GAS HYDRATE PRODUCTION FROM GENERATOR GAS AT UNDERGROUND COAL GASIFICATION

Saik P. B.
Doctor of Philosophy,
Associate Professor

Petlovanyi M. V.
Doctor of Philosophy,
Associate Professor

Lozynskyi V. H.
Doctor of Philosophy,
Associate Professor

Sai K. S.
Doctor of Philosophy,
Associate Professor
National Mining University
Dnipro, Ukraine

The energy system of Ukraine depends on imports of the leading fuel resource – natural gas. Thus, in 2017, the import of natural gas from the European Union make 14 billion cubic meters, while its own production by Ukrainian companies make 20.8 billion cubic meters or 60% of the state needs [1]. The largest consumers of natural gas are the following regions: Dnipropetrovsk, Kharkiv, Poltava, Odesa, Donetsk, and Lviv, whose consumption is about 45% of the national consumption, due to the high population density and the concentration of major industrial capacities. In addition, industrial enterprises consume 65% of the gas volume, and population – 35%. Therefore, for industrialized areas, the question of replacing the fate of natural gas with alternative fuels is always relevant.

The main coal reserves of the country are located in the main consumer areas of Dnipropetrovsk, Donetsk and Lviv, with a substantial part of them being unconventional (estimated at 17.3 billion tons) [2] and balance reserves remaining within the mine fields of closed mining enterprises, (estimated at more than 1.0 billion tons), and with the thermochemical effect there is the possibility of obtaining valuable energy and chemical products.

It is known that at the site of coal reserves in the underground coal gasification it is possible to obtain a generator gas (also known as syngas) [3; 4], where one of the combustible gas is methane with a concentration of 15-27%, which can be used as a substitute for natural gas and to supply it to industrial facilities and infrastructure of settlements. However, to ensure this, first, it is necessary to determine the appropriate aggregate state of gas methane, which will also affect the mode of transportation.

An important factor in choosing the transportation mode of generator gas is its efficiency. Transportation can be carried out in several ways: main gas pipelines; vehicles in liquefied or compressed state; in the form of gas-hydrated blocks.

Pipelaying is a labor-intensive process, and their operation requires constant monitoring of the pipelines state. In addition, the gas needs not only to be cleaned of harmful impurities, but along the entire length of the pipelines to further compress with the help of powerful compressor stations.

When transporting liquefied gas, it must first be converted to a liquid state, and then transported in a specially equipped vehicle at low temperatures with subsequent regasification. The disadvantage of liquefaction technology is the need to create a high-value liquefaction and regasification infrastructure.

The peculiarity of the technology of gas transportation in a compressed condition is its preliminary compression with subsequent transportation in tanks under high pressure. The basic physical properties of gas mixtures are given in Table 1.

Table 1

Comparison of physical properties of gas mixtures

Characteristics	**Gas hydrates**	**Liquefied gas**	**Compressed gas**
The state	**solid**	**liquid**	**gaseous**
Gas content in 1 m^3, m^3	145-200	600-620	250-300
Pressure, MPa	0.10	4.50	16-20
Temperature, °C	–5…–20	–162	0
Specific gravity, kg/m^3	850-950	420-470	0.60-0.70

Analyzing Table 1 it follows that gas hydrates can be transported at a higher temperature than liquefied gas. This allows us to argue about the cost-effectiveness of this transportation mode. You can also highlight the following benefits: capital and operating costs, energy intensity, greenhouse gas emissions during the formation and transportation, and, most importantly, the safety of gas transportation, as the possibility of a sudden explosion are reduced to zero.

Therefore, in order to improve the system of providing infrastructure for mining regions with gas, an alternative to natural gas is proposed to transfer gas-methane from underground gasification into the solid crystalline gas-hydrated state.

A new method for obtaining hydrates from the generator gas of underground coal gasification is proposed, including the preliminary removal from the gas well of a gas mixture, mixing it with the simultaneous submission of the sprayed water jet into the active hydration zone until the crystallization centers of the gas hydrate, storage and transportation of gas hydrates to the consumers (Fig. 1).

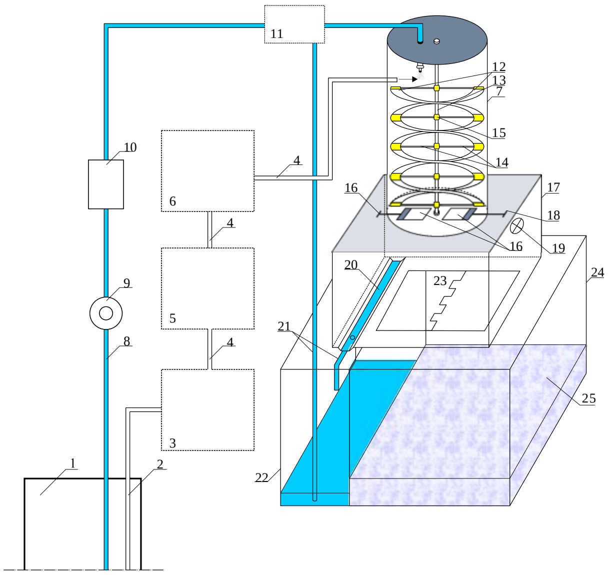

Fig. 1. Flowsheet of gas hydrates production

The novelty of the proposed technological solution are characterized by the fact that the received generator gas is present to a cooling and purification complex for the separation of the associated gases, fine particles and resinous substances, its pressure is determined, under which is fed into a directed vortex stream, which simultaneously meets the sprayed jet of the mine water under pressure that exceeds the pressure of gas supply.

The method is implemented as follows. The production gas, regardless of qualitative and quantitative composition, comes from a pipeline for discharging generator gas *2* along the main shaft of mine *1*. It is then sent to a cooling and purification complex *3* for the separation of associated gases, fine particles and resinous substances. After cooling and purification, the resulting gas-methane is fed through the pipeline *4* to the storage tank *5*. From the tank *5*, the gas enters the high-pressure compressor *6*. The gas pressure and temperature in the hydrate formation reactor *7* are determined. The pressure is set in the range of 6 to 8 MPa, and temperature +1…+3°C. From the compressor *6*, the gas is fed into the active hydration zone of the reactor *7* in a directed vortex stream. Simultaneously, through the pipeline *8*, the pump *9* is fed into the recovery tank *10*, which is purged of insoluble weighed particles and which is subsequently sprayed with a jet of shaft of water into the hydrate formation reactor *7* under pressure higher than the gas supply pressure. This contributes to the formation of a microparticle for better capture of the spray liquid from the interface gas, which accelerates the process of dissolving gas molecules in water molecules and, respectively, the formation of gas hydrate. The process of interaction of gas methane and mine water takes place under special conditions: determination and setting of temperature and pressure in the hydrate formation reactor. Also, the activation of the hydration process is also ensured by the creation of directed vortex flow in the hydrate formation reactor using flat strips *10*, which are connected to the shaft *11* by means of a cylindrical traverse *12*, which are attached to the shaft *11* by the sleeves *13*. The shaft *11* is fixed on both sides by means of sealed roller bearings.

The formed crystalline methane hydrate, passing through the unloading windows *14*, accumulates in the collector *15*. After the collector filling *15*, the automatic closing of its unloading windows by latches *16* ensures the continuity of the process of gas hydrates production. The automatic closure is provided by the pickup sensor *17*. After closing the unloading windows *14*, the pre-escaped from the excess water that drains to the drainage groove *18*. Excess water through the conduit *19* enters the drainage vessel *20*. After the water is recycled, the unloading hatch *21* opens and the crystalline hydrate pours under its own weight into mobile refrigeration chamber *22*. After full discharge of the collection *15*, the unloading hatch *21* is closed and the latches *16* are opened. The sequence of the unloading process takes place but as required collection *15*. Recovered and collected water in collector *20* re-used to form a crystalline hydrate. The resulting product is suitable for further storage and transportation.

One of the variants of transporting crystalline gas hydrates is the creation of automobile refrigerators, with the control of the stability of the required pressure and temperature, which are sufficiently mobile and capable of delivering fuel to certain industrial and civilian objects [5]. The application of the proposed method will allow for the possibility of gas hydrates production during local and/or noncommercial coal reserves gasification with their subsequent transportation in a continuous cycle, to improve the efficiency of the process and to manage the specified parameters.

References:

1. Naftogaz Group. (2017). Retrieved from http://www.naftogaz.com
2. Rudko H.I., Lytvyniuk S.F., & Lovyniukov V.I. (2016). Heoloho-ekonomichna otsinka vuhilnykh rodovyshch Ukrainy. Mineralni resursy Ukrainy, (2), 23-28.
3. Falshtynskyi V., Saik P., Lozynskyi V., Dychkovskyi R., & Petlovanyi M. (2018). Innovative aspects of underground coal gasification technology in mine conditions. Mining of Mineral Deposits, 12(2), 68-75. https://doi.org/10.15407/mining12.02.068.
4. Dychkovskyi R.O., Lozynskyi V.H., Saik P.B., Petlovanyi M.V., Malanchuk Ye.Z., Malanchuk Z.R. (2018). Modeling of the disjunctive geological fault influence on the exploitation wells stability during underground coal gasification. Archives of Civil and Mechanical Engineering, 18(4), 1183-1197. https://doi.org/10.1016/j.acme.2018.01.012.
5. Sai K., & Ganushevych K. (2014). Utilization of mine methane and their transportation in gas hydrates state. Mining of Mineral Deposits, 8(3), 299-307. https://doi.org/10.15407/mining08.03.299.