Two-Phase LNG Expanders, a New Integral Part of the Liquefaction Train

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Five years of successful field operation of two-phase expanders designed and manufactured by the Cryodynamics Division of Ebara International Corporation (EIC) usher in the next evolution in liquefaction train technology.

In the early days of gas liquefaction technology it was recognized that two-phase cryogenic expanders would improve the thermodynamic efficiency of gas liquefaction processes. Carl von Linde described the advantages of two-phase expansion engines more than a century ago. Two-phase expanders expand static energy, in the form of the available pressure differential, from the liquid phase into the liquid-vapour phase across the saturation line of the fluid. The enthalpy of the liquefied gas is reduced significantly more than it would be with single phase expanders due to the vaporization heat extracted from the liquid portion of the two-phase fluid. In addition, by replacing a Joule-Thomson (J-T) valve with a Two-phase expander to accomplish the two-phase expansion in a liquefaction train, a more efficient process and an even greater liquid temperature decrease is achieved.

Two-phase expander design concepts fundamentally follow the existing single-phase expander technology. The hydraulic energy of the pressurized fluid is converted by first transforming it into kinetic energy, then into mechanical shaft power and finally to electrical energy through the use of an electrical power generator. The generator is submerged in the cryogenic liquid and mounted integrally with the expander on a common shaft. The cryogenic induction generator uses insulation systems specifically developed for cryogenic service giving submerged windings significantly superior dielectric and life properties. Thrust balancing and bearing lubrication is achieved by an internal system which utilizes a small portion of the liquid passing through the expander and routing this through a variable orifice and the bearings.

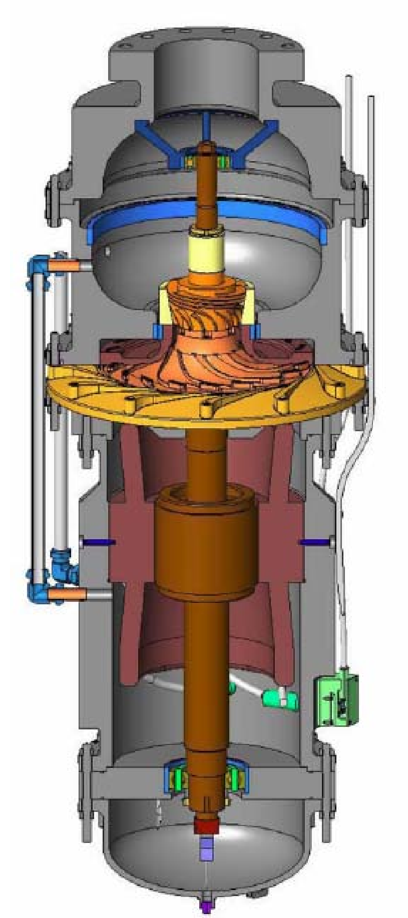

Fig. 1: Cross-section of EIC's two-phase submerged expander

Figure 1 shows the cross section of a typical EIC cryogenic two-phase submerged expander. The expander consists of a nozzle ring generating the rotational fluid flow, a radial inflow reaction turbine runner and a two-phase jet exducer. Symmetrical flow is achieved in the two-phase expander by utilizing a vertical rotational axis to stabilize the flow and to minimize flow induced vibrations, with the direction of flow being upward to take advantage of the buoyant forces of the vapour bubbles. (Expanders with horizontal rotational axis generate asymmetric flow conditions which can result in higher vibration levels). The hydraulic assembly is designed for continuously decreasing pressure to avoid any cavitation along the two-phase flow passage. Figure 2 (a) and (b) show the solid model and actual hydraulic assembly of EIC's two-phase expander respectively.

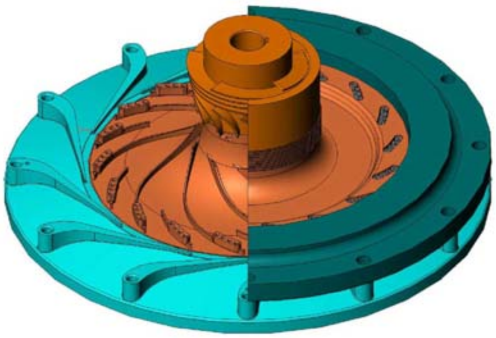

Fig. 2 (a): Solid model of hydraulic assembly with cut-away

Fig. 2 (b): Machined hydraulic assembly

Two EIC two-phase expanders have been installed and successfully operating in two liquefaction trains for the past five years at Polskie Górnictwo Naftowe I Gazownictwo S.A. (PGNiG) Nitrogen Rejection (NRU) plant in Odolanow, Poland. Figure 3 was taken during installation of one of the machines. Due to a change in feed gas composition the expanders were installed as replacements for J-T valves with the purpose of achieving lower temperatures and maintaining plant stability.

Fig. 3: Installation of EIC two-phase expander

The two-phase expanders operate at variable speeds in order to adjust to the changing mass flows and pressure conditions of the plant. Figure 4 presents the hydraulic performance of the two-phase expanders. At the duty point, the estimated hydraulic power to be extracted by each two-phase expander was 65kW. The actual power extracted from the turbine generator into the grid was between 80 and 85kW. This clearly demonstrates that the gas expansion energy was being utilized effectively. When calculating the overall expansion, thermodynamic efficiency, the value was found to be relatively low (below 60%) compared with the large single phase gas expanders of today which regularly achieve over 80%; however, this is a small machine where friction losses are high in proportion to the flow and these losses reduce in significance as such machines increase in scale.

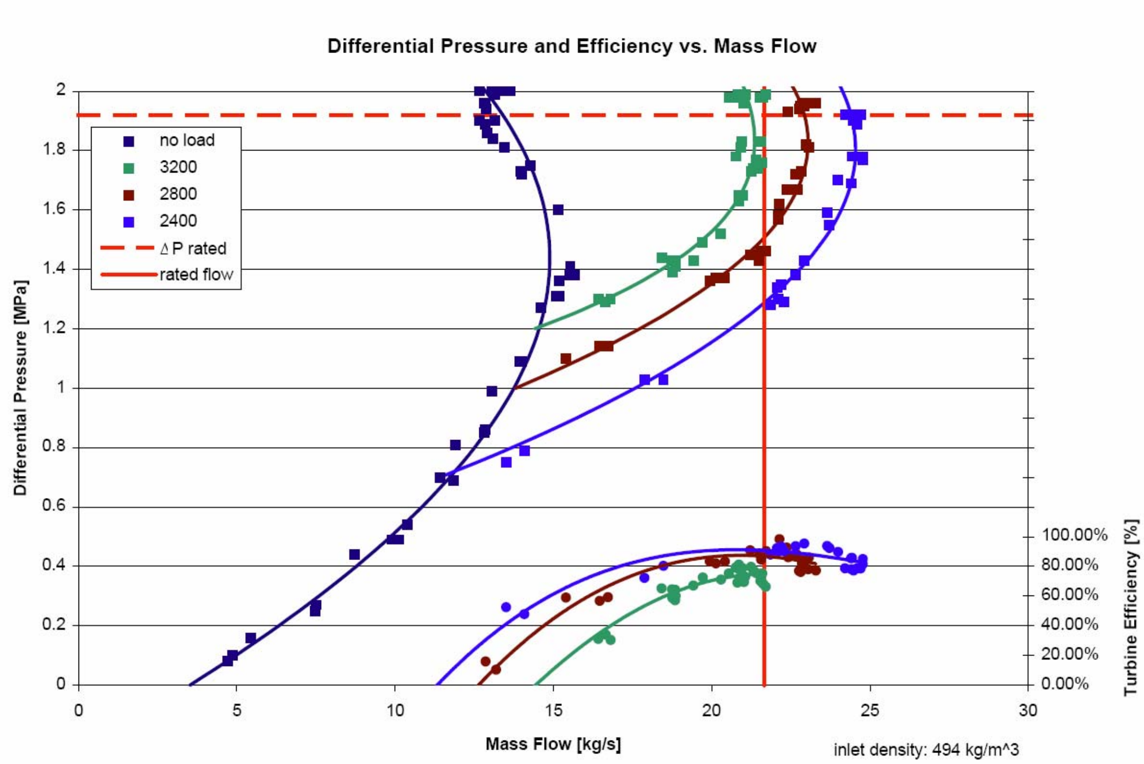

Fig. 4: Actual two-phase expander performance

Based upon the operational experience of the two-phase expanders at the PGNiG NRU plant several statements can be made.

The expanders require little modification of the existing equipment and consequently their installation is simple and retrofitting can be done very quickly. The machines are surprisingly quiet with noise levels during operation of the two-phase expanders averaging below 80dB. In addition, throughout operation, regular inspections showed no incipient failures in the bearings or materials and vibration levels have been less than 20% of API 610 allowable limits.

The two-phase expanders have made the process flexible in terms of adjustment to changing mass flows which vary up to 100%. Even with these considerable changes in the mass flow the expanders assure easy and precise regulation of liquid level in the lower columns of both trains, which is of fundamental value for a stable running process. One of the most significant benefits of the two-phase expander operation has been the enormous flexibility that the plant now has. The process is easy to operate and is controllable with no danger of shut-down, even with considerable changes of feed gas parameters.

Cooling the liquid feed to the upper column is significantly more efficient using two-phase expanders rather than single-phase expanders or other devices such as J-T valves. Figure 5 presents the LNG temperature drop versus the power output for one of the two-phase expanders. The cooling effect on the LNG stream is seen to be directly related to the power output.

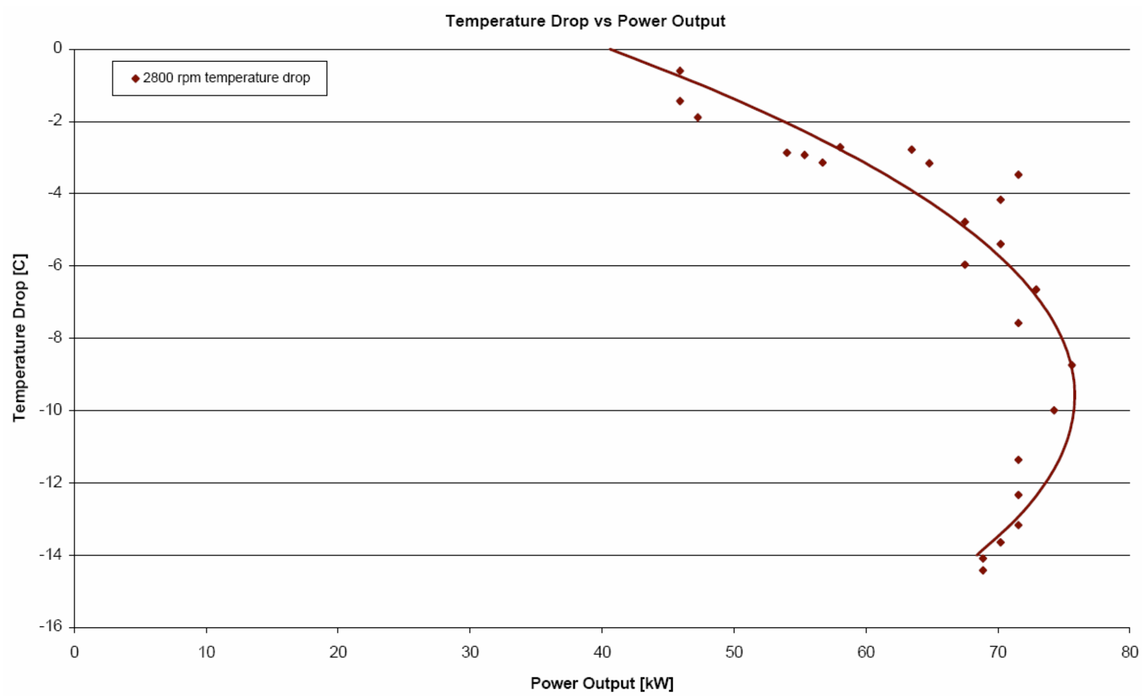

Fig. 5: Temperature verses power output of two-phase expander

Due to this greater temperature difference achieved by the two-phase expanders in comparison to the original J-T valves, the heat exchangers operate in a more efficient and flexible way resulting in the production of colder waste gas temperatures leaving the upper column than was previously possible. This, in turn has the effect of reducing the methane content of the waste gas which is both environmentally and economically beneficial.

The PGNiG facility also has the capability to produce either liquid nitrogen or LNG for sale to third parties. With the two-phase expanders operating there is a significant increase of up to 250% in LNG output from the NRU compared to when Joule-Thomson valves were in operation. Alternatively, the plant is able to produce similar quantities of liquid nitrogen for export due to the utilization of the expanders.

Finally, employing the two-phase expansion turbines in the liquefaction train generates electrical energy which can be exported or used as drive power for another duty, thus increasing overall plant efficiency.

Installation of these two-phase expanders fulfilled and in some instances exceeded the initial design expectations. Two-phase expanders improved operational stability, allowed greater LNG or liquid nitrogen production and increased overall plant on-line time. The result of operating the two-phase expanders at PGNiG offers a persuasive example of the significant benefits that this two-phase expansion technology provides. Integration of two-phase expanders is already revolutionizing the liquefaction trains at PGNiG.