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Research Paper

Novel mixed fluid cascade natural gas liquefaction process configuration using absorption refrigeration system

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HIGHLIGHTS

- Novel process configuration for large scale liquefied natural gas process.
- Replacement of vapor compression refrigeration cycles.
- Ammonia/water absorption refrigeration system.

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ABSTRACT

In this study, a novel process configuration for large scale natural gas liquefaction process is introduced and analyzed. This configuration is based on replacement of vapor compression refrigeration cycle by absorption refrigeration system. The required heat duty in the absorption refrigeration system is obtained by available waste heat in the plant. Process simulation is done by Aspen HYSYS software which is a conventional chemical process simulator. Coefficient of performance of the ammonia- water cycle is 0.48. Specific power consumption of the introduced process is 0.172 kWh/kgLNG which shows 30% reduction in the power consumption. The required heat transfer area of the modified process can be decreased up to 31%.

1. Introduction

Natural gas liquefaction is one of the two major industrial methods to transport natural gas besides using pipelines. In 2012, about 32% of natural gas imports are done by Liquefied Natural Gas (LNG) transportation [1,2]. Liquefaction process has a critical role in economic output of a LNG project. On the other hand, the most important issue in LNG plants is increasing the energy efficiency of the liquefaction processes. LNG technologies consume high amount of energy to liquefy and sub-cool the natural gas to temperatures under −160 °C. Most of this energy is related to the power of the compression refrigeration cycles (CRCs). Power needed to drive the cycle compressors is the main sink of energy in a LNG plant. A parameter of efficiency named specific power consumption (SPC) is defined to show the amount of the required power to produce 1 kg of LNG. Based on the processes used for natural gas liquefaction, SPC can vary from under 0.3 to 0.8 $\left(\frac{kW\,hr}{kg\,LNG}\right)$ [3]. Actually, high amount of power is required for an industrial LNG plant which produces up to 10 MMTY (million million tons per year) of liquefied natural gas for each train [4]. Regarding above issues, reducing the power consumption is an effective way to enhance the plant performance. Several technologies have been developed in LNG industries. Among them, some are more famous and have been used in actual plants. Mixed fluid cascade (MFC) process is one of the popular technologies which is used in high capacity LNG plants [5,6]. Linde and Statoil MFC process consists of three refrigeration cycles in which a mixture of methane, ethane, propane or nitrogen is used as refrigerant in the cycles for pre-cooling (about −25 °C), liquefaction (about −86 °C) and sub-cooling (about −160 °C) of the natural gas respectively [5,7]. Fig. 1 shows a schematic of MFC process simulated in Aspen HYSYS simulation software.

As explained, CRCs are used to produce the required refrigeration. They are widely used for supplying the required refrigeration in different processes especially in oil and gas fields and many research have been done to improve their efficiency [8–13]. In the case of LNG, several studies have been done to enhance efficiency of the process by improving the refrigeration cycles performance. Operating pressure of the cycles, flow rate and composition of the refrigerant are some of the operating parameters which have been used for optimization of the refrigeration systems [14–18]. In some research in this area replacements of expansion valves with turbo expanders are considered [19,20]. Also, some procedures have been

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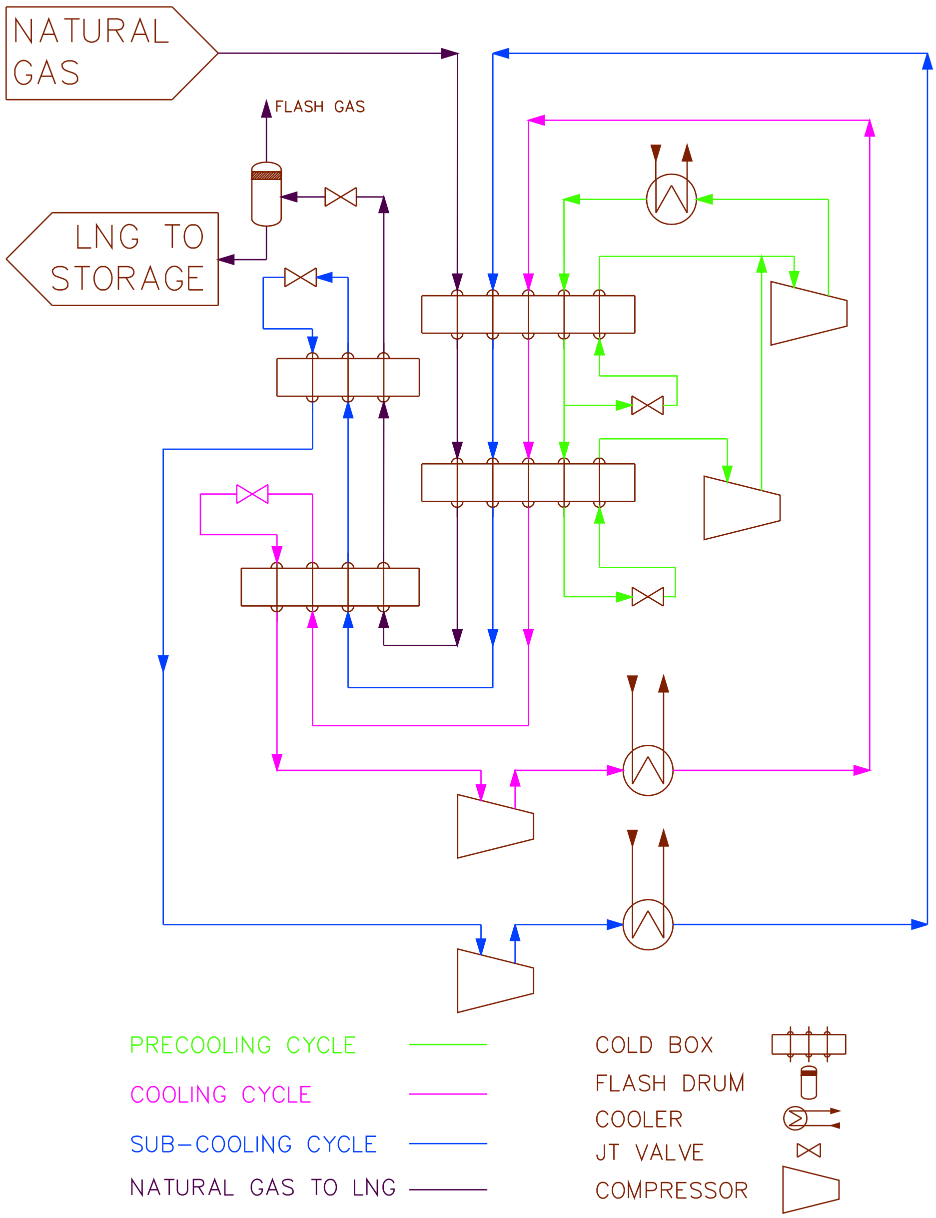

Fig. 1. Schematic of MFC process.

proposed based on the results gained from exergetic analysis of the LNG processes [21,22]. Co-production of natural gas liquid (NGL) and LNG is another way which can be used to reduce the required refrigeration in LNG and NGL processes [23]. Available waste heat from the various parts of the plant can be utilized for increasing the efficiency of the liquefaction process [18]. Using absorption refrigeration cycles (ARC) is a suitable way to produce the refrigeration from waste heat. ARCs can produce refrigeration by medium temperature thermal energy instead of the power. This characteristic of ARCs makes them proper to utilize waste heat energy in the plant [24–26]. There are some studies which shows this technology can be used especially in the power plants [27], food industries [28,29] and oil and gas processes [30,31]. In the field of LNG industry, there are some studies on indirect use of ARCs to improve the cooling performance [32–34]. Another procedure which has not been considered deeply is investigation of using ARCs instead of CRCs. In reference 35, a potential replacement of propane chillers with ARCs in a LNG process is investigated. The results show that 1.9 MW can be saved using waste heat of a 9 MW gas turbine. Nonetheless, results of this study are not sufficient and clear for designing new and efficient real LNG processes. Also new processes performance should be comparable with the conventional and efficient proposed technologies. This article investigates the feasibility of such replacement in MFC process. ARCs have been widely used in different industries such as food and chemical [36]. These kinds of refrigeration processes operate with a solution as working fluid. The most common pairs of such fluids are water–lithium bromide (commonly for refrigeration above 0 °C) and ammonia–water (commonly for refrigeration under 0 °C). The required power in the cycle is limited to the pump power (or fan power of air cooled heat exchanger in the case of using air as the medium temperature reservoir) which is so much less than the CRCs. But it is not the only advantage of ARCs in comparison with CRCs. The required thermal energy of ARCs can be supplied by available waste heat in the plant [32,33]. Also ARCs are soundless and their maintenance cost is much less due to absence of large rotary equipment. Some exchangers may