HELIUM PRODUCTION TECHNOLOGY BASED ON NATURAL GAS COMBUSTION AND BENEFICIAL USE OF THERMAL ENERGY

by

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Helium is widely used in all industries, including power plant engineering. In recent years, helium is used in plants operating by the Brayton cycle, for example, in the nuclear industry. Using helium-xenon mixture in nuclear reactors has a number of advantages, and this area is rapidly developing. The hydrodynamics and mass transfer processes in single tubes with various cross-sections as well as in inter-channel space of heating tube bundle were studied at the Institute of Thermophysics, Siberian Branch of the Russian Academy of Sciences. Currently, there is strong shortage in helium production. The main helium production method consists in the liquefaction of the natural gas and subsequent separation of helium from remaining gas with its further purification using membranes.

Key words: *natural gas, combustion, helium, thermal energy*

Introduction

Helium belongs to the noble gases whose demand is constantly growing. Due to its properties, helium (He) finds broad application in various industrial fields such as aviation, electronics, space-rocket, nuclear industries, and medicine. Helium is used to prepare breathing gas, including that for the manned spacecraft and deep diving apparatuses, for filling airships and balloons, as well as for the treatment of asthma. It is non-toxic, thus inhaling helium in small amounts along with the air is completely harmless.

The unique properties of this substance are also used in metallurgy to create protective environment at welding of metals, and in nuclear power engineering – as a coolant in some types of nuclear reactors. Helium is mostly extracted from natural gas. In Russia it is produced only by one plant, the gas processing plant in Orenburg, which is part of LLC "Gazprom Production Orenburg". The Orenburg oil and gas condensate field relates to the "poor" deposits in terms of helium content; the volumetric fraction of helium in natural gas is up to 0.055%. "Rich" fields contain more than 0.5% of helium, while ordinary deposits contain from 0.1 to 0.5%. All deposits with helium content less than 0.1% are classified as "poor" deposits.

The extraction of helium from natural gas is a strategic task when operating field with significant helium content. For Russia this problem is especially urgent, because in rich oil and gas fields, such as Chayanda and Kovykta, volumetric content of helium ranges from

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0.25% to 0.5%. The primary technology of helium production is liquefaction of natural gas in the columns that are manufactured by Air Products (USA), Linde (Germany), and Air Liqide (France) companies. Apparently, one of the first patents in this field was filed by Air Products Inc., which protects combined technology of liquid methane production and simultaneous production of enriched helium product. At that, the volumetric fraction of helium even at the first stage of the process reaches at least 80% [1-8].

Russia possesses most rich helium deposits, though to locate the liquefied gas production facilities directly at the deposit sites is quite risky because of possible gas losses during the transportation on long distances. Location of facilities in the direct vicinity of the deposits is profitable only for co-produced gas, because it is unprofitable to liquefy whole amount of gas directly at the deposit due to the lack of economically viable liquefied gas transportation technology.

To produce highly concentrated helium one should include into the process separation of sufficiently pure helium through the synthesis gas production technology. Basically, all existing patents concern helium production through the synthesis gas production technology with subsequent extraction of helium.

We propose brand new method of helium production through natural gas combustion in gas turbine or steam generator. At the completion of the combustion process we obtain gaseous product, which contains nitrogen, carbon dioxide, steam, helium, argon, and possibly other impurities. In case of incomplete combustion the gas mixture can contain small amounts of methane. When producing helium, the main difficulty is getting rid of CO_2, since CO_2 does not undergo liquefaction, and the only method to release this gas out of the mixture is passing remaining mixture through the polymeric membranes.

The proposed combustion based method can certainly be used to process gas at Kovykta gas condensate field in the frameworks of "Power of Siberia" project. Even if we assume significant gas leak along the pipelines when transporting to a projected helium production plant, which is assumed to be built on the border with China, the proposed technology may prove to be more effective than any other technology, such as synthesis gas production based method. As far as is known, the "Power of Siberia" project does not involve full liquefaction of natural gas on the border with China. Surely, burning whole amount of gas to produce electricity and heat is a wonderful solution for the Chayanda gas field as well. Power plant and boiler can be placed in Yakutsk to provide heat and electricity to the entire region and to produce helium at the same time. At that, the problem of helium storage in Yakutia is solvable.

It is also possible to extract gas throughout the whole "Strength of Siberia" pipeline, provided construction of electricity, heat and helium production complexes in the cities and places located along the pipeline such as, for example, Irkutsk.

Our technology is proved experimentally on the installation shown in fig. 1.

The installation consists of a burner for methane combustion. A certain amount of helium is added to the air supplied to the burner. The gas escapes from the burner to heat exchanger, where it is cooled to a temperature safe for the membrane material. Afterwards it flows to additional compressor, which increases the pressure to overcome the membrane resistance. The mixture then flows to the membrane separator to separate helium from other gases. Our laboratory has a sufficient number of membranes with parameters necessary for carrying out these experiments. The helium flow rate and concentration measurements were carried out with high precision using Agilent chromatograph followed by data processing on high-performance personal computer. The efficiency of the membrane performance was tested in a series of special experiments on the separation of a He-Xe gaseous mixture and the experiments on separation of helium from the air.

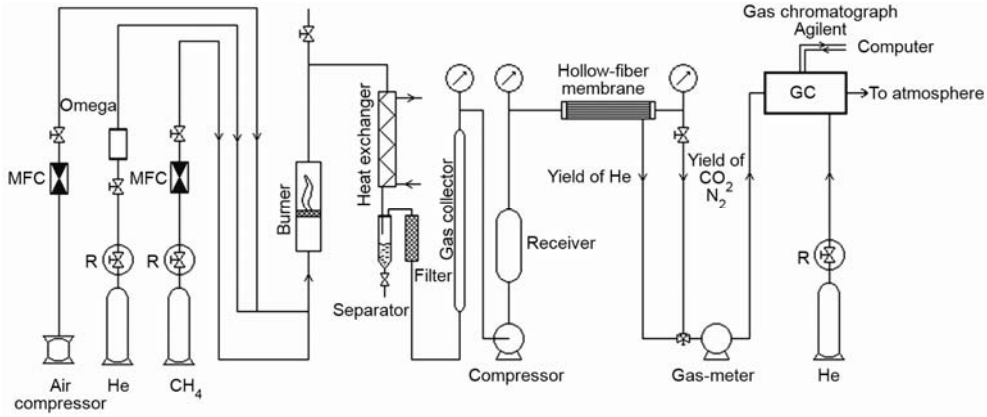

Figure 1. Diagram of the experimental set-up for the combustion of natural gas with helium
MFC – mass flow gas controller (Bronkhorst), Omega – measuring the gas volumetric flow rate

In the actual process of helium extraction at the wellhead (fig. 2), natural gas enriched with helium is burned in the backpressure combustion chamber. After passing the gas turbine, which produces electricity, the gas enters the boiler and then gas mixture, composed of CO_2, N_2, He, and CO (in case of incomplete combustion) passes through the separation membrane. Further He can be injected into the cylinders or liquefied and transported for sale. At the moment, experiments carried out on above installation, prove the possibility of producing He with a concentration of at least 90% at the first stage and subsequent purification to the desired concentration (99% and higher).

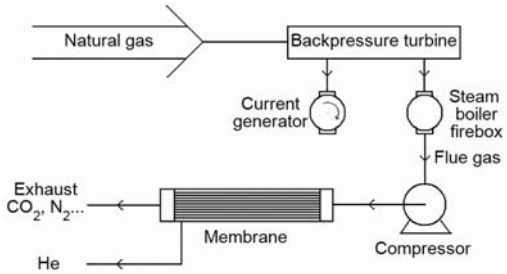

Figure 2. Diagram of helium extraction process in the vicinity of natural gas fields

The process observed becomes very efficient with regard to generating electricity and heat. We are working out a financial model which justifies a huge advantage of proposed technology over other methods of producing helium based on production of syntheses gas. The proposed method is at least two times more efficient than currently used conventional methods.

We should also note that at on-site production of helium the gas pressure at the outlet from the well is so high that it provides a sufficient pressure head to overcome the membrane resistance without additional equipment that also contributes to increased efficiency. Economic efficiency is evaluated based on the basic economic model outlined in the book *Accelerating Innovation: Improving the Process of Product Development* by Marvin L. Patterson [9]. Basic scheme of cash flow during project realization is presented in fig. 3.

Our work relates to the time intervals T_0-T_f, and reduces the amount of the initial investment, while maintaining the amount of the expected profit.

Conclusion

The paper proposes a new method of helium production based on combustion of natural gas and production of electricity and heat, with subsequent extraction of helium from a

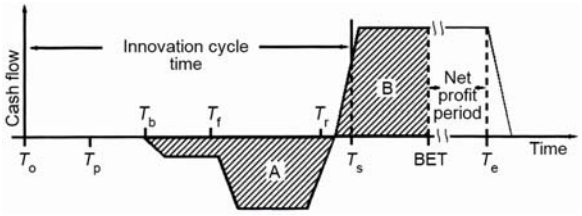

Figure 3. Schematic presentation of economic efficiency in period of project realization; T_o – opportunity occurs, T_p – opportunity is perceived, T_b – project activity begins, T_f – product definition and plans freeze, T_r – product is released to production, T_s – first customers are satisified, BET – break-even time, T_e – project becomes extint

mixture, which consists of carbon dioxide, some amount of carbon oxide, nitrogen, helium, argon, and steam. Further fine purification is carried out using membranes. The proposed method has been tested on a small laboratory installation. The experiments confirmed the possibility of using the proposed method in industry.

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