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Methane Hydrates: Energy Prospect or Natural Hazard?

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Summary

Methane hydrate is a methane-bearing, ice-like material that occurs in marine sediments and in permafrost regions. The amount of methane contained in hydrate deposits is enormous, although it is likely that much of the hydrate occurs in low concentrations and would have no commercial potential. Hydrate deposits are estimated to contain a much greater amount of natural gas than conventional accumulations, however, there is today no practical and environmentally safe way to produce the gas. Destabilization of the hydrates with uncontrolled release of large volumes of methane is a significant hazard. Legislation was introduced into the 105th Congress, which would have authorized an interagency research and development program to develop methane hydrate resources. The bill passed the Senate and hearings were held in the House before Congress adjourned. The measure was reintroduced in the 106th Congress as S. 330, which was reported from the Committee on Energy and Natural Resources on March 22, 1999 (S. Rept. 106-33). The Senate passed S. 330 on April 19, 1999. Subsequently, H.R. 1753 was introduced into the House and jointly referred to the Committees on Science and Resources. The bill was reported from both Committees (H.Rept. 106-377, Parts I and II) and passed the House on October 26, 1999. H.R. 1753 passed the Senate as amended on November 19, 1999.

Background and Analysis

Methane hydrate is a mixture of methane and water that is frozen into an ice. The crystalline structure of the frozen water molecules forms a cage-like lattice inside of which are trapped high concentrations of methane molecules. Methane hydrates form in generally two types of geologic environments, in permafrost regions (where cold temperatures dominate) and beneath the sea in sediments of the outer continental margins (where high pressures dominate). Methane hydrates can form at temperatures above the freezing point of water. While methane (the chief constituent of natural gas), propane, and other gases are included in the hydrate structure, methane hydrates are the most common.

In the Arctic where the near-surface temperature is low, methane hydrates form in the permafrost and can form a seal for gas seeping toward the surface. The thickness of the hydrate zone is determined by the geothermal gradient, or how fast the Earth warms with depth. Combined information from Arctic gas-hydrate studies shows that, in permafrost regions, gas hydrates may exist at subsurface depths ranging from about 130 meters to 2,000 meters. Direct evidence for gas hydrates on the North Slope of Alaska comes from cores and petroleum industry well logs, which suggest the presence of numerous gas hydrate layers in the area of the Prudhoe Bay and Kuparuk River oil fields. Currently, there is no commercial development of methane hydrates with the possible exception of the Messoyakha gas field on the eastern margin of the West Siberian basin, in which some increased gas pressure since conventional production first began may be attributed to dissociation of surrounding hydrates.

Methane hydrate is also stable in ocean floor sediments at water depths greater than 500 meters. Where hydrates occur they are known to cement loose sediments into a layer several hundred meters thick. Most of the methane hydrate accumulations are expected to be in sea floor deposits along continental margins. When hydrates were first encountered by the offshore oil industry in the 1970s, they were viewed primarily as a curiosity. Since then, oil and gas production has advanced into water depths deep enough to have significant amounts of methane hydrates in the sea floor.

The world's currently known natural gas reserves are estimated at 5,000 trillion cubic feet. The amount of methane contained in the world's gas hydrate accumulations is enormous. Estimates of the amounts are speculative and range over three orders of magnitude from about 100,000 trillion cubic feet to 279,000,000 trillion cubic feet of gas. Despite the enormous range of these estimates, gas hydrates seem to be a much greater resource of natural gas than conventional accumulations. However, it is likely that most of the hydrate occurs in low concentrations and has no commercial potential.[1] The goal of a research program would be to find locations where the methane hydrates are sufficiently concentrated to warrant commercial interest, in addition to proving the technological feasibility and safety of their production.

In 1995, the U.S. Geological Survey (USGS) completed a systematic appraisal of the in-place natural gas hydrate resources of the United States, both onshore and offshore. The mean (expected value) is estimated to be 320,000 trillion cubic feet of gas. This assessment did not address the problem of hydrate recovery. Subsequent refinements of the data in 1997, using information from the Ocean Drilling Program, have suggested that the mean should be adjusted slightly downward, to around 200,000 trillion cubic feet. For comparison, the estimated conventional gas resources and reserves in the United States are 1,400 trillion cubic feet. If it could be safely and economically recovered, one 50 by 150 kilometer area off the coast of North and South Carolina is estimated to hold enough methane to supply the needs of the United States for over 70 years.

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[1] Arthur H. Johnson, Senior Staff Geologist, Chevron USA Production Co., testimony before the House Committee on Science, Subcommittee on Energy and Environment, Hearing on S. 1418: The Methane Hydrate Research and Development Act, September 15, 1998, unpublished. See also [http://www.hydrate.org/resources.htm].

Sea floor stability and safety are two important issues related to gas hydrates. Sea floor stability refers to the susceptibility of the sea floor to collapse and slide as the result of gas hydrate disassociation. The safety issue refers to petroleum drilling and production hazards that may occur in association with gas hydrates in both offshore and onshore environments. The safety issue affects current oil and gas production as well as being of concern to possible hydrate development in the future.

Throughout the world, oil and gas drilling is moving into regions where safety problems related to gas hydrates may be anticipated. Oil and gas operators have recorded numerous drilling and production problems attributed to the presence of gas hydrates, including uncontrolled gas releases during drilling, collapse of well casings, and gas leakage to the surface. In the marine environment, gas leakage to the surface around the outside of the well casing may result in local sea floor subsidence and the loss of support for foundations of drilling platforms. These problems are generally caused by the dissociation of gas hydrate due to heating by either warm drilling fluids or from the production of hot hydrocarbons from depth during conventional oil and gas production. Subsea pipelines may also be affected by loss of sea floor support from hydrates destabilized by warming.

Hazards arise because gas hydrates are only quasi-stable; if the temperature is increased at a fixed pressure or the pressure decreased at fixed temperature, or both temperature increased and pressure decreased, it is easy to pass out of the stability regime of hydrates. The hydrate structure encases methane at very high concentrations. A single unit of hydrate, when heated and depressurized, can release 160 times its volume in gas. It is possible that both natural and human-induced changes can contribute to in-situ gas hydrate destabilization, which may convert an offshore hydrate-bearing sediment to a gassy water-rich fluid, triggering sea floor subsidence and catastrophic landslides. Evidence implicating gas hydrates in triggering sea floor landslides has been found along the Atlantic Ocean margin of the United States.[2] The mechanisms controlling gas hydrate-induced sea floor subsidence and landslides are not well known, but these processes may release large volumes of methane to the Earth's oceans and atmosphere. Methane is a "greenhouse" gas, 10 times more effective than carbon dioxide in the process believed by many to cause climate warming.

In 1981, a drill core containing methane hydrate was recovered on a National Science Foundation-sponsored scientific drilling program. Studies of this core led to federal efforts to investigate gas hydrates. From 1982 to 1992, the Department of Energy (DOE) spent $8 million to develop a foundation of basic knowledge about the location and thermodynamic properties of methane hydrates. DOE's initial methane hydrate research ended in 1992 as priorities shifted at that time to more near-term and immediate exploration and production R&D.

In 1997, the Energy Research and Development Panel of the President's Committee of Advisors on Science and Technology (PCAST) recommended that DOE begin a major 5-year, $44 million initiative to work with the U.S. Geological Survey, the Mineral

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[2] M. D. Max and W. P. Dillon, "Oceanic Methane Hydrate: The Character of the Blake Ridge Hydrate Stability Zone, and the Potential for Methane Extraction," *Journal of Petroleum Geology*, vol. 21, no. 3, July 1998, 343-357.

Management Service, the Naval Research Lab, and industry to evaluate the production potential of methane hydrates in U.S. coastal waters and worldwide.[3] In FY 1997 and FY 1998, DOE provided a small amount of funding from its Natural Gas Supply Program to support limited R&D activities on methane hydrates. In FY 1999, DOE allocated $.51 million specifically for methane hydrate research. For FY 2000 the Department requested $1.985 million for that research and Congress appropriated $2.96 million. DOE's budget request for FY 2001 includes $2.00 million for methane hydrate research

Congressional Action

Late in the 105th Congress, the Senate passed The Methane Hydrate Research and Development Act, and hearings were held in the House, but Congress adjourned before further action could be taken. The legislation was reintroduced into the 106th Congress (S. 330) and reported from the Committee on Energy and Natural Resources on March 22, 1999 (S.Rept. 106-33). The Senate passed S. 330 on April 19, 1999. The legislation directs the Secretary of Energy to coordinate an interagency research and development program to develop methane hydrate resources. In doing so, the Secretary of Energy is directed to consult with the Secretaries of Defense, Interior, and the Director of the National Science Foundation. The bill did not specify funding levels, but authorized the appropriation of such available discretionary funds as are necessary to carry out the methane hydrate R&D program. Based on information in DOE's 1998 program plan for methane hydrates, the Congressional Budget Office (CBO) estimated this activity would require appropriations totaling about $45 million over the next 5 years and outlays totaling $35 million over the next 5 years.[4] While the legislation would not give DOE authority it does not already have, it would provide a clear endorsement from Congress of federal and cooperative research efforts to understand better the energy potential of methane hydrates. The Administration is reported to support the measure.[5]

On May 11, 1999, H.R. 1753 was introduced into the House and referred to both the Committee on Science and the Committee on Resources. The bill differed from the Senate bill primarily in authorizing funding of $42 million over five years. As introduced, H.R. 1753 authorized appropriations of $5 million for FY 2000, $7.5 million for FY 2001, and $10 million for each of fiscal years 2002 through 2004. Both committees ordered the bill to be reported with a number of amendments (H.Rept. 106-377, Parts I and II). The House passed the bill on October 26, 1999 funding the research program at $47.5 million over a 5-year period in the amounts of $5, 7.5, 11, 12, and 12 million for FY 2000 through FY 2004 respectively. The Senate passed H.R. 1753 as amended on November 19, 1999. Among the differences, the House-passed bill would terminate the program at the end of

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[3]President's Committee of Advisors on Science and Technology, Energy Research and Development Panel, *Federal Energy Research and Development Challenges of the Twenty-First Century,* November 1997. See [http://www.whitehouse.gov/WH/EOP/OSTP/Energy/].

[4]House Committee on Science, Subcommittee on Energy and Environment, *S. 1418: The Methane Hydrate Research and Development Act*, 105th Congress, 2nd sess., September 15, 1998, 13.

[5]Leslie Ann Duncan, "Senate Energy to act on leftovers from 1998," *Congressional Green Sheets Weekly Bulletin,* March 1, 1999, 12-14. See also House Committee on Science, Subcommittee on Energy and Environment, *S. 330 and H.R.. 1753, The Methane Hydrate Research and Development Act of 1999,* 106th Congress, 1st sess., May 12, 1999, 28.

fiscal year 2004, whereas the Senate-passed bill would continue the program thereafter with such sums as necessary.