Improvement of Natural Gas Liquefaction Process by Application of Carbon Dioxide Boiling in Triple Point

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ABSTRACT

The most capital-intensive phase of technology LNG has been found: it is the main cryogenic heat exchanger with mass-dimensional parameters which depend on the efficiency of gas pre-cooling process. Improving the efficiency of this process will reduce the cost of LNG production, hardware costs and size of the equipment. The analysis showed that carbon dioxide with triple point coordinates can be used for natural gas pre-cooling before supplying it into the cryogenic exchangers. The usage of carbon dioxide at the triple point coordinates increases the efficiency of pre-cooling due to the energy of the phase transition.

KEY WORDS: LNG; carbon dioxide; coolant; pre-cool; refrigerant; three-phase condition.

INTRODUCTION

Improvement of natural gas liquefaction process in order to cut specific capital costs is a relevant issue. The most capital intensive element in natural gas liquefaction cycle is the main cryogenic heat exchanger, the dimensions of which are predominantly defined by efficiency of precooling process. Application of phase transition in triple-point conditions can be one of the ways to intensify heat exchange processes.

EXISTING TECHNOLOGIES

Nowadays the most common ways of liquefaction of natural gas are:
1. Classic cascade cycle with consequential application of propane, ethylene and methane as refrigerants gradually lowering their boiling - Optimized Cascade process (ConocoPhillips Company, 2015).
3. Expansion liquefaction cycles.
4. Autorefrigerant cascade cycle (ARC), in which hydrocarbons condense in stages and are used as refrigerants at further stages of cooling with simultaneous circulation of non-condensing nitrogen.

Liquefaction processes developed by Air Products make up the majority of methods utilized in production of LNG and their only rival is Optimized Cascade. Expansion liquefaction cycles and ARC don’t have a serious market share. Therefore, according to the current paradigm of liquefaction technologies, processes deploying precutting will be further improved. These processes are developed by Air Products&Chemicals.

The following methods of precutting of natural gas prior to liquefaction are known:
1. Cooling method in cryogenic heat exchanger, including its feed to evaporator of a propane refrigeration unit, where it’s cooled to - 35°C, heat being removed with propane, which has boiling temperature - 42°C, atmospheric pressure (Gaumer and Newton, 1973).
2. Cooling method in cryogenic heat exchanger, including its feed to evaporator, where natural gas is cooled to - 50°C heat being removed with a refrigerant consisting of mixture of various compounds (usually ethane and methane), with average boiling temperature of - 55°C, atmospheric pressure (Grootjans, Nagelvoort and Vink, 2002).
3. Method of cooling of natural gas prior to its feed to a cryogenic heat exchanger with carbon dioxide (CO2). (Varma and Roberts, 2010) CO2 is non-combustible which makes it useful for fire extinguishing.

FIELDS OF APPLICATION OF REFRIGERANTS

The main task of optimization of natural gas liquefaction is decreasing mass and dimensions parameters of the main cryogenic heat exchanger. In order to achieve this it is necessary to remove greater quantity of heat at the precooling stage.

Most common refrigerant at this stage is propane. Same refrigerant is applied in AP-C3MR technology. This method has the following drawback - the temperature of natural gas prior to its feed to cryogenic heat exchanger is not low enough which results in excessive heat load on it. Further cooling of natural gas in a propane refrigeration unit can be achieved only by lowering pressure in an evaporator, therefore lowering boiling temperature of propane. Although this process is going in an evaporator at pressure below atmospheric, i. e. in vacuum,