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РАЗВИТИЕ РОССИЙСКИХ ТЕХНОЛОГИЙ КРУПНОТОННАЖНОГО ПРОИЗВОДСТВА СЖИЖЕННОГО ПРИРОДНОГО ГАЗА

Платонов В.И., Че В.С., научный руководитель: Гульков А.Н., научный руководитель: [1]Минакова П.С.
ФГБОУ ВО "ДАЛЬНЕВОСТОЧНЫЙ ФЕДЕРАЛЬНЫЙ УНИВЕРСИТЕТ", Владивосток, Россия (690922, Приморский край, город Владивосток, остров Русский, п Аякс, д. 10), e-mail: [1]thescienceguysforever@gmail.com

В статье описывается состояние российской индустрии производства сжиженного природного газа. Анализируются перспективы производства данного вида энергоресурса в России, описывается необходимость разработки собственных технологий сжижения газа в связи с уходом из страны зарубежных компаний. Описываются примеры иностранных технологий на российских СПГ-заводах. Приводится характеристика запатентованных отечественных технологий получения сжиженного газа.

Ключевые слова: Сжиженный природный газ (СПГ), смешанный хладагент, каскадный процесс, C3MR, DMR, Арктический каскад, Арктический микс.

THE EXPANSION OF RUSSIAN TECHNOLOGIES FOR LIQUEFIED NATURAL GAS LARGE TONNAGE PRODUCTION

Platonov V.I., Che V.S., scientific supervisor: Gulkov A.N., scientific supervisor: [1] Minakova P.S.
FAR EASTERN FEDERAL UNIVERSITY, Vladivostok, Russia (690922, Primorsky Krai, Vladivostok, Russky Island, Ajax village, 10), e-mail: [1]thescienceguysforever@gmail.com

The article decomposes the status of the Russian liquefied natural gas production industry. The prospects of this type of energy source in Russia are analyzed. The relevancy of domestic liquefaction technologies in the context of the withdrawal of foreign companies from the Russian market is described. Examples of foreign technologies at Russian LNG plants are described. The article characterizes patented domestic technologies of liquefied gas production. Moreover, patented Russian technologies of liquefied gas production are defined.

Keywords: Liquefied natural gas (LNG), mixed refrigerant, cascade process, C3MR, DMR, Arctic Cascade, Arctic Mix.

The state of Russian natural gas export has significantly changed since the early 2010s. The production of liquefied natural gas (LNG) is the fastest-growing and potentially productive in Russia's oil and gas industry despite the expansion of the natural gas network and the increment of supply to the Asia-Pacific markets. According to the forecasts, Russian LNG supplies will reach 105 billion cubic meters per year and will equal the level of pipeline gas deliverables by 2030 [2]. Nowadays Russia sits at 4th place in the global LNG market.

The prime producers of liquefaction equipment and technologies at Russian LNG plants were foreign companies, such as Linde and Shell until 2022. However, they had to leave the country due

to European and American sanctions against Russia's oil and gas area. Foreign LNG production (including low tonnage processing) solutions are used in 80 percent of Russian plants (table 1) for 2023 [1].

Table 1 – Technological solutions for Russian LNG plants

Technology	**Licensor**	**Description of the method**	**Production rate**	**Применение в России**
DMR (Double Mixed Refrigerant)	Shell	Cooling of natural gas by two mixed refrigerant streams including nitrogen and light hydrocarbons	2-5 MTPA	«Sakhalin-2»
C3MR (Propane Precooled Mixed Refrigerant)	Air Products & Chemicals Inc. (APCI)	Liquefaction by propane precooling and following cooling with mixed refrigerant in a spiral coil-wound heat exchanger	greater 5 MTPA	«Yamal-LNG» (3 LNG trains)
MFC (Mixed Fluid Cascade Process)	Linde	Stepped liquefaction of gas by mixed refrigerant (cascade process) on three cooling lines	greater 4,3 MTPA	«Arctic LNG-2» (modification MFC4), «RusChimAllianc e» (until 2022)
LIMUM3 (Linde Multistage Mixed Refrigerant)	Linde	Three-stage liquefaction in coil-wound heat exchangers with different mixed refrigerant flows	no greater 2,5 MTPA	LNG plant «Portovaya»

Hence the conclusion can be drawn that the development of domestic natural gas liquefaction cycles is a high-priority task for the Russian energy field. Unfortunately, an active designing of the domestic cooling systems of natural gas liquefaction started only in the 2010s.

The only one Russian implemented LNG technology is an Arctic Cascade cycle process designed as a part of 4th LNG train of «Yamal-LNG» plant (Figure 1)

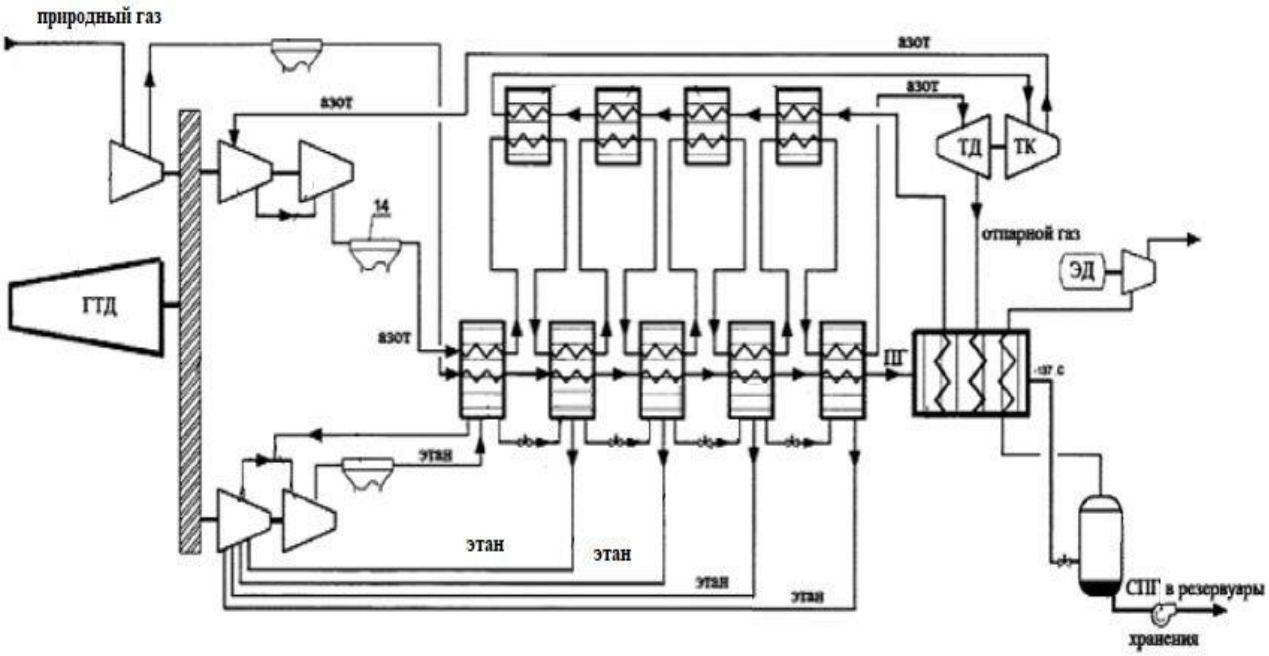

Figure 1 – Process flow scheme of the Arctic Cascade cycle process [3]
Source: Patent of the Russian Federation №2017108800

The advantage of this technology is the step-by-step cooling with pure refrigerants: ethane (extracted from feed gas) and nitrogen, as well as the use of arctic temperatures for cooling at the first liquefaction stage. The process reduces the energy costs of LNG production to 220 kW/t of LNG.

The technology includes the following technological steps:

- Step-by-step gas treatment: separation of mechanical impurities, removal of mercury, acid gas, gas dehydration, and separation of heavy hydrocarbons (if necessary);
- Pre-cooling (by Arctic air or water) and ethane extraction (for use as a pure refrigerant in liquefaction);
- Re-cooling of the gas by nitrogen;
- Pressure reduction and separation of non-liquefied gas;
- LNG storage and offloading.

However, at the Eastern Economic Forum 2021, Leonid Mikhelson, head of “NOVATEK”, stated that the running of 4th «Yamal-LNG» train was unstable due to domestic equipment. An operator of the field had to revise its plans for the Obsky LNG project and postpone it until 2024-2025. By experience of Yamal-LNG exploitation, “NOVATEK” patented the "Arctic Cascade Modified" technology, as well as its analog without using the nitrogen subcooling ("Polar Star") [3].

In 2023, “NOVATEK” developed a natural gas liquefaction technology, called «Arctic Mix» (Figure 2).

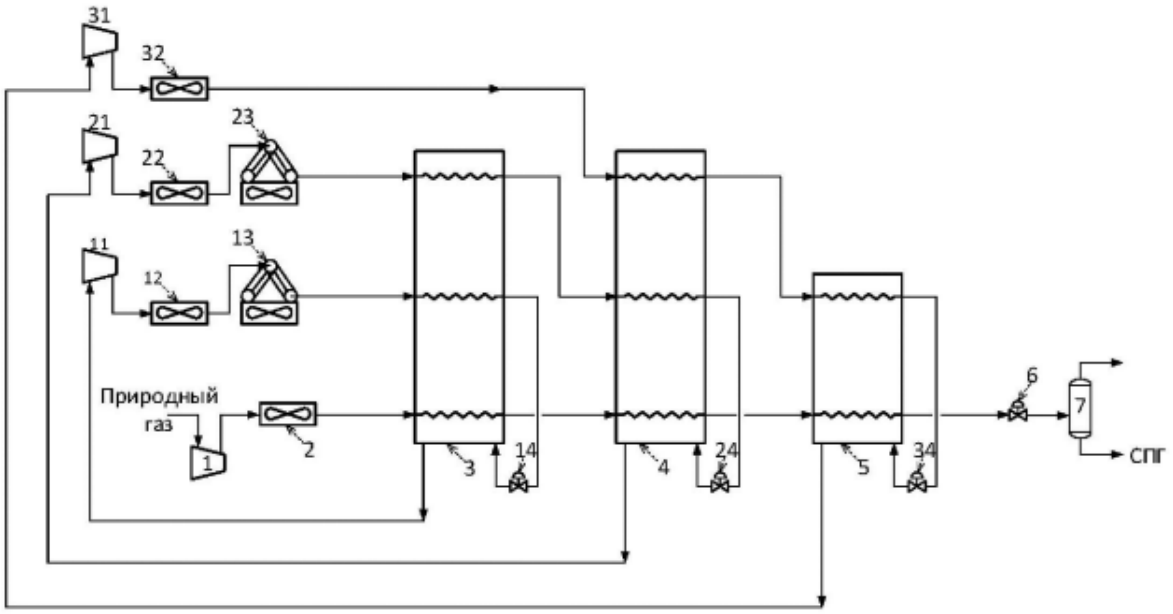

Figure 2 – Process flow scheme of the Arctic Cascade cycle process [4]
Source: Patent of the Russian Federation №2023103701

The main difference from the Arctic Cascade is the self-sufficiency of cycle. It can be applied in any environmental conditions. Moreover, the production rate of plant increases (greater 6 MTPA). Natural gas enters the liquefaction section and is cooled by a mixed refrigerant from the heat exchangers in several streams with different pressures and temperatures. The technical result of technology is an enhanced stability of exploitation (in comparison with the cascade process) [4]. "NOVATEK" expects the usage of this cycle for the implementation of Murmansk LNG plant project. In addition, the spread of the technology will allow "NOVATEK" to act as a licensor in the designing of domestic LNG projects to replace foreign companies that have left. Consequently, it will increase production safety and sustainability of the LNG industry in Russia.

In conclusion, it can be stated that development of Russian LNG production t and processes is expanding more slowly than the need for such technologies. However, we also agree that sanction pressure and inaccessibility of foreign methods of gas liquefaction gives us a chance to focus on domestic research and experimental development. Besides, it will allow our country not only to hold a high level of LNG supply, but also to increase the quantity of LNG exported to global markets. "NOVATEK" experience has shown the promising potential of domestic technologies and the possibility of effective import substitution in crisis situations.

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