Study focuses on six LNG regasification systems

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CB&I of the US has been involved in the design and construction of terminal facilities for LNG for more than two decades. Here their experts consider import plant options

Throughout the world about 20 new liquefied natural gas import facilities are currently being built, while many more projects are in the planning stages in the US, Europe and Asia.

Not only is the number of import terminals growing, but also the size of the planned regasification facilities to meet the increasing need for natural gas.

As the size of these plants increases, it becomes more important than ever to understand the economics behind the various options available in designing and constructing them.

In performing these economic evaluations, import terminal owners realize that the energy cost associated with regasifying the LNG for delivery to a natural gas pipeline is the most significant cost to consider, in terms of both the operational and capital investment required.

For each facility, the most cost-effective regasification system will vary depending on the operational features of the terminal and the delivery system available to reach its markets.

A study of six regasification systems was conducted to provide an economic evaluation of each system in conjunction with the conditions that might influence its viability. The regasification systems evaluated in this study were:

- Fired heaters with water/ethylene glycol (WEG) intermediate fluid
- Submerged combustion vaporizers
- Sea water vaporizers with open rack
- Heating towers with intermediate water
- Gas turbine generators with waste heat recovery units
- Steam turbine generator cycle (Rankine Cycle)

Study parameters

For the purpose of the study, a fairly typical regasification terminal size of 1,200 million standard cubic feet per day (MMSCFD) and a 20-year life cycle were used as the basis for the design.

A net present value over the 20-year life cycle was used for the purpose of comparing the costs associated with each system. A comparison was performed of the capital costs and present value energy costs of all six systems.

The following process parameters were used for the evaluation:

- Natural gas sendout rate: 1,200 MMSCFD
- Natural gas sendout pressure: 1000 psig
- Natural gas sendout temperature: 45º F min.
- Total vaporizer duty: 700 MMBtu/hr (68% usage)
- Vaporizer inlet/outlet temperature: -245/45 °F

The following costs, deemed to be typical at the time of the study, were assumed for comparison purposes:

- Gas cost: 5.0 $/MMBtu
- Power cost: 0.07 $/kW-hr
- Interest rate: 5%
- Inflation rate: 2%

Capital costs were taken from recent terminal studies and deemed to be typical for these systems. The fired heater system with WEG intermediate fluid was used as the base case for this study.

Result analysis

An analysis of the study results showed that while some systems have low capital costs but high operating costs, others have low operating costs but moderate or high capital costs.

Finding the optimal system for the environment is essential to designing the most cost-effective system over the long term.

Weighing the net impact of capital costs compared to operating costs within the environmental constraints of the terminal is likewise vital to selecting the system that will provide the most cost-effective solution for terminal owners.

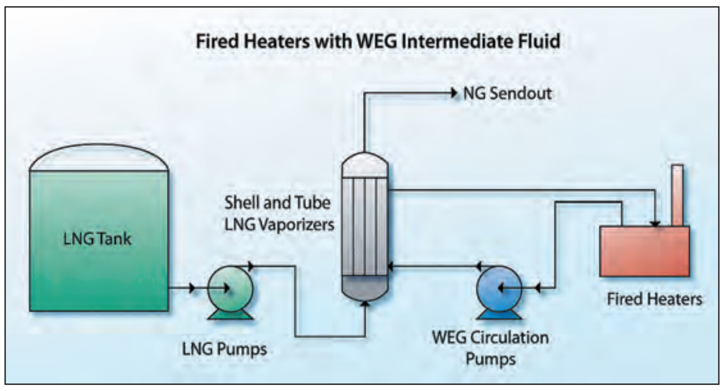


Figure 1 - Fired heaters that use a closed-loop fluid as the heating medium.

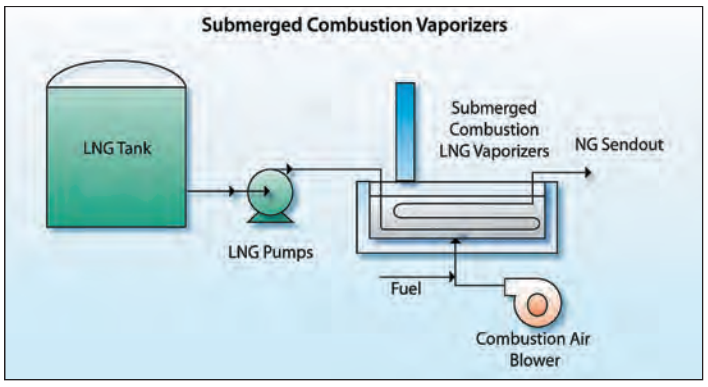


Figure 2 - Submerged vaporizers that use combustion as a heat source.

Maintenance costs, as a subset of operational costs, were also considered when they significantly influenced the overall cost of operating the facility over the life of the terminal.

Highs and low: Both the WEG system and the submerged combustion vaporizer have relatively low installed capital costs but maintain high operating costs.

The WEG system uses vertical shell-and-tube exchangers to vaporize and warm the LNG to a minimum outlet temperature of 45° F.

A hot WEG mixture (60/40% by weight) is used in a closed-loop system as the heating medium. The fuel required to operate the heaters makes the operating cost of this system high.

Approximately 1.5-2% of the send-out gas is consumed by the heaters. In environmentally sensitive areas, this system may require emission permits, specifically for NO_x, CO and CO_2, and penalties for exceeding emission levels could be incurred.

One of the advantages of this system is that the heat is provided within the system; therefore, the system is not sensitive to the climate of the region and can be located in any climate around the world.

Additionally, the equipment used in this system is also sold by many suppliers and an extensive maintenance plan is not required, thus reducing maintenance costs, lowering overall operating costs.

Submerged combustion vaporizers are considerably different than the closed loop heater and the WEG mixture. Submerged combustion vaporizers use combustion as the heat source.

Hot exhaust gases are used to heat a water bath, which in turn vaporizes the LNG.

The burners are designed so that the products of combustion flow down into the water bath that serves as the heat transfer medium for vaporizing the process LNG in the tube coil. The tube coil is completely submerged in the water.

The submerged combustion vaporizer is controlled by maintaining the vaporizer outlet temperature, and the water bath temperature is controlled by adjusting the amount of fuel gas to each vaporizer.

Consequently, the submerged combustion vaporizer is somewhat more fuel-efficient, which results in lower fuel gas consumption than the WEG system.

The submerged combustion vaporizer has 95 percent thermal efficiency compared to 85 percent for the WEG system. Like the WEG system, this system is not climate sensitive and can be located anywhere.

Contrary to the WEG system, though, the number of suppliers that sell the equipment for this system is limited, thereby increasing maintenance costs. Also, since the exhaust gas is passed through the water bath, it becomes acidic.

The water must be treated before disposal. The cost of treating and disposing of the effluent water could offset some of the savings gained through lowering the amount of fuel gas consumed.

Fuel cost for this system is still high compared to other available systems, since about 1.4 percent of the send-out gas is consumed, and the possibility of incurring emission costs is created.

Moderate and low: The sea water vaporizers and heating tower options have low operating costs but moderate capital costs. In a sea water vaporizer, sea water - used as the heating medium - flows down on the outside of tubes in which LNG is flowing bottom to top.

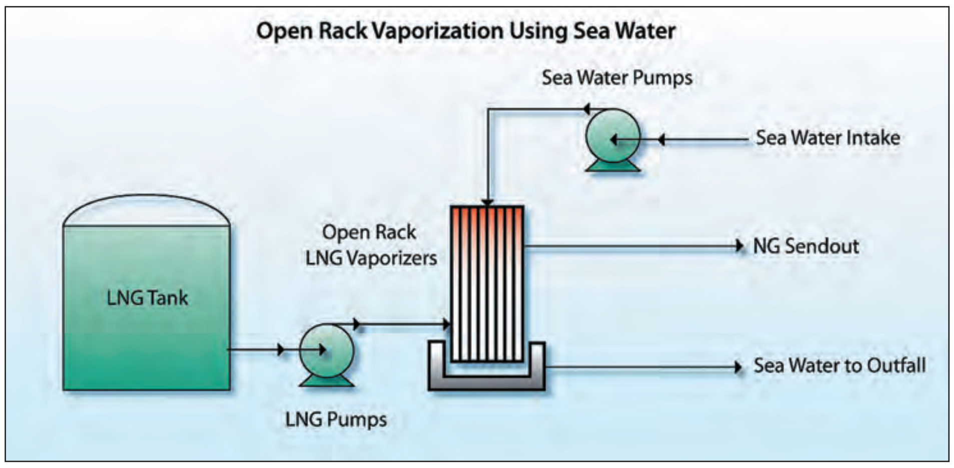
The sea water is collected in a basin and returned at 45° F minimum. The approximate flow of sea water required is 160,000 gallons per minute (gpm). Therefore, use of this system is dependent upon an ample supply of sea water.

Sea water vaporizers have low operating costs because they require no natural gas fuel consumption and have no emissions. However, they are climate sensitive.

While they are ideally located in warm climates, in some instances they can be used in colder climates if using the system for eight months per year is economically attractive.

Offsetting the lower operating costs of this system are possible environmental costs, depending on environmental regulatory requirements and any required treatment of the sea water before it is returned to the sea.

Figure 3 - Sea water vaporizers using open rack heat exchangers.



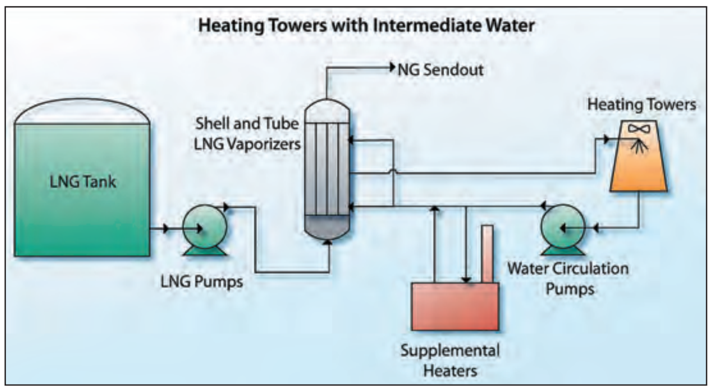


Figure 4 - Heating towers using intermediate water and supplemental fired heaters for cold weather.

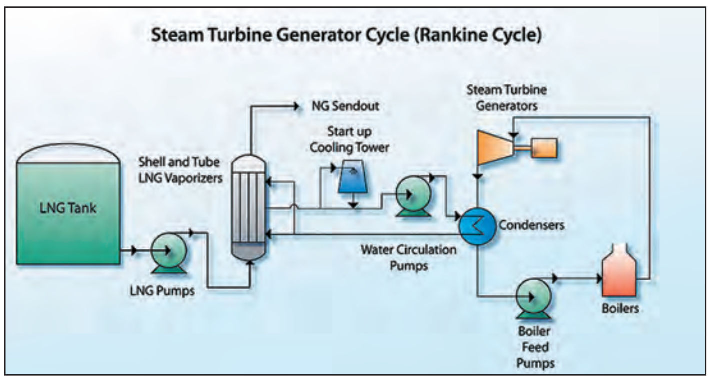


Figure 6- Rankine Cycle system, which uses exhaust steam to heat water.

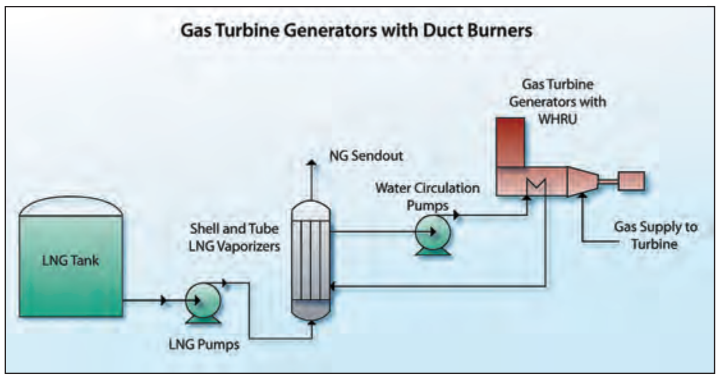


Figure 5 - Schematic of a gas turbine generator system with duct burners.

Similar to sea water vaporizers, heating towers are climate sensitive and found primarily in warm climates.

Heating towers use a water loop configured with circulating pumps. The discharge from the pumps is sent to the vaporizers where it is cooled to 40°F to provide the heat needed to vaporize the LNG.

The system is designed for a minimum wet bulb temperature of 65°F.

On days when the wet bulb temperature is lower than 65°F, supplemental heat must be added to the system from fired heaters. The tower fans operate only when the wet bulb is above 45° F.

For the purpose of the study, it was assumed that the fired heaters would provide roughly 20 percent of the total yearly heat required.

Fuel consumption for heating towers is therefore more than that required for sea water vaporizers, but still very low compared to other systems.

Emissions are likewise low. Capital costs are moderate compared to other systems. While the heating tower design provides many advantages, the concept has not yet been proven viable.

Capital cost: The capital cost of both gas turbine generators and steam turbine generator cycles are high compared to other regasification systems included in the study.

Both require a power plant to be constructed along with the terminal. Maintenance costs are also high, due to high-speed rotating equipment that require more care, and the possibility of incurring emissions costs is created.

The main emissions of concern are NO_x, CO and CO_2.

However, both systems offer the terminal owner the advantage of producing power as a byproduct of the vaporization process.

By selling the power produced to a local utility, the terminal owner can offset a significant portion of the cost of operating the facility, thereby lowering total operating costs.

Also, since the terminal produces its own power, it can continue to send out gas if the local electric power grid is down. These systems are not climate sensitive and can be located anywhere.

Gas turbine generator systems with waste heat recovery units heat water to 300°F and then circulate it to vaporize the LNG.

Once the circulated water cools to 200°F, it is reheated by the exhaust of the gas turbines.

When duct burners are used with four gas turbines, 107 megawatts (MW) of total electric power is produced. From this, 86 MW of excess power is available to be sold to an electric utility.

When duct burners are not used, seven gas turbines are installed to produce a total of 188 MW of power, producing 168 MW of excess power to sell to a utility.

In a steam turbine generator cycle system, also known as a Rankine Cycle system, water is heated to 90° F and circulated to vaporize the LNG.

Once the circulated water cools to 50° F, it is used to condense exhaust steam, which in turn heats the water back to 90° F. The steam cycle can produce 91 MW total electric power.

Of this total, approximately 65 MW is excess power that can be sold to an electric utility.

Thus, while gas and steam turbine generator systems have high maintenance costs, the potential of high emission costs and a high capital expense, they also have the advantage of offsetting their operating costs by selling excess power back to an electric utility and are not climate sensitive.

It should be noted that the Rankine Cycle has not yet been proven in LNG regasification systems; however, the components are widely used in other applications.

Optimal system

Because energy costs are a large factor in determining which regasification system is the most economically attractive method for vaporizing LNG, capital costs should be analyzed in conjunction with energy costs over the life of the plant.

By making this comparison, the optimal economic option can be selected.

The WEG system and the submerged combustion vaporizers compete much more favorably in terms of capital cost. When these systems are considered, a careful analysis should be made regarding the cost of fuel over the life of the plant and the impact, if any, of emissions control.

For the submerged combustion vaporizer, the cost associated with the treatment of effluent water must also be evaluated.

Sea water vaporizers and heating towers are attractive because they have lower operating costs over the life of the plant.

However, the cost of installing these systems can be moderately expensive, and the heating tower system has not yet been proven viable.

Gas turbine systems are favorable when power costs are high. However, when gas costs are also high, the operating costs of these systems become less favorable. In addition, the high capital costs of these systems may make them less attractive.

In the study conducted, the system that provided the best results over the life of the plant was the Rankine Cycle system.

Compared to fired vaporization systems, the economics for the Rankine Cycle are favorable over a broad range of energy costs.

Only when gas costs are high and power costs are low are the economics not as favorable.

In addition, the ability to sell the excess power to a utility must be available to achieve the favorable results indicated.

Generally, the economics of these systems remain favorable when the ratio of gas cost to power cost ($ per MMBtu/$ per KW-hr) is equal to 100 or less.

However, as gas prices recently have reached $7 per MMBtu, the economics have become less favorable. Still, if this concept is ever developed, under the right circumstances, it may prove to be the optimal solution.

As seen through this evaluation, the circumstances differ for every import terminal and its unique operating and delivery parameters.

While it is recognized that there are many variations to the six idealized regasification systems analyzed here - such as using sea water direct instead of an intermediate fluid or cooling the inlet air of a power turbine - the methodology is still useful.

An evaluation of both the capital and energy costs over the life of the plant is a valid methodology for determining the optimal regasification system to use when designing a new LNG import terminal. ■