Mallik 2002 Gas Hydrate Production Research Well Program

Gas hydrates are a naturally occurring "ice-like" combination of natural gas and water that have the potential to provide an immense resource of natural gas from the world's oceans and polar regions. The estimated amount of natural gas in the gas hydrate accumulations of the world greatly exceeds the volume of all known conventional gas resources. While gas hydrates hold great potential as an "environmentally-friendly" fuel for the 21st Century, the technical challenges of realizing them as a resource are substantial. Research is required to understand and develop new techniques to quantify their distribution in nature. Proposed gas recovery methods such as dissociating or melting the gas hydrate by heating and/or depressurizing the reservoir are untested.

Upon the occasion of the *From Mallik to the Future* International Gas Hydrate Symposium held December 7-10, 2003 in Chiba City, Japan, *The partners and participants in the Mallik 2002 Gas Hydrate Production Research Well* program are pleased to publicly release the results of the first modern, fully integrated field study and production testing of a natural gas hydrate accumulation: These results and their analyses, form the leading scientific and engineering data set for the realization of the energy resource potential of this non-conventional global source of methane gas.

Field Research

The Mallik 2002 Research Well Program drilled three wells (the JAPEX/JNOC/GSC et al. Mallik 3L-38 and 4L-38 observation wells and Mallik 5L-38 gas hydrate production well) in the Mallik Gas Hydrate Field on Richard's Island, in the Mackenzie Delta, Northwest Territories, Canada. This location was chosen as it represents one of the highest concentrations of gas hydrates found to date in the world, and it is thought to have many similarities to marine deposits such as those found offshore of Japan. Research conducted at Mallik has wide application to gas hydrate deposits around the world.

The Mallik 5L-38 well cored and recovered gas hydrates and associated sediments from an interval between 880-1150 meters depth. These cores have been the subject of intensive examination by members of the Mallik Partnership, including scientists and engineers enabled by the International Continental Drilling Program. Detailed information on the geology, geochemistry, geotechnical and microbiological properties of gas hydrate bearing sediments was complimented by an extensive research geophysics program, which included both surface, and down hole studies. This body of scientific data was designed to compliment a novel production test program to provide the world's most detailed scientific and engineering data set describing the occurrence and production characteristics of gas hydrates.

New Scientific and Engineering Discoveries

Core Studies Program

Over 150m of high quality gas hydrate cores were collected during the Mallik program allowing for a wide variety of studies that ranged from assessing the macroscopic to microscopic properties of the reservoir sediments. New work included investigations of the kinetics of gas hydrate dissociation from the solid to the gaseous form, studies of the petrophysical properties, investigations of the molecular chemistry and geotechnical properties such as compressive strengths and stress regime.

Geophysics Studies

A wide range of geophysical studies were carried out to quantify gas hydrate distribution. A key aspect of this program was to test new geophysical tools as methods must be proven to remotely quantify gas hydrates using a variety of geophysical surveys. Fiber optics instrumentation documented the geothermal regime with meter-scale precision. Surface, down hole and cross-hole seismic studies were carried out as were a number of advanced well log studies. Downhole geophysical measurements allowed for direct estimates of in situ permeability, gas hydrate content and investigations of the occurrence of natural fractures.

Gas Hydrate Production

Even though gas hydrates are known to occur in numerous marine and Arctic settings, little was known before this project about the technology necessary to produce gas hydrates. Due to logistics and cost constraints, rather than carry out long term production testing, a decision was taken by the partners to conduct carefully controlled production experiments. The response of gas hydrates to heating and depressurization was evaluated with careful attention to accurately measure both input conditions and reservoir responses. The overall goal was to combine the science and production program to allow for calibration and refinement of reservoir simulation models capable of prediction long-term reservoir response.

Depressurization Experiments: The Mallik 2002 production research well program pressure draw down experiments were designed to study the response of gas hydrate to a reduction in formation pressure conditions. The results of three short duration gas hydrate tests demonstrate that gas can be produced from gas hydrates with different concentrations and characteristics, exclusively through pressure stimulation. The data supports the interpretation that the gas hydrates are much more permeable and conducive to flow from pressure stimulation than previously thought. In one test the gas production rates were substantially enhanced by artificially fracturing the reservoir.

Thermal Heating Experiments: The Mallik 2002 production research well program thermal heating experiments were designed to destabilize gas hydrates by thermal stimulation. A five-day experiment was undertaken within a 17-m-thick section of highly concentrated gas-hydrate-bearing strata. Gas was continuously produced throughout the test at varying rates with maximum flow rate reaching 1500 cubic meters per day. The total gas flowed was small reflecting that the test was a controlled production experiment rather than a long duration test well. A decrease in production rate at 52 hours into the test is interpreted as a formation event, which may be indicative of sudden loss of produced gas. Several lines of evidence suggest that natural and enhanced fractures may have been conduits for gas transmission with reservoir storage away from the well.

Program Implications for Future Development of Gas Hydrates

Before this project, first order thermodynamic computer models had been developed to evaluate hydrate gas production by thermal stimulation and depressurization. These models predicted that gas could be produced from gas hydrates at sufficient rates to make them a technically recoverable resource. However, the economic cost associated with these types of enhanced gas recovery techniques were poorly understood. *The Mallik 2002 production research well program* has proven for the first time that gas production from gas hydrates is technically feasible.

With *The Mallik 2002 production research well program* thermal and depressurization production data, have allowed the calibration of several reservoir models used to simulate the thermal and depressurization tests. Part of the calibration process has been the recognition that gas hydrates deposits are much more permeable than previously thought, that they contain natural fractures, and that they may be fractured artificially. Calibrated models must therefore include full appraisal of the unique attributes of the specific gas hydrate field. The Mallik data have for the first time allowed for the rational assessment of the production response of a gas hydrate accumulation if the various tests had extended far into the future. These studies show that among the possible techniques for production of natural gas from in-situ gas hydrates, depressurization will produce more gas than just heating the formation. However, the combination of heating and depressurizing the gas-hydrate at the same time will produce the greatest amount of gas.

Global Implications

There are currently limited secure domestic supplies of energy, such as in Japan and other Asian countries. The realization of production from natural gas hydrates could provide an opportunity to develop a potentially very large and “environmentally” friendly fuel resource that could benefit various national economics throughout the world. The development of gas hydrate is also important for the future supply of gas in the North American market, with the added benefit of providing opportunities for indigenous Northern employment through the economic development of a sustainable energy resource.

The Mallik Partnership

The *Mallik 2002 Gas Hydrate Production Research Well Program* was undertaken as a partnership between Japan National Oil Corporation (JNOC); Geological Survey of Canada (GSC); United States Geological Survey (USGS); GeoForschungsZentrum Potsdam (GFZ); United States Department of Energy (USDOE); Gas Authority of India Ltd. (GAIL) and Oil and Natural Gas Corporation Ltd. (ONGC); the International Continental Drilling Program (ICDP); and the Mackenzie Delta exploration joint-venture of BP Canada Energy Company, Chevron Canada Resources and Burlington Resources Canada. The Japan Petroleum Exploration Company and Japex Canada Ltd. coordinated the field operations for the project and the Geological Survey of Canada coordinated the science program. In all more than one hundred engineers and scientists from more than six countries have worked to bring the results to the international gas hydrate research community.

Partner Perspectives

Japan

Japan, like many other countries with little indigenous energy resources, imported oil and gas accounts for 99% of Japan's total primary oil and gas supply. High import dependency is one reason why the government of Japan has been caring out a very ambitious research program to develop the technology needed to recover gas from oceanic hydrates. In 1999-2000, the Japan National Oil Corporation (JNOC), with funding from the Ministry of International Trade and Industry (MITI; Presently Ministry of Economy, Trade and Industry abbreviated as METI), drilled a series of gas hydrate test wells in the Nankai Trough off the southeastern coast of Japan and discovered distribution of methane hydrate in sandstone layers. In 2001, METI has started "Japan's Methane Hydrate Exploitation Program", a 16-year program in which methane hydrate is defined as a future energy resource that is expected to exist in large amounts offshore around Japan.

Canada

If a future global supply of energy is stored in gas hydrates, then an immense potential occurs in Canada, a northern nation bounded by three oceans. Canada is also the world's third largest producer of natural gas, the most environmentally friendly fossil fuel. Expected North American growth in demand for natural gas provides Canada with opportunities for economic and export growth, while contributing to commitments to a sustainable environment and a vibrant economy in northern communities. Gas Hydrates are being evaluated as a potential natural gas source through a new unified research program led by Natural Resources Canada. Canada has a long history of gas hydrate research that begins in the 1970's. Subsequently the most significant efforts to assess gas hydrates include the collaborative 1998 and 2002 Mallik gas hydrate research well programs. While the 1998 Geological Survey of Canada (GSC)-Japan National Oil Corporation (JNOC) program was a success, the producibility of gas hydrates was not evaluated. This motivated GSC and JNOC to established a wider partnership, including GSC, JNOC, USGS, USDOE, GeoForschungsZentrum Potsdam (GFZ), India Ministry of Petroleum and Natural Gas (MOPNG)/Gas Authority of India (GAIL) and the Chevron-British Petroleum-Burlington joint venture group that returned to Mallik in 2002, in collaboration with the International Scientific Continental Drilling Program and Imperial Oil Ltd. The Mallik 2002 program accomplished its ambitious fuel research goals, while also performing climate change studies and geohazard research. While North American Agencies recognize the vast fuel potential in gas hydrates they also note that knowledge is insufficient to know how and when gas hydrates will become part of the gas supply.

Germany

Beginning in 2004, the Ministry for Education and Research (BMBF) and the German Research Council (DFG) will launch the second phase of GEOTECHNOLOGIEN, with special emphasis on "Methane in the Geo/Biosystem". Its five research areas will be: (1) Methane in gas hydrate provinces, (2) Climate impact of methane, (3) Gas hydrates as GeoBio-Systems, (4) Natural hazards, and (5) Structure and properties of gas hydrates. Of special importance in this context are two methodological thrusts. The first is the monitoring component, which encompasses geochemical properties and secular temperature variations especially in permafrost settings and their influence on atmosphere and climate. The second is the modeling component, where gas hydrate occurrence in time and space (3-D/4-D) will be addressed. Here, interdisciplinary investigations will study the physics, chemistry and microbiology utilizing evolving

natural, experimental and virtual laboratories, taking due consideration of (1) basin evolution- (2) subsurface water flow, (3) biogenic and thermogenic gas generation and (4) partition and phase behavior in the system water-gas-oil.

United States

The United States government is committed to ensuring clean, dependable, and affordable energy for today and into the future. Methane hydrates represent a potentially significant new source of energy that may provide a sound economic and environmental future as conventional resources are depleted. The U.S. Department of Energy (USDOE) in partnership with the U.S Geological Survey (USGS), industry, academia, and other government agencies, are working to ensure a long-term supply of natural gas by developing the knowledge and technology base to allow commercial production of methane from domestic hydrate deposits by the year 2015. USGS and USDOE are committed to participating in international research programs to advance the understanding of natural gas hydrates and the development of these resources for future energy demand.

India

India, like Japan, has also initiated a very ambitious national gas hydrate research program. In March of 1997, the government of India announced new exploration licensing policies, which included the release of several deep water (>400m) lease blocks along the east coast of India between Madras and Calcutta. Recently acquired seismic data have revealed possible evidence of widespread gas hydrate occurrences throughout the proposed lease blocks. Also announced was a large gas hydrate prospect in the Andaman Sea, between India and Myanmar, which is estimated to contain as much as six trillion cubic meters of gas. The government of India has indicated that gas hydrates are of "utmost importance to meet their growing domestic energy needs".

4. The Mallik 2002 Gas Hydrate Production Research Well Program

Well Program Statistical Data

Program name: Mallik 2002 Gas Hydrate Production Research Well Program
Production well name: JAPEX/JNOC/GSC et al. Mallik 5L-38
Observation well names: JAPEX/JNOC/GSC et al. Mallik 3L-38
JAPEX/JNOC/GSC et al. Mallik 4L-38
Previous well: JAPEX/JNOC/GSC Mallik 2L-28
Original well: Imperial Oil Mallik L-38

Location: Richards Island, Mackenzie Delta, Northwest Territories, Canada
5L-38 69° 27’ 39.30” N 134° 39’ 38.90” W
4L-38 69° 27’ 40.29” N 134° 39’ 36.18” W
3L-38 69° 27’ 38.32” N 134° 39’ 41.61” W

Base of permafrost: For general considerations the depth of permafrost in the immediate vicinity of the Mallik wells is estimated to be 600 m beneath ground level.
Ground elevation: Mallik 3L-38, 4L-38, 5L-38 1.0 m above SEA LEVEL
Kelly Bushings: Mallik 3L-38, 4L-38, 5L-38 4.6 m above GROUND LEVEL

Spud dates: Mallik 3L-38 December 25, 2001

Mallik 4L-38 January 11, 2002
Mallik 5L-38 January 25, 2002

Completion dates: Mallik 3L-38 January 5, 2002
Mallik 4L-38 January 21, 2002
Mallik 5L-38 February 20, 2002

Rig Release dates: Mallik 3L-38 January 7, 2002
Mallik 4L-38 January 23, 2002
Mallik 5L-38 March 14, 2002

Total well depths: Mallik 3L-38 1188 m KB (KB = 5.6 m ASL)
Mallik 4L-38 1188 m KB (KB = 5.6 m ASL)
Mallik 5L-38 1166 m KB (KB = 5.6 m ASL)

Cored interval: Mallik 5L-38 885.6-1151.4 m KB
MDT test zones: MDT Test No. 1: 1106.0-1106.5 m KB
MDT Test No. 2: 1089.5- 1090.0 m KB
MDT Test No. 3: 1071.5 – 1072.0 m KB
MDT Test No. 4: 999.0-999.5 Test failed due to blockage
MDT Test No. 5: 974.0-974.5 m KB
MDT Test No. 6: 992.5-993.0 m KB
Thermal test zone: 907.0 – 920.0 m KB