Proceedings of the 6th International Conference on Gas Hydrates (ICGH 2008),
Vancouver, British Columbia, CANADA, July 6-10, 2008.

COMPREHENSIVE UTILIZATION OF GEOTHERMAL AND SOLAR ENERGY TO EXPLOIT GAS HYDRATES BURIED IN OCEANIC SEDIMENTS

Fulong Ning * Guosheng Jiang Ling Zhang
Faculty of Engineering
China University of Geosciences
388 Lumo Road, Wuhan, Hubei, 430074
China

ABSTRACT

How to exploit and make use of natural gas hydrates in oceans will weigh much in the future researches. Unlike the oil or gas reservoirs, the distributions of natural gas hydrate are very complicated and don't congregate massively in oceanic sediments. Besides, factors such as seafloor geohazards and climate must be taken into account, which makes it much more difficult and complicated to exploit oceanic gas hydrates than conventional oil or gas. Nowadays neither of such methods as thermal stimulation, depressurization, inhibitor injection, carbon dioxide replacement and mixing exploitation etc. is applied to exploit gas hydrates in marine sediments because of their disadvantages. This paper introduces a conception of combining solar and geothermal energy for gas hydrates exploitation. The model mainly includes five parts: solar energy transferring module, sea water circulating module, underground boiler module, platform and gas-liquid separating module. Solar cells and electric heaters are used to heat the formations containing hydrates. Because they become relatively more mature and cheaper, it's the key of how to utilize the geothermy to exchange heat in developing this conception, which needs solution of fluid leakage, circulating passages and heat-exchange interface problems in building underground boiler. Probably it's a feasible measure to use an effective hydraulic control system and hydraulic fracturing. The idea should be a good choice to exploit marine gas hydrates by combining solar and geothermal energy since this method has a great advantage either in terms of efficiency or cost.

Keywords: marine gas hydrates, exploitation methods, geothermal and solar energy, underground boiler

INTRODUCTION

Since the gas hydrates have been firstly found existing on a large scale in nature[1-2], many countries have turned their eyes to this new latent energy resource with the traits of high energy density, large reserves and cleanness[3]. After entering the 21st century, with the increasingly severe shortage of energy resources and high oil & gas prices, the world has mend her pace to exploit and utilize the gas hydrates. Some developed countries such as America, Japan and Canada have invested heavily in the relatively theoretical and technical researches on gas hydrates exploitation. American has made a mid-long term plan for studying and developing the methane hydrates and a commercial testing exploitation will be expected

* * Corresponding author: Ning Fulong, E-mail: nflzx@cug.edu.cn.
This work was supported by NSFC(No.50704028), 863 Program (No.2006AA09Z316), Program for New Century Excellent Talents in University (No.NCET-05-0663) and the Research Foundation for Outstanding Young Teachers, China University of Geosciences (Wuhan)(No.CUGQNL0623, CUGQNL0725)

in 2015 while Japan has planned to begin in 2016. Because most of the gas hydrates are found in sea area[4-5], how to exploit them should be a hot research in the future. However, the existing states of marine gas hydrates are very complicated[6], which do not deposit to some extent like oil or gas on a large scale. The exploitation methods are also different from those traditional ones of the oil, gas, coal and so on. It does not send the gas hydrates intactly to the ground but recover the natural gas by some ways that control the solid gas hydrates to be decomposed in original places. Besides, the marine geological hazard and climate also should be taken into account. All the factors make the exploitation of marine gas hydrates much more complicated and difficult than that of the traditional oil & gas. Therefore, it's justifiable that some wholly new exploiting modes should be established.

SUMMARY OF PRESENT EXPLOITATION METHODS

In a word, the exploitation of marine gas hydrates means to break the phase balance of gas hydrates by some ways so as to collect the natural gas resulted from their dissociation. According to this idea, such methods have been put forward in this field as thermal stimulation, depressurization, inhibitor injection, CO2 replacement and mixing exploitation, three of which are typical that are shown in Fig.1. Some novel ideas such as fire flooding[7], burial of nuclear wastes[8]and the use of electromagnetic heating[9] are other innovative ways of dissociating hydrates, but none have been tried. For the thermal stimulation methods, heat is introduced into the reservoir, causing destabilization of the hydrate particles. The thermal energy may be achieved from the surface by the injection of hot fluids, including water, brine, or steam, or may involve a downhole process, such as in-situ combustion or electric and electro- magnetic heating[10]. For the Depressurization method, the decomposition is realized by reducing deposits' pressure. A well is drilled through the hydrate layer and completed in the free-gas zone. Gas production from this layer leads to pressure reduction and decomposition of the overlying hydrate. The Messoyakha field was based primarily on this depressurization technique to produce gas from the hydrate reservoir. Obviously, this method needs no expensively continuous stimulation. Therefore, it can be an effective method in largely exploiting gas hydrates in the future. For the inhibitor injection method, such chemicals as salty water, methanol, ethanol, glycol and glycerin and so on are pumped into the formation, which causes decomposition of a gas hydrate by shifting its thermodynamic-equilibrium curve.

The above-mentioned methods have only been tried in permafrost area[11-15]and so far haven't been introduced into the exploitation of marine gas hydrates. Except the restrictions of such external factors as environment and marine geological hazard, the disadvantages themselves are also the important reasons. For the thermal stimulation, the

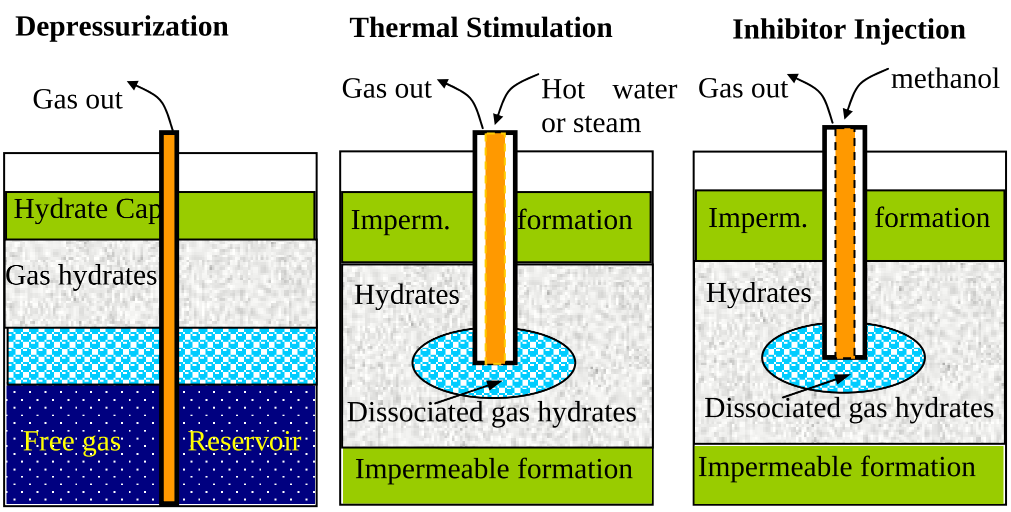

Fig.1 The three common methods of hydrates production. (Modified according to Makogon,1997[16])

biggest shortages are the great heat loss, low efficiency and high energy consumption. Since most of the gas hydrates are distributed in the marine sediments that are more than 500m deep in water and some even reach several kilometers and the embedding depth also has certain thickness, both of which will make the hot liquid circulate in a very long pipeline, then a great heat loss will occur inevitably. Although the depressurization and inhibitor injection can reduce the energy consumption, they work slowly and can't meet the commercial production requirements. When there is no free gas reservoir or much water under the hydrate formations, the depressurization can't be adopted suitably. The inhibitor injection is also unsuitable because it is very expensive, pollutes environment and there is a high pressure in the formations where marine gas hydrates exist. Therefore, it's better to combine the three methods, for example, combining the depressurization and thermal stimulation. However, the energy consumption, cost and pollution are still the difficulties that they must be confronted in large-scale commercial exploitations.

A CONCEPTION OF UTILIZING GEOTHERMAL AND SOLAR ENERGY TO EXPLOIT MARINE GAS HYDRATES

Against the above problems, it may be a good idea to integrate the geothermal and solar energy to exploit marine gas hydrates. It's well known that solar energy is a clear and reproducible energy and the earth itself is a huge heat reservoir, the closer to its inside, the higher the temperature will be. The unceasing geothermal energy dissipates outwards through rock conductivity, thermal spring, earthquake and so on. It can greatly reduce the heat consumption and cost if the geothermal energy and solar energy were collected to stimulate the dissociation of marine gas hydrates. Because solar energy technology relatively comes to maturity, the key of this conception is that how to use the geothermal energy. For it, it's best that the thermal spring or underground hot fluid exists near the area containing gas hydrates, yet this situation would be encountered luckily but not required. Hence, only the establishment of geothermal boiler can realize the idea of utilizing geothermal energy to exploit gas hydrates. That means circulating passages should be artificially created in the dry and hot rocks to let the liquid touch with the rocks so as to obtain warm liquid. For the warm liquid, it doesn't need higher temperature but just enough temperature to make the gas hydrates be decomposed. According to this idea, if seabed temperature was supposed as 0 ℃, then the temperature of the formations 2300m away from the sea bottom may be enough, which is about 80 ℃, calculated from the average geothermal grads (35℃/km) of the gas hydrates reservoir surveyed by ODP Leg 164[17]. It's able to get into the depth for the drilling equipments and building technologies of present oceanic oil and gas industry.

Based on the instructive trials of obtaining the geothermal energy from dry and hot rock in Los Alamos Scientific Laboratory(LASL) and the former Soviet Union mining industry[18], a simple conception mode utilizing hot rock and solar energy to heat up the sea water was formed so as to exploit marine gas hydrates. Considering the low efficiency of a single well circulation and the dispersal of marine gas hydrates, several production wells can be arranged into a triangle, quadrilateral or circle, which is determined by the geological structure of gas hydrates buried in marine sediments. Here is an example for the conception mode as shown in Fig.2.

The system can be divided into five parts: solar energy transferring module, sea water circulating module, underground boiler module, platform and gas-liquid separating module. Solar energy transferring module includes solar cells 1 and electric heaters 2. The solar cells, also called photovoltaics (PVs) by solar cell scientists, convert sunlight directly into electricity which is used to drive the electric heaters 2 through insulated wires. The heaters 2 are buried in and/or under the gas hydrate reservoirs and produce heat that will be transferred by rocks and fluids. In sea water circulating module, pumps in unit 3 are used to suck the sea water and pump it into the dry-hot rocks through the injection pipes 4.The water is heated by the heat exchangers 5 buried in the artificial underground boiler. Then the heated water returns along the annular space between the water injection pipes 4 and the casing 7 but is blocked at the packer 6 and it has to penetrate into the formations containing gas hydrates through the holes around the casing 7. The sea water is almost no cost and contains abundant salt, which is of great advantage to heat transfer and speed up the

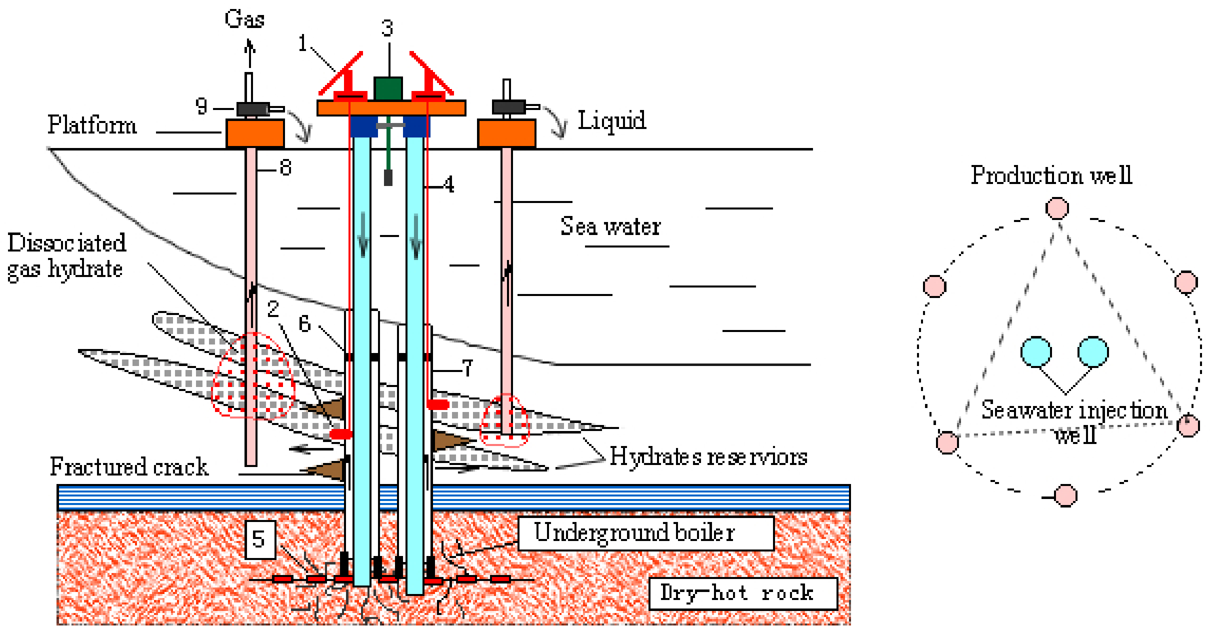

Fig.2 a sketch of utilizing the solar and geothermal energy to exploit gas hydrates
1. Solar cells 2.Electric heaters 3. Corrosion-resistant pumps unit 4.Injection pipes 5. Geothermal heat exchangers 6.Packer 7.Casing 8.Recovery pipe 9.Gas-liquid separator

decomposition when penetrating into the formations containing gas hydrates. Because experiments has found that the heat transmission is faster when there is a higher salt content in the formation for the reasons that heat conductivity of salt is often 3-4 times higher than that of sediments [19].Besides, the sea water can prevent the decomposed gas from forming gas hydrates again, which is as good as killing several birds with a stone. The sea water, decomposed gas and water are gathered in recovery pipes 8 through the passages fractured in advance and return up to the platforms. On the platforms, gas-liquid separators 9 are used to separate the gas and liquid. The former is collected while the latter is directly drained into sea.

DISCUSSION OF THE CONCEPTION

In the conception, solar energy is converted firstly into electric energy and then into heat energy while is not used directly as a source of heat. Because the direct thermal solar heating needs bulky solar collectors and storage tanks which lead to build a very large platform. It's unpractical in the ocean. In addition, the efficiency and reliability of solar water heaters are not very good. They often need a long time to heat bulky water up and are affected easily by weather. Moreover, a great heat loss will occur when the heated water is circulating in the injection pipes. In contrast, there is almost no loss before stimulating hydrates decomposition by using solar cells and can realize "fixed point" heating by using electric heaters. Now the technological breakthrough in Photovoltaics (PVs) has been achieved to convert normally and continuously even though in the overcast sky. What's more, solar cell prices fell from $27 per watt of capacity in 1982 to less than $4 per watt today[20].

So, obviously, the utilization of geothermal energy is the pivotal of this conception. How to build a high-efficient circulating system of heat exchanger and geothermal boiler is the most important thing when utilizing the geothermal energy to exploit gas hydrates. Two problems should be solved: one is fluids leakage. The circulating and heating can run availably when the dry-hot rock is highly penetrable but there is difficulty in remaining the fluids and recycling them. The other is the circulation passages and heat-exchange interface. When there is a bad permeability in the rocks, it needs to create freely circulating passages for the fluids. Furthermore, the rock's heat conductivity is very low. A good heat-exchange effect can be obtained only when there is a very large interface. For the first problem, the technologies and experiences can be used to deal with it for reference from the water injection exploitation in oil&gas field. It's best to build an effective hydrodynamic control system over the whole exploiting area so that the leakage can be reduced to the least. And for the second one, breakage by blasting and hydraulic fracturing can be used to expand the circulating passages and heat-exchange interface. However, the blast can destroy the balance conditions of gas hydrate in the formations and lead to be decomposed suddenly and largely, which will cause seabed landslide to destroy the drilling platform, therefore, it's better to adopt hydraulic fracturing. Besides, to prevent the decomposed gas from seeping up to seafloor through the cracks between the recovery pipes and sediments, it's better to wrap the surrounding of those pipes touched with seafloor by using cements or other sealing substances.

CONCLUSION

The above-mentioned exploitation conception is just a preliminary assumption, prospective well arrangement and technical parameters, for instance, pump pressure and water injection rate can be established in practice after situations such as the distribution of gas hydrates, properties of the formations as well as conditions of the geothermal fields are made clear. It will directly help to determine these parameters by strengthening researches on the rules of heated fluids penetrating, diffusing and heat transferring in the formations containing gas hydrates by experimental and numerical simulations. And it will also present significant instructions to enhance the exploitation efficiency as well as realize safe and controllable production.

It is firmly believed that solar and geothermal energy can be utilized to exploit marine gas hydrates through building solar cells and geothermal boilers. In the future, if problems such as gas transportation, seafloor geological hazard induced by hydrates exploitation and global climate change and so on can be well solved, and because this conception has great advantages either in terms of efficiency or cost, it will be adopted in the commercial exploitation of marine gas hydrates.

REFERENCES

[1] Kvenvolden K. A. *Gas hydrate-geological perspective and global change*. Rev. Geophys. 1993; 31:173-187

[2] Sloan E. D. *Clathrate Hydrates of Natural Gases*. New York: Marcel Dekker, 1998

[3] Collett T.S.. *Energy resource potential of natural gas hydrates*. AAPG Bulletin 2002; 86: 1971-1992

[4] Dickens G.R. *The potential volume of oceanic methane hydrates with variable external conditions*. Organic Geochemistry 2001a; 32: 1179-1193

[5] Sloan E.D. *Fundamental principles and applications of natural gas hydrates*. Nature 2003; 426 (20):353-359

[6] Gong J.M., Wang H.X., Chen J.W., et al. *Distribution model for gas hydrate in sediments. Marine Geology Letters*(China) 2004;20 (6):6-8

[7] Halleck P.M., Byrer C.W., McGuire P.L., Judge A.S., Corlett R.C., Barraclough B., *in Proc. Methane Hydrate Workshop, Morgantown, WV, Mar 29–30, 1982*

[8] Malone R.D. *Gas Hydrates Topical Report*, report no.DOE/METC/SP-218. U.S. Department of Energy, 1985

[9] Islam M.R. *A new recovery technique for gas production from Alaskan gas hydrates*. Journal of Petroleum Science and Engineering 1994; 11: 267-281

[10] Kamath V.A. *A perspective on gas production from hydrates. JNOC's Methane Hydrate Intl. Symposium, Chiba City, Japan, 20-22 October 1998*

[11] Makogon Y.F. *Natural Gas Hydrates: The State of Study in the USSR and Perspectives for Its Use*. *Third Chemical Congress of North America,Toronto, Canada, ,1988*

[12] Dallimore S.R. et al. *Overview of the 2002 Mallik gas hydrate production research well Program.Proc. In: Fourth Intl. Conference on Gas Hydrates, Yokohama, Japan, 2002*, P.19-23

[13] Hancock S. et al. *Overview of pressure drawdown production test results for the japex/jnoc/gsc Mallik 5l-38 gas hydrate research well. Mallik Intl. Symposium, Makuhari, Japan, 8-10 December 2003*

[14] Hancock S., et al. *Overview of thermal stimulation production test results for the japex/jnoc/gsc Mallik 5l-38 gas hydrate research well, presented at the Mallik Intl. Symposium, Makuhari, Japan, 8-10 December 2003*

[15] Williams T. E., McDonald W. J., Millheim K. *Methane Hydrate Production from Alaskan Permafrost*. Technical Progress Report, report no. DE-FC26-01NT41331. Sugar Land, TX: Maurer Technology Inc., 2003

[16] Makogon Y.F.,1997. *Hydrates of Hydro-carbons*. Tulsa: PennWell Publshing Co.,1997. p.482

[17] Jin C.S., Wang J.Y. *The progress in geothermal studies on gas hydrates*. Advance In Earth Sciences(China) 2001; 16(4): 540-543
[18] Wang W.Y., Huang S.Y., et al. *Study on the basic theories of geothermy*. Beijing: Geological Publishing Company, 1982
[19] Seiichi N., James M.B., et al. *Application of marine heat flow data important in oil, gas exploration*. Oil &Gas Journal, 2002;July 8
[20] *SolarBuzz. PV Demand from "Solar Energy Growth",2006. See also: http://www.solarbuzz.com/StatsGrowth.htm, accessed 9/20/06*