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THE POSSIBILITY OF NATURAL GAS TRANSPORT BY SHIPS IN STATE OF METHANE HYDRATES

It was presented the methane properties in state of hydrate and the stability hydrate area. In that state there is a reach resources, mainly in seabed and as sediments underneath seabed. It occurs essential difficulties in production that energy resource. The problems are: the depth of deposits, major threat for marine environment connecting with the deposit stability and the risk of the methane gas leakage to the atmosphere (methane is a potent greenhouse gas). It was indicated the possibility of methane hydrates transport by sea and the interest of some states for extracting methane from hydrates. Overcoming the technical problems and assurance the safety of extracting deposits are the basic problems to solve.

Keywords: *methane, hydrate, natural gas transport, states of natural gas, stability area of methane hydrates, sea transport.*

INTRODUCTION

Potential sources concentrate large quantities of natural gas are methane hydrates. This is a big hope for new source of ecological fuel and a bigger threat for environment due to out-of-control emission to atmosphere of methane (one of the potent green-house gases). These crystalline formations (Fig. 1) [17, 18] are present in the permafrost glacial regions (Alaska, Russian Siberia, Canadian Arctic, Greenland Island) and ocean floors (all over the world). The estimated resources remain attractive: between $2 \cdot 10^{14}$ and $3 \cdot 10^{18}$ m^3 [3, 5, 12], such a lot that well beyond the current and future demand for natural gas (it says that over 10 thousand years [7]). Research programs on methane hydrates have increased over the last twenty years, particularly in China, Japan, India and the United States [12].

Generally hydrates are clathrates in which water is the host molecule trapping gas molecules like: methane, ethane, propane and carbon dioxide and other. Hydrates can trap large amounts of gas: ideally, reported at normal temperature and pressure, one cubic meter of methane hydrate is composed of 0.8 m^3 of water enclosing up to 164 m^3 of methane gas (about 110 kg) [3].

Formation and stability of methane hydrates require very accurate temperature and pressure conditions (high pressure and relatively low temperature), provided that the amounts of water and methane are available in sufficient quantities.

Fig. 1. Methane hydrates: as an ice and burning ice [7]

The methane hydrates stability zone was shown on the Fig. 2.

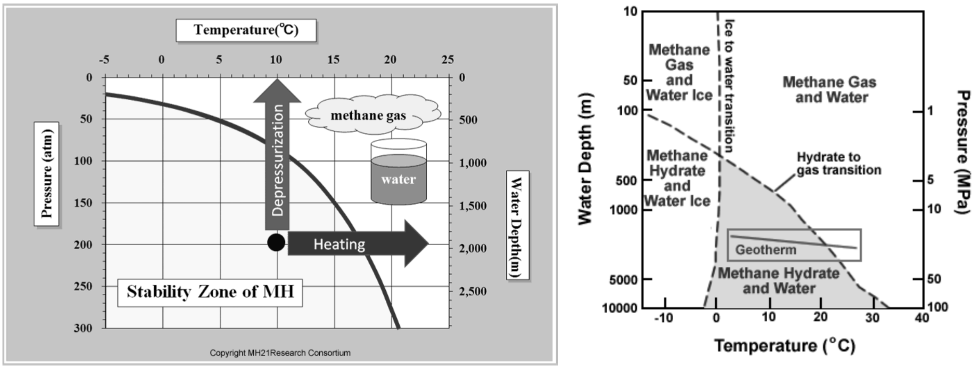

Fig. 2. Methane hydrate (MH) stability zone curve [12]

For example, the Gulf of Mexico: for pressure equivalent to 2500 meters (about 25 MPa), when the deposit is made up exclusively of pure methane, the base of the stability zone is characterized by a temperature of 21°C. For the same value of pressure, if the gas deposit is composed of 62% methane, 9% ethane and 23% propane, this characteristic temperature is then 28°C [9].

Sediments of MH contain a lot of microbiological organisms, mainly bacteria from $1 \cdot 10^6$ to $1.5 \cdot 10^9$ cells in one gram [1, 11], when the temperature of sediments is between 15÷50°C (the maximum bacteria quantity is at water temperature and sediments of 40°C).

1. EXTRACTION METHODS OF METHANE FROM MH

The history of methane hydrates production have started in 2002 by a Japanese Research Consortium MH21 at the Mallik site (first onshore production test) in MacKenzie Delta (Canada). In 2008 China announces a 100 million USD funding for research into methane hydrates extraction. In 2010 University of Bergen (Norway) develops CO_2 injection and exchange method for methane extraction. In 2011 Conoco Philips, JOGMEC and US Department of Energy announced plans to trial CO_2 injection in Alaska. In 2012: JOGMEC started first offshore gas production testing in the Nankai (Japan's south-west coast), German IFM-GEOMAR-SUGAR consortium announces plans for MH exploration, Dutch Statoil completes study – methane hydrates are a major energy resource for the future etc. [3, 4, 10]. The race for new resources of energy and techniques of extraction from MH have started.

Methane production methods are based on [6, 8, 12, 13, 15]:

- the dissociation of hydrates under specific conditions;
- use techniques similar to those used for conventional hydrocarbons;
- thermal stimulation;
- depressurization;
- injection of inhibitors.

Many technical challenges are still being studied, such as maintaining optimal production rates during the extraction process, the long-term management of water production and understanding the behavior of hydrates at low temperatures and low pressure [8]. The possibility of hydrates formation is shown on the Fig. 3. It was presented hydrate equilibrium curve in terms of pressure and temperature.

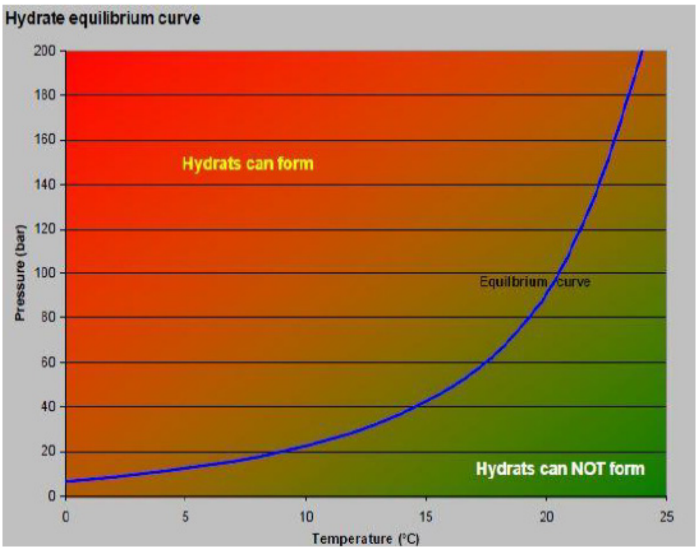

Fig. 3. Methane hydrates diagram (Kristian Sandengen, Statoil, 2012)

For the water temperature of 5°C the minimal pressure is about 12 bar for forming the MH, when the temperature is 20°C the pressure ought to be over 90 bar etc.

Methane hydrate – existing as a solid substance in layers – as an energy resource, we must dissociate methane hydrate to methane gas and water and collect only the methane gas. This process is called “the production of methane hydrate” or “the methane hydrate production”. Since methane hydrate is a solid substance, you can think it can be mined as coal. However, it is not efficient to mine methane hydrate because it is contained in geologic layers under a deep ocean. The production of methane hydrate means dissociating methane hydrate in the layers and collecting the resultant methane gas through wells and production systems. Once methane gas is generated from dissociated methane hydrate, then the above approach may be used to collect it using a similar principle, methods, equipment and facilities as employed for the development of natural gas.

To dissociate methane hydrate that is stable at low temperature and under high pressure, we must as first increase the temperature or as second decrease the pressure. Therefore, the operation of the “increasing temperature” or “decreasing pressure” of layers bearing methane hydrate is the actual way of the production of methane hydrate. The production method that involves increasing the temperature is called the “heating method,” and another that involves decreasing the pressure is called the “depressurization method” [8, 14].

The following methods are used for extraction methane from MH:

- heating (Fig. 4) or hot water injection or flooding (Fig. 5);
- depressurization (Fig. 5);
- heating and depressurization (Fig. 5);
- inject CO_2 to displace methane;
- direct removal;
- inject inhibitors.

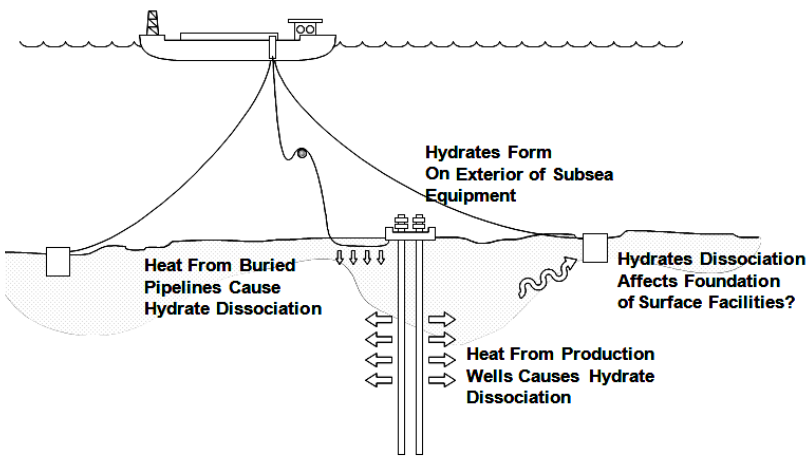

Fig. 4. Potential impact of MH in the seafloor sediments on deepwater production facilities [2]

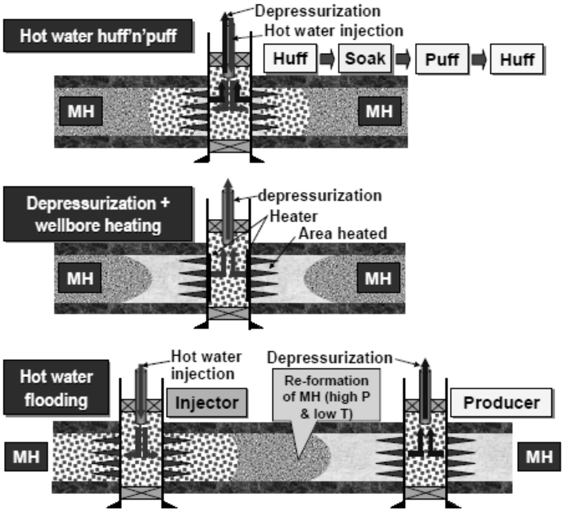

Fig. 5. A variety of thermal methods for methane extraction [8]

CO_2 injection is one of new technique being pioneered in this field. Warm, pressurized CO_2 in a supercritical state is injected into MH formation. The molecules of CO_2 insert themselves into the MH, forming a stable lattice and simultaneously liberating the CH_4 (exchange CH_4 and CO_2) which is then pumped to the surface [13, 16]. This process has dual advantages of: methane hydrate formation during extraction and sequestering unwanted industrial CO_2. The modification of this method is added chemicals to the injection process which would make the process more viable [16].

In conclusion three types of sub-surface methane hydrate deposits are confirmed for methane production:

- pore filling type MH reservoir (the most promising as energy source);
- naturally fractured MH reservoirs;
- massive/nodule MH deposits [8].

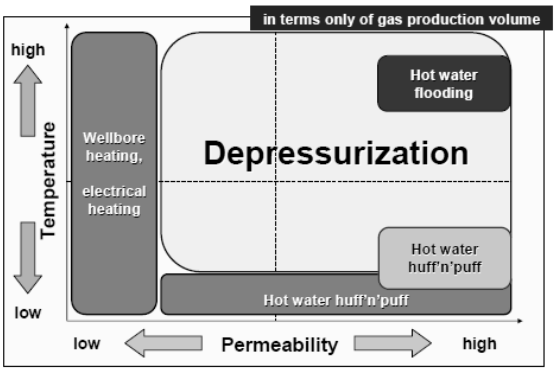

Fig. 6. Methane production from methane hydrates in different methods in terms of reservoir permeability and temperature [8]

Due to many different opinions on the development of MH, only experience during MH production may be essential for reducing uncertainties. The target is improving the quality of research work to obtain the economic methods for methane production.

2. METHANE HYDRATES METHODS OF SEA TRANSPORT

There are some possibilities for methane transport presented on the Fig. 7.

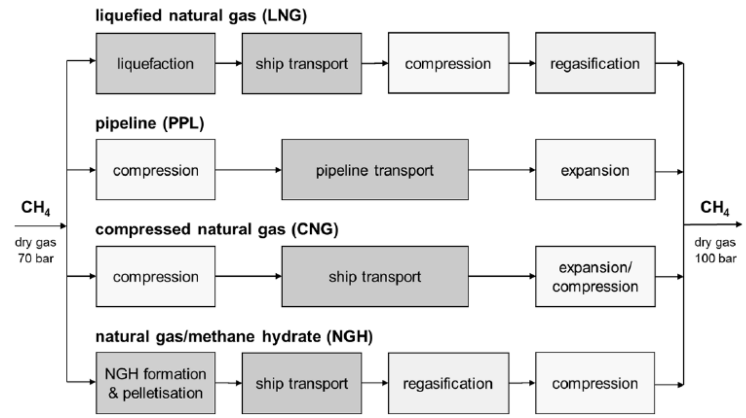

Fig. 7. Technologies and system boundaries for a comparative assessment of methane transport options [16]

Three options of them are used in the ship transport. Two ways of methane transport as LNG or CNG are known and applied. Now it is the time for discover and research may be better method for methane transport in form of pelletisation the methane hydrates deposits.

The required parameters of transport the pellets of MH are rather simple for fulfillment. It needs the temperature of about –20°C (248÷255K) (see Fig. 8.) at ambient pressure.

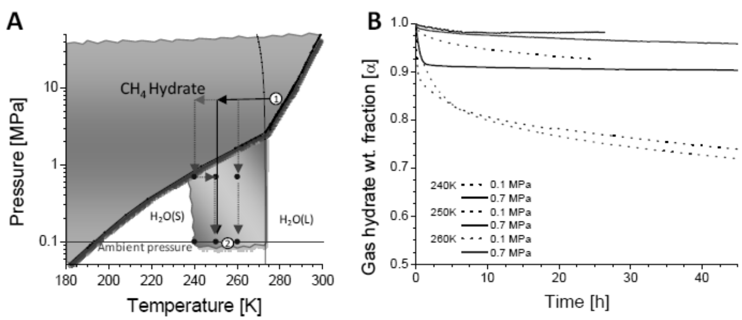

Fig. 8. A – The needed temperature for methane hydrates transport at ambient pressure; B – The needed time for pelletisation process in terms of pressure [16]

Extracting methane in gas state on the ocean surface needs preparing for ship transport. On the Fig. 7 three of four technologies are ready for ship transport. Two of them:

- liquefaction to LNG (liquefied natural gas);
- compression to CNG (compressed natural gas)

are known very well and more often applied.

The new one NGH formation and pelletisation is still during research but there are some concepts how to do it and how to transport the pellets. The conceptual flow diagram for the methane hydrate production and pelletisation process is presented on the Fig. 9.

It needs a lot of fresh water besides methane in gas state. After the process of methane hydrates formation under pressurization (again to that state) and dewatering (the excess of water) through pelletisation process and cooling to about – 20°C with decompression to storage.

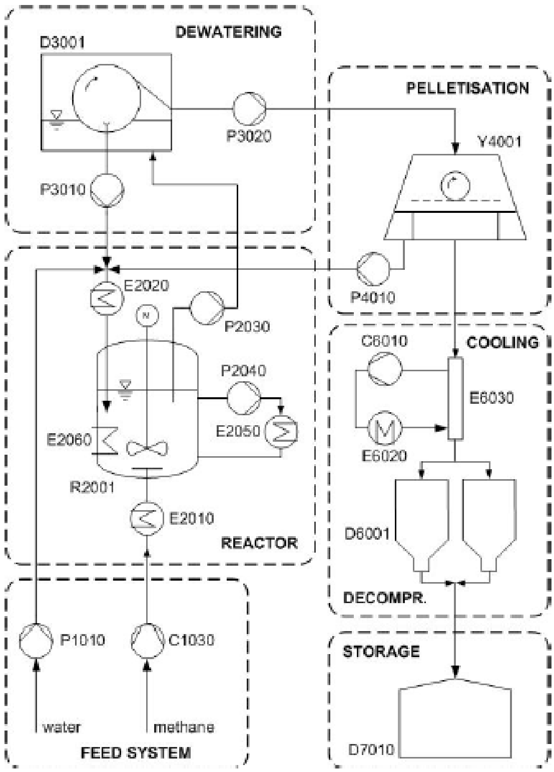

Fig. 9. Conceptual flow diagram for the methane hydrate production and pelletisation process [16]

Next the pellets of NGH may be transport to ship's tanks as cargo. The drawings of pellet carrier is shown on the Fig. 10.

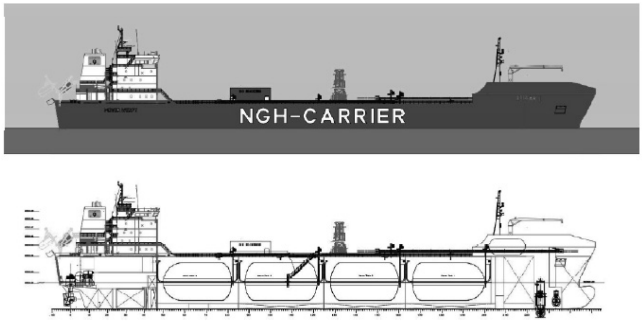

Fig. 10. Drawings of the pellet carrier [16]

The regasification of methane from pellets of NGH and compression to about a 100 bar may be done on a vessel or onshore facilities (Fig. 7). If we do it on a vessel we will unload about 110 kg of methane gas from each 1 m^3 of cargo and will leave onboard about 0.8 m^3 of water to once more use.

The main characteristics of pellet carrier presented on the Fig. 10 are indicated in the Table 1.

Table 1. Pellet carrier main characteristics [16]

Parameter	Unit	
Length overall	m	176.60
Length between perpendiculars	m	166.00
Breadth	m	30.60
Height	m	16.90
Maximum draught	m	8.40
Deadweight	t	16,650
Tank volume at 100%	m^3	20,000
Engine concept	–	Dual fuel
Dynamic positioning	–	DP 2
Classification	–	DNV-GL

It may be important for discussion, comparing and assessment the energy efficiency for the transport options LNG, CNG and NGH. It was calculated – taking into account the scenario of methane production 20,000 Nm^3 per hour and transport of natural gas on distance 1000 km – received respectively 88%, 89% and 76% [16].

CONCLUSIONS

The exploitation of gas hydrate deposits can have a major impact on gas markets if the technical and economic feasibility of extraction is validated. It may change the world energy market.

Several advantages of gas hydrate technology do exist: an inherent safety against ignition, controlled burning, safety during transport, easy to get the temperature of pellets transport in tanks at ambient pressure. The disadvantages are efficiency of NGH transport and economy. It may quickly change if would be developed other methods and possibility of transport.

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MOŻLIWOŚCI TRANSPORTU STATKAMI GAZU NATURALNEGO W POSTACI HYDRATÓW METANU

Streszczenie

W artykule przedstawiono właściwości metanu w postaci hydratów oraz obszary stabilności. W tej formie występują bogate złoża tego gazu, głównie na dnie oceanów lub pod dnem morskim. Występują istotne trudności w wydobyciu tego surowca energetycznego. Problemem wydobycia hydratów metanu jest głębokość złóż, a zarazem poważne zagrożenie dla środowiska morskiego związane z naruszeniem stabilności złóż i ryzykiem przedostawania się dużych ilości metanu do atmosfery (metan jest gazem cieplarnianym). Wskazano na możliwości przewozu drogą morską gazu naturalnego w tej postaci oraz zainteresowanie niektórych krajów pozyskiwaniem metanu ze złóż hydratów. Pokonanie problemów technicznych oraz zapewnienie bezpieczeństwa eksploatacji złóż są podstawowymi problemami do rozwiązania.

Słowa kluczowe: *metan, hydrat, transport gazu naturalnego, stany gazu naturalnego, obszar stabilności hydratów metanu, transport morski.*