FLNG / LNG Liquefaction Plants

Gas Pre-Treatment Systems

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In an effort to design engineer, and manufacture the most cost effective, space and weight efficient facility possible, many factors must be considered. The first thing that must be determined is what detrimental contaminants exist in the entering gas stream. These contaminants can include, but are not limited to, oxygen, nitrogen, water, carbon dioxide (CO_2), hydrogen sulfide (H_2S), mercury, arsenic and/or heavy hydrocarbons (C_3+). Each of these components can create significant problems for the operation of an LNG plant. For example, the CO_2 content in a gas stream entering an LNG Plant must be reduced to less than 50 ppmv to avoid the formation of dry ice within the system which can plug off equipment and shutdown the plant. Similarly, mercury in the gas stream can attack the aluminum components often used in LNG Plant heat exchangers and other equipment.

Depending on the amount of H_2S contained in the inlet gas, an H_2S scavenger system may be used to remove the sulfur before entering any other part of the plant system. A few general rules of thumb for deciding to use an H_2S scavenger include:

- Total sulfur content in the gas stream of less than 400 pounds per day
- Gas volumes less than 50 MMSCFD
- H_2S content of less than 500 ppmv
- Oxygen is contained in the inlet gas

If none of these general rules apply, it is typically best to remove the H_2S later on in the treatment process.

Oxygen is typically not found in the gas stream feeding an LNG Plant, but this must be verified before proceeding further. If oxygen is present, it must be removed before entering the downstream amine unit where it would degrade the amine and form heat stable salts and other undesirable byproducts. Newpoint's X-O_2, catalytic reactor system, removes any contained oxygen by reacting the oxygen with a portion of the inlet hydrocarbon to form CO_2 and water (H2O). The X-O_2 plant can be designed to handle up to 3% oxygen with no special requirements or design features and will typically deliver a product stream containing less than 100 ppmv oxygen.

Depending on the amount of CO_2 contained in the inlet gas stream and the volume of gas entering the plant, it may be beneficial to remove the bulk amount of CO_2 using a membrane treating system in order to minimize the size of the downstream amine plant and reduce the overall energy consumption of the plant. For example, a plant having an inlet of 100 MMSCFD of gas containing 10% CO_2 would require a 1300 gpm amine plant if this were the only means available, whereas a two-stage membrane unit could be used to reduce the CO_2 to 2% and then be followed by a 225 gpm amine plant, resulting in an energy consumption equal to only 20% of that of the amine plant alone. (Of course, if a Waste Heat Recovery Unit (WHRU) is available, the system heat input requirement is essentially "free" and use of the membrane system may not be economical or an efficient use of space.) Additionally, since membranes deal only with the gas phase and no liquid hydraulics are involved, the membranes systems can be configured in any way necessary to fit within existing plot space limitations and constraints and are not concerned with plant dynamics that may occur on offshore applications.

An amine plant is used to remove essentially all of the CO_2 and H_2S from the inlet gas stream. In order for the LNG Plant to operate properly and reliably, the CO_2 should be removed to a level of less than 50 ppmv. For the product to be considered "sweet", the H_2S needs to be less than 4 ppmv. Amine systems are capable of meeting both of these criteria. The concentration of these two contaminants and the operating conditions of the plant (pressure, temperature, remaining gas composition, etc.) will determine what amine should be used and what the required circulation rate will be. The amine plant process is essentially identical in all cases, though the configuration can usually be manipulated to fit within a specified plot area. However, as amine systems are liquid systems, care must be used in ensuring that the liquid hydraulics are acceptable and that any dynamic movement that may be incurred in offshore applications are incorporated into the detailed design of the overall system.

Upon leaving the amine plant, the oxygen, CO_2 and H_2S have all been removed to acceptable levels to enter the LNG Plant. The next step is to dry the gas to the point that it will contain less than 1 ppmv of H_2O. A Molecular Sieve (mol sieve) dry desiccant is the industry standard for performing this function. The number of beds is generally determined by the volume of gas being dehydrated and the water content in the inlet gas stream. One or more of the dehydration beds operate in the adsorption phase, where water vapor is adsorbed onto the desiccant, while one bed is heat regenerated to strip water from the mol sieve. Regeneration gas can be either a slip-stream of dehydrated inlet gas that will be recycled back to the front end of the plant for re-processing, or a stream of residue or off-gas that can be routed to the sales gas line or into the fuel system after regenerating the mol sieve. Mol sieves can also be designed to remove trace amounts of CO_2, H_2S and mercaptans, if it is known before hand that these contaminants are present and need to be removed. Additionally, if residue gas is used to regenerate the mol sieve, a regenerative mercury removal sieve, such as UOP's HgSieve, can be used to remove mercury from the inlet gas stream. Properly designed mol sieve systems will remove water to less than 1 ppmv and PLC programming will automatically control switching beds between adsorption and regeneration and switching between heating and cooling in the regeneration step.

If mercury is present, but the regenerative HgSieve is not used for mercury removal, a separate vessel, filled with activated carbon, is typically used to remove mercury gas stream. These beds are typically located downstream of the mol sieve system to keep water from deactivating the bed. Mercury removal systems are generally designed to reduce the mercury content in a gas stream to less than 10 nano-grams per cubic meter.

Arsenic removal systems are a virtual duplicate of mercury removal systems in appearance, but utilize a different bed material to remove arsenic and the various arsines that may be present in the gas stream.

Finally, depending on the quality of the inlet gas and how “clean” of an LNG product is desired, the gas may be “conditioned” to remove the heavy-end hydrocarbons from the gas stream before it enters the actual LNG liquefaction plant. The recovery of these heavy-end hydrocarbons can be accomplished using something as simple as a propane refrigeration plant to a full-scale cryogenic gas plant, complete with turbo-expander. Depending on the extent that the ethane and heavier components (C2+) are removed, the feed to the LNG liquefaction plant may consist of only methane and nitrogen. The nitrogen will be separated from the methane in the LNG liquefaction plant.