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Study and Design of Flare Reduction Initiative in the Region: A Case Study of Gas Flaring Reduction at Oman Liquefied Natural Gas Company

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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Case Study

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ABSTRACT

In this paper examines the feasibility of eliminating flaring at Oman LNG Company by capturing the CO_2 present in the incoming gas during LNG ship gassing up operation. The gas containing CO_2 is flared to prevent CO_2 ice up and blockage at lower temperature. The project proposes a design and installation of two exchangers to cool the CO_2 present to de-sublimation temperature of -132℃ at which 99% of CO_2 solidifies on the heat exchanger fins which then direct the free CO_2 gas to fuel gas system. A stream of cold LNG product available at -161℃ on loading line was utilized as cooling medium to achieve the target temperature. The design takes into consideration energy optimization and efficiency of the system by which a multi-passes stream exchanger is used to pre-cool the incoming gas before it's further cooled to CO_2 frosting point in the main exchanger.
A Honeywell UniSim software was used to simulate the process and the outputs were outlined. The results were found to be optimistic and targeted temperatures for 99% removal of CO_2 were found to be achievable. The 7% of the total flaring responsible by gassing up operation can be eliminated.

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1. INTRODUCTION

Flaring in hydrocarbon industries is known as a controlled burning of off gases in the course of routine oil and gas or chemical manufacturing operation [1]. Flaring of Natural Gas is becoming a Global Concern and continues to be a hot topic. The statics from World Bank report shows an increase in flaring in every year in cross ponding with exploration expansion and high market demand of energy. This amount of flare gas which yearly flared is a warning sign for the world to take measure towards protecting the environment.

Gas flaring can take place during various petroleum industry operations. In the upstream petroleum sector, waste gases are flared at gas plants, natural gas batteries, pipelines, and during well tests. Gas processing plants produce market ready natural gas by removing water, sands, hydrogen sulphide, carbon dioxide, and natural gas liquids from the natural gas mixture produced at the wellhead. Waste gases, including hydrogen sulphide-rich gases, and gases burned during emergencies are flared at these facilities. Natural gas batteries collect and process gas collected from one or more wells. Flaring at these facilities and pipelines can occur during emergencies, equipment upsets or failures, and maintenance operations. Flares are located at wells, dehydrators, compressors, and gathering pipelines.

The latest figures from satellite data shows about 140 billion m^3 of gas are flared [2]. This amount almost equivalent to 4.7% of total gas consumed by the world [3]. According to the World Bank's Global Gas Flaring Reduction (GGFR) flaring charts, GCC (Gulf Cooperation Council) countries were came among top 20 gas flaring countries. Gas flaring not only wastes a voluble energy resources but it also has several effects for the environment. Flaring is known to cause production of toxic gases, cause heat radiation, generate and disperse particulate and produce high noise level [4].

Oman flared a total of 1.9 billion cubic meters of gas. Comparing with 2005 quantity of 2.6 billion, there is about 26% of reduction in gas flaring due to the implementation of some projects and initiative of reduction. However, still that flaring amount is high and has made Oman in 19th position of biggest flaring nation (World Bank Report, 2015) [5].

The study discusses and reviews the initiative carried out by some of the major oil and gas industries in GCC who has achieved significant reduction in flaring and found a solution to recover or utilized the gas economically. The obtained results were evaluated and along with Tech used in market for recovering these gases with affordable cost [6].

Based on analysis carried out on flaring sources in 2012 (Fig. 1), ship gassing up operation accounts around 7% of the total flaring at Oman Liquefied Natural Gas Company [7]. The gassing up activity is a process where vaporize LNG used to replace the inert gas (mainly CO_2 & N_2) from ship tanks after arrival from dry dock. Due to the fact that CO_2 freeze at low temp, the return gas cannot be recovered and instead flared until its concentration falls below the acceptable limit. Gas flaring has several impacts to the environment [8]. Flaring is known to cause direct impact to the environment, Lead to the production of toxic gases, produce high noise level, and emitted high amount of carbon dioxide (CO_2) to the air.

Reduction of emission, conserving valuable nonrenewable resources and saving energy are important requirements for every industry. Every company looks seek for possible methods to reduce emissions and achieve their set out goals.

The key objective of this project is to contribute significantly to cost effective way of reducing gas flaring and conserve valuable nonrenewable resource [9]. The study evaluates initiative carried out in the region by different hydrocarbon industries and utilizes available best practice procedure and technology to come up with idea to implement in one of downstream gas processing hydrocarbon plant.

1.1 Specific Objectives are

- Investigate and carry out case studies in region flaring reduction initiative.
- Evaluate the issue of flaring in one of the hydrocarbon industry in Oman.
- Identify the main sources of gas flaring and wastages in selected company.
- Set up and assess measures required or which can be implemented to overcome or reduce volume of gas flaring.

1.2 Overview of Oman LNG Loading Facility

Fig. 2 gives a simplify diagram of the current loading facility at Oman LNG. The Liquid LNG received from process trains is stored at -162℃ in two fully insulated tanks. The liquid LNG is delivered to the ship using submerge pumps inside the tanks. Loading Arms are used to connect with ship manifold in order to deliver the product to the ship. The ship normally arrives to the terminal with their tank in cold temperature and contain only hydrocarbon. In this case, the ship is called cold, gassed-up and loading will commence directly without the requirement of cooling the ship and the return vapor from ship is all routed to fuel gas system.

However, in some instances if ship come from dry dock (maintenance) where its tank is temperature is warmed and filled with inert gas (N_2,CO_2), the ship is called warm, inert and required gassing up and cool down. The ship in this case uses a vaporized control amount of LNG from loading line to replace the inert gas with hydrocarbon and in this process the return gas from ship is sent to flare due to CO_2 content.

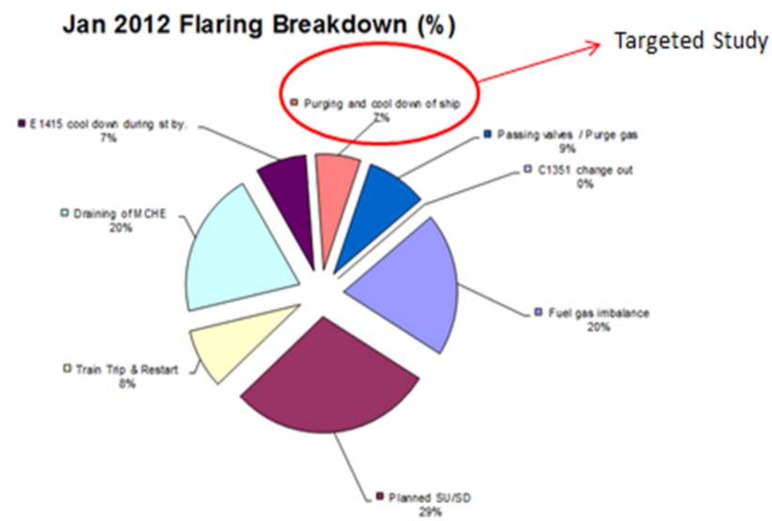

Fig. 1. Oman LNG flaring breakdown
Source: Challenge to reduce flaring at OLNG, Scott Mills, 2012

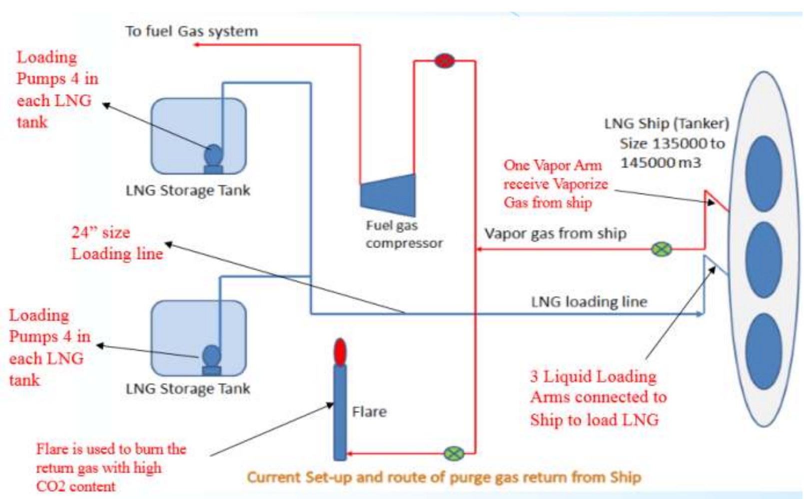

Fig. 2. A simple diagram of existing loading facility at Oman LNG

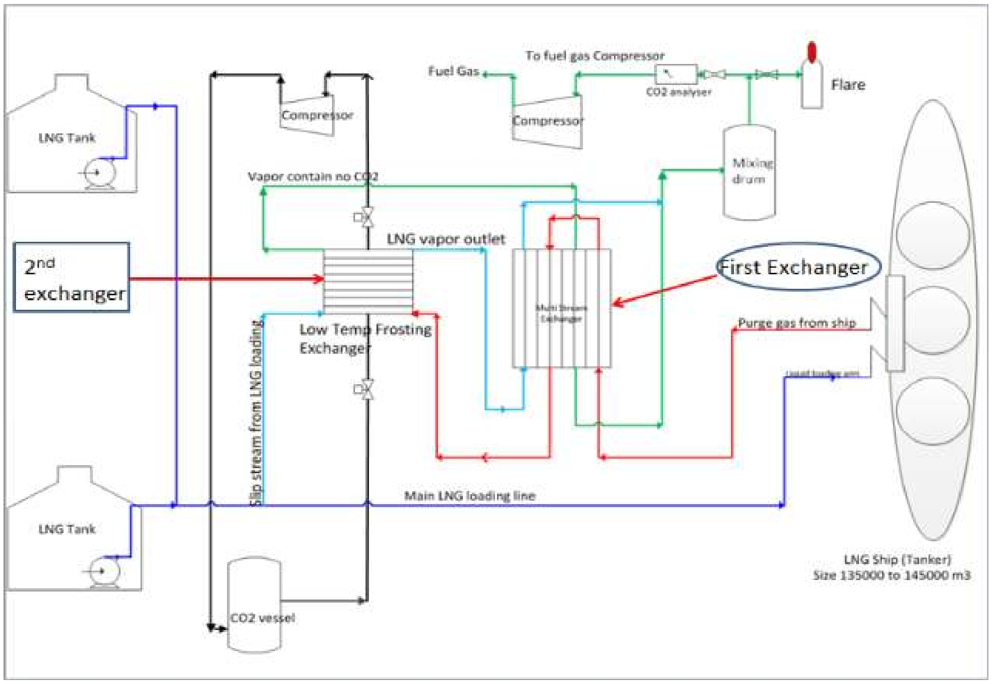

Fig. 3. Proposed CO_2 removal process by including two exchangers and CO_2 recovery vessel

2. METHDOLOGY DESIGN

2.1 Proposed CO_2 Removal Process

The proposed design (Fig. 3 above) was developed to capture the CO_2 present in the low pressure return gas by cooling it to de-sublimation temperatures and then separating the solid CO_2 that forms from the return gas. The return gas (free CO_2) is then recovered and compressed into the fuel gas system. The pressure of the return gas is below CO_2 triple point, at this pressure CO_2 never enters the liquid-vapour region and it freezes directly.

The separation is achieved by passing first the return gas in to a multi-pass heat exchanger where it cools by the two cold streams coming from the low temp frosting exchanger. This exchanger helps in reducing the load in second exchanger and also for energy optimization and recovery. The gas exists the multi-pass heat exchanger at – 90℃ and then enters the second exchanger (frosting exchanger). In this frosting exchanger, the gas is cooled to -135℃ by using cold LNG stream (at -161℃) coming from loading line. At this temperature 99% of CO_2 is frosted in the exchanger fins (blades) and gas that exists the exchanger is free of CO_2 [10]. The cold free CO_2 gas is passed to the multi-pass heat exchanger for cooling the warm gas from ship before being mixed with vaporized LNG and compressed to fuel gas system.

3. RESULTS AND ANALYSIS

Throughout the proposed project, the potential of removing the CO_2 from the return gas by utilizing the cold LNG flow in the loading line was found to be feasible. Since the purge gas return with low pressure, below the triple point of CO_2, the CO_2 gas is capture by anti-sublimation (solidification in low temperature surface of exchanger). The proposed project take an advantage of utilizing a slip stream of low temperature liquefied Natural gas (-161℃) as a cooling medium to freeze-out and remove the CO_2 present in the return gas. The project proposed installing two exchangers where by the first one is for energy optimization and reduce the duty in the second exchanger where the CO_2 frosting takes place.

For the UniSim simulation, the starting freezing point of the CO_2 under the given condition of 0.7bar pressure and 14% v/v concentration is at -103℃. The model has been designed such that 99% of CO_2 will freeze on the second heat exchanger (froster) where temperature of -131℃ is achieved.

Table 1 indicates the condition of the CO_2 return gas as it exists the first exchanger (multi-pass) where it is cooled to a temperature just above the CO_2 freezing point. The UniSim indicates that at this temp, there is no formation of CO_2 frost.

The UniSim simulation Fig. 4, the starting freezing point of the CO_2 under the given condition of 0.7bar pressure and 14% v/v concentration is at -103℃. The model has been designed for such 99% of CO_2 will freeze on the second heat exchanger (froster) where temperature of -131℃ is achieved.

The results shown in Tables 1 and 2 shows the vapor existing in the second exchanger (Froster) clearly indicates that solid CO_2 formation occurs on intended heat exchanger fins.

Table 1. Streams and status of CO_2 in froster

Stream: CO_2-Rich to Froster		CO_2 Freeze Out: CO_2 Freeze Out-1	
Properties			
CO_2 Freeze out data			
CO_2 Freeze temp: -101.1C		Formation flag: Does not form	
Stream properties			
	Overall	**Vapour phase**	**liquid phase**
Vapour/Phase fraction	0.9999	0.9999	0.0001
Temperature: (C)	-95.00	-95.00	-95.00

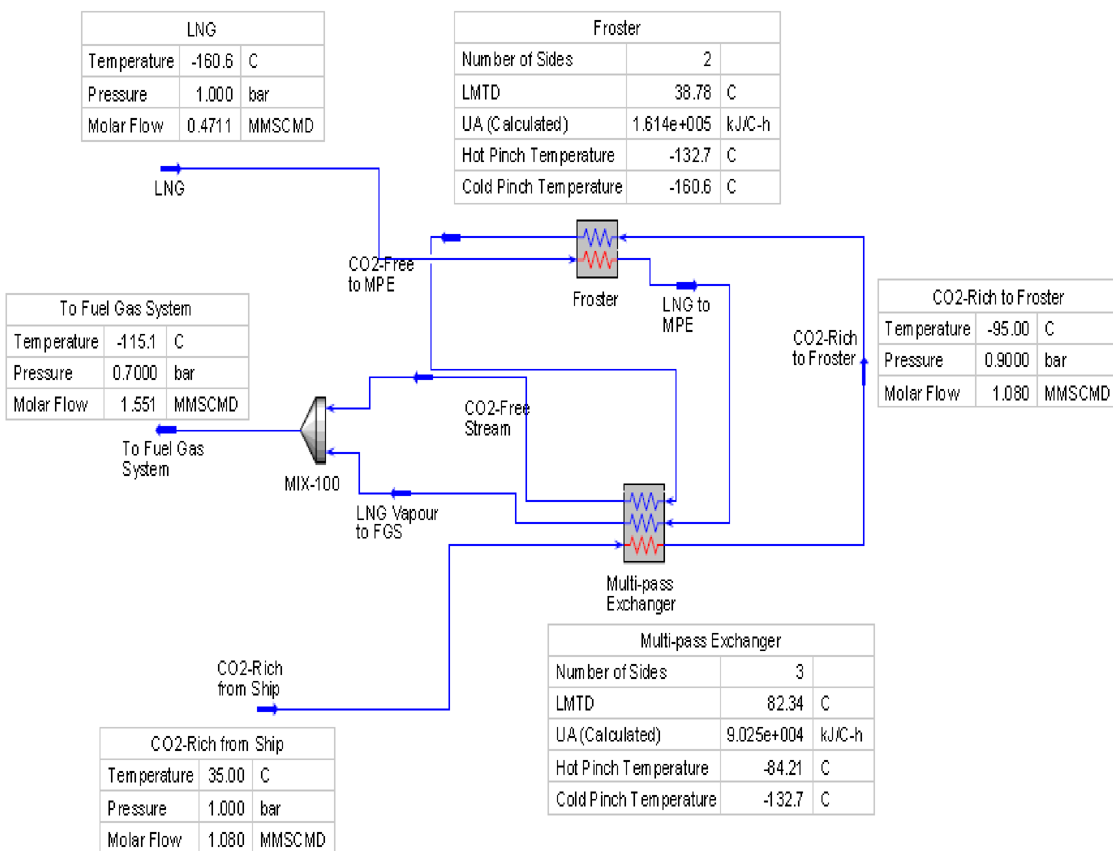

Fig. 4. UniSim simulation of the project

Table 2. Streams and status of CO_2 in froster

Stream: CO_2-Free to MPE	CO2 Freeze Out: CO_2 Freeze Out-5		
Properties			
CO_2 Freeze out data			
CO_2 Freeze temp: -102.2C	Formation flag: Solid CO_2 present		
Stream properties			
	Overall	**Vapour phase**	**Liquid phase**
Vapour/Phase fraction	0.8845	0.8845	0.1155
Temperature: (C)	-132.7	-132.7	-132.7
Pressure: (bar)	0.8000	0.8000	0.8000
Molar flow (MMSCMD)	1.080	0.9550	0.1247
Mass flow (kg/h)	5.760e+004	4.794e+004	9665
Std ideal Liq Vol Flow (m^3/h)	70.98	59.28	11.71
Molar enthalpy (kJ/kgmole)	-6.204e+004	-1.563e+004	-4.175e+005
Mass enthalpy (kJ/kg)	-2049	-548.7	-9491
Molar entropy (kJ/kgmole-C)	120.1	130.2	42.26
Mass entropy (kJ/kg-C)	3.967	4.573	0.9607
Heat flow (MW)	-32.79	-7.306	-25.48
Molar density (kgmole/M^3)	-7.798e-002	0.0690	31.94
Mass density (kg/M^3)	2.361	1.965	1405
Std ideal Liq mass density (kg/M^3)	811.5	808.7	825.7
Liq mass density @ Std Cond (kg/M^3)	---	---	824.9
Molar heat capacity (kJ/kgmole-C)	33.55	28.66	70.98
Mass heat capacity (kJ/kg-C)	1.108	1.006	1.614
Thermal conductivity (W/m-K)	---	1.307e-002	0.2058
Viscosity (cP)	---	9.380-003	1.184

4. CONCLUSION

A new proposed design to capture the CO_2 presence in the low pressure return gas was presented. The design uses liquid LNG stream at -161℃ to solidify CO_2 gas in the plate exchangers fins by anti-sublimation method of CO_2. The design was examined using UniSim application and the intended temperature was found to be achievable. The implementation of this proposed project has a potential of reduction of the 7% flaring responsible from shipping gas-up activity in Oman LNG and this percentage may increase in large scale LNG facility.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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