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EQUIPMENT SELECTION AND DESIGN FOR FLOATING LNG PLANTS

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ABSTRACT

PFLNG Satu was the first in the world LNG producing floater amidst the risks and challenges on safety, marine conditions, water sloshing movements, confined plot space, and weight. Safety is of utmost importance whereby the processing unit with hydrocarbon inventory is processed on the deck while LNG is stored underneath in the hull. In ensuring safety, inherently safer equipment and technology had to be selected at the beginning of the project. Storage tanks selected have to ensure that LNG and chemicals are safely stored amidst the sloshing movement of liquid. Equipment with liquid inventory such as vessels and columns are sensitive to fluid movement when the floater tilts and bends, hence internals have to be designed to ensure liquid level measurement in a vessel such as storage tanks and vessels are accurate under sloshing and water movement on the floater. The columns have to be designed with internal features and margins to ensure no vapour bypass to meet product specifications continuously. Heat exchangers selected have to balance between being compact and light but yet deliver the demanding duty requirements. Flare and utility design need to include critical safety features. This paper details the design of equipment and selection for FLNG.

INTRODUCTION

Conventionally, LNG processes consist of gas production from the platform offshore. Then the gas is sent via pipeline to the LNG plant onshore. It is stored as a cryogenic liquid, then offloaded in a tanker at a terminal jetty. LNG transported by LNG tankers will typically be received by onshore LNG terminals, whereby the LNG is stored and regasified and later sent to users. Floating LNG (FLNG) consists of taking gas from offshore at the field itself via turret and riser system followed by series of treatment units to remove impurities. The natural gas is then liquefied and stored. All the three processes are on a single floater, together with the hull, living quarters, and marine facilities.

FACTORS AFFECTING EQUIPMENT SELECTION AND DESIGN

Plot Space Constraints

Although PFLNG length is equivalent to about three soccer fields, space is still a constraint since almost 500 pieces of equipment or about 20 modules are fitted on the topside. The underlying principle is the same plot space, and weight in FLNG is more expensive than the offshore platform, hence more expensive than the onshore LNG plant. Larger equipment would require a larger plot area plot and tend to be heavier. This larger plot area requires more steel structures to support the weight, hence higher cost is anticipated. Therefore, equipment selected on the topside and hull had to occupy as the minimum plot as possible. Vertical vessel orientation is generally selected as horizontal as the former takes up less plot space on the floater. This selection also applies to heat exchangers. For the Acid gas Removal Unit (AGRU), large heat duty requires

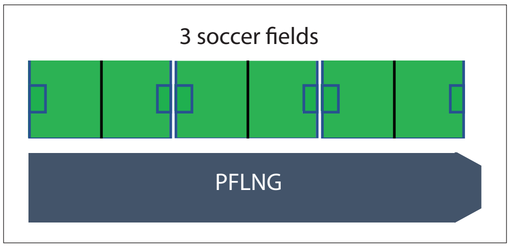

Figure 1 Comparison of PFLNG size

large and many heat exchangers to be used. Vertical and compact heat exchangers can be used instead of horizontal heat exchangers to save the plot.

Sloshing in Vessels and Storage Tanks

The operation equipment in FLNG will always subject to permanent sea movement, tilt condition, roll, and degree of inclination. Sloshing is irregular, splashing movement. The impact is more prominent and adverse in a horizontal vessel than in a vertical vessel. In some cases, the use of horizontal vessels cannot be avoided, e.g., separators in condensate stabilisation units where liquid-liquid separation requiring a large settling area is needed. Sloshing will disrupt liquid-liquid separation processes, which would affect liquid levels measurement and separation product purity.

Computational fluid dynamics (CFD) is required to analyse the impact of sloshing on the separation. If necessary, baffles are added to minimise the effects of fluid movement on the vessels.

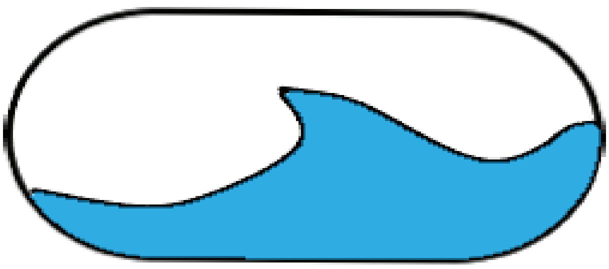

Figure 2 Sloshing of liquid occurring in a vessel due to sea movement

Photo courtesy of AFP Tech (www.AFPTech.eu)

Figure 3 Calming baffles installed in a vessel

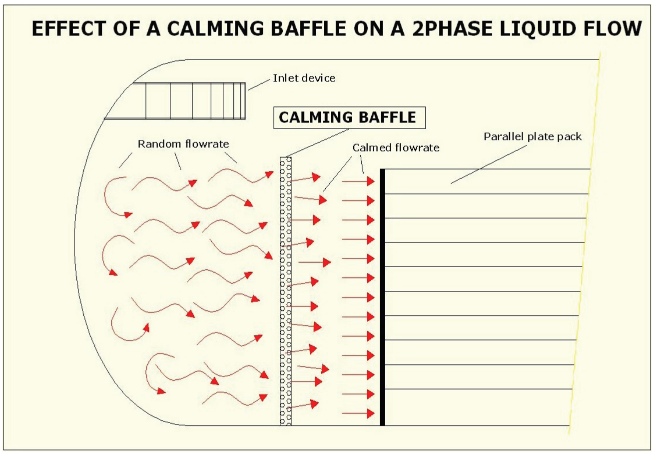

Image courtesy of AFP Tech (www.AFPTech.eu)

Figure 4 Effect of a calming baffle on a 2 phase liquid flow

Liquid Level Measurement in Vessels

There are also concerns on effects of inclination to the liquid level hold-up in the vessel horizontal vessel. During sea movement, the floater will tilt at a certain angle. The inclination of the vessel will result in errors in liquid level measurement. Margins are added, taking into account the length of liquid affected due to the inclination to ensure sufficient hold-up height and volume at liquid level. This margin will be added to the vessel's design or separator length for control purposes when the floater tilts.

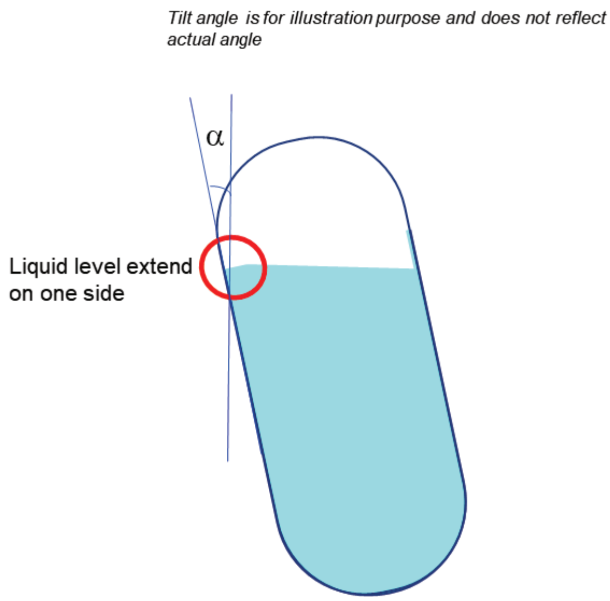

Figure 5 Liquid Level Extend on One Side of a Vessel When Floater Tilts

Acid Gas Removal Technology in FLNG

The technology used in FLNG shall be based on proven technology, i.e., robust offshore environment, flexible, efficient, and safe design.

For the Acid Gas Removal Unit (AGRU), extensive technology selection has been made to select the most suitable technology to remove bulk acid gases such as CO_2 and H_2S. Two options were studied. They are membrane and solvent-based, and solvent-based technology. The membrane has been well used and is reputable offshore for bulk acid gas removal due to the small plot space and weight requirement. In a case study done, to reduce CO_2 from about 20 mol% to about 7 mol%, the plot space required of membrane unit is 41% of amine unit. The weight of 2 stage membrane unit is only 36% of the amine unit. However, the hydrocarbon loss is significant. The selection of bulk acid gas removal needs to compare plot space, weight and hydrocarbon loss factors before selecting the technology and equipment.

Acid Gas Removal Unit (AGRU) needs to remove H_2S and CO_2 too low parts per million (ppm) levels in the treated gas. CO_2 is removed to prevent it from freezing in the downstream cryogenic process and cause blockage to downstream equipment. H_2S, on the other hand, is corrosive. Typically, upstream operations use the membrane to remove acid gases. However, due to the low ppm level requirement, solvent-based AGRU is used to remove acid gases. In AGRU, sour gas enters from the bottom of an absorber and goes through a packed bed where lean amine solvent absorbs the acid gas, leaving through the bottom as rich amine.

Solvents such as amines are liquid. Refer to Figure 6 for a diagram that details out liquid inclination in the column. The inclination and sea motion will affect the amine column performance by creating gas/liquid maldistribution within the column, with the liquid is preferentially moving towards one side of the column, leaving the other side of the column depleted the liquid. As a result, the gas will tend to flow to the region with the deficit of the liquid. The region with the surplus of liquid will encounter less gas flow. This results in non-uniform distribution between the liquid and gas over the cross-section of the column and may lead to the performance drop or, worst, off-spec gas carrying acid gas to downstream units. Amine solvent circulation needs to include a significant margin to ensure sufficient amine to distribute across the inclined column.

Heating and Cooling System in FLNG

Utilities in FLNG shall be designed to cater to both topside process and marine requirements. As the floater is usually located in a remote field, the import

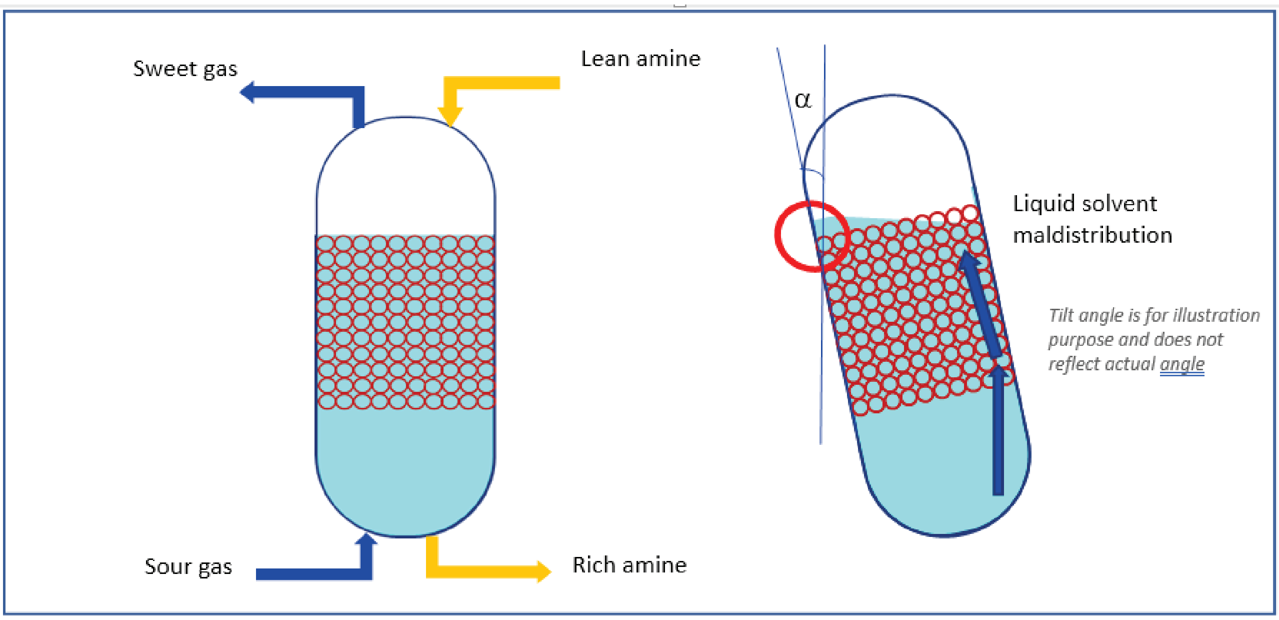

Figure 6 Gas/liquid maldistribution within column when subject to sea motion

of utilities can be very costly and impractical. The key criteria are the required utilities can be produced onboard, although there is concern on plot space and weight.

The selection of utilities requires careful studies to ensure the overall demand for heating and cooling duties can be met, with optimised equipment count and, most importantly, economically justified.

There is a choice to use either hot water, steam, heat transfer fluid, electrical heater, or various heating systems for the heating medium. Heat integration is recommended to optimise the utilisation of excess heat available from the gas turbine or power generator flue gas. Meanwhile, for cooling medium, there is a choice of using either cooling water, seawater cooling, or air-cooled.

Typically in a floater design, a combination of closed-loop fresh cooling water with seawater cooling is applied as much as possible to minimise the plot space and weight of the overall FLNG topside. Careful consideration is required to use air fin coolers due to their larger size hence more giant footprint and weight.

Direct seawater cooling is not recommended for process heat exchangers, given the need for a particular material to handle seawater corrosivity leading to higher CAPEX. There is also potential for many operational issues due to seawater properties that prone to marine growth if not treated, scaling, and fouling.

Cryogenic Spill in FLNG

Similar to other offshore installations, equipment in process modules are installed in the multi-deck arrangement. The Main Deck and Process Deck are typically plated to protect the storage area located in the hull from any topside events and cater drainage of accidental cryogenic spillage. With the multideck installation, the equipment layout design requires careful study to ensure no flanges or other potential leaks are located above any equipment, particularly concern on cryogenic spills.

A cryogenic liquid spill could potentially lead to brittle fracture hazards if not properly contained and managed. The general philosophy is to drain and remove LNG and refrigerant onboard as fast as possible. The use of cryogenic drip pans should be minimised due to safety reasons. Free draining lines from drip pans on each deck are typically routed to the module side to send the potential cryogenic spills to the main deck and subsequently to FLNG overboard. Typically, a water curtain will be provided to protect the LNG runoff from contact with the FLNG hull.

Flare System in FLNG

For the FLNG flare system, the warm/wet and cold/dry relief from various process units needs to be properly segregated for ultimate safety. The heavy hydrocarbon, mainly in the upstream and pretreatment part of FLNG, would condense, freeze, or form hydrate when mixed with a colder stream in the Liquefaction unit. This can lead to potential liquid formation in the flare system.

On the other hand, relief fluids from Liquefaction units are typically dry and usually at temperatures below 0°C. These fluids need to be contained in a disposal system that can handle cryogenic temperatures. Installation of high pressure and low-pressure flare system is also deemed necessary in FLNG to limit relief and flare headers and avoid heavier structures.

The Flare system, hazardous, will be located further away from the Living Quarter (L.Q.) and Helideck of FLNG. All vents are designed and positioned considering the prevailing winds flow direction to minimise exposure to personnel working at elevated areas and the risk of gas clouds drifting towards the process installation. Meanwhile, flare stack design in FLNG typically involves a very high stack structure considering the safe radius of thermal radiation on personnel working on FLNG and L.Q.

Fire and blast walls usually are provided on the Process Deck to avoid the propagation of blast waves in the event of an explosion.

CONCLUSION

Equipment selection and design on FLNG require careful studies to select safety, floatation effects, plot space, weight, and ability to generate utility onboard and maintenance aspects. Some equipment, such as the columns, requires rigorous technical studies to ensure it will perform onboard. Selection of utilities requires careful studies to support the process and meet overall demand on heating and cooling duties and ensure optimised equipment count and, most importantly, is economically justified. Operational and maintenance lessons learnt from the industry and latest technology need to be sought to make an informed decision.

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