

ECONOMIC AND ENVIRONMENTAL BENEFITS OF TWO- PHASE LNG EXPANDERS

AVANTAGES ECONOMIQUES ET ENVIRONNEMENT AUX DES DETENTEURS BIPHASIQUES DE GNL

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ABSTRACT

LNG liquefaction plants have a complex structure with numerous systems interacting to produce the desired output. Capital investment, operational costs and environmental burden of these plants are relatively high. These high economic demands have initiated new and additional efforts to reduce the costs and the environmental impact of natural gas liquefaction plants.

The conventional liquefaction process for natural gas is to operate at high pressure through the condensation phase, after which the high pressure of the liquefied natural gas is reduced by expansion across a Joule-Thomson valve. All LNG plants commissioned before 1996 are operating with an inefficient expansion valve. By replacing the existing JT-valve with a cryogenic LNG liquid turbine to expand the condensed liquefied natural gas from high pressure to low pressure the thermodynamic efficiency of the existing refrigeration process is substantially improved resulting in an increase of the total LNG output between 3 to 5%. These innovations are already applied to new LNG liquefaction plants in Oman and Malaysia and the attained economic and technical benefits are convincing.

The next step of economical improvement in LNG liquefaction is the most recent development of two-phase LNG expanders. Since the early days of the cryogenic industry it is known that two-phase cryogenic liquid expanders would improve significantly the thermodynamic efficiency of a gas liquefaction process.

Only in recent years has the mechanical and electrical technology become available to build and operate reliable cryogenic two-phase expanders capable of expanding LNG partially into the vapor phase. This paper presents a new generation of cryogenic two-

phase LNG expanders. It discusses the economic and environmental benefits, the interaction of these two-phase expanders with the liquefaction process, and the added advantage for nitrogen removal. Two-phase LNG expanders compared to conventional JT valve expansion increase the total LNG output between 5 to 8%.

RESUME

Les usines de liquéfaction de GNL sont des structures complexes comportant de nombreux systèmes reliés les uns aux autres pour produire le débit souhaité. Les investissements en capital, les coûts d'exploitation et la charge environnementale de ces usines sont en conséquence relativement élevés. Ces exigences économiques importantes ont donné naissance à de nouveaux efforts supplémentaires entrepris dans le but de réduire les coûts et l'impact environnemental des usines de liquéfaction de gaz naturel.

Le processus de liquéfaction conventionnel du gaz naturel consiste en une exploitation à haute pression pendant la phase de condensation, après quoi la haute pression du gaz naturel liquéfié est réduite par la détente au travers d'une vanne Joule-Thomson. Toutes les usines de GNL mises en service avant 1996 fonctionnent avec une de ces vannes de détente. En remplaçant les vannes JT existantes par une turbine cryogénique de GNL pour détendre le gaz naturel liquéfié condensé, l'efficacité thermodynamique du processus de réfrigération existant s'en trouve sensiblement améliorée et résulte en un accroissement du rendement total de GNL allant de 3 à 5 %. Ces innovations sont déjà mises en œuvre dans les nouvelles usines de liquéfaction de GNL en Oman et en Malaisie et les avantages économiques et techniques obtenus sont d'ores et déjà convaincants.

L'étape suivante d'amélioration économique dans la liquéfaction du GNL est le développement plus récent de détenteurs biphasiques de GNL. Depuis le début de l'ère de l'industrie cryogénique, il est évident que les détenteurs liquides cryogéniques peuvent améliorer de façon significative l'efficacité thermodynamique du processus de liquéfaction de gaz. Depuis quelques années seulement la technologie mécanique et électrique est-elle disponible pour construire et exploiter des détenteurs biphasiques cryogéniques fiables capables de détendre partiellement le GNL en phase vapeur. Cette publication présente la nouvelle génération de détenteurs biphasiques cryogéniques de GNL. Elle présente aussi les avantages économiques et environnementaux, l'interaction des détenteurs biphasiques avec le processus de liquéfaction et les avantages supplémentaires enregistrés pour l'élimination de l'azote. Les détenteurs biphasiques de GNL accroissent le rendement total de GNL entre 5 et 8 % par rapport à la détente avec des vannes JT conventionnelles.

INTRODUCTION

The conventional liquefaction process for natural gas is to operate at high pressure through the condensation phase, after which the high pressure of the liquefied natural gas is reduced by expansion across a Joule-Thomson valve. In a typical pressure reduction process the condensed fluid is flashed isenthalpically across the pressure letdown valve into a phase separator vessel [1]. The turbulent friction losses in a pressure drop across a Joule-Thomson valve are very high and energy is wasted in frictional heating of the fluid.

By contrast, a two-phase expander provides a compact step in which shaft power is generated from a near-isentropic expansion process. This means that the frictional heating in the process is kept to a minimum [2]. Substitution of Joule-Thomson valves by two-phase flow expanders in refrigeration applications generates power from previously wasted two-phase energy [3].

Further applications of two-phase expanders are in cryogenic distillation processes. Nitrogen dissolved in pressurized LNG degrades the quality of the LNG. By expanding the low grade pressurized LNG across a two-phase expander the Nitrogen is extracted from the LNG by vaporization and reduces the temperature of the remaining LNG. This Nitrogen rejection process is in principle a cryogenic distillation to upgrade the quality of the LNG and to increase the LNG production through temperature reduction [4].

DESIGN CONCEPTS

The design concepts of two-phase expanders follow essentially the existing technology of turbines and expanders. The hydraulic energy of the pressurized fluid is first transformed into kinetic energy and then into mechanical shaft power. The mechanical shaft power is converted to electric energy by an electrical power generator [2].

There are two basic concepts for the electrical power generator in cryogenic technology. The generator is externally cooled, mounted outside the cryogenic liquid and coupled to the expander described in details by T. Bond [3], or the electric generator is submerged in and cooled by the cryogenic liquid and mounted integrally with the expander on one shaft [4]. Cryogenic induction generators have special developed insulation for the submerged windings [5].

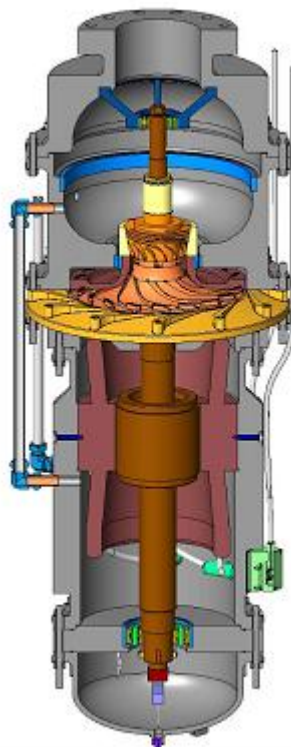


Figure 1. Ebara Two-Phase Expander Cross Section

Figure 1 presents a cross section of the two-phase expander submerged in the cryogenic fluid from Ebara International Corporation. The particular design shows the induction generator and the hydraulic expander mounted on one shaft. The hydraulic expander consists of the nozzle ring generating the rotational fluid flow, the radial inflow reaction turbine runner and the two-phase jet exducer. Figure 2 shows the enlarged cross section of the two-phase hydraulic runner assembly.

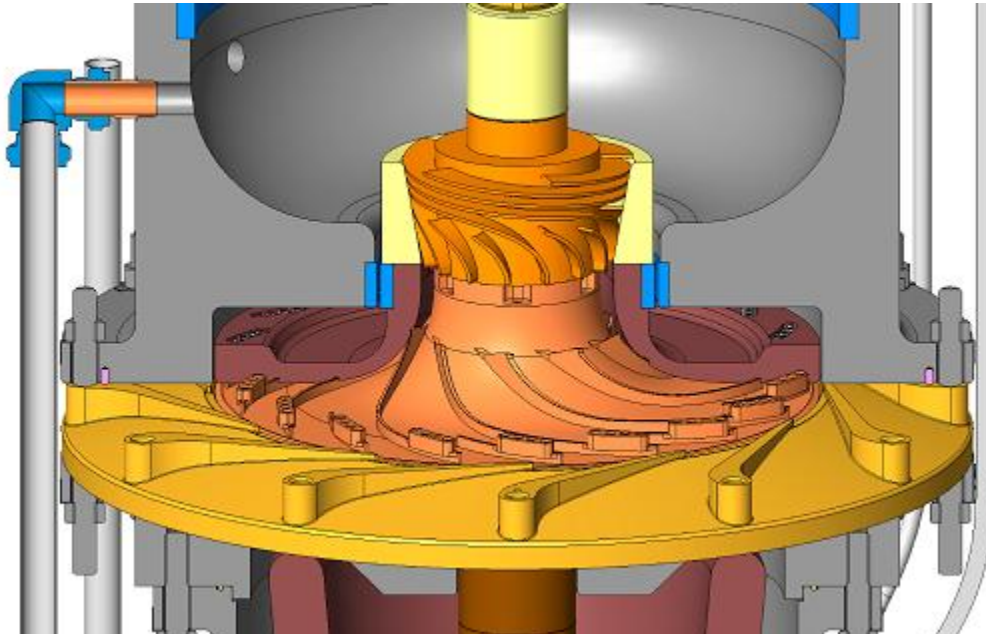


Figure 2. Two-Phase Hydraulic Runner Assembly

The Ebara two-phase expander is mounted with vertical rotational axis to generate symmetric flow conditions. Two-phase expanders with horizontal rotational axis [1,2,3] generate asymmetric flow conditions and are inclined to higher vibration levels. The flow direction of the Ebara two-phase expander is upward to take advantage of the buoyant forces of the vapor bubbles, to stabilize the flow and to minimize flow induced vibrations [6]. The hydraulic assembly is designed for continuously decreasing pressure to avoid any cavitation along the two-phase flow passage [7].

FIELD OPERATION OF TWO-PHASE FLOW EXPANDERS

To upgrade the LNG by extracting the undesired high content of Nitrogen, two Ebara two-phase expanders were built and installed at the existing Nitrogen rejection plant of Krio Polish Oil & Gas in Odolanow, Poland. Figure 3 shows the assembled two-phase expander and Figure 4 the installation of the expander at the site in Odolanow.



Figure 3. Assembled Two-Phase Expander



Figure 4. Expander Installation

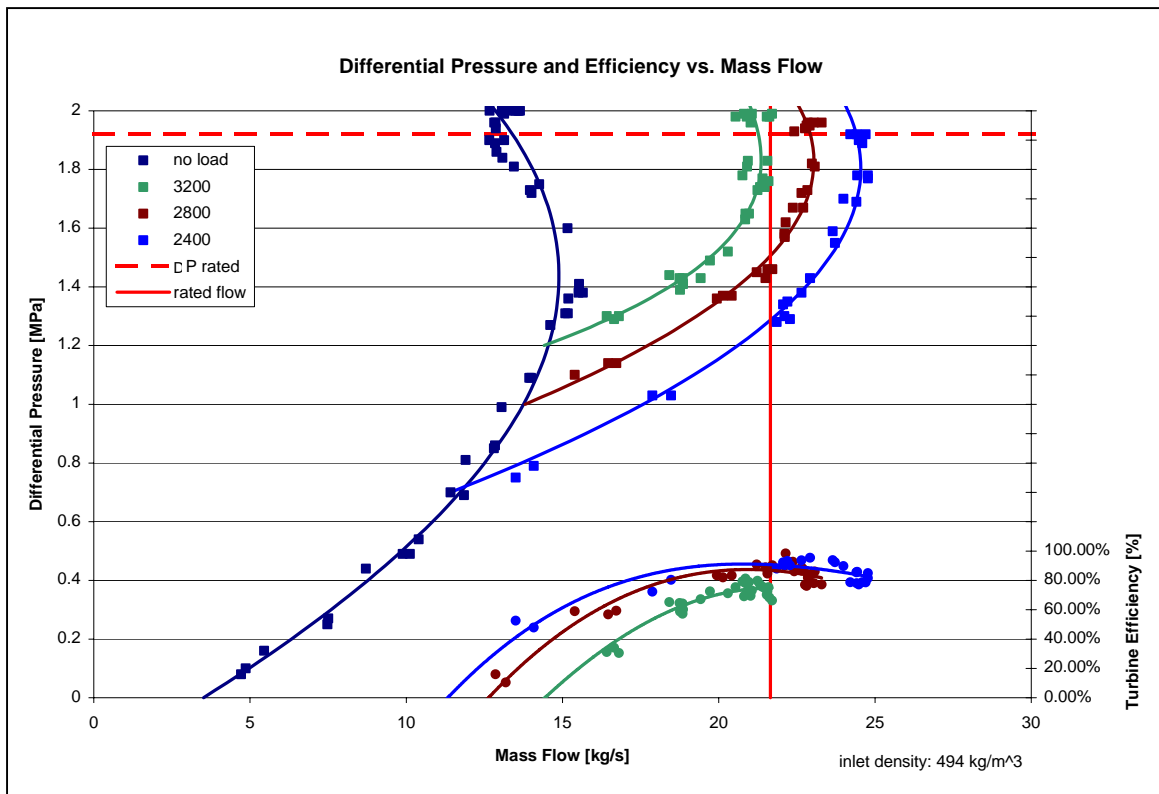


Figure 5. Two-Phase Hydraulic Performance

The two-phase expanders operate on variable speed to meet the changing mass flows and pressure conditions of the plant. Figure 5 presents the hydraulic performance of the two-phase expander with the differential pressure and efficiency versus mass flow for different rotational speeds.

The efficiency is defined as the ratio of electrical power generated over hydraulic power input. The hydraulic power input is the product of mass flow and differential pressure. The solid vertical line indicates the rated mass flow and the horizontal dotted line indicates the rated differential pressure.

Figure 6 presents the tested and measured points from Figure 5 but modified as the differential pressure and efficiency versus the volumetric flow. The specific volume of the fluid changes during the expansion process across the expander and is shown in Figure 7 as a quadratic interpolation between the inlet and outlet specific volume. The horizontal dotted line in Figure 6 indicates the rated differential pressure. The solid curve in Figure 6 indicates the rated volumetric flow. The rated volumetric flow is increasing with increasing differential pressure due to the expansion of the two-phase fluid.

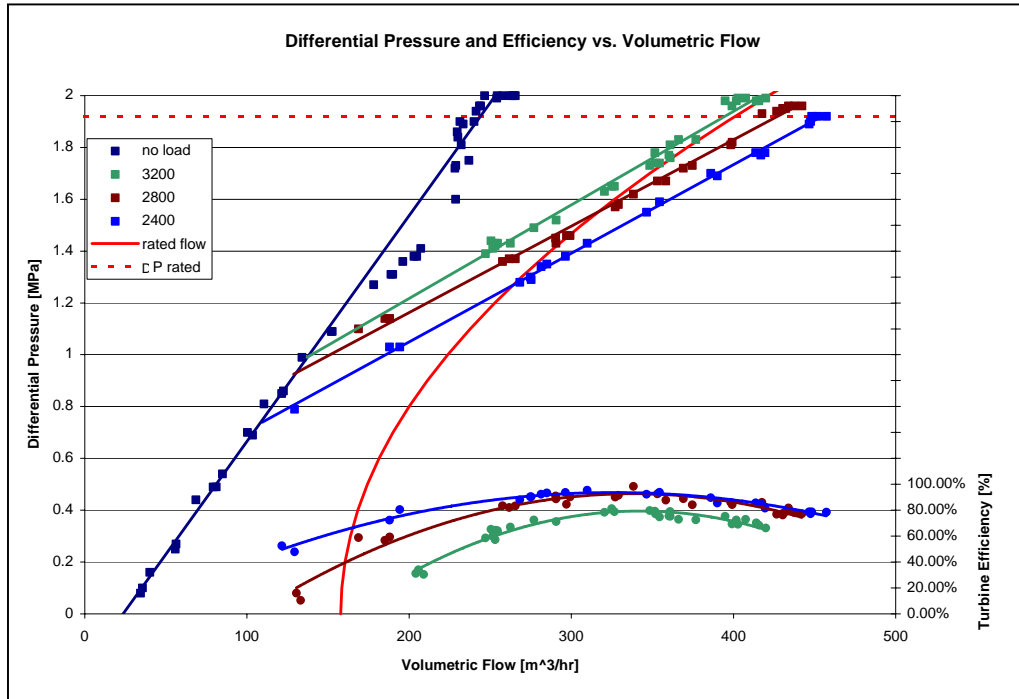


Figure 6. Two-Phase Hydraulic Performance

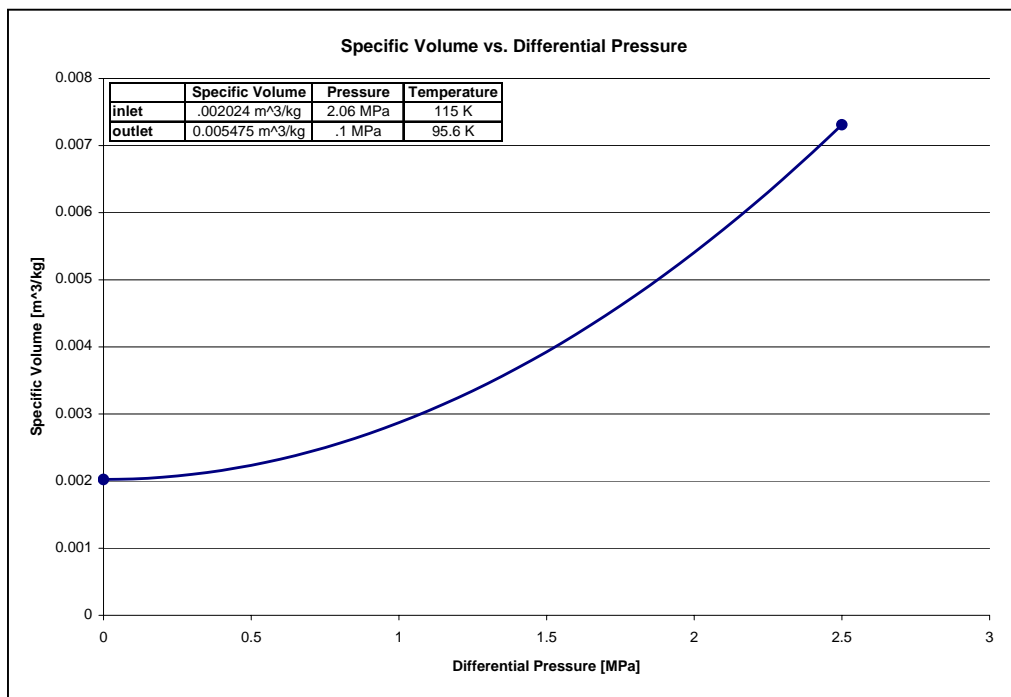


Figure 7. Two-Phase Flow Specific Volume

ECONOMIC AND ENVIRONMENTAL BENEFITS

The objectives of all developmental efforts in liquefaction process technology are to increase the economic benefits and to reduce the environmental impact of the LNG production. Replacing the Joule-Thomson valves with power recovery turbines for single-phase expansion or for two-phase expansion reduces the necessary plant power input by factors between 3 to 5 of the expander power output.

The cooling of the LNG stream is significantly more efficient using two-phase expanders instead of single-phase expanders. Figure 8 presents the LNG temperature drop versus the power output for the described two-phase expander. The cooling effect of the LNG stream is directly dependent on the power output.

SUMMARY

For over one year the Ebara two-phase expanders have been continuously and reliably operating at the Nitrogen rejection plant in Odolanow, Poland. Regular inspections show no failures in bearings or materials, the vibration levels are less than 20% of the API 610 allowable levels and the production of higher grade LNG with less power consumption is economically and environmentally beneficial.

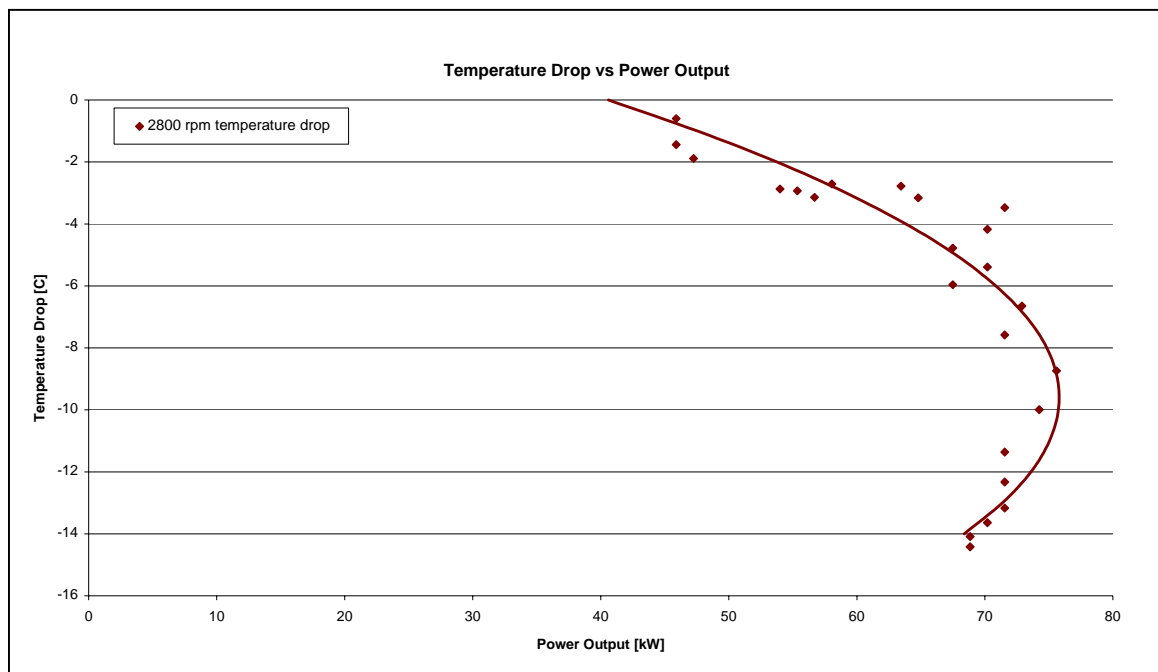


Figure 8. Cooling Effect of Two-Phase Expansion

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