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Field Testing of Gas Hydrates - An Alternative to Conventional Fuels

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Abstract

Consumption of conventional reserves of fossil fuel has created a demand for exploring the new resources. In Current Situation it is worthwhile addressing gas hydrates as one such alternative energy resource. Methane gas hydrates have captured double amount of carbon in comparison to fossil fuels, hence they are seen as substitute to Oil and Gas sector. They are present in permafrost regions and beneath the sea. They are considered as future generation fuels. Like several other countries, India has also started a national gas hydrate programme and possible exploitation of this important natural gas resource. This review article discusses their exploitation efforts put by different countries in near past. India has recently competed National Gas Hydrate Programme NGHP-01 and started NGHP-02 recently. The paper throws light on Field Testing of gas hydrates for Alaska North Slope Site, Mallik Site, SUGAR Project, Qilan Mountain Permafrost and Nankai Trough in brief.

Keywords: Gas hydrate; Oil and gas; NGHP-01; Alaska North slope site; Mallik site; SUGAR project; Qilan mountain permafrost; Nankai trough

Introduction

Methane gas hydrates are crystalline form of natural gas formed at high pressure and low temperature. Methane gas hydrates have captured double amount of carbon in comparison to fossil fuels. They are present in permafrost regions and beneath the sea. They are considered as future generation fuels. It is estimated that under the sea huge amount of methane of the order of trillion in the form of gas hydrate is present [1]. Hydrates are naturally occurring materials that are present on submarine continental margins and regions of Arctic permafrost [2-4]. Their presence is also supposed to be on large icy to medium-sized moons of the outer solar system [5,6] and also on the polar regions of Mars [7,8]. Natural gas hydrates are found throughout the world. They are supposed to present in oceanic sediments along continental margins as well as in polar continental settings [9]. Gas hydrates are scattered and they are present at south eastern coast of United States in the Gulf of Mexico on the Blake Ridge, western and eastern margins of Japan, the Middle America Trench and in the Cascadian basin near Oregon, Peru [10]. Gas hydrates are one of the cleaner forms of energy. Methane is their major contributing gas in sediments [11,12]. Gas hydrates are seen as future generation energy resource [2]. Keeping into this various studies have been reported gas hydrates as potential energy resource [2-16]. According to USA department of energy, if only feeble amount of the methane stored in the hydrates can be obtained, it will be more than the current domestic supply of USA of natural gas [17, 18]. The energy potential of methane hydrates is more than that of the other unconventional sources of energy [19]. Gas hydrates will be a mystery till their development potential is s assessed [20].

Global Efforts Put in the Field of Gas Hydrates

Global efforts have been put by various countries for exploiting this vast source of energy. India has already completed Nation Gas Hydrate Programme NGHP-01 and started NGHP-02. The field testing of gas hydrate is done globally as explained below:

Indian scenario (National Gas Hydrate Programme Nghp-01)

The drilling/coring operations were performed in four areas of India offshore while NGHP 01 from 28th April to 19th August 2006. Dedicated gas hydrate coring/drilling/LWD (logging while drilling)/ MWD (Measurement while drilling) operations were carried out while Indian Offshore during NGHP Expedition 01, 2006.

Sites of NGHP Expedition 01, 2006 Operational Programme

The total of 39 holes were drilled at 21 sites in 4 areas in Indian Offshore (1 site in Kerela-Konkan, 15 sites in Krishna-Godavari, 4 sites in Mahanadi and 1 site in Andaman) [21]. Presence of gas hydrates in the K-G and Mahanadi offshore basins and the Andaman regions have been confirmed. The richest gas hydrates deposits (~130 meter thick with ~70% saturation and 60% porous fractured shale) are in the K-G basin and the thickest (260-600 metres) in Andaman Sea. Although gas hydrates have not been found from the drill site in the KK basin, various geo-scientific investigations have shown that gas hydrates may be present in the Saurashtra and KK basins in western Indian margins [22,23] and Uma Shankar and Sain [24] also favoured the probability of presence of gas hydrates in western margins of India.

Outcome from NGHP expedition 01 and future NGHP 02

The NGHP expedition 01 has revealed the presence of gas hydrates in Krishna-Godavari, Mahanadi and Andaman basins. **NGHP 02 expedition has started by** operational experts on gas hydrates.

Field testing for producing natural gas from natural gas hydrates deposits of Alaska North Slope Alaska site

According to USGS assessment North Slope Alaska hosts about 85 trillion cubic feet of undiscovered recoverable gas hydrate resources [25]. Mount Elbert site was selected for drilling and data acquisition after comparative study of 14 sites in Alaska. Alaska Mount Elbert gas hydrate test well project was carried out from February 3-19, 2007

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which included the acquisition of pressure transient data from four short-duration open-hole, Schlumberger's wireline modular dynamic testing (MDT) was used for testing dual-packer pressure-drawdown [26]. While this programmes drilling, logging, coring, and transient pressure testing was performed at the Mount Elbert site. Oil based drilling was done in which mineral oil-based mud (MOBM) drilling fluid was used, which gave a good visual clue of the extent of fluid invasion, and also confirmed that all waters collected from the samples were formation waters [26]. Samples were cleaned using a Soxhlet extractor with chloroform–methanol azeotrope at a ratio of 87:13, before any test to remove drilling fluid and salts. Tests were done in open-hole and were designed on the basis of information obtained from cased-hole MDT tests performed while the Mallik 2002 testing programme.

Four 1-m thick zones were tested in the Mount Elbert well: two in unit D (tests D1 and D2) and two in unit C (tests C1 and C2). Each test has multiple stages of varying duration, along with that each stage has a period of fluid removal which reduced pressure enough to dissociate gas hydrate. Gas and water samples were collected during selected flow periods [27] and a fluid analyzer on the MDT tool enabled the identification of gas and water. The Mount Elbert MDT programme consisted of two types of tests. For examining the petro physical properties of the hydrate-bearing reservoirs, each MDT tests began with a "pre-flow test," in which pressure was reduced to a level so as to put in motion unbound formation water but not enough to start gas hydrate dissociation. Pre-flow tests were carried out after various test stages in which the pressure reduction was great enough to start the dissociation of gas hydrate. In the Mount Elbert unit D sand, the mobilized phase of water was calculated to be about 8 to 10% of total pore volume. In the unit C sand, its presence to upward range to roughly 15%, hence giving confirmation for application of depressurisation technique [28]. Cleaning and squeezing at the well site for Forty-six (46) samples were done to obtain pore water samples for interstitial water geochemical analyses [29].

For investigating the feasibility of carbon dioxide-methane exchange in gas hydrate reservoirs, a first field programme was completed on 5th May, 2012 in Prudhoe Bay Unit of Alaska methane hydrate site by Conoco Phillips jointly with the Japan oil gas and metal National Corporation and US department of energy. During 15-28 February 2012, 210,000 standard cubic feet of blended mixture of carbon dioxide and nitrogen along with some volume of chemical was used to displace methane from hydrate sites. Mixture gas is preferred over pure carbon dioxide because mixture gas promotes interaction of carbon dioxide with methane gas hydrate and prevents formation of undesired hydrates. The injected volume of 210,000 scf of mixture gas into well, was locked in for reconfiguration of back flow. Well was shut off on 4th March 2012. Under its own energy a mixture of gases was produced which carried on for 1.5 days before locking in. After that when well was shut off water and methane gas were produced at variable rates. Afterwards reinitiating of production was done on 23rd March 2012. For next nineteen days continuous flow was derived before final lock in on 11th April. Highest flow rate achieved was 175,000 scf/d but during last days of production testing, rates varied between 20,000 to 45,000 scf/d. There is environmental threat with increasing concentration of carbon dioxide and methane in seawater which were recorded so as to maintain their optimum amount [30].

CO_2-CH_4 exchange technique followed by depressurization forms the basis for the Ignik Sikumi field trials conducted on the Alaska North Slope during 2011 and 2012 [31]. Free water was found in the reservoir in the 2011 programme. Based on this finding, a mixture was implemented as free water blocks injection of pure CO_2. Injection used mixture of CO_2 (23%), N_2 (77%) and chemical tracers. While CO_2 achieves 64% exchange efficiency mixed gas injection improves it to 85% [32].

Field testing for producing natural gas from natural gas hydrates deposits of Mallik site

Mallik site: Mallik site is located in Richards Island, Mackenzie Delta, North West Territories of Canada. In 1972 hydrates were inferred while exploration drilling by Imperial oil Ltd. Mallik L-38 well was drilled during exploration [33,34]. In 1998 test were conducted under Mallik 2l-38 collectively undertaken by Japan and Canada. Gas Hydrate Research Well Program established that Mallik fields are one of the most concentrated gas hydrate accumulations in the world. Well Mallik 2L-38 was drilled to 1150 meters [35,36]. In Mallik 2002, there was international partnership between big organizations of many countries. Gas Hydrate Production Research Well Programme tests were carried out to confirm feasibility of natural gas production by depressurisation and by thermal stimulation techniques. New production well Mallik 5L-38 was drilled along with observation wells Mallik 3L-38 and Mallik 4L-38. It was a five day test. Mallik 3L-38 was drilled to 1188 m [34]. Results proved that gas can be recovered. In this test 500 cubic meter of methane gas was produced from gas hydrates [34]. This test gave signature for the first time that there is a technical feasibility for the production of gas from gas hydrates.

Another test was carried out in 2007-2008. First phase was carried out in April 2007 for 12.5 hours [37], without sand control measures to monitor and measure direct formation response to pressure drawdown. Well Mallik 2L-38(production well) was re occupied and hole section was further dug from 1150 to 1310 m. Production casing of 244.5 mm was installed to 1288 m. Another well Mallik 3L-38 (injection well) was dug from 1188 m to 1275 m [38]. This was done so as to enable production testing and reinjection of produced water into lower injection zone. Programmes inclusive of open and cased whole logging in order to characterize geology. In well Mallik 3L-38, 73 mm tubing casing was installed [35]. Two annulus wells were used, gas produced was recovered up the annulus well head. Though this test produced 830 cubic meters of gas which was more than gas produced in tests done in 2002, it resulted in accumulation of significant amount of sand as expected [37]. Second phase of this test was done in winter of 2008 which consisted of field operations of six day pressure draw down, during which stable gas flow was to be measured at the surface. Mallik 2L-38 production test well was re-entered, and a modified pumping system was used into the hole this time with sand control devices. The operation of the pump was started in the afternoon of March 10, 2008 and extended until the 12 noon on March 16, 2008 i.e. 139 h approximately. Successfully continuous gas flow varied from roughly 2000 to 4000 m^3/day, was maintained and cumulative gas production was approximately 13000 m^3 [39]. Along with that water produced was less than roughly 850 barrels. This test grant liability to gas production from gas hydrates by depressurization alone. Experiments were carried out on samples from Malliik 5L-38, which resulted in characterisation of effects of pore water salinity on in situ hydrate stability. An in situ pore salinity of approximately 45 ppt was detected [35]. Sediment porosities in both wells range from 30 to 40% [35]. This Site requires more fundamental experimental study for a kinetic gas hydrate model to qualify various scales which will be required for future reservoir simulations that may include investigation of larger areas.

German project SUGAR tested thermal stimulation method by in situ combustion using counter current heat exchanger in the large reservoir simulator (LARS) [40]. The main advantage of this method is that there is no energy lost for transportation. The method involves catalytic combustion of CH_4 in air and transfer of heat to the reactor shell. 10 wt% Pd supported on ZrO_2 was used as catalyst. In 12 hours of the test 288L of CH_4 was converted to CO_2 and H_2O and resulted in fluid expansion 23.5 L at 8 MPa (or 1880 L at 0.1 MPa). Thus, effectively 15% of produced CH_4 supplied the heat for dissociation of the hydrates. Later, this method was adopted as a borehole tool at site KTB in Windischeschenbach, Germany. This test proved safety of catalytic combustion of CH_4 at depth.

Several methods for gas production were implemented in Muri Basin, Qilan Mountain Permafrost, China in 2011 [41]. These were the depressurisation method done by keeping water level below hydrate layer in the borehole; thermal stimulation method done by injection of hot air or steam. In 84 hours, production by depressurisation yielded 81.97 m^3. On the other hand, hot air injection produced 9.73m^3 in 11 hours and steam injection produced 3.3 m^3 in 42 minutes.

Field testing for producing natural gas from natural gas hydrates deposits of Nankai trough

Nankai trough: Japanese government, in 1999, funded a drilling project in eastern Nankai Trough which indicated existence of bottom simulating reflectors (BSR) [37]. Under this project a test well 'MITI Nankai Trough' was drilled to study geological characteristics of BSRs [42]. In 2001, an optimal interpretation workflow to find exact location of gas hydrate rich zones, was developed which includes evaluation and integration of four indicators which are bottom simulating reflector (BSR), Turbidite sequence, Strong seismic reflector and relatively higher interval velocity. In this program, 2D, 3D seismic surveys were carried out and 32 Wells were drilled in water to depths of 722 to 2033 m. In this site base of hydrate stability zone ranges from 177 to 345 m below sea floor. 12 out of these 32 wells were cored, 16 of remaining were logged with logging while drilling (LWD) tools, 1 was equipped with temperature sensors and in remaining 2 wireline tools were used for logging [37]. After this test detailed analysis of gas hydrate rich sand samples and their geophysical properties was carried out for production test [43]. Density-magnetic resonance technique used to determine gas saturation in gas reservoirs was used to estimate saturation from wireline logs [37].

In July 2012, two controlled source electro magnetic (CSEM) surveys were conducted over the West Svalbard margin on the basis of seismic data collected previously. Its aim was to check out hydrate and free gas saturations in submarine sediments. Offshore production test was carried out at Daini Atsumi Knoll which is off the coasts of peninsulas, Atsumi and Shima. Test included prepatory drilling and flow tests along with well abandonment. Deep sea drilling vessel, Chikyu was used in this operation. Prepatory drilling commenced on 15th February, 2012. Vessel returned to Shimizu port on 26th March, 2012. Pressured ore samples were acquired from 29th June to 7th July, 2012. In January, 2013, in Sapporo, Japan, a suite of instrumented pressure chambers, Pressure Core Characterization Tools (PCCT), developed at Georgia Tech, were deployed. These tools were used to measure electrical, biologic, hydraulic, and mechanical properties of gas hydrate-bearing pressure cores recovered from the Eastern Nankai Trough in 2012 [44]. An average daily gas production of approximately 700,000 cubic feet was achieved and 4,200,000 of cumulative volume of gas were produced [44]. Test was conducted for six days during 12-18 March, 2013. Depressurization method for production was used [45]. The pressure dropped to 5 MPa from 13.5 MPa during the day with gas production beginning late morning. Six days of continuous gas production with stability was observed. 11950 m^3 (STP) of gas was produced in this time along with total water volume being 1162 m^3 [46]. Methane was produced for first time from this site in 2013. A lot of efforts are going on to make this operation successful.

Future Prospectives of Gas Hydrates

As there are limited resources of Conventional fuels like Coal, Petroleum and Natural Gas, hence with the available resources the demands for the energy of world can be met for a limited time. As far as the amount of gas hydrates is concerned no other resource can match this upcoming resource of energy. They are seen as future generation fuels moreover they are also clean source of energy and their exploitation is possible by CO_2 sequestration as it is clear from the field testing. So, this resource of energy can be exploited by the reduction in Global Warming. In future Gas Hydrates are seen as white gold provided a viable technology is developed for their exploitation.

Conclusion

Tremendous of methane is present in the form of the gas hydrates. They are present worldwide beneath the sea and in permafrost regions. They are considered as future generation fuel. From the NGHP 01 Expedition it was evident that the gas hydrates are distributed in the Krishna-Godavari, Mahanadi and Andaman off shores but were not observed in the Kerela Konkan Basin. Long term production test are planned in USA and Japan to establish the viability of production technologies. Various lesson have been learnt from the field trial for gas production from gas hydrate in Alaska North Slope Site, Mallik Site, Nankai Trough, if the experience gained from these trial is understood and applied properly then it can help in designing a novel technology for the exploitation of this natural novel resource of energy which can meet the energy demand for centuries. However, there is a strong need to prepare a suitable technology for exploiting this untapped energy resource.

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