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Hazards Identification and Quality Control for LNG Plant

Mohamed Halafawi[1], Daniela Popovici[2], Mirna Charif[3], Lazăr Avram[1]

[1] *Drilling and Production Engineering, Petroleum-Gas University of Ploiesti, Romania*
[2] *Petrochemical Engineering, Petroleum-Gas University of Ploiesti, Romania*
[3] *Chemical Engineering, Petroleum-Gas University of Ploiesti, Romania*

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Abstract

The liquefied natural gas (LNG) plant integrity problems appear during all processing unit operations for gas fields. In this paper, a hazard quality control analysis (PHQCA) model for the LNG plant has been developed. PHQCA studies have contributed to a focus on plant integrity from a life cycle perspective. In the PHQCA model, Hazards identification and risk assessment are implemented for the main units of 19 LNG processing plant units: U01, U02, U07, U08,U12, U13, U14, U15, U16, U18, U51, U55, U56, U58, U63, U71, and U76. Most of the LNG units' operations are in high and medium risk zones before controlling. However, all these hazards and risky operations are moved to safe zones after controlling. Quality control, quality assurance, and quality management are combined in one system to be part of the PHQCA model in order to ascertain the quality and the integrity of the LNG plant for the gas field.

Keywords: *Quality assurance and control, risk analysis model, LNG plant integrity.*

1. Introduction

Natural gas is a fossil fuel. LNG is Liquefied Natural Gas. LNG is mainly composed of methane (C1) supplemented by ethane (C2), propane (C3), and butane (C4). Natural gas is turned to LNG by cooling. The properties of LNG [1-4] are colorless, odorless, non-corrosive, liquefied at -161ºc at 1.0 bar, its vapor heavier than air < -130ºC, flammable, cold burn when in contact, and expands 600 x from liquid to gaseous. Gas could be associated with oil or non-associated (Natural gas with some condensate). Natural gas could be rich (methane 85%) or lean (methane 95%+). Gas can be monetized via Sale as fuel (LNG, LPG, and pipeline sales), methanol or GTL, and petrochemicals (Fig. (1-a)). To make LNG, the gas should pass through a certain number of processes as appeared in Fig. (1-b).

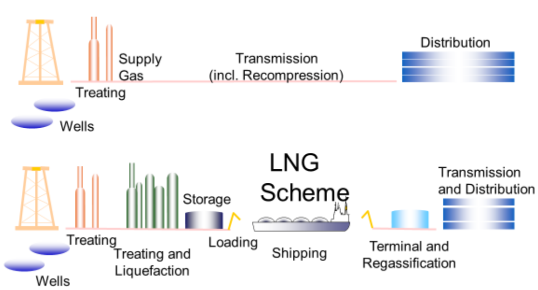

Fig.1a. Domestic gas scheme

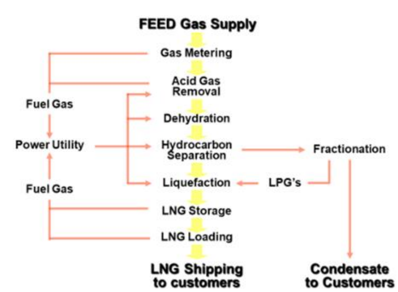

Fig. 1b. LNG technology processes and steps

LNG plants for oil and gas fields are widely distributed all over the world but have a lot of problems during operations. These problems, processes control and plant automatization, have been presented and discussed [1-3]. They, therefore, result in hazards to the environment, personnel, and production. LNG plants indeed will lose their integrity. Consequently, the demand for a model to study plant integrity, risk assessment and hazard analysis for the LNG plant became extensively desirable. Therefore, the aim here is to develop a plant hazard quality control analysis (PHQCA) model for ascertaining the LNG plant integrity.

The following described model procedures have been used satisfactorily to define risk analysis and quality control for the LNG plant. Then, risk evaluation and residual calculations would be implemented. The risk assessment would be done to define the riskiest units and areas, now and in the future. Quality control, assurance, and management methods for LNG processing plants would be selected. After that, quality control analysis would be done in order to fully determine the best solution or treatment for the risky plants whose integrity would be exposed to failure in the next years.

2. PHQCA developed model procedures and methodology

2.1. Hazards identification and risk assessment for the LNG plant

Since the improvement in LNG plant integrity is a continuous process, anything achieving a function by time becomes obsolete. This means the more waste, the more hazards to personnel and/or environment. Follow up of anything sustains integrity, and safety results in more profit [4-5]. Therefore, the risk assessment or risk analysis (RA) is not for doing a lot of amounts of paperwork, but for identifying hazards occurred, and sensible measures to control the risks in your workplace [6]. Risk analysis is any method-qualitative and/or quantitative-for assessing the impacts of risk on decision situations.

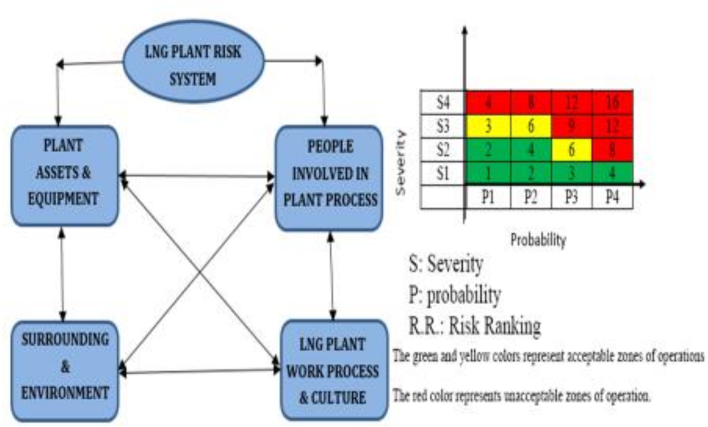

Fig. 2. General risk assessment and risk matrix for LNG plant

The goal of any of these methods is to assist the decision-maker in choosing a course of action, enabling a better understanding of the possible outcomes that could occur. The risk management process includes, generally, the following five main steps [4-7]:

1. System identification, which includes understanding the system work processes and work culture.
2. Hazard identification, which includes identifying all conditions that can potentially cause harm. Five steps or procedures, which have been introduced [3], will be followed for performing a HAZOP analysis and hazard identification.
3. Risk estimation and calculations (quantitative/qualitative probabilities and severity calculations.), which include building scenarios and determination of probabilities of Feared Event's (FE) occurrence and also determination the severity or impact is due to the occurrence of this FE. A scenario is a sequence of the related succession of events leading to an undesired event. That`s why, the main goal in this section is to express mathematically or define total risk (R_{total}) as the sum over individual risks (R_j), which can be computed as the product of potential losses or severity (S_j), and their probabilities (P_j)as follows [4-7]:

$$R_j = S_j x\, P_j(S_j) \qquad (1)$$

$$R_{total/residual} = \sum_{j=1}^{k} R_j = \sum_{j=1}^{k} S_j x\, P_j(S_j) \quad (2)$$

Management methods and techniques related to the oil and gas industry have been explained [8]. Through these methods and techniques, the risky LNG plant and the profitable one will be determined compared with others. One of these methods is risk measurement. This method is mathematically expressed as follows:

The expected monetary value (VM_i), or the average profitability for an alternative j is:

$$\overline{VM_l} = \sum_{j=1}^{k}(a_{ij}P_j) \quad (3)$$

The measurement of absolute risk is:

$$\sigma_i = \sqrt{\sum_{j=1}^{k}(a_{ij} - \overline{VM_l})^2 . P_j} \quad (4)$$

where σ_i = the average square deviation and represents a measure of risk; P_j= the probability of occurrence of a variant; a_{ij}= a consequence results from the association of a variant.

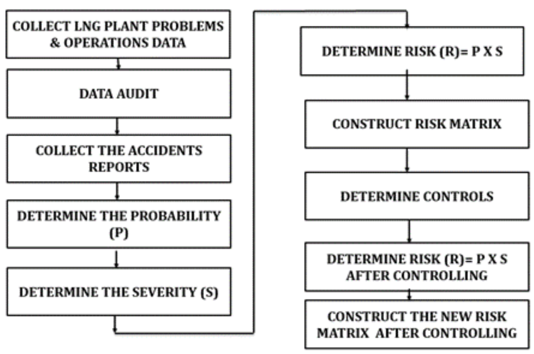

Fig. 3. Flow diagram for Building Risk Matrix and Controls for the LNG plant

4. Risk evaluation is the process of ranking the pre-calculated risk from step three and summarizes the scale of probabilities in a risk assessment process, as shown in the color matrix in Fig. (3).
5. Risk control (avoidance and prevention, risk transfer, and risk acceptance), which includes how to mitigate the occurrence of feared events and severities.

An application of technical, operational, and organizational risk assessment and hazard identification will be implemented based on the preceded procedures to reduce the risk of uncontrolled problems throughout the life cycle of the LNG plant units and increase their integrity.

2.2. Quality assurance, quality control, and inspection

Quality control [9-10] is a process through which the quality of all factors and units involved in plant production is reviewed, tested, inspected, and controlled. ISO 9000 [11] defines quality control as "A part of quality management focused on fulfilling quality requirements". Moreover, Quality assurance (QA) is a process through which a production plant's quality is evaluated and estimated to see if it meets sales or costumer specifications. Quality Management (QM) [9-12] can be defined as a set of policies, processes and procedures required for planning and execution (production / development / service) in the core business area of an organization. There is an interrelationship which is shown in Fig. (4-b) between QC, QA, and QM and they are connected together with a system called Quality Management System (QMS).

Therefore; in order to upgrade LNG plant safety, LNG quality and quantity and plant operations, advanced process control, QMS, and optimization may be applied in order to:

- Achieve on-specification (on-spec): any gas must be conformed to the agreed specifications in the sale and purchase agreement
- Ensure that the gas distributed is non-corrosive and non-toxic, below the upper limits for H_2S, total Sulphur, CO_2 and HG content

Additionally, the QC department for an LNG plant has to

- Save the equipment from any damage.
- Supervise and make an inspection of the equipment and tools in the LNG plant.
- Look for saving human lives by saving the equipment.
- Check on the 4 main inspection plans for an LNG plant:
  1. Static equipment plan
  2. Lifting equipment plan
  3. Piping system plan
  4. PRV's plan

To fulfill the preceded requirements, methods, or tools of QC, QA, and QMS, which are shown in Fig. (4-a&b), will be adapted and applied for an LNG processing plant. Any variations in the plant quality of a product and a unit, i.e., standards set caused by variations in raw material, men, machines, methods, and procedures of procedures of production and inspection, are noticed and controlled. The LNG plant quality products are therefore produced after checking and controlling these variations.

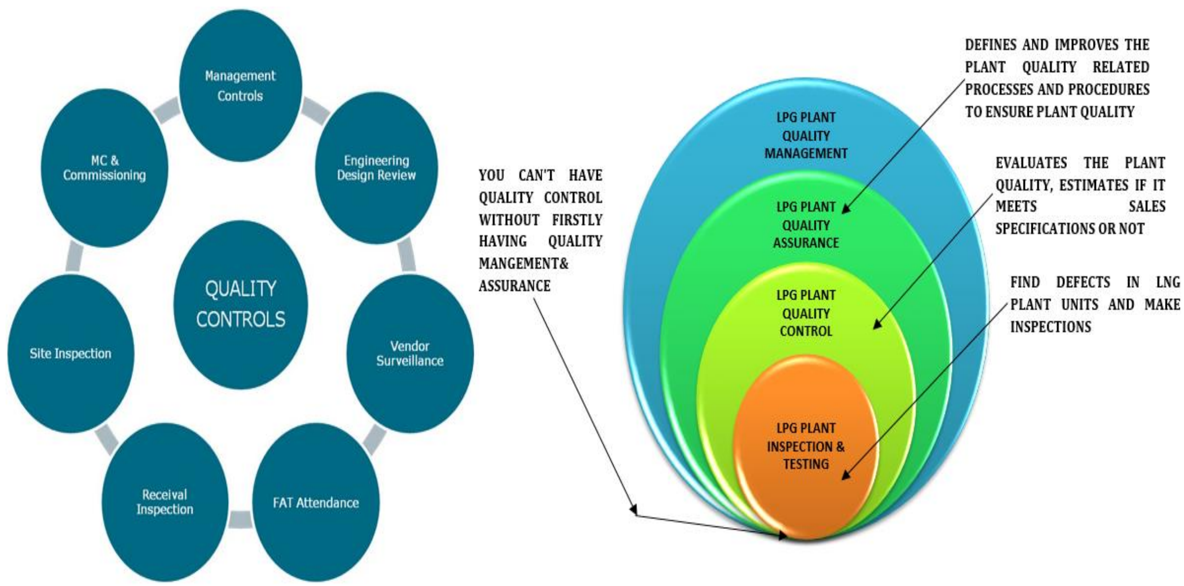

Fig. 4.(a). Basic concepts of quality control [12], (b). Quality management, assurance, control, and inspection for the LNG plant

3. LNG plant description and overview

The LNG facilities are located on the Mediterranean coast, within the sea port area. The plant is designed to take natural gas from the gas grid at about 35°C and 33bar$_a$ and produce and store liquid natural gas at about -161°C and 1.1 bar$_a$. The production capacity is 593tph. The plant consists of a number of process utility and offsite units. The configuration of these units is as shown on the Block Flow Diagram (Fig. (5)).

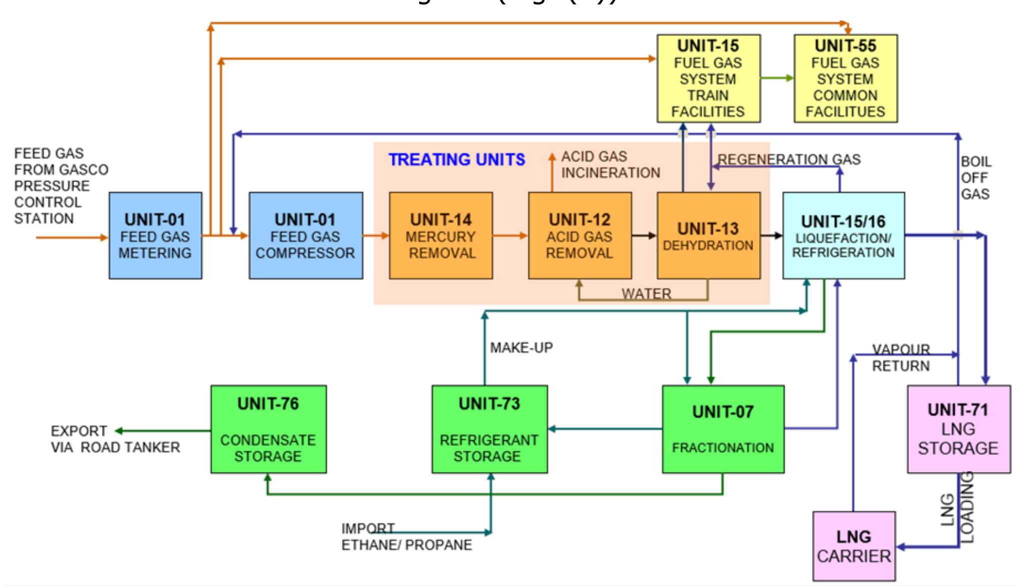

Fig. 5. LNG process main units and block flow diagram

The plant is capable of handling either "lean" gas having a low heavy hydrocarbon content or "rich" gas having a significant heavy hydrocarbon content. Feed gas will arrive at the site from the gas network. The feed gas consists of two alternate gas compositions, described as Lean Gas and Rich Gas. The feed gas will be metered by one of two ultrasonic flow meters 01-FT-3001 and 01-FT-3002. It is then compressed to 68bara, using a motor driven centrifugal compressor (01-MJ01), to feed the LNG train shown in Fig. (6). Surge protection is provided. The discharge pressure is controlled by varying the drive motor speed.

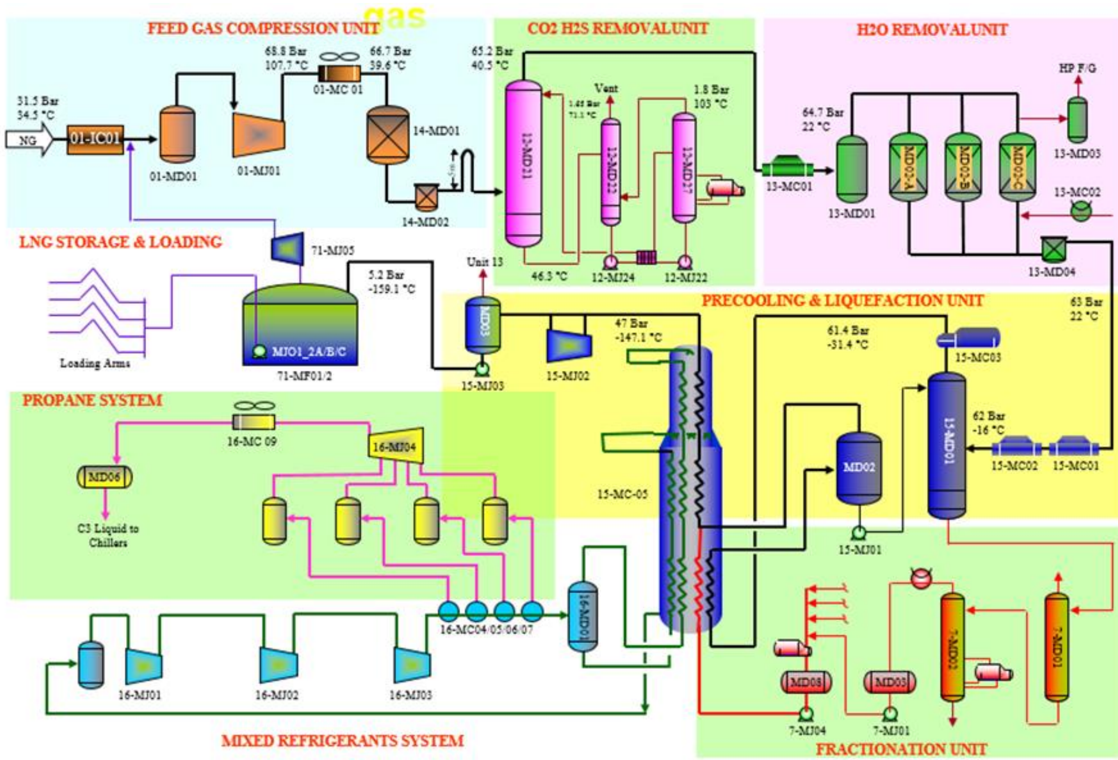

Fig. 6. LNG process train

The LNG Train comprises:

1. A mercury adsorber (14-MD01) and treated gas filter (14-MD02) to remove mercury and any fines that may be present in the feed gas.
2. An acid gas removal unit, Unit 12, to remove acid gases (CO_2, H_2S) from the feed gas by absorption into a MDEA, a proprietary solvent licensed by BASF.
3. A gas dehydration unit, Unit 13, to remove water from the feed gas.
4. A scrubber column, 15-MD01, to separate the heavy components from the feed gas.
5. A propane pre-cooled mixed refrigerant unit, units 15 and 16, to liquefy the gas once it has been treated.
6. An end flash gas stage, Unit 15, compressing evaporated LNG to be used for fuel gas. The acid gas is fed to a thermal combustion unit to oxidize the hydrocarbons.
7. LNG produced by the LNG train is run down to two LNG storage tanks, 71-MF01 and 71-MF02, and exported via a dedicated ship loading facility. A collection and compression system will be provided to recover boil-off gases during storage and loading activities.
8. A Fractionation Unit, Unit 07, will be in operation for rich feed gas. Fractionating columns 07-MD01, 07-MD02, 07-MD04, 07-MD06, and 07-MD09 separate and recover ethane, propane, butane and pentane. This unit is designed for a single LNG train and will provide refrigerant grade propane and ethane for making up the propane and/or mixed refrigerants. Condensate produced from this unit will be stored and then exported.

9. Refrigerant grade propane and ethane will also be imported and stored for making up the propane and/or mixed refrigerants. The plant utility scheme is based on the provision of gas turbines for refrigerant compressor drivers and five gas turbines, 51-MJ01-A/B/C/D/E, (four running and one back up) for electricity generation in open cycle. Electric drivers will be provided for pumps and other compressors. As a power generation back up for start-up three diesel engine emergency generator units, 51-MJ0-A/B/C, (two running and one back up), will be used.
10. Process heating will be provided by hot oil. The LNG Train will be heated by hot oil from unit 18 utilizing waste heat from the propane refrigerant compressor gas turbine driver exhaust. Heating for the fractionation unit will be supplied by hot oil from unit 58 utilizing heat from a Hot Oil Furnace, 58-MC01, run on fuel gas.
11. The primary cooling system will be air cooling.
12. Fire protection is provided through unit 63. A supply of water is held in the firewater storage tank, 63-MF01, topped up with fresh water. Jockey pumps, 63-MJ03 and 63-MJ03-A (one duty and one standby) take suction from the storage tank, 63-MF01, and maintain pressure in the plant fire main. Should the pressure fall in the fire main due to an off take from hydrants, one of the electrically driven fresh water fire pumps, 63-MJ01-A/B, will automatically start. Should the pressure continue to fall due to increasing demand, the second pump will cut in.
13. Fresh water diesel fire pump 63-MJ04 provides 100% back up to the electric pumps. Should the fresh water supply fail seawater fire pumps, 63-MJ02-A/B can supply the fire main. Seawater diesel fire pump 63-MJ05 provides 100% backup to these pumps.
14. Other utility demands will be met from the facilities, which will be sized so that they can be expanded to cater for a future LNG train. There is no provision for connecting the plant to the local electricity grid or to the local water supply system. The plant is sized to hold the capacity of a second future train, except for the fractionation unit, sized for just one.

4. LNG plant design data

Table 1. General input design data

Natural gas at inlet	5.93 bcm/year
Production capacity	487 ton LNG/hour–4.26 million ton LNG/year
Jetty berthing capacity	55,000 m^3–180,000 m^3 LNG Cargo Ships
LNG storage capacity	2x 35,000 m^3 (7-8 days of production)
Efficiency (outlet/inlet)	87.5 %
Availability	338 days/year (92.6%)
Turn Down Ratio	45%
Technology	APCI (90% of world plants)
Cooling media	Air (295 Air Coolers)
Gas supply	From sea gas grid
Completely self-sufficient in utilities	e.g.:Power generation (5 x 22.5 MW)

Table 2. Stage of cycle time (hours)

Process	Time (hrs)
Adsorption	16.0
Depressurization	0.25
Regeneration – Heating	6.25
Regeneration Cooling	1.25
Re-pressurization	0.25
Total	24

5. Results and discussion

Building the PHQCA model for the LNG plant illustrated in sections 3 and 4, Hazards identification and risk assessment are firstly done for the main units of 19 LNG processing plant units and operations: U01, U02, U07, U08,U12, U13, U14, U15, U16, U18, U51, U55, U56, U58, U63, U71, and U76. Risk calculations and analyses for LNG plant units are shown in

Table 1 through Table 19 in Appendix A. Also, the resulting risk matrix for these units and operations before and after risk control is shown in Fig. 7. It noticed that most of the LNG plant units are located in high and medium risk zones. After performing risk control, all units and operations are shifted to safe areas. Therefore, LNG plant integrity is increased and, based on the literature method presented [8], the LNG plant becomes less risky and more profitable after applying risk control.

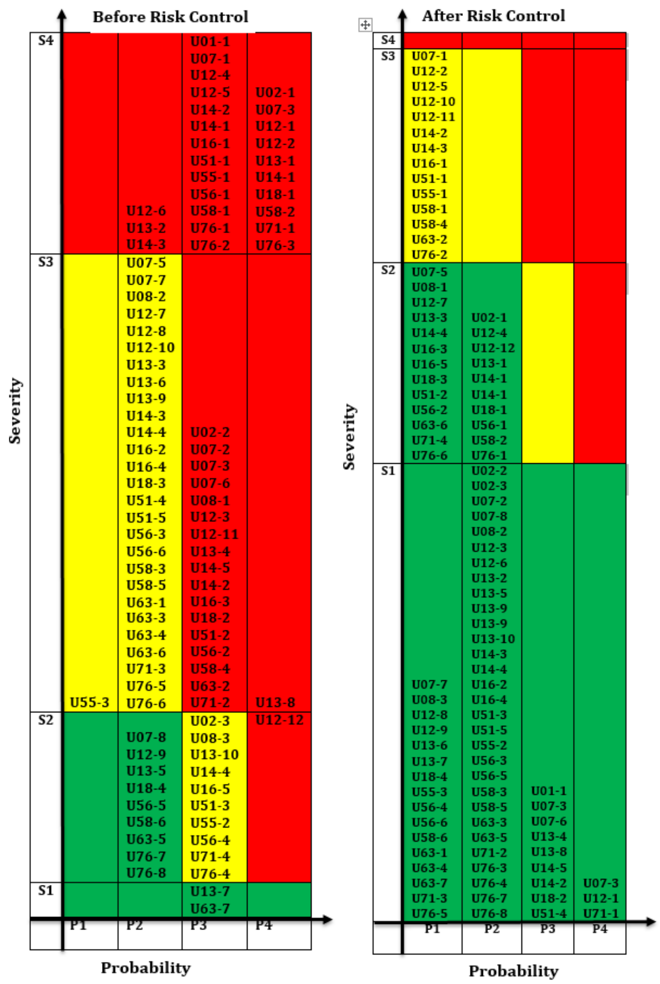

Fig.7. LNG plant risk matrix before and after controlling

QC, QA, and QMS are integrated and developed in the PHQCA model for the LNG plant of the gas field as shown in Table 20 Appendix B. Continuous loop analyzers and sampling points are positioned at parts of the process to manage the quality of fluids throughout the system. Incoming feed gas from the processing facility is analyzed at the feed gas metering system 01-IC01. The gas that has been dehydrated in Unit 13 is analyzed for moisture content at 13-AT-1100 before reaching the liquefaction area, Unit 15. LNG is also analyzed by 71-AT-3067 and 71-AT-3068 in the trestle piping as it is pumped to the jetty. 64-IC01 analyzes the composition of the effluent in the discharge holding basin, 64-CV02. Flue gasses exiting The Hot Oil Waste Heat Recovery Unit, 18-MC01, are analyzed at 18-AT-1027. Sampling points are also positioned throughout the process for laboratory analysis.

6. Conclusions and recommendations

Based on the results and analysis, the following conclusions are extracted:

- Risk analysis for LNG Plant units and operations is highly effective in determining the risky operations and necessary precautions.

- Application of risk analysis in processing operation will reduce the number of accidents and increase LNG plant performance.
- The more profitable LNG plant is achieved after applying the risk assessment method.

Appendix (A)

Table 1. PLANT FEED CONDITIONING UNIT 01 RISK ANALYSIS

Unit	Hazards	What can happen if it goes wrong?	Risk Evaluation			Methods of prevention	Residual risk		
			P	S	R		P	S	R
UNIT 01	Dealing with chemicals: Methane, Ethane, Propane	1. Health Effects: -Eyes: Blurred vision. -Skin: None. -Ingestion: None -Inhalation: Nausea, vomiting, dizziness, tingling sensation, suffocation, convulsions, coma	3	4	12	1-Refer to Material Safety Data Sheets (MSDS) 2-Applying of First Aid Measures 3-Rotating Equipment should not be operated without all safety guards securely in place. 4- Personnel should be aware of any hot surfaces that are unprotected.	3	1	3

Table 2. ACID GAS REMOVAL (COMMON FACILITIES) UNIT 02 RISK ANALYSIS

Unit	Hazards		What can happen if it goes wrong?	Risk evaluation			Methods of prevention	Residual risk		
				P	S	R		P	S	R
UNIT 02	Dealing with chemicals	N-Methyl Diethanol Amine Activated 05	1. Health Effects: -Eyes: Risk of serious damage -Skin: May cause sensitization -Ingestion: Harmful -Inhalation: May cause sensitization.	4	4	16	Same methods of prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	2	2	4
		N-Methyl-diethanol-amine Activated (1:1) Calc. 100%	2. Health Effects -Skin: Wash thoroughly with soap and water. -Ingestion: Immediately rinse mouth and then drink plenty of water. -Inhalation: If difficulties occur after has been inhaled: fresh air, summon physician.	3	3	9	Same methods of prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	2	1	2
	Loss of electrical power		3. All pump motors will stop. Solvent circulation/transfer will cease	3	2	6	2-Close pump isolation valves. 3-Close Solvent transfer valve from offloading Containers/Drums 4-Ensure all water make-up valves are closed to the solvent inventory	2	1	2

Table 3. TRAIN 1 FRACTIONATION UNIT 07 RISK ANALYSIS

Unit	Hazards		What can happen if it goes wrong?	Risk Evaluation			Methods of prevention	Residual Risk		
				P	S	R		P	S	R
UNIT 07	Dealing with chemicals	-Methane -Ethane -Propane	1.Same hazards as Unit 1, Number 1	4	3	12	Same methods of prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	1	3	4
		-N-Butane -I-Butane	2. Health Effects: -Eyes: No information -Skin: No information -Ingestion: Ingestion of gas is unlikely Inhalation: Irritation, nausea, vomiting…etc	3	3	9	Same Methods of Prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	2	1	2
		Pentane	3. Health Effects: -Eyes: No information -Skin: Irritation, etc. -Ingestion: Nausea, stomach pain, etc… -Inhalation: Irritation, nausea,	4	4	16	Same methods of prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	1	4	4
	Loss of Electrical Power		4.1- trip the pumps and would result in a loss of reflux to the columns, 4.2- The Fractionation Refrigeration Package will shut down.	3	3	9	1- The system is safeguarded by low flow alarms on the discharge of the reflux pumps 2- All the liquid from the Scrub Column will be required to be manually routed to another unit for disposal.	3	1	3
	Loss of instrument air		5.1- force all control valves to manual and fail to their safe position 5.2- rapidly cause interruption of the main process flow 5.3- NGL feed will cease, and all the liquid will remain in the Scrub Column	2	3	6	1-The operator should take the necessary precautions to depressurize the Unit in advance of an entire loss of instrument air.	1	2	2
	Loss of Feed		6.1-total shutdown of the LNG train 6.2- a high liquid level accumulating in the Scrub Column 6.3- Reduced flows will feed the downstream columns, and the Unit will go into full recycle 6.4- fall in the reflux drums and product purity may be affected	3	3	9	1- Safeguard by a high-level alarm. 2- The overhead vapor flows will reduce to maintain column pressure 3- A low liquid level, sensed in the LPG Reinjection Drum positioned less than 80% open, will initiate an interlock, LPG Reinjection Backflow Protection. 4- A controlled manual shutdown of the Unit should be initiated if the feed cannot be restored.	3	1	3
	Loss of Hot Oil		7. Loss of this heating medium will effectively stop all fractionation of the feed	2	3	6	1-a controlled manual shutdown should be initiated to stop the feed flow forward	1	1	1

Unit	Hazards		What can happen if it goes wrong?	Risk Evaluation			Methods of prevention	Residual Risk		
				P	S	R		P	S	R
	Loss of Cooling Water		8. supplying the propane coolant to the LPG Reinjection Cooler these vapors will fail to be sufficiently condensed	2	2	4	1- To stabilize the plant a manual shutdown should be initiated	2	1	2

Table 4. HOT OIL SYSTEM – COMMON FACILITIES- UNIT 08 RISK ANALYSIS

Unit	Hazards		What can happen if it goes wrong?	Risk Evaluation			Methods of prevention	Residual Risk		
				P	S	R		P	S	R
UNIT 08	Dealing with chemicals: Oil Shell Thermia B		1. Health Effects: -Eyes: moderate irritation to the eyes. -Skin: Mildly irritating to skin. -Prolonged and repeated skin contact may cause dermatitis; -Ingestion: gastric irritation. -Inhalation of vapor	3	3	9	Same methods of Prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	1	2	2
	Loss of Electrical Power		2.1- trip the motor of the hot oil	2	3	6	1-shut down of the pump	2	1	2
	Trouble-shooting	Low discharge pressure	3.1-Air in system – pump gassed up 3.2-Suction strainer dirty 3.3-Pump wear rings worn	3	2	6	1-Vent pump 2-Change over pumps, clean strainer 3-Change over pumps to check.	1	1	1

Table 5. ACID GAS REMOVAL UNIT 12 RISK ANALYSIS

Unit	Hazards		What can happen if it goes wrong?	Risk Evaluation			Methods of prevention	Residual Risk		
				P	S	R		P	S	R
UNIT 12		N-Methyl Diethanol Amine Activated 05	1. Same hazards as Unit02, number 1.	4	4	16	Same Methods of Prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	1	4	4
		N-Methyl-diethanol-amine Activated (1:1) Calc 100%	2. Same hazards as Unit02, number 2.	4	4	16	Same Methods of Prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	1	3	3
		Ameral 1500	3. Health Effects: -Eyes: Irritation. -Skin: Irritation. -Ingestion: irritation. -Inhalation: Nasal and respiratory irritation	3	3	9	Same Methods of Prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	2	1	2
		Hydrogen Sulphide	4. Health Effects: -Eyes: irritation. -Skin: irritation. -Ingestion& Inhalation: Short Term Effects. Long Term Effects	3	4	12	Same Methods of Prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	2	2	4
		Methane, Ethane, Propane	5. Same Hazards as Unit 01, Number 1.	3	4	12	Same Methods of Prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	1	3	3
	Loss of Electrical Power		6. Shut down of the Unit	2	4	8	1-The train emergency shut down interlocks will ensure the safe shut down. 2-Load shedding is provided to cater for transient disturbances.	2	1	2

	Loss of instrument air		7. Requires immediate train shut down. The main air receiver has a capacity for fifteen minutes back-up supply if both instrument air compressors fail.	2	3	6	1-Operation of the train emergency shut down interlocks will ensure the safe shut down 2-Valves on critical service are provided with air reservoirs which supply sufficient air 3-The action of control and trip valves on air failure is selected to move into the safe position. 4-The control / trip valve isolations should be backed up by manual isolations where appropriate.	1	2	1
	Loss of Feed Gas		8. shutdown of the Unit	2	3	6	1-The diesel generators will supply essential power and will allow restart of the gas turbine generators when feed gas is restored.	1	1	1
	Troubleshooting	Re-establish Solvent Circulation	9. If the trip occurred due to Charge or Booster pump failure	2	2	4	1- Restart the spare Pumps in the system to re-establish flows. 2- The analyzers must be closely monitored for the first signs of breakthrough during this period.	2	1	2
		Loss of Heat Transfer Fluid	10. Result in the loss of solvent regeneration capability resulting in a train shutdown, if prolonged.	2	3	6	1- The feed gas flow should be reduced. 2- The analyzer must be closely monitored for the first signs of breakthrough during this period.	1	3	3
		Loss of Reflux Pumps	11. All pumps and fin fan motors will stop. Feed gas flow and solvent circulation will cease.	3	3	9	1- Check all column and vessel levels, close level control valves after ensuring a good liquid inventory for subsequent startup. Ensure that all water make-up valves are closed to the solvent inventory.	1	3	3
		Troubleshooting for the anti-Foam injection package	12. 1-Flow rate too low 2-Flow rate too high 3-Electrical Motor Overheating 4-Noisy Operation 5-Pipe Vibrations	4	2	8	1-Check valve has jammed closed 2-Pressure relief valve in operation or leaking 3-Excessive leakage through packing 4-Wrong stroke length 5-Discharge pressure too high 6-Excessive wear of the mechanism / Gearbox	2	2	4

Table 6. DEHYDRATION UNIT13 RISK ANALYSIS

Unit	Hazards		What can happen if it goes wrong?	Risk Evaluation			Methods of prevention	Residual Risk		
				P	S	R		P	S	R
UNIT13	Dealing with chemicals	Methane, Ethane, Propane	1. Same hazards as Unit 01, Number 1.	4	4	16	Same Methods of Prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	2	2	4
	Loss of Electrical Power		2.1- Cause the fan motors for the Regeneration Gas Cooler to stop. 2.2-If the regeneration cycle is in its heating stage, this may cause a high temperature and interrupting the flow of regeneration gas	2	4	8	1-The emergency Diesel Generator, however, provides emergency lightening and other essential facilities.	2	1	2
	Loss of instrument air		3.1-cause control valves to fail to their safe position. 3.2-cause interruption of both the main gas processing flow and also the drier regeneration process.	2	3	6	1-Valves on critical service are provided with air reservoirs which supply sufficient air for three strokes of the valve independent of the main air supply.	1	2	2
	Loss of Feed Gas		4. Result in a total shutdown of the LNG train.	3	3	9	1-It may be necessary to pause the regeneration cycle if the interruption is lengthy.	3	1	3
	Troubleshooting	Gas product moisture content is too high.	5. 1-Bed insufficiently regenerated. 2-Gas flow rates in excess of design. 3-Outlet temperature is too high. 4-Beds kept on line for too long 5-Low process gas flow resulting in channeling through beds. 6-Molecular sieve becoming inefficient or contaminated.	2	2	4	1-Check that regeneration gas flow, heater outlet temperature and heating time 2-Reduce gas production rate. 3-Decrease propane refrigerant pressure 4-Increase gas throughput to a minimum of 40% 5-Investigate cause and replace molecular sieve	2	1	2
		Process gas flow restricted.	6. 1-Hydrate formation 6.2-Filter elements clogged.	2	3	6	1-Increase propane refrigerant pressure 2-Clean filter.	1	1	1
		Regeneration gas flow restricted	7. Hydrate formation	3	1	3	1-Reduce cooling	1	1	1
		Gas product moisture content is too high.	8.1-Bed insufficiently regenerated. 2-Gas flow rates in excess of design. 3-Outlet temperature is too high. 4-Beds kept on line for too long 5-Low process gas flow resulting in channeling through beds. 6-Molecular sieve becoming inefficient or contaminated.	4	3	6	1-Reduce gas production rate. 2-Decrease propane refrigerant pressure. 3-Increase gas throughput to a minimum of 40% 6-Investigate cause and replace molecular sieve	3	1	3
		Process gas flow restricted.	9.1-Hydrate formation 9.2-Filter clogged.	2	3	6	1-Increase propane refrigerant pressure. 2-Clean filter.	2	1	2
		Regeneration gas flow restricted	10. Hydrate formation	3	2	6	1-Reduce cooling	2	1	2

Table 7. MERCURY REMOVAL UNIT 14 RISK ANALYSIS

Unit	Hazards		What can happen if it goes wrong?	Risk Evaluation			Methods of prevention	Residual Risk		
				P	S	R		P	S	R
UNIT 14	Dealing with chemicals	Mercury	1. Health Effects -Eyes: irritation. -Skin: irritation & has a short- and long-Term Effects -Ingestion: nausea, etc...& has a short- and long-Term Effects -Inhalation: irritation, etc...& has a short- and long-Term Effects.	4	4	16	Same Methods of Prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	2	2	4
		Methane	2.Same hazards as Unit 01, Number 1.	3	4	12	Same Methods of Prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	1	3	3
	Loss of Electrical Power		3. Cause interruption of the main process gas flow.	2	3	6	1- the system can remain static until conditions are stabilized and the gas flow re-established.	2	1	2
	Loss of instrument air		4.1-cause control valves to fail to their safe position 4.2-cause interruption of the main process gas flow	3	2	6	1- the system can remain static until conditions are stabilized and the gas flow re-established.	1	2	1
	Loss of Feed Gas		5.1-result in a total shutdown of the LNG Train. 5.2-A trip initiated downstream of Unit will have the effect on reducing the gas flow then completely stopping the flow	3	3	9	1- the system can remain static until conditions are stabilized and the gas flow re-established.	3	1	1

Table 8. LIQUEFACTION UNIT 15 RISK ANALYSIS

Unit	Hazards		What can happen if it goes wrong?	Risk Evaluation			Methods of prevention	Residual Risk		
				P	S	R		P	S	R
UNIT 15	Dealing with chemicals: Liquefied Natural Gas (LNG), Methane, Ethane, Propane		1.Same hazards as Unit 01, Number 1.	3	4	12	Same Methods of Prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	2	2	4
	Loss of Electrical Power	Scrub Column Reflux Pump	2.1- Not relevant during lean operation. -During rich or mixed feed mode, loss of pump causes reflux drum overheads temperature to rise resulting in an off-specification product. -Level in reflux drum will rise, trip may occur.	3	3	9	1-Applying the good operating practice on pumps and electrical motors	3	1	3
		LNG Expander	2.2-LNG Expander exports electricity. If connection to grid fails the expander bypass will open.							
		LNG Product Pump	2.3-Loss of LNG Product pump will cause level to rise in the End Flash Gas Drum.							
		End Flash Gas Compressor	2.4-Loss of power to the End Flash Gas will result in a loss of the normal supply of fuel gas and regeneration gas to the Unit.							
		End Flash Gas Coolers	2.5-Loss of coolers will not necessarily trip the End Flash Gas Compressor but it is likely							

Unit	Hazards		What can happen if it goes wrong?	Risk Evaluation			Methods of prevention	Residual Risk		
				P	S	R		P	S	R
			the End Flash Gas Compressor throughput will have to be reduced.							
	Loss of instrument air		3.1-cause control valves to fail to their safe position 2-cause interruption of both the main gas processing flow and the major liquid flows on the unit. 3- for a prolonged period, depressurization of the entire plant is needed.	2	4	8	1-The operator must make a judgement as to the best course of action should the instrument air failure persist for a prolonged period. 2- Action should be taken to depressure the plant in advance of a total loss of instrument air – should this unlikely event occur.	1	3	3
	Loss of Feed Gas		4. Loss of feed gas will result in over cooling of the MCHE.	2	3	6	Operator action: Rapidly identify cause of loss of feed gas and rectify, if possible	2	1	2

Table 9. REFRIGERATION UNIT 16 RISK ANALYSIS

Unit	Hazards		What can happen if it goes wrong?	Risk Evaluation			Methods of prevention	Residual Risk		
				P	S	R		P	S	R
UNIT 16	Dealing with chemicals: Liquefied Natural Gas (LNG), Methane, Ethane, Propane		1.Same hazards as Unit 01, Number 1.	3	4	12	Same Methods of Prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	1	3	3
	Loss of Electrical Power	Mixed Refrigerant Compressor	2.1-Loss of power will trip the motor driven Compressor Lube Oil system and result in a shutdown	2	3	6	1-Applying the good operating practice on pumps and electrical motors	2	1	2
		MR Compressors Inter and After Coolers	2.2-Loss of cooling will not necessarily trip the MR Compressors, it will reduce the compressor output.							
	Loss of instrument air	Impact on compressor	3.1-cause control valves to fail to their safe position. 3.2- shut-off valves downstream of both the MR and Propane Compressors as well as the shut-off valves downstream of their Inter and After Coolers will fail close.	3	3	9	1-The operator must make a judgement as to the best course of action should the instrument air failure persist for a prolonged period.	1	2	2
	Loss of Feed Gas		4. Result in a partial shutdown of the Plant and a Train shutdown. However, the MR and Propane Compressors can remain on full recycle until the conditions are stabilized and the gas flow is re-established.	2	3	6	Operator action: Rapidly identify cause of loss of feed gas and rectify, if possible	2	1	2
	Troubleshooting MR Liquid Expander	High Pressure Propane Section	5.1-Tube rupture in kettles 5.2- Injection of off-spec propane from storage	3	2	6	1-Sampling required throughout propane system to ensure leakage not occurring. 2-Sampling required of offsite propane	1	2	2

Table 10. HOT OIL SYSTEM UNIT 18 RISK ANALYSIS

Unit	Hazards	What can happen if it goes wrong?	Risk Evaluation			Methods of prevention	Residual Risk		
			P	S	R		P	S	R

UNIT 18	Dealing with chemicals	Shell Thermia-B Heat Transfer Oil	1. Same Hazards as Unit 08, Number 1.	4	4	16	Same Methods of Prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	2	2	4
	Loss of Electrical Power		2. Loss of Electrical Power will trip the motor of all the Pumps and the fin fans of and Hot oil circulation will cease.	3	3	9	1-Restart the system as per the normal start procedure.	3	1	3
	Loss of instrument air		3.1-the Dampers will automatically revert to the fail-safe position. 3.2-the flow of hot oil through the unit will cease	2	3	6	1-Applying the good operating practice on air instrument.	1	2	2
	Troubleshooting	Low discharge pressure	4.1-Air in system – pump/gassed up 4.2- strainer dirty 4.3-Pump wear rings worn	2	2	4	1-Vent pump 2- clean strainer 3- pumps to check.	1	1	1

Table 11. POWER GENERATION / DIESEL FUEL SYSTEM UNIT 51 RISK ANALYSIS

Unit	**Hazards**		**What can happen if it goes wrong?**	**Risk Evaluation**			**Methods of prevention**	**Residual Risk**		
				P	**S**	**R**		**P**	**S**	**R**
UNIT 51	Dealing with chemicals:	Methane, Ethane, Propane	1. Same Hazards as Unit 01, Number 1.	3	4	12	Same Methods of Prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	1	3	1
		Inergen (gas)	2. Health Effects: -Eyes: Non-irritating -Skin: Non-irritating -Ingestion: Non-irritating -Inhalation: Breathing very high concentrations of vapor can cause light headedness… etc.	3	3	9	Same Methods of Prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	1	2	2
	Loss of Electrical Power		3.If the generation capacity s is not able to reach the power demanded by the loads connected to the Plant Electrical System the Plant Management System (PMS) will indicate this through commutated contacts, voltage free, wired to terminals, to disconnect those loads of the plant defined as “dispensable”	3	2	6	1-Applying the good operating practice on pumps and electrical motors	2	1	2
	Loss of instrument air		4.1-Instrument air to the power generator system will be lost through either air compressor failure or blockage of the header. 4.2-The Instrument air receiver holds 15 minutes’ worth of air supply after which the whole distribution will depressurizes.	2	3	6	1-The operator must make a judgement as to the best course of action should the instrument air failure persist for a prolonged period.	3	1	3
	Loss of Feed Gas		5.1-Total loss of feed gas will result in a loss of all fuel gas. 5.2-If the loss of feed gas is due to a Feed Gas Compressor trip then ‘back up’	2	3	6	Operator action: Rapidly identify cause of loss of feed gas and rectify, if possible	2	1	2

		fuel gas will still be available from Unit 01 Feed Gas Metering to maintain a supply of fuel gas to Unit 51.							

Table 12 FUEL GAS SYSTEM UNIT 55 RISK ANALYSIS

Unit	**Hazards**		**What can happen if it goes wrong?**	**Risk Evaluation**			**Methods of prevention**	**Residual Risk**		
				P	**S**	**R**		**P**	**S**	**R**
UNIT 55	Dealing with chemicals: Methane, Ethane, Propane		1. Same Hazards as Unit 01, Number 1.	3	4	12	Same Methods of Prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	1	3	3
	Loss of Electrical Power		2.1- valves will fail close at inlet to safeguard equipment 2.2-Nitrogen is introduced manually to prevent air being present through a drop in pressure.	3	2	6	1-Applying the good operating practice on pumps and electrical motors	2	1	2
	Troubleshooting	No Heat to Fuel Gas	3. Fault with Start-up Fuel Gas Heater 55-ML01	1	3	3	1-See vendor manual for 55-ML01.	1	1	1

Table 13. INSTRUMENT & SERVICE AIR UNIT 56 RISK ANALYSIS

Unit	**Hazards**		**What can happen if it goes wrong?**	**Risk Evaluation**			**Methods of prevention**	**Residual Risk**		
				P	**S**	**R**		**P**	**S**	**R**
UNIT 56	Dealing with chemicals	Forane 407C Refrigerant for Air compressor	1. Health Effects: -Eyes: Vapor is irritating to eyes -Skin: Contact with liquid can cause tissue to freeze -Inhalation: irritation.	3	4	12	Same Methods of Prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	2	2	4
		Activated Alumina used for Air Drying	2. Health Effects: -Eyes: Slightly irritating to eyes -Inhalation: Slightly irritating	3	3	9	Same Methods of Prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	1	2	2
	Loss of Electrical Power		3. the air compressor within the system will fail and hence air supply will cease.	2	3	6	1-Applying the good operating practice on pumps and electrical motors	2	1	2
	Loss of instrument air		4- The Instrument air receiver holds 15 minutes' worth of air supply after which the air distribution will depressurizes.	3	2	6	1-Pressure, Level and temperature measurement is electronic or mechanical and therefore loss of instrument air should not affect their operation.	1	1	1
	Troubleshooting, Air compressor	Compressor starts running, but does not load after a delay time	5.1-Pressure in air net is above pre-set loading pressure	2	2	4	1-Compressor will load when pressure in air net drops to pre-set loading pressure	2	1	2
			5.2-Located solenoid valve inoperative				2-Check, replace if necessary			
			5.3-Full-load/no-load valve malfunctioning				3-Have valve inspected			
		Compressor capacity or	6.1-Air consumption exceeds capacity of compressor	2	3	6	1-Check pneumatic plant	1	1	1

Unit	Hazards		What can happen if it goes wrong?	Risk Evaluation			Methods of prevention	Residual Risk		
				P	S	R		P	S	R
		working pressure lower than normal	6.2-Safety valve leaking				Remove leaking valve and have it inspected			
			6.3-Unloading pressure incorrectly set							

Table 14. FRACTIONATION HOT OIL SYSTEM UNIT 58 RISK ANALYSIS

Unit	Hazards		What can happen if it goes wrong?	Risk Evaluation			Methods of prevention	Residual Risk		
				P	S	R		P	S	R
UNIT 58	Dealing with chemicals	Methane, Ethane, Propane	1. Same hazards as Unit 01, Number 1.	3	4	12	Same Methods of Prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	1	3	3
		Shell Thermia-B Heat Transfer Oil	2. Same Hazards as Unit 08, Number 1.	4	4	16	Same Methods of Prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	2	2	4
	Loss of Electrical Power		3.1-will trip the motor of all the Pumps and the fin fans. 3. 2-Hot oil circulation will cease.	2	3	6	1-Restart the system as per the normal start procedure.	2	1	2
	Loss of instrument air		4.1- will activate the hot oil furnace trip as a result of the closure of fuel gas isolation valves. 4.2-The flow of hot oil through the unit will cease	3	3	9	1-Applying the good operating practice on air instrument.	1	3	3
	Loss of Fuel Gas		5. trip in Hot Oil furnace due to flame out of burners.	2	3	6	1- re-start the furnace as per the normal start-up procedure.	2	1	1
	Troubleshooting	Low discharge pressure	6. Same Hazards as Unit 08, Section 3, Numbers 1,2 & 3.	2	2	4	1. Same Methods of prevention as Unit 08, Section 3, Numbers 1,2 & 3.	1	1	1

Table 15. FIRE PROTECTION SYSTEM UNIT 63 Risk ANALYSIS

Unit	Hazards		What can happen if it goes wrong?	Risk Evaluation			Methods of prevention	Residual Risk		
				P	S	R		P	S	R
UNIT 63	Dealing with chemicals	High Expansion Foam	1. Health Effects -Eyes: irritation -Skin: irritation	2	3	6	Same Methods of Prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	1	1	1
		Foam Concentrate	2. Health Effects: -Eyes: Moderate Irritation, etc… -Skin: Moderate irritation	3	3	9	Same Methods of Prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	1	3	3
	Loss of Electrical Power		3. fresh and seawater fire pumps have standby diesel pumps therefore no loss in capacity is envisaged.	2	3	6	1-Applying the good operating practice on pumps and electrical motors	2	1	2

	Loss of instrument air		4. the bubbler tube level transmitters on Firewater Storage tank will be affected.	2	3	6	1-Applying the good operating practice on air instrument.	1	1	1
	Troubleshooting	No water / foam flow at foam generator	5.1-lack of water /intercept ional valve is closed 2-blockage in the piping line 3-malfunction of the automatic deluge valve 4-foam concentrate shut-off valve closed 5-malfunction of the solenoid 6-malfunction of the automatic 7-deluge valve unit 8-malfunction of the automatic proportionier unit	2	2	4	1-operate at feeding source open the valve 2-Check piping line 3-Check automatic deluge valve 4-Check the solenoid valve 5-Check the automatic 6-deluge valve unit 7-Check the automatic proportioner unit	2	1	2
		Water/foam flows at foam generator without any fire alarm	6. Malfunction of the solenoid valve Malfunction of the automatic deluge valve unit.	2	3	6	1-Check the solenoid valve check automatic deluge valve unit.	1	2	1
		waterflow pressure switch does not send any signal when clapper of automatic deluge valve is open	7. alarm exclusion valve closed blockage in trim line malfunction of the waterflow pressure switch	3	1	3	1- Open the valve check trim line check waterflow pressure switch	1	1	1

Table 16. EFFLUENT AND WASTE WATER TREATMENT UNIT 64 RISK ANALYSIS

Unit	Hazards		What can happen if it goes wrong?	Risk Evaluation			Methods of prevention	Residual Risk		
				P	S	R		P	S	R
UNIT 64	Dealing with chemicals	Shell Thermia-B Heat Transfer Oil	1. Same Hazards as Unit 08, Number 1.	4	4	16	Same Methods of Prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	2	2	4
		Foam Concentrate	2. Same Hazards as Unit 63, Number 2.	3	3	9	Same Methods of Prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	1	3	3
		Diesel Fuel for Emergency Generator/Fire Water Pumps	3. Health Effects -Eyes: Mild irritation -Skin: Short term exposure: irritation, Long term exposure: kidney damage -Ingestion: nausea, -Inhalation : irritation, nausea, vomiting, etc..	3	4	12	Same Methods of Prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	2	2	4
		Seal Oil for compressors	4. Health Effects: -Eyes: severe irritation/ burns. -Skin: irritation. - Ingestion: burns to mouth, throat, etc.. - Inhalation: irritation	3	4	12	Same Methods of Prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	1	4	4
		Lube Oil for compressors and motors	5. Health Effects: -Eyes: No significant adverse effects. -Skin: skin disorders -Ingestion: digestive disorders -Inhalation: No significant adverse effects	3	3	9	Same Methods of Prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	2	1	2
	Loss of Electrical Power		6. All motors will stop. As the pumps and air blowers are in intermittent operation loss of power will not have an immediate effect	2	3	6	1-Applying the good operating practice on pumps and electrical motor	1	1	1
	Loss of instrument air		7.1- the bubbler tube level transmitters on the Discharge Holding Basin will be affected. 7.2-An apparent low level in the holding basin, a trip of the running Effluent Discharge, an apparent low level in the oil separation section.	3	2	6	1-Applying the good operating practice on air instrument.	1	1	1
	Troubleshooting	High pressure drop across carbon filter	8. Buildup of hydrocarbons on filter	2	2	4	1- Backwash with service water	2	1	2
		Water specification of treated water exceeds oil in water of 0.5 ppm	9. Insufficient treatment	2	3	6	1- Recycle oily water to treatment unit	1	1	1
		Treated water specification from Bio unit does not meet specification	10. Insufficient oxidation	3	2	6	1- Modify air injection rates and liquid residence times	2	1	2

		Treated water specification from discharge holding basin does not meet specification	11. Various	3	3	8	1- Recycle to Oily Water Treatment Unit, or Remove by truck for disposal	3	1	3

Table 17. FLARE SYSTEM UNIT 65 RISK ANALYSIS

Unit	Hazards		What can happen if it goes wrong?	Risk Evaluation			Methods of prevention	Residual Risk		
				P	S	R		P	S	R
UNIT 65	Dealing with chemicals	Methane, Ethane, Propane	1. Same Hazards as Unit 01, Number 1.	3	4	12	Same Methods of Prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	1	3	3
		N-Butane/I-Butane	2. Same Hazards as Unit 07, Number 2.	3	3	9	Same Methods of Prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	1	2	2
		Pentane	3. Same Hazards as Unit 07, Number 3.	3	3	9	Same Methods of Prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	1	2	2
	Loss of Electrical Power		4. Emergency Shutdown.	3	2	6	1-Applying the good operating practice on pumps and electrical motors 2-the emergency diesel generators supply power to the essential services	2	1	2
	Loss of instrument air		5. The unit will fail-safe and the process units will shut down	2	3	6	1-Applying the good operating practice on air instrument.	1	1	1
	Loss of Feed Gas		6. have no direct effect on this system. Should the feed Gas be shut down and the LNG train shut down the whole system/ equipment will be isolated depressurized and inerted to stop the ingress of air into the flare header.	1	3	3		1	1	1

Table 18. LNG STORAGE AND LOADING UNIT 71 RISK ANALYSIS

Unit	Hazards		What can happen if it goes wrong?	Risk Evaluation			Methods of prevention	Residual Risk		
				P	S	R		P	S	R
UNIT 71	Dealing with chemicals: Liquefied Natural Gas (LNG), Methane, Ethane, Propane		1. Same Hazards as Unit 01, Number 1.	4	4	16	Same Methods of Prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	1	4	4
	Loss of Electrical Power	1- LNG Loading Pump directly affected 2- Boil Off Gas Compressor directly affected	2.1- shutdown of loading operation. 2.2- Loss of power to the Boil Off Gas Compressor will result in shutdown of rundown and loading operation, and therefore shutdown of the LNG train.	3	3	9	1-Applying the good operating practice on pumps and electrical motors	2	1	2
	Loss of instrument air		3.1-The plant will continue to operate satisfactorily until air header and accumulator pressures fall.	2	3	6	1-The operator must make a judgement as to the best course of action should the instrument	1	1	1

			3.2-cause control valves to fail to their safe position, unless protected by air accumulators. 3.3-cause interruption of both the main gas processing flow and the major liquid flows on the unit. 3.4-closedown of rundown and loading operations.				air failure persist for a prolonged period.			
	Loss of Feed Gas		4. LNG rundown to storage will cease.	3	2	6		1	2	2

Table 19. CONDENSATE STORAGE SYSTEM UNIT 76 RISK ANALYSIS

Unit	**Hazards**		**What can happen if it goes wrong?**	**Risk Evaluation**			**Methods of prevention**	**Residual Risk**		
				P	**S**	**R**		**P**	**S**	**R**
UNIT 76	Dealing with chemicals	N-Butane/I-Butane	1. Same Hazards as Unit 07, Number 2.	3	4	12	Same Methods of Prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	2	2	4
		Pentane	2.Same Hazards as Unit 07, Number 3.	3	4	12	Same Methods of Prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	1	3	3
		Foam Concentrate	3. Same Hazards as Unit 63, Number 2.	4	4	16	Same Methods of Prevention as Unit 01, Section 1, Numbers 1,2,3 & 4.	2	1	2
	Loss of Electrical Power		4-Emergency Shutdown Valves will fail closed and the Condensate Storage Bullet will be isolated.	3	2	6	1-Applying the good operating practice on pumps and electrical motors	2	1	2
	Loss of instrument air		5-Emergency Shutdown Valves will fail closed and the Condensate Storage Bullet will be isolated.	2	3	6	1-Applying the good operating practice on air instrument.	1	1	1
	Loss of Fuel Gas		6.1-A loss of condensate may mean a low level in the Condensate Storage Bullet, if it is being transferred to tanker. 6.2-At a low level the unit will trip, the Emergency Shutdown Valves will fail closed and the Condensate Storage Bullet will be isolated. 6.3-A loss of High-Pressure Fuel Gas would mean a loss of fuel to the power generators and a plant shutdown.	2	3	6		1	2	2
	Troubleshooting	Less Condensate flow to 76-MD01	7-Malfunction of 76-ESDV-1003 to close.	2	2	4	1-Halt, flow of Condensate to road tanker. 2-Route condensate flow to warm liquid header, BO-76002	2	1	2
		Less Condensate flow to Tanker	8-Malfunction of 76-ESDV-1010 to close.	2	2	4	1-Route condensate flow to warm liquid header, BO-76001	2	1	1

**1-Applying the good operating practice on pumps and electrical motors
**1-Applying the good operating practice on air instrument.

Appendix (B)

Table 20. QUALITY CONTROL FOR LNG PLANT UNITS

Unit	Sampling points	Purpose	Online Analyzer
01 – PLANT FEED CONDITIONING UNIT	Feed metering system. Sample point is located downstream of 01-IC01 for the measurement of aromatics - benzene, toluene, ethyl benzene, metaxylene, paraxylene and orthoxylene.	Chromatograph analyzer to measure the composition of the feed gas. A separate IR analyzer is used to measure the composition of ethane A gas flow meter used to measure the flow of feed gas through the complete metering system.	-on-line process chromatograph analyzer is located in the local analyzer house 01-IC02. -IR analyzer is located in analyzer house 01-IC02. -A gas flow meter is located in analyzer house 01-IC01
02 - ACID GAS REMOVAL – COMMON FACILITIES	Sampling points are positioned on the pumps	To manage the quality of fluids throughout the systems.	No on-line analyzers in this unit.
07 - TRAIN 1 FRACTIONATION	Type C on PG-07001	To monitor the Demethaniser overheads.	
	Type C on PG-07005	To monitor the Deethaniser overheads.	
	Type F on PC-07022	To monitor the quality of propane leaving the Depropaniser Reflux Drum.	
	Type F on PC-07030	To monitor the quality of butane leaving the Debutaniser Reflux Drum.	
	Type F on PC-07044	To monitor the quality of pentane leaving the Depentaniser Reflux Drum.	
	Type F on PC-07005	To monitor the quality of the condensate leaving the Condensate Product Cooler while it is transferred to storage.	
	Analyzer, layout type A	The purpose is to analyze and monitor the levels of C2, C3, IC4 and NC4 in the distillate from the Depropaniser Column.	
08 – HOT OIL SYSTEM – COMMON FACILITIES	Type A sampling point is located in line O-08005 in order to test for oxygen levels of the oil.	The tank is provided with a nitrogen blanket to minimize the ingress of air, which would introduce oxygen and water vapor, which may result in degrading the oil, and causing operational problems.	No on-line analyzers in this unit.
12 - ACID GAS REMOVAL		To reduce the CO_2, H_2S, Total Sulphur and Mercaptans content of the feed gas to the levels quoted in the table	Component analysis is required for the determination of CO_2 and H_2S, for this purpose, an analyzer in the gas metering station is provided. An online CO_2 analyzer, 12-AT-1004, is provided in the treated gas line at 12-MD21 overheads to determine the product gas composition.
13 - DEHYDRATION	Sample points are installed in the piping immediately upstream and downstream of each drier vessel to facilitate performance monitoring of each bed.	To remove water from the sweet feed gas received from the Acid Gas Removal unit. The gas is to be dried to a residual water content of less than 0.5ppmv.	Permanent on-line sampling of the water content of the gas is carried out downstream of the driers to ensure that the product gas water specifications are met.
14 - MERCURY REMOVAL	Sampling points are positioned throughout the process for laboratory analysis to manage the quality of the gas throughout the system: On the Mercury Adsorber and downstream of the Treated Gas Filter	To reduce the mercury level in the feed gas. The treated gas will have a mercury level of less than 5 ng/Nm^3, whilst in the presence of 25 ppmv of oxygen and 8 ppmv of hydrogen sulphide.	
15 - LIQUEFACTION		To further process and liquefy the treated dried gas to the LNG Product Specification	The natural gas to the main cryogenic heat exchanger (15-MC05) from the scrub column reflux drum; 15-MD02 is monitored by a gas chromatographic analyzer, to ensure that the C5+ and benzene levels in the gas do not exceed 0.1mol% and 1ppm respectively.

Unit	Sampling points	Purpose	Online Analyzer
			The LNG produced is monitored using a gas chromatographic analyzer.
16 - REFRIGERATION		To provide refrigeration for the MCHE. The quality of the refrigerant produced shall be to the specification	No on-line analyzer on the refrigeration unit, however, sample connections are provided at the following locations: -LP MR Compressor, 16-MJ01 suction. -HP MR Vapor feed line to the MCHE. - HP MR Liquid feed line to the MCHE. to monitor the quality of the refrigeration feedstock at 16-MJ01 suction as well as the quality of the refrigerant supply to the Liquefaction Unit.
18 - HOT OIL SYSTEM	Type B sampling point is available on-line O-18009	To monitor the quality of the oil returning to the Hot Oil Surge Drum in order to check for degradation. A Sample/Analyzer point is located on the exhaust stack to monitor the quality of the exit gas from the WHRU.	No on-line analyzers in this unit.
51- POWER GENERATION / DIESEL FUEL SYSTEM		To supply power to the site under normal and emergency conditions and to maintain this supply of generated power the specification of fuel gas during normal operations and diesel fuel during emergency or abnormal operations must be maintained and checked on a regular basis. Fuel gas conditions entering the turbine generator packages at Pressure 23 bar and Temperature 64ºC	On line analyzers constantly monitor the composition of the Feed Gas and the HP Fuel gas supply to the Fuel Gas Common facilities.
55 – FUEL GAS SYSTEM	No sampling points		No continuous loop analyzers
	During start up	Fuel gas must be heated above 28ºC superheat by the Electric Start Up Heater or by HP Fuel Gas Heater under normal operation to ensure that the fuel gas is kept above its dew point.	
	Under start up conditions	The temperature through 55-ML01 is controlled by 55-TIC-1005 which detects the downstream temperature from 55-TT-1005.	
	Under normal operation	The temperature differential controller, 15-TDC-1187, receives inlet and outlet temperature readings from 15-TT-1167 and 15-TT-1161 respectively	
56 - INSTRUMENT AND SERVICE AIR	No sampling points	Air from the compressors passes through a receiver where free water is removed before being distributed to the service air system and the dryers.	No continuous loop analyzers
58 – FRACTIONATION HOT OIL SYSTEM	Type B sample point is located on the hot oil return line to the Hot Oil Surge Drum,	To monitor the quality of the hot oil returning to the surge drum. This monitoring is necessary as degradation of the oil may cause problems in operation.	A local analyzer monitors the oxygen concentration in the body of the Hot Oil Furnace. This is accompanied with an alarm to notify whether the level of oxygen is either too high or too low.
	Type E sample point is available on the Hot Oil Furnace stack	To monitor flue gas quality.	
	Type C sample point	To monitor the quality of fuel gas leaving the HP Fuel Gas KO Drum, 58-MD02.	
63 – FIRE PROTECTION SYSTEM	No Quality Control	No Quality Control	
64 – EFFLUENT AND		The water in the Discharge Holding Basin is continuously monitored for pH, BOD5, COD,	

Unit	Sampling points	Purpose	Online Analyzer
WASTE WATER TREATMENT		TOD, turbidity and conductivity to ensure satisfactory quality before discharge to sea.	
65 – FLARE SYSTEM	Type A Sample point on is located on line BO-65006	To take samples from the Blowdown from the Warm Flare Knockout Drum, 65-MD01.	
71 – LNG STORAGE AND LOADING	Type D point is available on-line LG-71202.	To monitor the quality of LNG which is pumped from LNG Storage Tank 71-MF02.	This LNG is loaded to Jetty and finally shipping.
	Type D point is available on-line LG-71102.	To monitor the quality of LNG which is pumped from LNG Storage Tank 71-MF01	
76 – CONDENSATE STORAGE SYSTEM	Sampling point downstream of the Condensate Storage Bullet,	To analyze the composition of the condensate flowing to the tankers.	

References

[1] Mokhatab S, Mak JY, Valappil JV, Wood DA. Handbook of Liquefied Natural Gas. 1st edition, Gulf Professional Publishing, Elsevier, USA, 2014.

[2] Mokhatab S, Poe WA, Speight JG. Handbook of Natural Gas Transmission and Processing. 1st edition, Gulf Professional Publishing, Elsevier, USA, 20O6.

[3] Mokhatab S, Poe WA, Mak JY. Handbook of Natural Gas Transmission and Processing- Principles and Practices. 3rd Edition, Gulf Professional Publishing, Elsevier, USA, 2015.

[4] Halafawi M, Avram L. Well Integrity, Risk Assessment and Cost Analysis for Petroleum Fields and Production Wells with CO_2. International Journal of Innovations in Engineering and Technology (IJIET), Petroleum Engineering Section, 2018, 10(4): 39-52.

[5] Halafawi M, Avram L. Application of Risk Analysis in Drilling Well Problems and Operations - Field Case Study. Journal of Engineering Sciences and Innovation, Petroleum and Mining Engineering Section (F), 2018, 3(4): 393–404.

[6] http://www.hse.gov.uk/index.htm.

[7] www.GEKEngineering.com.

[8] Avram L. Elemente de Managementul Forajului. 2nd Editura Universității Petrol-Gaze Din Ploiești, România, 2011.

[9] Vaxevanidis NM, Petropoulos G, Dašić P. Key Elements for Improved Organization's Performance: Quality Management, Statistical Techniques, and Cost of Quality. 1st International Conferences:"Application of New Technologies in Management", 2009, ANTIM2009, 08-11 Feb, Vrniacka Bania, Serbia.

[10] Evans JR, Lindsay WM. The Management and Control of Quality. 4th edition, Cincinnati, Ohio: South-Western College Publications, 1999.

[11] ISO 9000:2005, Clause 3.2.10.

[12] https://www.blog-g.com/basic-concepts-of-quality-control/.

To whom correspondence should be addressed: Dr. Mohamed Halafawi, Drilling and production Engineering, Petroleum-Gas University of Ploiesti, Romania, E-mail halafawi@upg-ploiesti.ro