US company Ebara outlines designs and uses of pumps for the heart of global LNG industry

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It is asserted that pumps are the second most common machines on earth, second only to electric motors.

Whether this is true or not, it is human nature for us to take them for granted, to think of all pumps as similar.

In fact, pumps are so ubiquitous that many people are unaware of the significant role they play in the industries which profoundly affect our lives. There are so many configurations of pumps that entire books have been written to explain them.

Designs

Once the most beneficial features have been worked out for the wide variations of pump applications, industries lock in on the best designs, while the pump manufacturers keep busy optimizing reliability, performance, cost, lead-time and support.

It is a remarkable and fascinating business.

The LNG Industry is special in many ways. It certainly requires some of the most unusual and specialized pump configurations of all.

LNG pumps apply unusual materials, mount the pump and motor on a common shaft and then completely submerge the pumps in a hydrocarbon.

At first glance, this sounds outrageous. Although counter intuitive, this is absolutely the safest way to pump LNG.

Centrifugal

Typical centrifugal pump units couple a pump, or wet end, to an electric motor. The standard pump must have a shaft seal to allow the shaft to extend outside of the pump casing and couple to a motor.

Seals are susceptible to failure and the safety issues become readily apparent. The piping to an external pump, the pump seals and the prospect of leaking LNG to atmosphere are all unacceptable risks.

Since LNG is dielectric, the best method for safe pumping is to completely submerge the combined pump and motor in the LNG.

The unit is then isolated from any oxygen, motor gaps and voids are filled with LNG and the need for seals or couplings is completely eliminated.

The system is intrinsically safe. This technology was first applied in 1961 and has been the prescribed pump configuration for LNG ever since.

Achieving the safety benefits with a submersible pump is the primary design goal, but this is only one aspect of the challenges faced with pumping LNG at cryogenic temperatures or approximately minus 120°C.

Typical pump materials, usually metals, cannot provide the properties needed for LNG. Rather than utilize materials such as iron or steel, LNG requires aluminum for casings, housings and many rotating components.

This is not a totally foreign material for all but a few pump manufacturers and it is rarely seen in the process industries.

Standards

If you refer to the ANSI/API Standard 610 for Centrifugal Pumps, the cornerstone of hydrocarbon pump standards, you will see Table H1 defines some 14 classes of different materials for pump parts.

There is no mention of aluminum. Unique to cryogenic liquefied gas pumps, aluminum is the preferred material for LNG. It can be cast in the complex geometries required for the designs and the enhancement of manufacturing.

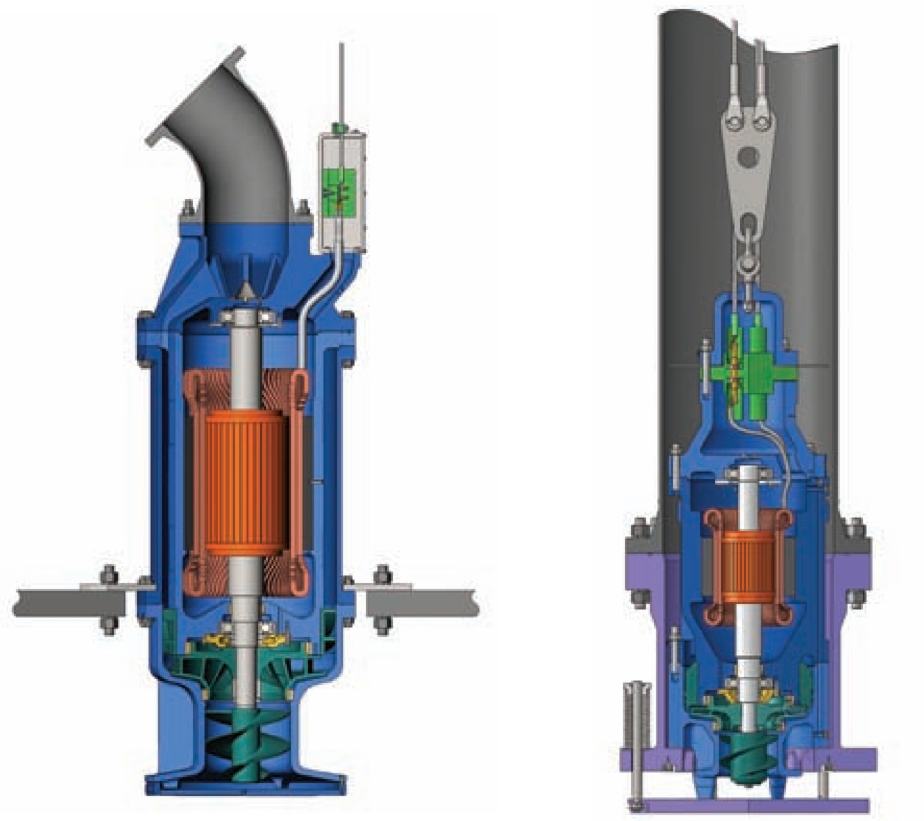
Aluminum yield-strength actually increases as the temperature decreases, while not becoming brittle. It is corrosion resistant with thermal expansion properties which maintain exact fits and clearances in temperatures ranging from tropical ambient to the extremely cold installed pump environment.

Aluminum pump components, especially those which cast at foundries and designed to provide pressure containment, are relatively oversize and expensive compared to typical centrifugal pump components.

Bearings

LNG pump bearings are also a specialized and important design focus. The typical sealed bearing is not suitable for the LNG environment. Grease would freeze instantly at minus 120°C.

Therefore, open cage product lubricated bearings are applied, with a small amount of LNG directed to the bearings for both lubrication and cooling.



The cargo pump (left) and retractable pump (right) as designed by Ebara

As LNG has a very low viscosity, early LNG pump developments used angular contact bearings which were disappointing, with premature bearing degradation.

The evolved use of deep-groove radial bearings has proven successful and is now typical for all manufacturers. In recent years, hybrid bearings using ceramic balls have been effective for certain applications such as methane wash, with even lower viscosity than LNG.

Full speed

Axial loads are well managed with these bearings, but the low viscosity of LNG was a problem for thrust bearings.

To solve this, pump manufacturers successfully set about providing thrust balancing mechanisms to reduce the thrust loads on their bearings.

There are several techniques which have provided improved reliability and on-line pump availability as well as maintenance economics demanded by the industry. The typically clean, always cool LNG environment is excellent for close-tolerance tight fit cryogenic submersible pumps.

With average centrifugal pump applications, motors are usually rated below 75kW, but LNG applications generally have large capacity and often high head (pressure) requirements.

These ratings demand large motors often rated upwards of 500kW, with many high-pressure applications over 2000kW.

It is interesting to note that these power requirements are in spite of the motors driving pumps designed explicitly for low specific gravity LNG.

As power requirements to drive a pump are directly proportional to the specific gravity of the fluid, LNG with a specific gravity of approximately 0.50 requires one half the power of an identically performing water pump.

As you can see, a 2000kW LNG pump is a very substantial machine (See photo).

Testing

While addressing unique characteristics, another remarkable difference in the production of specialized LNG pumps is our methods for testing.

With LNG pumps being destined for installation at multi-billion dollar facilities or aboard ships for long voyages, it is essential that every pump be fully tested. Although most generic centrifugal pumps do not require factory tests, many industrial process pumps are tested as required by the customer.

Virtually all centrifugal pumps, even refinery pumps, are tested using water. Once again, the singular exception is found with LNG pumps. This is very major distinction.

As discussed earlier, LNG pumps are designed for 0.50 Specific Gravity fluid. To perform a full-speed test using water would require the transmission of twice the power, meaning the pump shafts, bearings and all components would be designed and enlarged to pump water.

This would be an untenable waste. Besides, the pump materials used are not appropriate for water and the potential for trapped water to eventually be exposed to cryogenic LNG would be potentially dangerous.

Stands

LNG pumps are actually tested using expensive and sensitive LNG. Rather than operate a typical pump test stand with economical water in a water pit with a closed-loop test stand, pump manufacturers operate their test stands with miniature process plants including pressure vessels, storage tanks for methane, propane (LNG) as well as heat exchangers and nitrogen tanks for keeping the liquefied gas at required cryogenic temperatures.

Boil-off gas, or vaporized LNG, is substantial and is eventually flared. Large pumps can require a literal fleet of nitrogen and LNG tank trucks on hand to support a series of tests.

The nitrogen is for cooling and the LNG is for proving the pumps' capabilities in conformance to our customer's specifications.

With multiple guaranteed rating points along the required performance curve, plus NPSH and drawdown tests, it is not unusual for a pump test cost to exceed $50,000 or even $100,000, multiplied by the number of pumps being tested for an individual contract.

Supply chain

With the advent of Floating LNG, whether considering a Floating Production Storage Offloading (FPSO) vessel or a Floating Storage Regasification Unloading (FSRU) vessel, there are now four possible facility segments in the global LNG supply chain:

1) Liquefaction/Export
2) LNG Marine Carrier
3) Regasification/Import
4) FLNG, which replaces either Liquefaction/Export or Regasification /Import.

The submersible pumps which are applied to these segments of the LNG supply chain each have characteristics specific to their use, but they all share common characteristics for providing inherent safety in these demanding services.

LNG is an inert liquid, void of oxygen and non-conductive. To completely immerse the pump in this liquid is inherently safe. Furthermore, the combining of the pump and motor on a common shaft eliminates misalignment potential as well as the need for rotating seals.

Leakage is not an issue. Oxygen is not present in LNG. Also, typical concerns for heat dissipation or motor temperature rise are negated through the cryogenic environment, with LNG actually passing through the bearings and motor windings assuring a cool, clean and longevity enhancing environment for the machine.

Shipboard pumps

Considering specific applications, shipboard units include three or four types of submersible pumps.

The cargo pumps are used to offload LNG upon arrival at the import terminal. These pumps need to offload the LNG carrier quickly and efficiently to allow the ship to return for the next load of LNG. Offloading is usually accomplished within 12 hours.

Also, these pumps are designed to draw down the tank liquid to extremely low levels, leaving as little LNG in the tank as possible.

Primary

This is a primary goal of the manufacturer to reduce the undesirable remnant LNG from being returned to the source, rather than efficiently delivered as usable LNG cargo.

These pumps are installed in a stationary position and are removed during scheduled drydock maintenance, often for inspection without need for maintenance. Maintenance is usually limited to bearing and wear ring replacement.

All LNG carriers also carry what is called an "emergency" pump. In the unlikely event of a cargo pump failure, the emergency pump can be applied to empty stranded LNG from a tank.

An emergency pump deployment has not taken place during the 40-year history of LNG shipping.

Other onboard pumps are the spray pumps which spray LNG onto the inside top of the cargo tanks to help keep them cold and reduce boil-off gas vapor.

Lastly, but of increasing importance, fuel pumps feed the ship engines with clean, efficient LNG.

This is a growing LNG application for all configurations of new ships which is lauded for reducing the carbon emissions from the tremendous number of ocean vessels, especially as compared to diesel-powered vessels.

Land plants

Land-based liquefaction plants clean and liquefy natural gas for storage and ship loading for export.

Each plant has unique characteristics depending on the processes being applied, the size and location of the plant, the source and chemical makeup of the natural gas.

Liquefaction plants are located in many countries and continents ranging from Australia, Qatar, Sakhalin Island, Africa and even above the Arctic Circle in Norway. The varying challenges in designing and constructing these plants are remarkable and represent some of the greatest industrial accomplishments of mankind.

The pumps are a major contributor to the effectiveness of these huge investments. Storage tanks, whether in Nigeria or Norway, require pumps capable of being safely installed and removed as necessary, without emptying or decommissioning the immense tanks.

Where shipboard cargo pumps are stationary, storage tank, or "In-Tank" pumps are retractable, employing a system to insert the pumps into a stationary column which is almost, within millimeters, as deep as the tank itself.

The large high-pressure pump can be used for send-out or vaporizer feed

The weight of the pump pushes on a spring-loaded suction valve which opens to allow the column to be flooded with LNG.

Capacity

The pump then generates the required capacity and head to discharge LNG to the ship loading arms at the shoreline jetty.

For maintenance, when the pump is lifted from above, the suction valve closes and is sealed, allowing the column to be purged with inert nitrogen.

The pump is then safely removed for inspection and maintenance, as required. Since the pumps are installed and removed through the top of the tanks, all peripheral tank connections which would otherwise be required are safely eliminated.

This allows the integrity of the tanks to be enhanced by removing any potential for leaks from connections. This feature also allows tanks to be located below ground level, if required.

The last major configuration of pumps used for large-scale LNG facilities are the high pressure pumps for send-out or vaporizer feed.

These pumps are extremely powerful, with flow ratings as high as 3000 m3/hr (1100 gpm) with heads as high as 3,300 meters.

These pumps are completely contained in a pressure vessel built to the appropriate codes as specified. These pumps often operate 24/7 for prolonged periods.

Reliability is essential for the constant delivery of LNG being transformed back to a gaseous state for pipeline delivery to natural gas users.

These pumps are often mated with variable speed drives to enhance flexibility and optimize pump performance by varying the pumps speed with complete control.

Propagating

Floating LNG facilities, which are propagating as both import facility vessels and now liquefaction facility vessels, use all combinations of the pumps described.

There are some unique issues which apply to these pumps, including marine Class Certifications, shipboard retraction systems and sometimes stability enhancements to meet the demands of floating facilities enduring major storms.

Radial and axial forces due to the roll, pitch and yaw dynamics are important to understand and must be carefully accommodated in the design and installation.

Marine pump experience and references are very helpful to the manufacturers who are serving the FLNG movement.

Conclusion

This is an abbreviated explanation of LNG pumping and many details are omitted.

Regardless of our individual role in the industry, it is interesting to appreciate the many people, machines and disciplines which are orchestrated to fulfil the overall mission.

People devoted to the LNG pump industry are particularly proud of their role, especially with the need for unique designs and features to meet the exceptionally demanding requirements.

Safety, quality, performance and reliability are our goals. Whether serving clients on land and sea or engineering contractors or shipbuilders, providing exceptional service is our paramount mission. ■

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