node 9.3 point 1	ATEX level 3	Natural gas ORV outlet line	Mechanically generated sparks	Carrying out of repair, maintenance, cleaning operations with improper instrumentation	FAULT	HIGH	Remote	LOW	LOW	Negligible	D
72	Releases of natural gas to atmosphere through pipeline PSVs	Node 9.3 point 3	ATEX level 2	Natural gas ORV outlet line	Electrical apparatus	During malfunction or short-circuit of measuring and control equipment	FAULT	HIGH	Occasional	MEDIUM	LOW	Negligible	D
73	Releases of natural gas to atmosphere through pipeline PSVs	Node 9.3 point 3	ATEX level 2	Natural gas ORV outlet line	Static electricity spark discharges	Deterioration and/or lack of continuity of earthing and equipotential union of conductive parts (loose connections)	FAULT	HIGH	Occasional	MEDIUM	LOW	Negligible	D
74	Important natural gas releases to atmosphere through vaporizers PSVs	Node 11.2 point 4	ATEX level 2	Submerged Combustion Vaporiz	Flames and hot gases (including hot particles)	Products of BOG combustion in Submerged Combustion Vaporizers	NORMAL OPERATION	MEDIUM	Occasional	MEDIUM	LOW	Negligible	D
75	Important natural gas releases to atmosphere through vaporizers PSVs	Node 11.2 point 4	ATEX level 2	Submerged Combustion Vaporiz	Electrical apparatus	During malfunction or short-circuit of measuring and control equipment	FAULT	HIGH	Occasional	MEDIUM	LOW	Negligible	D
76	Important natural gas releases to atmosphere through vaporizers PSVs	Node 11.2 point 4	ATEX level 2	Submerged Combustion Vaporiz	Static electricity spark discharges	Deterioration and/or lack of continuity of earthing and equipotential union of conductive parts (loose connections)	FAULT	HIGH	Occasional	MEDIUM	LOW	Negligible	D

	Hazard Identification								Risk Estimation				
Ref.	Type	Reference to HAZOP	Frequency of occurrence or release	Location	Type	Cause	Likelihood	Effectiveness of ignition sources	Frequency of Occurrence	Quantity and characteristics of product and installation	Confinement and capacity of propagation	Severity	Risk level
77	Naural gas releases due to damage to sealing in pipeline components	Node 11.3 point 1	ATEX level 3	Natural gas SCV outlet line	Electrical apparatus	During malfunction or short-circuit of measuring and control equipment	FAULT	HIGH	Remote	LOW	LOW	Negligible	D
78	Naural gas releases due to damage to sealing in pipeline components	Node 11.3 point 1	ATEX level 3	Natural gas SCV outlet line	Static electricity spark discharges	Deterioration and/or lack of continuity of earthing and equipotential union of conductive parts (loose connections)	FAULT	HIGH	Remote	LOW	LOW	Negligible	D
79	Naural gas releases due to damage to sealing in pipeline components	Node 11.3 point 1	ATEX level 3	Natural gas SCV outlet line	Static electricity spark discharges	Use of improper shoes, clothing, instrumentation during repair, maintenance, cleaning operations	FAULT	HIGH	Remote	LOW	LOW	Negligible	D
80	Naural gas releases due to damage to sealing in pipeline components	Node 11.3 point 1	ATEX level 3	Natural gas SCV outlet line	Mechanically generated sparks	Carrying out of repair, maintenance, cleaning operations with improper instrumentation	FAULT	HIGH	Remote	LOW	LOW	Negligible	D
81	Releases of natural gas to atmosphere through pipeline PSVs	Node 11.3 point 3	ATEX level 2	Natural gas SCV outlet line	Electrical apparatus	During malfunction or short-circuit of measuring and control equipment	FAULT	HIGH	Occasional	MEDIUM	LOW	Negligible	D
82	Releases of natural gas to atmosphere through pipeline PSVs	Node 11.3 point 3	ATEX level 2	Natural gas SCV outlet line	Static electricity spark discharges	Deterioration and/or lack of continuity of earthing and equipotential union of conductive parts (loose connections)	FAULT	HIGH	Occasional	MEDIUM	LOW	Negligible	D
83	Releases of natural gas to atmosphere through venting line PSVs	Node 13.3 point 1	ATEX level 2	Torch horizontal liquid separator	Electrical apparatus	During malfunction or short-circuit of measuring and control equipment	FAULT	HIGH	Occasional	MEDIUM	LOW	Negligible	D
84	Releases of natural gas to atmosphere through venting line PSVs	Node 13.3 point 1	ATEX level 2	Torch horizontal liquid separator	Static electricity spark discharges	Deterioration and/or lack of continuity of earthing and equipotential union of conductive parts (loose connections)	FAULT	HIGH	Occasional	MEDIUM	LOW	Negligible	D
85	LNG leakages in collecting channels	Node 13.3 point 2	ATEX level 3	Torch horizontal liquid separator	Static electricity spark discharges	Use of improper shoes, clothing, instrumentation during repair, maintenance, cleaning operations	FAULT	HIGH	Remote	MEDIUM	LOW	Negligible	D
86	Natural gas vapours from collecting basin	Node 13.3 point 2	ATEX level 2	Torch horizontal liquid separator	Electrical apparatus	During malfunction or short-circuit of measuring and control equipment	FAULT	HIGH	Occasional	MEDIUM	MEDIUM	Minor	B
87	Natural gas vapours from collecting basin	Node 13.3 point 2	ATEX level 2	Torch horizontal liquid separator	Static electricity spark discharges	Deterioration and/or lack of continuity of earthing and equipotential union of conductive parts (loose connections)	FAULT	HIGH	Occasional	MEDIUM	MEDIUM	Minor	B

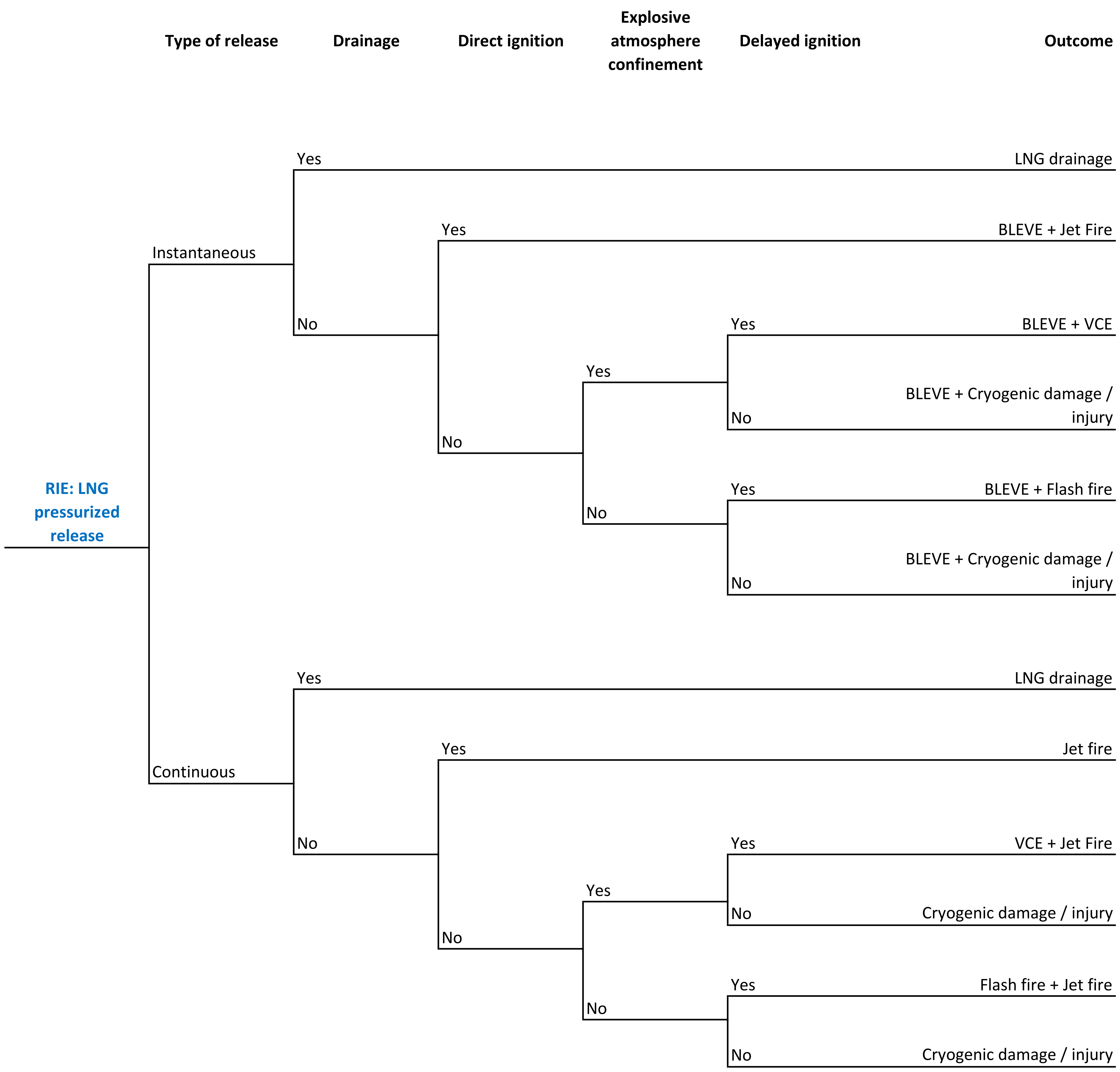
	Hazard Identification								Risk Estimation				
Ref.	Type	Reference to HAZOP	Frequency of occurrence or release	Location	Type	Cause	Likelihood	Effectiveness of ignition sources	Frequency of Occurrence	Quantity and characteristics of product and installation	Confinement and capacity of propagation	Severity	Risk level
88	Natural gas vapours from collecting basin	Node 13.3 point 2	ATEX level 2	Torch horizontal liquid separator	Static electricity spark discharges	Use of improper shoes, clothing, instrumentation during repair, maintenance, cleaning operations	FAULT	HIGH	Occasional	MEDIUM	MEDIUM	Minor	B
89	Natural gas vapours from collecting basin	Node 13.3 point 2	ATEX level 2	Torch horizontal liquid separator	Mechanically generated sparks	Carrying out of repair, maintenance, cleaning operations with improper instrumentation	FAULT	HIGH	Occasional	MEDIUM	MEDIUM	Minor	B
90	LNG releases due to ERS of liquid loading arm	Node 14.1 point 2	ATEX level 3	LNG truck loading platform	Electrical apparatus	During malfunction or short-circuit of measuring and control equipment	FAULT	HIGH	Remote	MEDIUM	LOW	Negligible	D
91	LNG releases due to ERS of liquid loading arm	Node 14.1 point 2	ATEX level 3	LNG truck loading platform	Static electricity spark discharges	Deterioration and/or lack of continuity of earthing and equipotential union of conductive parts (loose connections)	FAULT	HIGH	Remote	MEDIUM	LOW	Negligible	D
92	Important natural gas releases to atmosphere through truck tank PSVs	Node 14.2 point 1	ATEX level 3	LNG truck loading platform	Electrical apparatus	During malfunction or short-circuit of measuring and control equipment	FAULT	HIGH	Remote	MEDIUM	LOW	Negligible	D
93	Important natural gas releases to atmosphere through truck tank PSVs	Node 14.2 point 1	ATEX level 3	LNG truck loading platform	Static electricity spark discharges	Deterioration and/or lack of continuity of earthing and equipotential union of conductive parts (loose connections)	FAULT	HIGH	Remote	MEDIUM	LOW	Negligible	D
94	Natural gas releases to atmosphere due to ERS of vapour arm	Node 14.2 point 1	ATEX level 3	LNG truck loading platform	Electrical apparatus	During malfunction or short-circuit of measuring and control equipment	FAULT	HIGH	Remote	MEDIUM	LOW	Negligible	D
95	Natural gas releases to atmosphere due to ERS of vapour arm	Node 14.2 point 1	ATEX level 3	LNG truck loading platform	Electrical apparatus	Deterioration and/or lack of continuity of earthing and equipotential union of conductive parts (loose connections)	FAULT	HIGH	Remote	MEDIUM	LOW	Negligible	D

ANNEX X

Event Tree Analysis



Type of release
Drainage
Direct ignition
Explosive atmosphere confinement
Delayed ignition
Outcome
RIE: LNG non-pressurized release
Instantaneous
Continuous
Yes
No
LNG drainage
Pool fire
Vapour Cloud Explosion (VCE)
Cryogenic damage / injury
Flash fire
Cryogenic damage / injury
LNG drainage
Pool fire
VCE + Pool fire
Cryogenic damage / injury
Flash fire + Pool fire
Cryogenic damage / injury


Type of release
Drainage
Direct ignition
Explosive atmosphere confinement
Delayed ignition
Outcome
RIE: LNG pressurized release
Instantaneous
Continuous
Yes
No
LNG drainage
BLEVE + Jet Fire
BLEVE + VCE
BLEVE + Cryogenic damage / injury
BLEVE + Flash fire
BLEVE + Cryogenic damage / injury
LNG drainage
Jet fire
VCE + Jet Fire
Cryogenic damage / injury
Flash fire + Jet fire
Cryogenic damage / injury

ANNEX XI

Risk reduction options – safety measures

Ignition sources legend		
	Hot Surfaces	H
	Flames and hot gases (including hot particles)	F
	Mechanically generated sparks	M
	Electrical apparatus	E
	Static electricity	S

Risk Level	Type of hazard	Location/Equipment	Ignition sources	Risk Reduction Options	Safety measures to be adopted
B	Natural gas vapours from collecting basin	- Docking port (flash drum) - Area between LNG storage tanks - BOG liquid separator - BOG reliquefier - Torch liquid separator	- M - E - S	- Low temperature detectors on collecting basin walls - High espansion foam generators	- No tools which can cause sparks should be allowed - Welding and cutting works must strictly be subject to a "permit to work" system - Limit or avoid the use of any material or part with poor electric conductivity - Workers must be provided with appropriate working clothes consisting of materials which do not give rise to electrostatic discharges that can ignite explosive atmospheres - Regular and periodic ispection and maintenance of measuring and control equipment
B	Explosive natural gas/air mixture	- LNG storage tanks - space between suspended roof and external tank in proximity to the highest part of the dome	- E	- Injection of inert gas (ex. nitrogen) to avoid reaching natural gas LEL	- Regular and periodic ispection and maintenance of measuring and control equipment

Ignition sources legend		
	Hot Surfaces	H
	Flames and hot gases (including hot particles)	F
	Mechanically generated sparks	M
	Electrical apparatus	E
	Static electricity	S

Risk Level	Type of hazard	Location/Equipment	Ignition sources	Risk Reduction Options	Safety measures to be adopted
B	Natural gas in vapour form	- Primary pupm well (LP container) - Secondary pump well (HP container)	- H - M - E - S	- Electric suction pump for vacuum creation around electrical connection box above flanged cover - Gas detectors above flanged cover	- Electric cables connecting the connection box with the pump motor must work at -196°C - Limit or avoid the use of any material or part with poor electric conductivity - Regular and periodic ispection and maintenance of measuring and control equipment

Ignition sources legend		
	Hot Surfaces	H
	Flames and hot gases (including hot particles)	F
	Mechanically generated sparks	M
	Electrical apparatus	E
	Static electricity	S

Risk Level	Type of hazard	Location/Equipment	Ignition sources	Risk Reduction Options	Safety measures to be adopted
B	Natural gas releases to atmosphere from safety valves, compressor seals	- BOG compressor	- M - E - S	- Compressor placement in semi-open stands for facilitating natural ventilation - Improvement of vibration transmission system on compressor carter - Gas detectors near compressor seals - Temperature sensors on overwarming components	- Only tools which can cause single sparks when they are used should be allowed. The use of this tools should be subject to a "permit to work" system - Welding and cutting works must strictly be subject to a "permit to work" system - Limit or avoid the use of any material or part with poor electric conductivity - Workers must be provided with appropriate working clothes consisting of materials which do not give rise to electrostatic discharges that can ignite explosive atmospheres - Regular and periodic ispection and maintenance of measuring and control equipment

Ignition sources legend		
	Hot Surfaces	H
	Flames and hot gases (including hot particles)	F
	Mechanically generated sparks	M
	Electrical apparatus	E
	Static electricity	S

Risk Level	Type of hazard	Location/Equipment	Ignition sources	Risk Reduction Options	Safety measures to be adopted
B	Important LNG spillages	- Open Rack Vaporizer	- S	- Design proper to uniform seawater distribution along panels - Temperature sensors on panels bottom section	- Periodic metallic painting of panels - Workers must be provided with appropriate working clothes consisting of materials which do not give rise to electrostatic discharges that can ignite explosive atmospheres
C	LNG spillages due to water hammer causing pipe rupture	- LNG unloading line from unloading dock to storage tanks (32"-36" pipeline)	- E - S - M	- Low temperature detectors around pipe flanged connections - Revision of pipe support structure design	- Welding and cutting works must strictly be subject to a "permit to work" system - Limit or avoid the use of any material or part with poor electric conductivity - Workers must be provided with appropriate working clothes consisting of materials which do not give rise to electrostatic discharges that can ignite explosive atmospheres - Regular and periodic ispection and maintenance of measuring and control equipment

Ignition sources legend		
	Hot Surfaces	H
	Flames and hot gases (including hot particles)	F
	Mechanically generated sparks	M
	Electrical apparatus	E
	Static electricity	S

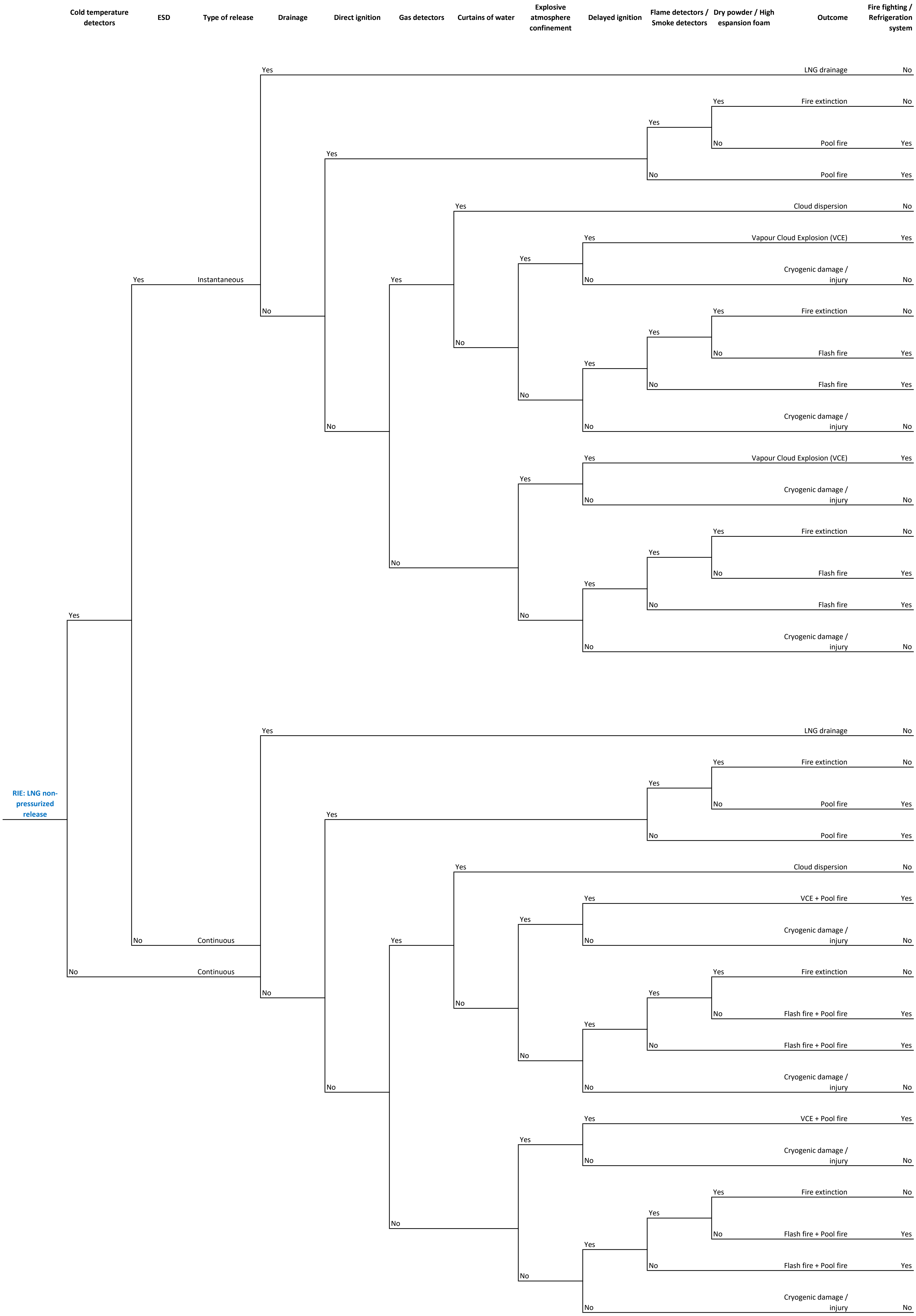
Risk Level	Type of hazard	Location/Equipment	Ignition sources	Risk Reduction Options	Safety measures to be adopted
C	Important natural gas releases to atmosphere	- LNG storage tanks - dome venting lines and PSVs	- E - S	- Gas detectors - Flame arresters for endurance burning	- Welding and cutting works must strictly be subject to a "permit to work" system - Limit or avoid the use of any material or part with poor electric conductivity - Workers must be provided with appropriate working clothes consisting of materials which do not give rise to electrostatic discharges that can ignite explosive atmospheres - Regular and periodic ispection and maintenance of measuring and control equipment
C	Natural gas releases to atmosphere from safety valves, compressor seals	- BOG compressor	- H - M	- Compressor placement in semi-open stands to facilitate natural ventilation - Improvement of vibration transmission system on carter - Gas detectors - Temperature sensors on overwarming components	- Temperature sensors set for all compressor components not reaching the 80% of natural gas ignition temperature

Ignition sources legend		
	Hot Surfaces	H
	Flames and hot gases (including hot particles)	F
	Mechanically generated sparks	M
	Electrical apparatus	E
	Static electricity	S

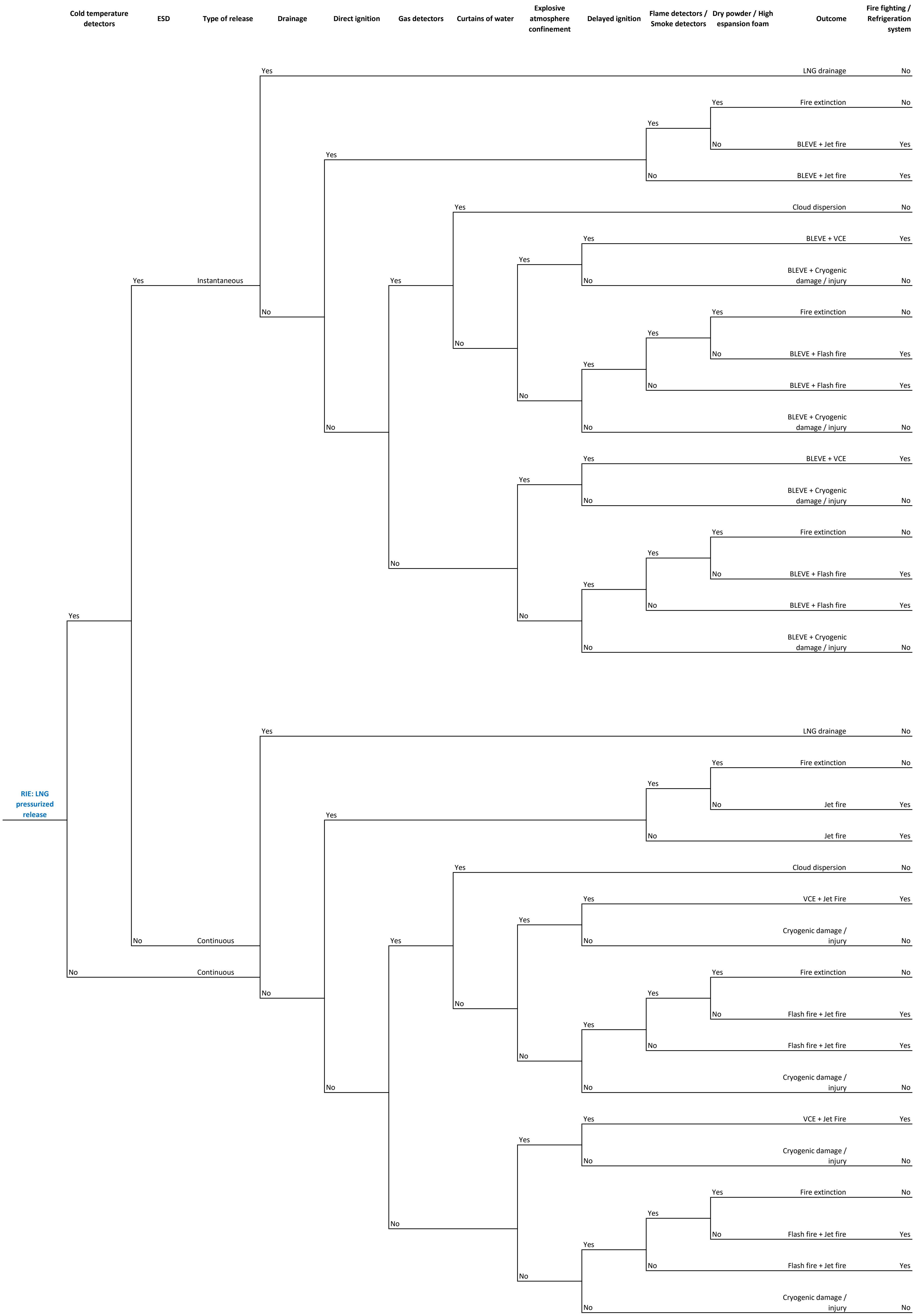
Risk Level	Type of hazard	Location/Equipment	Ignition sources	Risk Reduction Options	Safety measures to be adopted
C	Important LNG spillages	Open Rack Vaporizer LNG panels	- M	- Design proper to uniform seawater distribution along panels - Temperature sensors on panels bottom section	- Revision of panels material properties according to the capability of producing mechanical sparks at rupture

ANNEX XII

Event Tree Analysis
(safeguards implementation)



Cold temperature detectors
ESD
Type of release
Drainage
Direct ignition
Gas detectors
Curtains of water
Explosive atmosphere confinement
Delayed ignition
Flame detectors / Smoke detectors
Dry powder / High espansion foam
Outcome
Fire fighting / Refrigeration system
RIE: LNG non-pressurized release
Yes
No
Instantaneous
Continuous
LNG drainage No
Fire extinction No
Pool fire Yes
Pool fire Yes
Cloud dispersion No
Vapour Cloud Explosion (VCE) Yes
Cryogenic damage / injury No
Fire extinction No
Flash fire Yes
Flash fire Yes
Cryogenic damage / injury No
Vapour Cloud Explosion (VCE) Yes
Cryogenic damage / injury No
Fire extinction No
Flash fire Yes
Flash fire Yes
Cryogenic damage / injury No
LNG drainage No
Fire extinction No
Pool fire Yes
Pool fire Yes
Cloud dispersion No
VCE + Pool fire Yes
Cryogenic damage / injury No
Fire extinction No
Flash fire + Pool fire Yes
Flash fire + Pool fire Yes
Cryogenic damage / injury No
VCE + Pool fire Yes
Cryogenic damage / injury No
Fire extinction No
Flash fire + Pool fire Yes
Flash fire + Pool fire Yes
Cryogenic damage / injury No



Cold temperature detectors
ESD
Type of release
Drainage
Direct ignition
Gas detectors
Curtains of water
Explosive atmosphere confinement
Delayed ignition
Flame detectors / Smoke detectors
Dry powder / High espansion foam
Outcome
Fire fighting / Refrigeration system
RIE: LNG pressurized release
Instantaneous
Continuous
Continuous
LNG drainage
Fire extinction
BLEVE + Jet fire
BLEVE + Jet fire
Cloud dispersion
BLEVE + VCE
BLEVE + Cryogenic damage / injury
Fire extinction
BLEVE + Flash fire
BLEVE + Flash fire
BLEVE + Cryogenic damage / injury
BLEVE + VCE
BLEVE + Cryogenic damage / injury
Fire extinction
BLEVE + Flash fire
BLEVE + Flash fire
BLEVE + Cryogenic damage / injury
LNG drainage
Fire extinction
Jet fire
Jet fire
Cloud dispersion
VCE + Jet Fire
Cryogenic damage / injury
Fire extinction
Flash fire + Jet fire
Flash fire + Jet fire
Cryogenic damage / injury
VCE + Jet Fire
Cryogenic damage / injury
Fire extinction
Flash fire + Jet fire
Flash fire + Jet fire
Cryogenic damage / injury

ANNEX XIII

Check-list on static electricity and electrical apparatus

Annex XIII

Check-list on static electricity and electrical apparatus.

Equipment / Installation	**A**	**B**	**C**
Is all electrical equipment appropriate for use in the designated flammable area (category and temperature class according to 2014/34/EU)?			
Is use of tools in zones 1 and 2 subjected to a "permit to work" system?			
Are bolts, cable input devices and silencers firm and of correct type?			
Are not present evident damages in cables?			
Are connection and junction boxes correctly closed?			
Are flat and sealing joints clean and without damages?			
Are characteristic, type and position of lamps correct?			
Is the insulation resistance correct?			
Are the ends of cables not in use correctly protected?			
Are floors adequately conductive?			
Are lift trucks and other vehicles used in the vicinity fully protected to the appropriate standard?			
Are operators supplied with anti-static dissipative footwear, gloves and are provided with natural fiber clothing (cotton or linen clothing instead of wool, silk, or synthetic materials)?			
Are all containers, pipework, hoses, plant, etc. conductive, bonded together and earthed?			
Is liquid flow velocity of filling vessels under control and inside allowed range?			
Is earthing present when needed all through the installation?			
Are all earthing straps, clamps, wires and monitoring systems regularly inspected and maintained in good working order in relation to the characteristics of the installation and the intended use?			
Are electric switchboards provided with over-current and short circuit protections (circuit breakers)?			
Is there presence of residual-current devices (RCD)?			
Are electrical protection automatic devices operating inside allowed ranges?			
Are connections of uncovered electrical sockets avoided?			
Are sockets power surges avoided?			
Is electrical apparatus selected and installed according to EN 60079 and EN 1127?			
Is relative humidity being controlled in all working areas?			

A = already verified	**B = not applicable**	**C = requires a more detailed study**