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Gas Hydrate: Challenges to crack and Opportunities awaiting

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Summary

The Earth's natural gas hydrate deposits potentially offer a vast new source of low-polluting, carbon-based energy that could provide a comfortable and very much needed bridge to an eventual carbon-free energy future. The production of gas hydrates as a commercial venture is becoming a reality. As an energy source the potential reserves of gas hydrates exceeds all the conventional oil and gas by at least a factor of 2; but the production of gas hydrates has unique economic, environmental and technical challenges. By cracking the challenge with increased knowledge of the deposits, coupled with a few breakthroughs regarding their production we can solve world energy problem and the opportunities are unlimited.

Introduction

The most pressing and urgent questions facing mankind today involve the security for future energy resources. This in turn has led to intensification and extension of exploration and development efforts for new sources of oil and gas.

In a country like India where there exists a persistent widening gap between demand of natural gas and its supply, gas from gas hydrate may play a major role for mitigating this gap of demand-supply. Production from Indian oil and gas fields has been apparently decreasing with little reserve growth despite intensive exploration efforts by national and private oil companies. India gas hydrate resources are 1,894 trillion cubic metres, which is over 1,700 times as much as the proven natural gas reserves with the country of about 1.08 trillion cubic metres. To put the resource into perspective, India consumes 90 million standard cubic metres a day of natural gas. If the estimate gas hydrate reserves hold true, the energy source is infinite and can last several tens of thousands of years.

Gas hydrate is a white ice-like material that naturally occurs under very low temperatures in permafrost regions, and in the low temperature and high-pressure conditions in the continental slope and rise areas and shallow sediments of deep oceans around the globe. Methane and other gases are thermodynamically stabilized within gas hydrates by hydrogen bonding within a crystalline lattice of water molecule (Figure 1). The compact nature of the hydrate structure makes for highly effective packing of methane. Gas from the hydrates is truly unconventional because of its origin, conditions of existence, trapping mechanism and conceivable production methods. A cubic volume of methane contains gas that will expand to about 160 cubic volumes at standard pressure and temperature. Most marine hydrates seem to confined to edges of continents where water is about 500 m deep and where nutrient rich waters unload organic detritus for bacteria to convert to methane. Gas hydrates have been found at the sea floor, but their usual range is 100 to 500 m beneath it. In permafrost regions they can occur at shallower depths because surface temperatures are lower.

Hydrate and related gas deposits are a newly recognized vast store of combustible energy and industrial feed stock. They may contain twice as much carbon as all known

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natural gas, oil and coal deposits and constitute the single largest store of fixed carbon on the earth (Figure 2).

Future gas hydrate R&D efforts will not only vastly improve knowledge of natural gas hydrates, they will also lead to the development of new multiple-application technologies and a greatly improved understanding of the mid- and deep ocean and of the interaction of the oceans and the atmosphere.

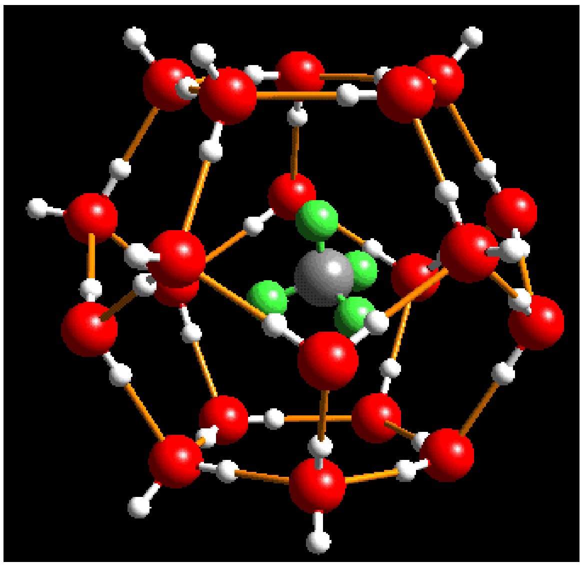


Figure 1: Model of methane hydrate's cage-like structure in which methane (green/gray molecules) are enclosed - without direct chemical bonding - in voids within a solid water lattice (red/white molecules) (Heriot- Watt U.)

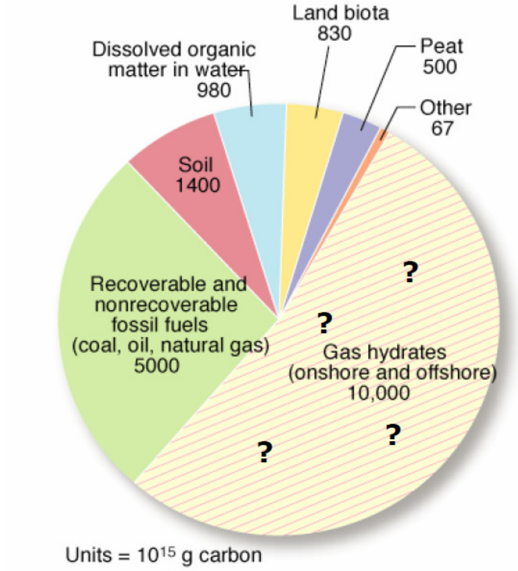


Figure 2: Organic Carbon Distribution

Production Methods under consideration for Gas hydrate exploration

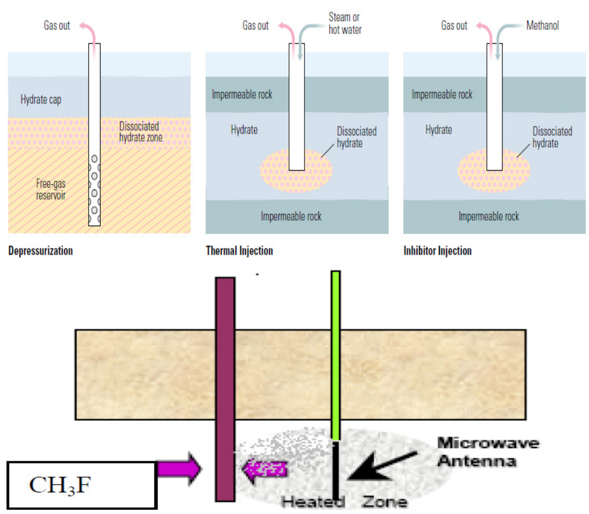
Gas can be produced from gas hydrate reservoirs by inducing dissociation using one or more of the following four main methods (Figure 3):

- Depressurization methods can utilize existing production technologies and facilities but require a permeable or mobile fluid zone to produce the gas released from dissociating hydrate.
- Thermal injection typically involves injection of hot water or steam into, the formation which requires a heat source, additional equipment and costs.
- Inhibitor injection can involve the injection of hydration inhibitors such as salts and alcohols which can lead to rapid dissociation and fracturing, potentially causes breach of reservoir.
- Recovery with fluorine and microwave. This technique deals with the new method for recovery of gas hydrate; it involves the electromagnetic heating of the gas hydrates using an electro strip antenna. In this process we have emission of high power Electromagnetic waves of frequency 2450 MHz which align the molecules according to electric field and

whose alteration causes molecular movement and thus causes melting of gas hydrates which are similar to ice.

Gas hydrate challenges

Technical, environmental and economic hurdles have made gas hydrate development a distant goal of the industry rather than near-term possibility. Recovering methane and economically transporting it, pose a challenge to technologists and scientists. However, this view is changing with realization that gas hydrates could be developed with existing conventional oil and gas production technology.



Microwave Heating

Figure 3: Method under consideration for hydrate exploitation

- **Economic challenges**

➢ It appears however that the complexities and challenges for exploration and production of methane hydrates from the hostile and difficult marine environment require considerable focused R&D effort in various fields, for which adequate financial support is lacking. This is perhaps due to the perception that methane hydrate exploitation will be economically viable only when the price of conventional hydrocarbon and other fuels rises substantially.

➢ The R&D is high cost…
  - India :$36M expedition ('06)
  - Japan: $60M field test('06-'07)
  - Deepwater and arctic locales

➢ The R&D is high risk…
  - Science is still new
  - Occurrences are complex

➢ High costs of long pipelines across unstable continental slopes

➢ Economic competitiveness with conventional resources

➢ Hydrates need to be located near existing infrastructure facilities or the cost to prove hydrate production will be too large.

- **Environmental Challenges**

➢ Damage to sensitive chemosynthetic communities

➢ The potential connection, between the gas hydrate reservoir and the earth's climate is little understood and the quantitative contribution of different elements in this complex loop needs to be established through further research. Lack of understanding between gas hydrate reservoir and the earth's climate could be an even bigger inhibitor on hydrate exploration than present low oil prices and lack of funding support for hydrate research. The balance may lie between mounting intensive campaigns on climate research and safety procedures on the extraction and use of gas hydrates.

➢ The possible short and long term impacts of large scale hydrate exploitation on the geological environment and global climate need to be studied to develop safe standardized procedures for exploration and production before attempting to exploit this resource. It is also necessary to systematically collect base line information on related environmental indicators and continuously monitor short and long term effects on them. Perturbations associated with exploiting methane hydrates need to be analyzed by careful modeling and techniques have to be developed to avoid or mitigate them.

- **Technical Challenges**

- Hydrates decompose releasing hydrocarbons as a gas when removed from low temp/high pressure environment.
- Gas hydrate, flow assurance and system implications- Methane hydrate contains methane in concentrations up to 160 times its volume. Gas hydrates are solids with densities greater than those of typical fluid hydrocarbons and this has practical implications for flow assurance and the safety thereof. However, of more immediate concern to the natural gas industry is the fact that methane hydrate also can form within pipelines under certain pressure and temperature conditions, forming a solid or semi-solid mass that can slow or completely block gas flow. While the problem is particularly serious for producers moving gas from offshore wells to onshore processing facilities, methane hydrates can also be found in many other elements of the network of gas storage facilities and transmission pipelines.
- Seismic analysis of hydrate deposits is developed to point where we can predict with reasonable accuracy the location and concentration of some hydrate deposits. More needs to be done to improve the quantification of the deposit and also to locate hydrates that are not in conventional horizontal deposits. Collecting pressure core samples for testing and verification of hydrates is needed.
- Developing a recovery scheme compatible with a permafrost environment
- Tailoring existing production technologies and equipment for use in hydrate production.
- Drilling and completion (stimulation) technology development. Drilling for recovery of methane from the hydrate is a challenging task because of the characteristics of the hydrates especially, its unstable nature with change in pressure temperature conditions. Hydrates may dissociate during the process of drilling and initiate a process of uncontrolled gas release and site subsidence. Well completion for hydrate production has not been addressed. Some of potential problems are sand control and hole stability (Figure 4).

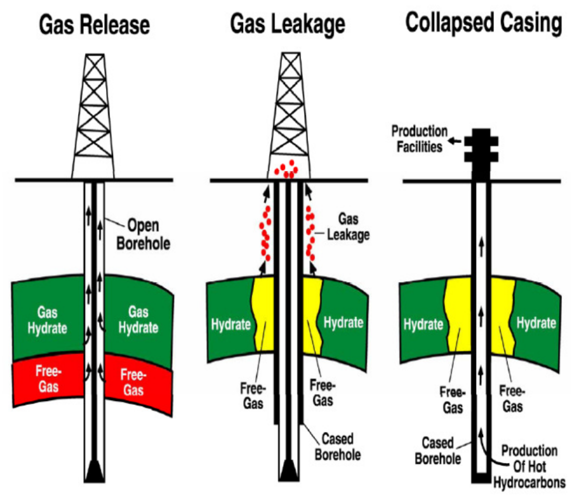


Figure 4: Gas Hydrate Drilling and Production Problems (Ref: USGS)

- Establishing means for safe/profitable production. Extracting natural gas from hydrate formations using any of the above techniques would have an impact on the formation itself and its surrounding area. In the case of undersea hydrate reserves, the dissociation and extraction would have to be done without contributing to the instability of the seafloor.
- Reservoir models have been developed and limited testing completed. However, more tests and data on reservoir properties and performance is required before acceptance of model predictions. More production test will be required to gain confidence in models. Integration of field production testing data with numerical simulation.
- Hydrate recovery will in all probability involve forced dissociation, which will involve significant demand for heat. Supplying and managing this heat and maintaining an artificial thermodynamic balance that allow the controlled dissociation of hydrate and the safe recovery of methane will probably prove the key to commercialization.

Opportunities

Deep below the seabed is an infinite source of energy waiting to be tapped. The global gas hydrate resources are estimated to be huge i.e. around 19822 trillion cubic metres and are uniquely distributed (Figure 5). Although

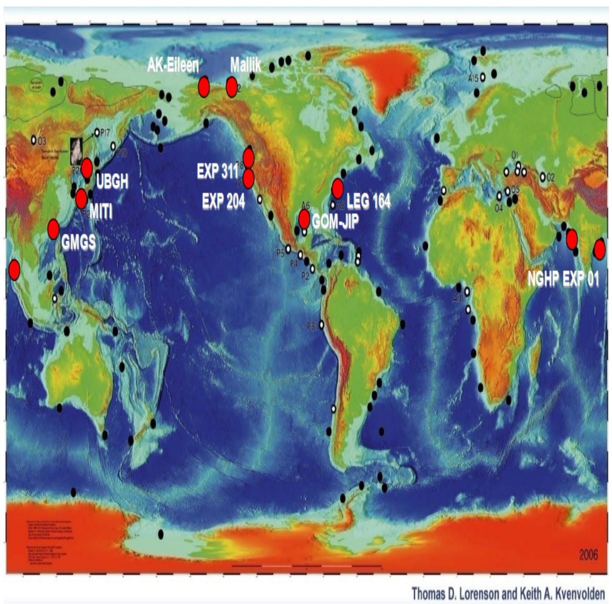


Figure 5: Global Inventory of Natural Gas Hydrate Occurrence

- o Gas hydrate recovered
- • Gas hydrate inferred from other data.

exploration and exploitation of gas hydrates pose significant challenges. But crack the challenge; you have solved the country's energy problem and the opportunities are unlimited.

- Economic & Energy security- Countries that have strong economic bases, or are witnessing high industrial growth rates, but have low energy resource potential, could potentially become energy independent, an event that would affect international affairs, foreign policy and other interrelations. The repercussions would extend to world trade, regional power equations, and foreign currency balance of existing major importers, when gas hydrate begins to be exploited.
- Environmental- Cleaner fuel source than oil, coal, and oil shale. Use of natural gas will expand far into the 21st century due to increasing demand for cleaner burning fuels and greater use in the transportation sector. It may well be that government policy, responding; for example, to growing concern about climate change, will also influence the development of methane hydrates.
- Education science leadership- The real challenge begins as nowhere in the world does the technology for commercially extracting gas out of hydrates exist. Considerable technology development is required with a paced approach.
- Greater need for academic institution efforts to explore gas hydrates- Gas hydrates trapped in the marine sediments require extensive efforts to bring them into world energy balance. Government organizations, laboratories and oil industry have recently taken up projects to explore gas hydrates in the Indian offshore areas. However, participation from the academic institutions is negligible due to lack of collaboration among them. There should be greater involvement of researchers from academic institutions to intensify efforts in the exploration of gas hydrate horizons.
- Apart from using methane hydrate as a source of fuel energy several applications of gas hydrates are currently investigated such as
  - Hydrate as a Fresh Water Resource- Each volume of gas hydrate contains 0.8 volumes of fresh water.
  - Massive marine hydrate formations may contain some solids, such as diatoms and clay that would need to be filtered from produced water.
  - Desalination of sea-water- It was suggested that if sea-water is combined with methane in a suitable pressure temperature controlled vessel, then hydrate will form. The brine can be separated from the hydrate and the hydrate then be allowed to disintegrate. This hydrate disintegration will yield fresh water and methane. The methane can again be returned to the system for continuing hydrate formation with sea-water.
  - Natural gas and hydrogen hydrates can be used for safe storage and transportation of natural gas and hydrogen. Like liquefied natural gas (LNG), frozen

hydrate can be transported long distances when pipelines are not available.

- Gas hydrates can be used for gas separations. It was demonstrated that using the differing tendencies of gases towards hydrate formation, good separation factors can be obtained by allowing the gaseous mixtures to form hydrates. Nitrogen, carbon-dioxide and hydrogen sulphide can be separated from methane through hydrate formation.
- CO_2 hydrate can be used in ocean carbon sequestration. Carbon dioxide from the environment can be converted into hydrate in deep-sea environmental condition and stored there till dissociation back in terms of CO_2 in geological time scale. This subject is the basis of much debate and speculation.

Conclusion

An enormous amount of methane is sequestered in the shallow geosphere, even a small percentage of which could meet the energy requirement of the world for centuries. Gas hydrate research has opened a new frontier in ocean and earth sciences that crosses many disciplinary boundaries.

Lack of suitable production technology is a major barrier in exploitation of this resource. However the past few years has witnessed a dramatic improvement in drilling technologies for oil and gas in deep water areas, where hydrate deposits occur. There has also been a distinct reduction in deep-water development costs. All these are positive factors for hydrate exploration and development. Much of the engineering required to exploit these deposits can be achieved by suitably adopting proven technology currently used in connection with exploitation of deep-water oil and gas reserves. Corporate sector is not willing to venture into this field. At present, whatever research is ongoing is mostly supported by governmental sources. The industry view is that when hydrate development is required, challenges will be met, just as industry has mastered other difficult environments in energy resource development.

One interesting outcome of R & D in gas hydrates has been the identification of several possible uses of gas hydrates other than as fuel. Since the benefits from those uses are quite significant, the importance of gas hydrate is increasing. If continued research can find an increasing number of such alternate uses, the economics of exploiting methane hydrates will improve and such activities will gain momentum.

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