COMMERCIALIZATION OF METHANE HYDRATE GAS

EXPLORATION/ EXTRACTION

By

AMIT KUMAR SINHA
SAP ID : 500070597
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Guided By

MORTEN LARSEN, SR. MANAGER, AKER SOLUTIONS

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Declaration by the Guide

This is to certify that Amit Kumar Sinha, a student of MBA Oil & Gas, SAP ID 500070597 of UPES has successfully completed this dissertation report on "Commercialization of methane hydrate gas exploration/ extraction" under my supervision.

Further, I certify that the work is based on the investigation made, data collected and analyzed by him and it has not been submitted in any other University or Institution for award of any degree. In my opinion it is fully adequate, in scope and utility, as a dissertation towards partial fulfillment for the award of degree of MBA/BBA/B.Sc.

Morten Gunnar Larsen
Senior Manager
Aker Solutions

Visiting Address: Joseph Kellers Vei 20, 3408 Tranby, Norway
Postal address: P.O.Box 73, 3401 Lier, Norway

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Name: Amit Kumar Sinha
e-mail: amitsinha0905@gmail.com
Date: 01.01.2020
Place : Bangalore/ Oslo

Table of Contents

List of Figures

Executive Summary

Fossil fuels have always been the key aspect of any technological advancement ever made, be through usage of coal, oil or gas which has driven most of the industries and undoubtedly is the most important commodity used in everyday life. Of late with oil reserves depleting, search has intensified to harness energy from unconventional sources but scalability is always a concern about these sources. So it is prudent to keep searching for a resource which is in essence same as naturally occurring oil and gas and which can keep the industrial furnaces running for a long time. Methane Hydrate which occurs in ocean bed as well as permafrost regions has estimated reserves of more than 75 times than that of natural gas and is quite promising.

Even though technology exists for natural oil and gas extraction for onshore and offshore, these fall short of refinement needed for extraction of methane hydrate. For reasons that methane has a warming impact that is 56 times greater than carbon dioxide over a period of twenty years, accidental spillage could potentially be catastrophic to environment. Also not just spillage but removal of hydrate from sedimentary layers itself can cause instability and landslides on submarine continental slopes.

Notwithstanding these challenges, experimental wells have been dug in two promising locations at Mallik in Canada and in Nankai in Japan. The former is permafrost region while the later is subsea. These initial explorations have been particularly significant in research and development catering to gathering of data for analysis and formulating plans for validation and improvement of technology for production wells in future. Being research projects with lot of unknown variables in play, economic justification of extracting methane hydrate has been quite depressing. Moving towards commercialization, advancement of related technologies, besides those specific to the oil and natural gas is very much essential to ascertain safe, economically viable and environmentally stable operations.

The report gives a background about methane hydrate and deposits around the world with success stories from Mallik and Nankai. Also captures major challenges related to geography, technology, cost and environment. Building on the research outcomes from experimental wells, findings and analysis have been done on technological advancement as well as towards commercialization of the methane hydrate industry.

Chapter 1 Introduction

1.1 Overview

Depleting Oil & Gas reserves across the globe calls for rapid commercialization of alternative energy resources including shale gas, wind power, tidal energy and solar power – to replace Oil & Gas as primary energy provider. Oil apart from being an energy source is also a raw material in almost everything we see around. If we can find a viable, scalable alternative form of energy source replacing oil, we might be able to prolong the use of world oil reserves for producing only essential products like specialized solvents, lubricants, polymers, chemicals and medicinal formulations. Even though the alternative energy sources are gaining traction, they may not be able to seamlessly transition into most of existing industrial and commercial process/ machinery as an alternative to Oil & Gas.

Methane hydrates trapped in subsea and permafrost regions might be the closest form of energy source which can be exploited to fill in for naturally occurring gas.

"Methane hydrate resource is 21000 TCM, which is 75 times greater than current natural gas reserves and about 50 times greater than ultimate natural gas resource estimates. These are widely spread across the world with over 90% of methane hydrate existing as finely dispersed particles on the ocean floor and also occurring as permafrost deposits in arctic region which are infact much more concentrated." So it becomes quite prudent to realistically realize methods for extraction of Methane Hydrate to fill in the void created by declining conventional oil and gas production.

The extraction of these with available and current technologies hasn't been successful till date, with very few success stories like Mallik Gas Hydrate Production Research Well in Canada and Nankai Trough Gas Hydrate site in Japan. Major challenge is environmental concern because of release of large amount of greenhouse gas in the process with the current technology. Also the advancement needed in technical as well as economic sustainability of such operations.

1.2 Background

Methane hydrate is also called "fiery ice" and looks like an ice while it starts burning when exposed to open flame with water only as combustion residual. Methane hydrates constitute gas reservoirs trapped in crystalline structures within the ocean floor and in permafrost glacial regions. Recent assessments of available resources have reported huge economic potential.

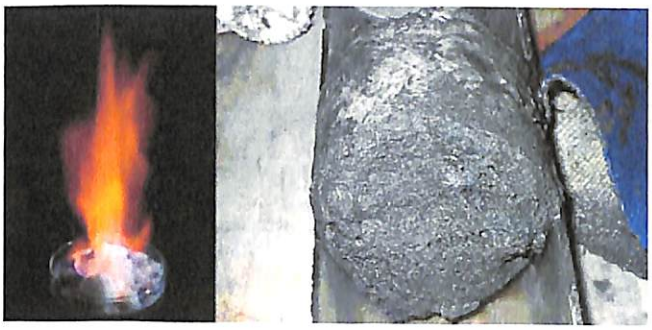

Fig 1: (Left) "Fiery ice," burning artificial methane hydrate
(Right) Core sample of layers that bear target natural methane hydrate
Source: Research Consortium on Developing Methane Hydrate Resources

How much methane is contained in methane hydrate?

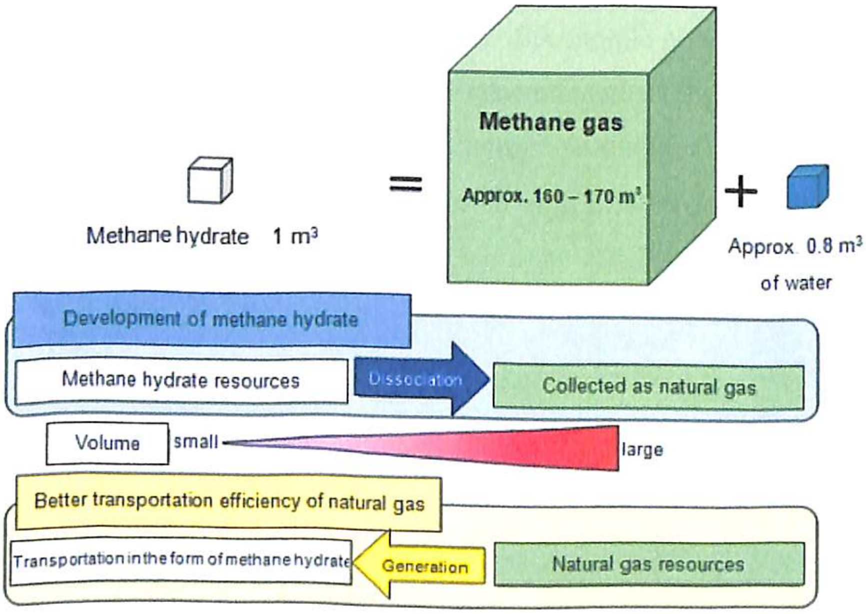

Fig 2: Volume of methane hydrate
Source: Research Consortium on Developing Methane Hydrate Resources

Analyzing the above figures, it becomes quite evident that there is a lot of potential if methane hydrate crystals can be safely tapped to produce methane.

The next stepping stone invariably leads to answering the following questions.

1. Methane hydrate layers existing in what conditions should be developed? (methane hydrate existence conditions)
2. What methods should be used to produce methane gas from methane hydrate? (production methods)
3. What equipment and facilities should be used for development? (development system)

MH21 Phase 1 project dealt with these aspects of methane hydrate realization. The initial project has been experimental with no business objectives attached to it apart from being able to promulgate economic benefits which may transform into a profitable business model. When methane hydrate production technology is established and commercialization is realized, it will become a new energy source that will significantly contribute to the securing of stable supplies of energy for the world.

To achieve the above objectives, following steps have been envisioned for commercialization of methane gas hydrate exploration.

1. Clarification of methane hydrate occurrences and characteristics.
2. Assessment of methane gas amounts trapped in promising locations.
3. Selection of resource fields and deliberation of economic potential.
4. Implementation of production tests in the selected methane hydrate resource fields.
5. Improvement of technologies for the commercial production.
6. Establishment of a development system complying with environment.

1.3 Purpose of the Study

Natural gas consumption is continuously increasing throughout the world. This is in line with the increased energy needs by developed nations as well as rapid industrialization of developing world. More so since we have been trying to move away from coal based gas fuel which has been comparatively a cheaper source to mine and produce. Naturally occurring gas is abundant and meets the electricity needs of many industrialized nations. As the industrial apparatus for processing natural gas is already existing, it is but natural to find alternatives which move right into the same processing facilities with minor changes and continue to keep the supplies uninterrupted for a foreseeable future. In this scenario, Methane Hydrate fits in just right and with technology maturing in near future with commercial costs factored in, it could very well lead the world as major energy source.

This report is undertaken primarily to explore the feasibility and commercialization of safe extraction of methane hydrate deposits from subsea as well as perma-frost regions. Also analysing the prospects of implementing current and future technologies, with a special interest to know about the scalability of the operations to meet commercial expectations.

In course, we also see some success stories from Mallik Gas Hydrate and Nankai Trough gas hydrate projects, type of technologies involved and the challenges and solutions envisioned in future prospects.

Chapter 2 Historical Review

2.1 Success Story: Mallik Exploration

Mallik Methane Hydrate Site (or Mallik Gas Hydrate Production Research Well, Mallik test well) is located in the Beaufort Sea, Canada. Well logging have confirmed gas hydrate layers exceeding 110m in total thickness, with them occurring in pore spaces of medium grained sands with concentrations between 50 and 90%.

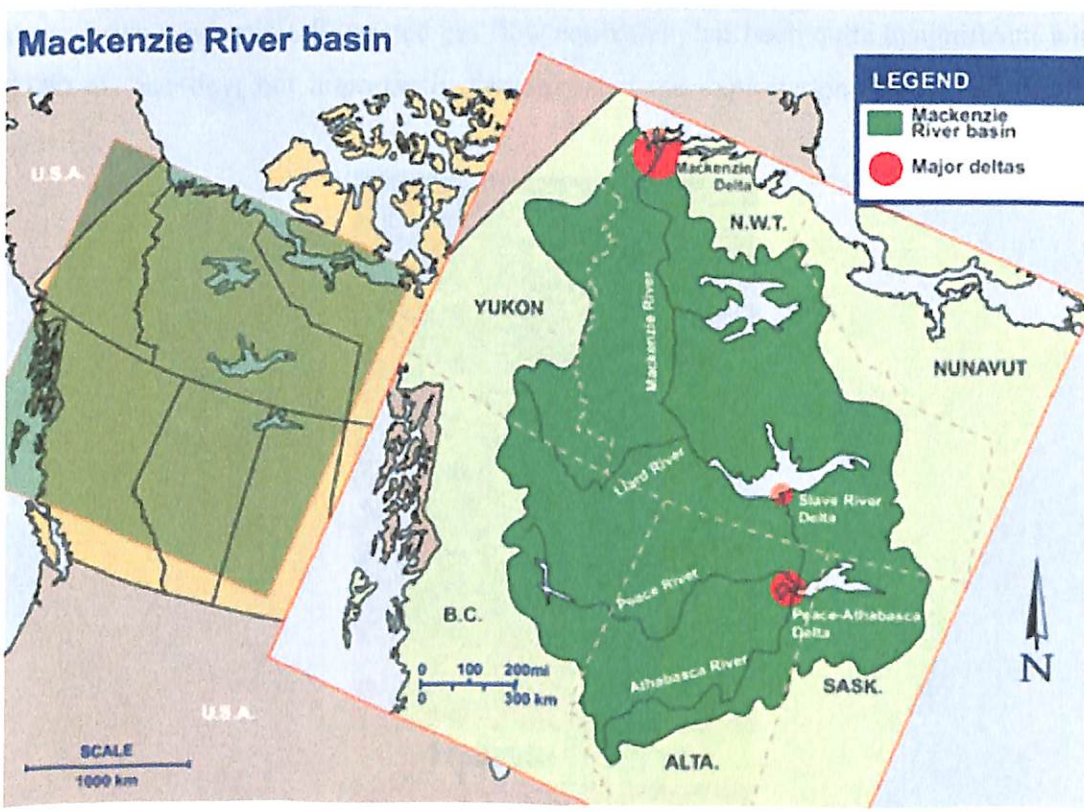

Fig 3: Overview Map of the MacKenzie River Delta in Canada
Source: By Environment Canada

It is the first dedicated site wherein research activities have been performed for permafrost gas hydrates. Aim has been to get information on in-situ physical and geophysical properties of gas hydrates, production testing and impact of gas hydrates to energy, climate and geohazard. The program also studied the greenhouse effect of burning methane and environmental change.

The collaboration began between Japan, Canada and the United States, and the partnership first led to an initial drilling in 1998. The success of this first project led to the development of new drilling methods, coring and the evaluation of the strata constituting the pockets. Later the partnership expanded with India, Germany and oil companies such as Chevron, BP and Burlington coming on-board.

In 2001 and again in 2007-08, 3 successful wells have been drilled to a depth of 1160m. Field operations included the acquisition of a full suite of open-hole logs, permafrost and hydrate-bearing continuous core and also cross-hole tomography experiments before, during and after production testing. Various production techniques have been researched at this site including full scale thermal and pressure draw down production. Extracted gas flow equivalent has been quite insignificant with 1500 m3 per day, but importantly demonstrated the exploitation from hydrates was feasible.

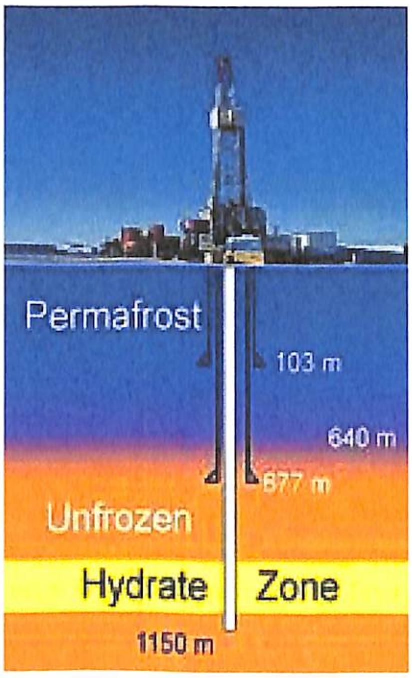

Fig 4: Cross-section of the Mallik drilling site
Source: By Geological Survey of Canada

Ongoing analysis of the data collected throughout the program will lead to a greater and better understanding of gas hydrate properties and its formation, production response and the effectiveness of conventional production technologies. Scientific and engineering results were made publicly available to scientists, stakeholders and engineers through the Bulletin of the Geological Survey of Canada.

2.2 Success Story: Nankai Exploration

Nankai Methane Hydrate Site (or Japanese Methane Hydrate R&D Program at Nankai, Nankai Trough Methane Hydrate Site) is located in the Nankai Trough, Japan and extends more than 700km in a southwest-northward trending direction.

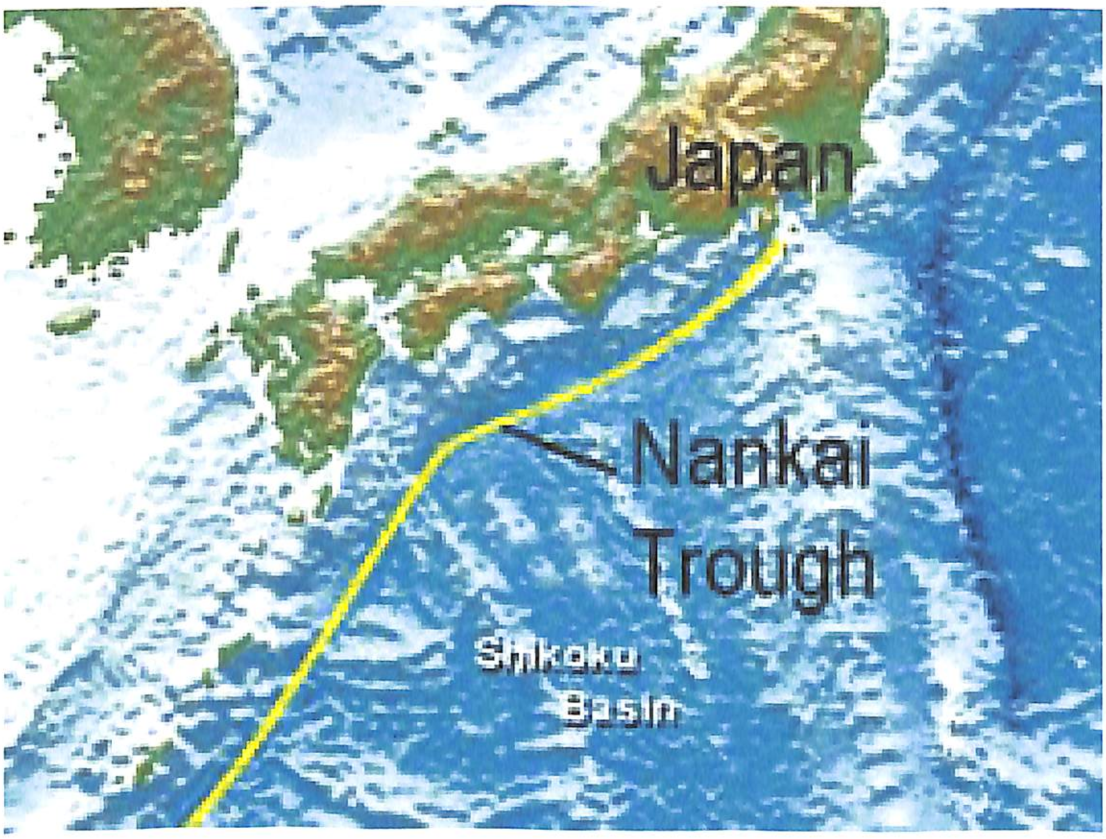

Fig 5: Location map of the Nankai Trough
Source: By U.S. Department of Energy

Development at Nankai Trough promoted the technology needed for the commercial exploration and production of methane gas from hydrates. Also facilitated its use and contribution to a long-term national energy strategy.

Nankai Trough region occur at a depth of around 290 to 300 meters below the seafloor (1,240 meters below sea-level). In order to extract the gas, specialized equipment was used to drill into and depressurize the hydrate deposits, causing the methane to separate from the ice. The gas was then collected and piped to surface where it was ignited to prove its presence and was the world's first offshore experiment producing gas from methane hydrate. Previously, gas had been extracted from permafrost deposits at Mallik site in the MacKenzie delta in Canada but offshore deposits are much more common which made this project ground breaking.

Japan estimates that there are at least 1.1 trillion cubic meters of methane trapped in the Nankai Trough, enough to meet the country's needs for more than ten years. This obviously paves the roadmap for developing economically viable extraction methods by investing in technology and cost modeling of the methane hydrate resource.

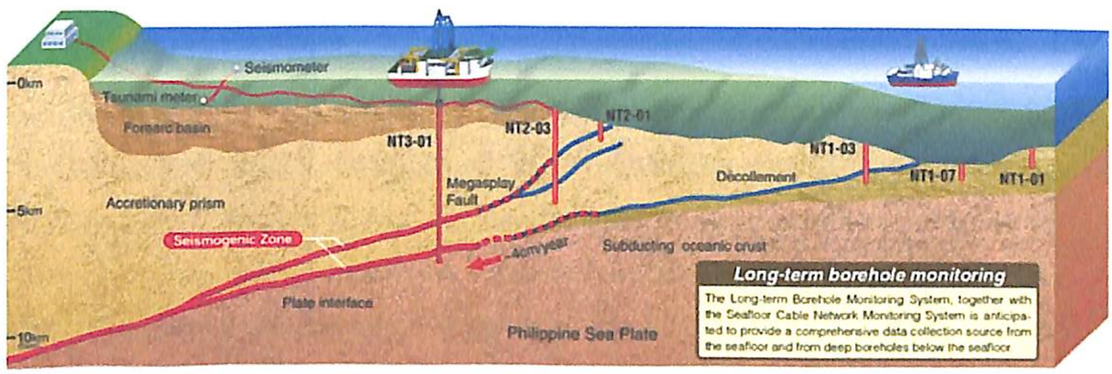

Fig 6: The Nankai Trough Fault Line
Source: By The NanTroSEIZE Scientific Team

A consortium named 'MH21 – The Research Consortium for Methane Hydrate Resources in Japan' was formed with the Japan National Oil Corporation, the Japanese Petroleum Exploration (JAPEX), the United States Department of Energy (DOE), industry partners and Japanese Ministry of Economy, Trade and Industry (MITI). MH21 aim is to establish a process for commercial production from offshore gas hydrates.

A lot of research and study material has come out from MH21, including the development of safe and dependable technology, as dissociation of methane in shallow waters can produce very high pressures and cause submarine landslides. Furthermore, the scientific study aimed to develop new safety techniques guarding against any hazardous conditions created by gas hydrate drilling and pipeline construction and give insights into drilling and production technology with regard to a new industrial development. It also gave scientists the opportunity to monitor the physical response of gas hydrate deposits and investigate marine gas hydrates in one of the most active earthquake zones on the planet.

Chapter 3 Research Aspects

This research is exploratory in nature with a aim to gain familiarity with the subject, by studying the developmental work done so far by research institutes, oil & gas operators and capital drilling equipment manufacturers.

3.1 Geographical Presence

A clathrate is a chemical compound composed of a set of host molecules forming a solid lattice with several thousands of "guest" molecules trapped within it. Hydrates are clathrates in which water is the host molecule trapping gas molecules: methane, ethane, propane and carbon dioxide. 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 m3 of water enclosing up to 164 m3 of gas.

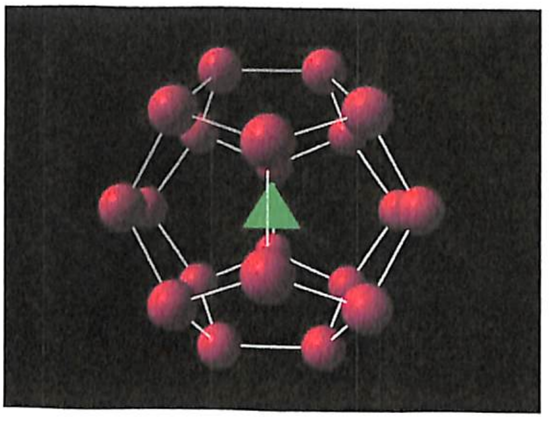

Fig 7: A small cage composed of the crystalline structure of methane hydrate
Green: methane molecule Red: water molecule
Source: Research Consortium on Developing Methane Hydrate Resources

Methane hydrates was discovered by Sir Humphry Davy in 1810. In 1934, Hammerschmidt discovered that the plugging of pipelines in the polar regions was due to the crystallization of hydrate and not to the presence of ice. It was not until the mid-1960s that the first methane hydrates were found in the natural environment, in the sub ground sediments of gas fields in Messoyahka in western Siberia, in the Black Sea and in Alaska. These findings were the starting point of the first research programs launched across the world.

The formation of compounds occurs in a narrow sediment band called the Hydrate Stability Zone, parallel to the earth's surface. Several physicochemical factors have a strong impact on the size of the band: a high salinity level limits for example the formation of compounds, while the presence of other gases in deposits like carbon dioxide, sulfide hydrogen and heavier hydrocarbons such as ethane increase the stability area.

Gas hydrates thus form naturally in permafrost regions and beneath the oceanic floor. Proven or estimated deposits are located in regions which are generally sensitive (low temperatures, difficult access, deep drilling), which complicates the exploration, development and delivery of the product to markets for which it is intended.

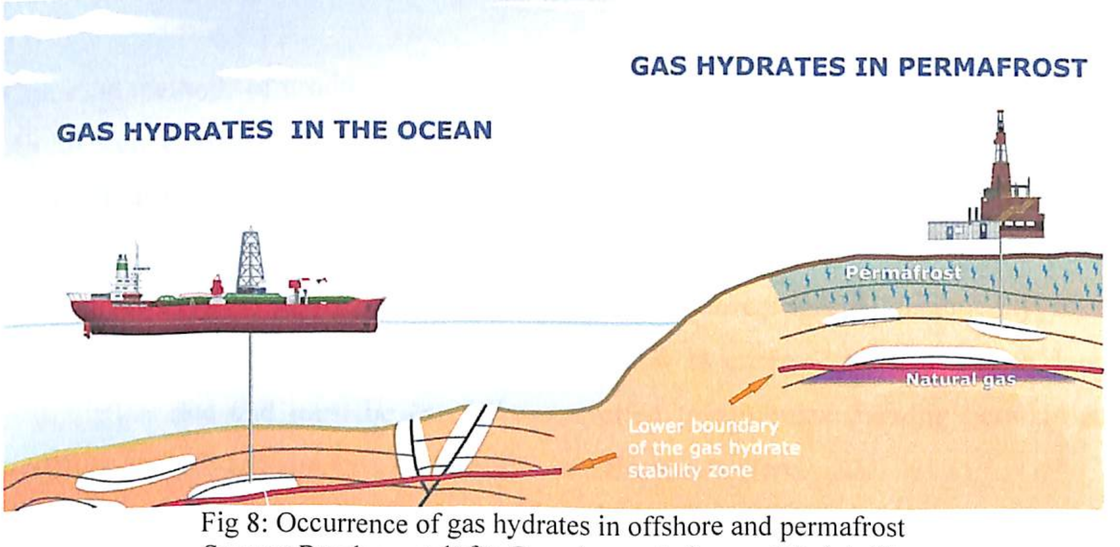

Fig 8: Occurrence of gas hydrates in offshore and permafrost
Source: Bundesanstalt für Geowissenschaften und Rohstoffe

These crystalline formations, which remain stable under very strict pressure and temperature conditions, are present in the permafrost glacial regions and ocean floors. Oceanic methane hydrate is situated deep under the sea bed stabilizing the ocean floor, and extraction carried out will result in destabilizing the tectonic plates and may trigger tsunamis and earthquakes, submarine slumping, landslides or subsidence that can not only damage production equipment and pipelines but will prove to be environmentally very disturbing. Also leakage of the methane gas while its extraction and transportation poses significant risks. Methane is a greenhouse gas and its danger levels are 20 times more than that of carbon dioxide which can lead to significant global warming. The probable solutions to these problems are being worked out through continuous research and feasibility analyses.

3.2 Technology Implications

Methane production techniques are similar to those used for conventional hydrocarbons with the additional need for maintaining optimal production rates during the extraction, the long-term management of water production and understanding the behavior of hydrates at low temperatures and low pressure. Methane hydrate is present in deep below the ocean bed under pressurized conditions, with one liter of methane clathrates containing 168 liters of methane gas indicating that how highly compressed it is. The production of methane hydrate means dissociating methane hydrate in the layers and collecting the resultant methane gas through wells and production system.

Common methods of producing natural gas from gas hydrate deposits include thermal stimulation, depressurization and injection of inhibitors.

Thermal stimulation method consists of injecting steam or hot pressurized water in order to locally destabilize the hydrates, provoking an area of instability and thus allowing the freed gas to be extracted. This is not considered technically and economically viable when used alone because it is energy-intensive, has a low dissociation rate and must be carefully controlled to minimize thawing permafrost which could lead to the release of methane into the atmosphere.

Depressurization, consists of lowering the pressure in the hydrate layer to cause dissociation. Considered as the most economical because of limited energy expenditure and significant volume of hydrate dissociated rapidly. Thermal stimulation and depressurization were used together in the Mallik and Nankai.

Injection of inhibitors is a process using organic compounds (glycol, methanol) or ionic (salt water) modifying the conditions of equilibrium (pressure-temperature) in the compounds. While this method does not pose major technical difficulties, it remains unattractive with high volume of inhibitors requiring high costs, production yields collapses rapidly due to the dilution of inhibitors and environmental risks.

Many technological challenges remain with regards to the exploitation of hydrate deposits and the principal results from the scientific community still rely on laboratory experiments and modeling. Field data is coming slow and will be gathered over the long term. Research programs undertaken will therefore validate the feasibility of exploiting various types of deposits and consolidate existing theories.

3.3 Cost Implications

Cost of sustained production with future technologies and economic aspects of hydrate gas reserves is somewhat difficult to analyze at present, though cost of experimental data is available from Mallik as well as MH21 projects. Primary reports say the price of gas has to be USD 6 per Mcf for freely available permafrost gas while with enhanced recovery, the price would be around USD 10 for viable production.

Natural gas is an example of market in which the structure and development do not entirely result from purely economic aspects. Cost modeling for hydrates involves assessing a wide range of variables whose description and analysis requires a multidisciplinary perspective. Direct market benefits of gas hydrate resources derive fundamentally from the sale of the produced natural gas. Other important aspect is massive levels of investment required, substantial freight costs and heterogeneity of resources. Geographical dispersion of market makes the growth of gas markets closely linked to geostrategic issues which translates into new and expanded economic activity, employment and taxation. Economically viable methods for safe methane extraction and minimization of the environmental impacts are necessary. Therefore the first deposits to be worked should be those containing the most optimal conditions according to the current accumulated scientific knowledge. Gas hydrate research and development will also provide insight into the nature of geohazards relevant to conventional oil and gas drilling with substantial economic impacts on deep-water and Arctic energy development. Further efforts aimed at realizing production will generate scientific knowledge about the development and physical/ chemical nature of gas hydrate bearing sediments. These activities will have its economic value transforming to knowledge could potentially be considerable.

Gas hydrate research is one area where private investment may not be in accord with the potential public benefit. As a consequence, public-sector programs might be desirable in some instances. Other unconventional energy resources, such as coal bed methane and shale gas, have been developed with the aid of government supported research due to high cost involved during the nascent stages before production.

3.4 Environmental Challenges

Gas hydrates deposits in sediments have a significant influence on the climate if large quantities of gas were to be released during the extraction of resource either by leaks or accident. Methane has a warming impact that is 56 times greater than carbon dioxide over a period of twenty years. Reduction of hydrostatic pressure or a general increase in ambient temperature could trigger the dissociation of the compounds of some deposits, eventually increasing global warming and causing a chain reaction of degradation of other reservoirs. The conditions of temperature and pressure on the ocean floor in the geothermal gradient are practically stable over hundreds or even thousands of years therefore hydrate pockets are generally not affected in the short term. The phenomenon of dissociation for onshore deposits, can be much faster. In the Gulf of Mexico and the American margin located in North of California, warm currents temporarily activate the dissociation of compounds, a phenomenon observable at the sediment-water interface level by the emission of gas bubbles.

The effects of the natural release of methane into the ocean is still widely debated because many parameters must be taken into account as:

(i) The amount and the transfer rate of methane in the sediments which depend on the bacterial activity at a local level.

(ii) The volume of methane which is dissolved in the water column.

(iii) The volume of methane finally escaping into the atmosphere.

The real impact of dissociation whether natural or accidental of methane hydrates on climate change must be carefully studied to determine its real contribution to the environment. The effect is transposed to the polar regions, where an increase in the air temperature or the level of the sea may cause the dissociation of the compounds. Also the hydrate reservoirs play an important role on the stability of sedimentary layers that contain them. In case of disturbance of the deposits, these layers can be found weakened and cause landslides on the submarine continental slopes. These instabilities can also occur on a smaller scale during drilling, therefore putting at risk offshore installations and in the process also releasing large amounts of gas into the atmosphere.

Chapter 4 Findings and Analysis

4.1 Technological Advancements

Lot of field and laboratory efforts have been on for Methane Hydrate operational development, the Nankai project at least has confirmed that the depressurization method works well as the optimal production method for the methane hydrate extraction and the validity of the method through onshore gas hydrate production tests.

Significant achievements have been made but overall commercialization has not yet reached at a level where the private sector may consider participation. At best we can say extraction of methane hydrate is possible using crude methods but is it sustainable with current technology. The current world dynamics is quite different from what it was way back during oil and gas exploration boom in 1960-70. Since then onshore and offshore advancement has been made but also stringent environmental concerns, HSE and industry regulations have come in effect which just doesn't mean "resource extraction" but makes sure it is done in the safest way.

4.2 Commercialization

Can we make a profit or not?

This is the most practical question that can be asked to say whether a business is viable and further investment in technology and infrastructure will happen or not. To formulate the cost model, MH21 has comprehensibly evaluated the cost-effectiveness at the last stage of Phase 1 in Nankai project in a concentrated zone named Alpha-1. If the cost-effectiveness of the given development is totally infeasible, it cannot be promoted as a national project. Various conditions were input to "MH-ECONOMICS BM," a cost-effectiveness evaluation program, to select the most cost-effective development scenario among various scenarios simulated by the program. In addition to cost-effectiveness, a sensitivity analysis relevant to the cost-effectiveness was also carried out with an aim to determine "How economic efficiency can be enhanced by improving which technologies and parameters?"

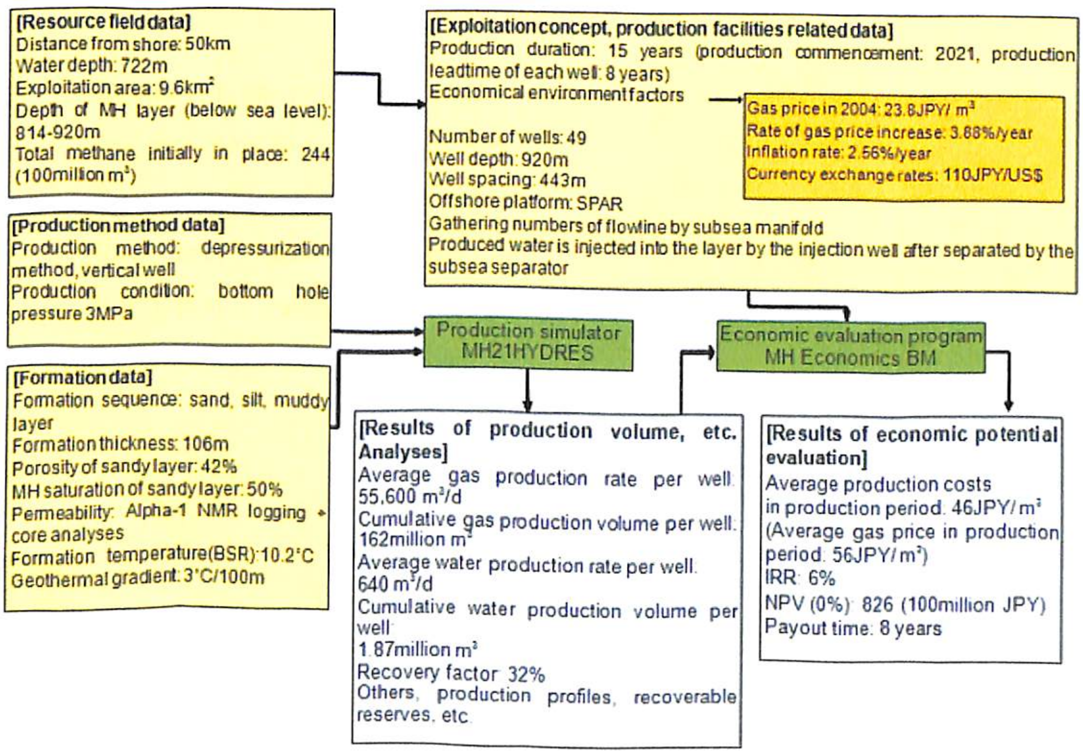

Fig 9: Result of the evaluation of cost-effectiveness
Source: MH21 Research Consortium

The following shows the result of a calculation performed on the production costs.

Methane hydrate production costs: 46~174 (JPY/m3)

(1) A case postulating present construction costs: 92JPY/m3
(the base price was set at that of 2004, and is assumed to have temporarily tripled)
(Cost-effectiveness was calculated using the construction costs in 2004 as the base price. However, 2007 construction costs have doubled or tripled compared with those of 2004 due to the escalated price of oil. The above calculation is based on the assumption that construction costs have tripled from those of 2004.)
(2) All the assumed conditions come into effect: 46JPY/m3
(the base price of 2004)
(3) Production volume lower (by a quarter) than expected: 174JPY/m

Fig 10: Production costs in methane hydrate development
Source: MH21 Research Consortium

MH21 has investigated how cost-effectiveness will be smoothly enhanced by varying the parameters entered into MH-ECONOMICS BM. As a result, following improved parameters were found important to enhance cost-effectiveness.

1. Increase in gas production rate
2. Improvement in recovery factors
3. Reduction in water production rate
4. Reduction in sand production rate
5. Reduction in subsea system costs

Chapter 5 Conclusion and Scope for Future Work

In order to move toward commercialization, advancement of related technologies, besides those specific to the oil and natural gas is very much essential to ascertain safe, economically viable and environmentally stable operations. Active participation of private oil and gas development companies with operating experiences and technologies is essential. Further studies needs to be undertaken with regards to field development technology, production method development, resources assessment, environmental impact assessment and formulation of economic models.

Methane Hydrate definitely is fuel of the future though might take some more time before it becomes commercially viable.

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