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Methane Hydrates: A Major Energy Source for the Future or Wishful Thinking?

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Methane Hydrates: A Major Energy Source for the Future or Wishful Thinking?

OUTLINE

• Why study methane hydrates?
• What are methane hydrates?
• Where do they occur?
• Technology and Data Needs
• Current R&D Programs
• Conclusions/Discussion
Why Study Methane Hydrates?

• Worldwide estimate of methane in methane hydrates:
  – 700,000 Tcf [20,000 trillion cubic meters]
  – Conventionally recoverable methane – 8,800 Tcf [250 trillion meters]
  – > two times total energy in coal, oil and conventional gas
• United States estimate of methane in methane hydrates:
  – 200,000 Tcf gas-in-place in hydrates (38,000 Tcf GOM)
  – Remaining technically recoverable natural gas - 1,400 Tcf

If 1% of gas-in-place in hydrates is recoverable: 2,000 Tcf

From USGS and DOE/NETL
Methane Hydrate Locations

- Permafrost regions
- Ocean Margins
Types of Methane Hydrate Deposits

Solid methane hydrate ice forms in bands and lenses close to bitterly cold surface.

Trapped methane gas under pressure

Impermeable solid methane hydrate embedded in mud

Slow seepage of methane gas from below

Depths greater than 1,500 feet

Sediment perhaps 4 miles deep

Arctic deposit

Frozen surface ground

Deep ocean deposit

Drilling rig

Hydrate stability zone regions indicate vertical extents of from 1,000-2,000 feet and can cover large horizontal areas.
Why Study Methane Hydrates?

- Potential as a major resource of clean energy
- Sea-floor stability & drilling safety
  - Ensure safety of deepwater oil and gas recovery through or near marine hydrate sediments
- Global climate impact
  - The role of natural hydrate in global climate and deep sea life
- Production problems
  - Pipeline flow assurance
What are Methane Hydrates?

- Methane hydrates - cages of water molecules that surround and trap gas molecules in a lattice network
- Structure and appearance similar to ice
- 1 cubic foot hydrate contains 150 to 180 cubic feet gas at STP (164 for methane)

Hydrate structure showing carbon (center) and hydrogen (attached to center) trapped in ice lattice (Source USGS)
Methane Hydrates Structure

**Structure I**
Methane, ethane, carbon dioxide, etc.

**Structure II**
Propane, Iso-butane, etc.

Comparison of Hydrate Phase Boundaries

Hydrate Phase Boundary

- **Pressure (psi)**
  - 0
  - 500
  - 1,000
  - 1,500
  - 2,000
  - 2,500
  - 3,000
  - 3,500

- **Temperature (deg. Farenheit)**
  - 23
  - 32
  - 41
  - 50
  - 59
  - 68

- **Methane**
- **Methane 80 mol %, Ethane 20 mol %**
- **Methane + 10% NaCl**

E. Dendy Sloan, Hydrate Engineering, SPE Monograph 21
Methane Hydrate Stability Regions

[Image: Diagram showing the stability regions of methane hydrate with depth and temperature.]
Inferred Nature of Hydrate Accumulations

(Courtesy Collett USGS)
How have hydrate accumulations been assessed?

- Small portion of evidence for hydrate accumulations is from direct sampling
- Mostly inferred from other sources
  - seismic reflections
  - well logs
  - drilling data
  - pore-water salinity data
Blake Ridge Hydrate Occurrence

- Seismic profiles marked by bottom-simulating reflectors (BSRs) along Atlantic margin of US
- Water depths - 2,000 to 4,800 meters
- Methane hydrate stability zone from 0 to 700 meters

(Courtesy Collett USGS)
Blake Ridge - ODP Leg 164 Line 1

Sea Bottom

BSR

(Courtesy Collett USGS)
Hydrates disseminated within interval from 190 to 450 mbsf

Hydrate saturations inferred from interstitial water chloride data and log data

Estimated maximum hydrate saturation
- 7% in Hole 994
- 8.4% in Hole 995
- 13.6% in Hole 997

Hydrate saturation in ocean sediments about 4 to 6% average.

(Courtesy Collett USGS)
Cascadia Continental Margin Occurrence

Site 889 - Inferred hydrates saturation: 5% to 39%

(Courtesy Collett USGS)
Prudhoe Bay-Kuparuk River Area in Alaska

- 1972 - Gas hydrates recovered in pressure core from 2 NW Eileen
- Thickness of gas-hydrate stability zone - 210 to 950 m [690 to 3120 ft]
- 50 North Slope wells revealed hydrates in six zones (Collett USGS)
- 1.0 to 1.2 trillion cubic meters [35 to 42 Tcf]
North Slope Alaska

(Courtesy Collett USGS)
Mackenzie Delta, Northwest Territories, Canada - Research Well Mallik 2L-38

Oilfield Review Summer 2000
Mackenzie Delta, Northwest Territories, Canada

Mallik 2L-38

Inferred hydrate in 25 wells

EXPLANATION
- Well with gas hydrate
- Well

Contours of base of methane hydrate (m)

Oilfield Review Summer 2000
Mackenzie Delta Mallik 2L-38

- 37 m core from 878 to 944 m
- Wellbore images and core indicate high quality sandstone
- Well log inferred gas hydrate from 890 to 1100 m
- 20 to 40% porosity
- Archie calculated saturation - up to 90%
Mallik Methane Production from Hydrates
Research Well-International Collaboration

- Drilling - February 2002
- Mackenzie Delta, NWT, Canada
- Follow-up test well to investigate methane hydrates in and below permafrost
- Effort focused on producing from hydrate stability zone
- Japan, Germany, India, Canada, United States
Dozen areas identified by BSRs

Exploratory well drilled in 1999/2000 in 945 m of water

Main well drilled to 3300 m

Cored and logged

Maximum gas-hydrate saturation estimated at about 80%.
Summary of Gas Hydrate Occurrences

• Continental margins - many location worldwide
  – Mostly based on BSRs, a few coring and logging operations, and ocean bottom sampling
  – BSR’s are apparently rare in GOM
  – Hydrates generally thought to be disseminated and low saturation (however, 15 cm long solid piece in Blake Ridge Hole 997 at 331 mbsf)
  – Biogenic and thermogenic origin (amounts of each uncertain)

• Permafrost regions - most information from Arctic Alaska and Canada, and Siberia
  – Higher saturations, more wells
  – Biogenic and thermogenic origin
## Relative Value of Hydrocarbon Reservoirs

<table>
<thead>
<tr>
<th></th>
<th>Oil</th>
<th>Natural Gas&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Hydrates</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Porosity (%)</strong></td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td><strong>HC Saturation (%)</strong></td>
<td>75</td>
<td>90</td>
<td>50&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Recovery (%)</strong></td>
<td>30</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td><strong>HC Value/Price ($)</strong></td>
<td>20/bbl</td>
<td>3/Mscf</td>
<td>3/Mscf</td>
</tr>
<tr>
<td><strong>Dollar Density ($/m^3)</strong></td>
<td>8.50</td>
<td>2.75</td>
<td>1.60</td>
</tr>
</tbody>
</table>

<sup>1</sup> reservoir at 3000 psi, 200ºF

<sup>2</sup> hydrate saturation – assumed for illustration
Production Options
Production Options

- 2002 Mallik well will include testing of depressurization and thermal heating processes.
- Other options that have been discussed include injection of inhibitors such as methanol.
- A possible option involves use of CO2 to initiate production or to replace methane from methane hydrates\(^1\) or both.
- Horizontal well technology for completions in hydrate zones.

\(^1\) Sohio idea from 1982 – Private communication, Horton (M-I Technology Center)
Technology and Data Needs

• Characterize hydrate accumulations
  – Location, quantity, and properties
  – Seismic diagnostics R&D

• Production Technology
  – Retrieve, preserve and analyze cores
  – Develop core analysis procedures
  – Develop reservoir simulation for methane production
  – Well drilling and completion technology
  – Field testing of conceptual production scenarios

• Economic data for decision making
U.S. Methane Hydrates R&D

  – Established the existence of hydrates in Kuparuk Field, Alaska
  – Completed studies of 15 offshore hydrate basins
  – Developed preliminary estimates of gas in-place for gas hydrate deposits
  – Developed preliminary production models for depressurization and thermal production of gas from hydrates

• Current Program - A Comprehensive and Coordinated National R&D Effort: 1997- Present
  – Laboratory studies (Pure hydrate & Hydrate-bearing sediments)
  – Field studies (Onshore Alaska & Offshore GOM, Atlantic and…)
  – Improved remote sensing tools
  – Model & database development
U.S. Methane Hydrates Program Participants

Federal Agencies
- DOE Office of Fossil Energy
- DOE Office of Science
- U.S Geological Survey
- Minerals Management Service
- Naval Research Laboratory
- U.S. Army Corps of Engineers
- National Oceanic and Atmospheric Administration
- Ocean Drilling Program

Universities
- Clarkson University
- Colorado School of Mines
- Georgia Institute of Technology
- Louisiana State University
- Texas A&M
- University of California, San Diego
- University of Mississippi
- University of Pittsburgh
- University of Texas
- University of Wyoming
- West Virginia University

National Labs
- Brookhaven
- INEEL
- Lawrence Berkeley
- Lawrence Livermore
- Oak Ridge

Industry and Other
- BP (Alaska) Exploration
- Chevron Petroleum Techn. Corp.
- Conoco, Inc.
- Environmental Defense
- Halliburton Energy Services
- Maurer Technology
- Monterey Bay Aquarium Rsch. Inst.
- Phillips Petroleum Company
- Schlumberger Techn. Corporation
U.S. Public Funding for Hydrates Research ($M)

DOE
- FY 1999  $ 0.5
- FY 2000  3.0
- FY 2001  10.0
- FY 2002  10.0

Others FY 2001
- MMS  0.5
- NOAA  0.6
- NRL  1.4
  - Hawaii  1.5
- NSF  1.7
- USGS  1.3
New Projects to Explore Energy Potential, Safety Issues of Methane Hydrates

• University of California at San Diego, Scripps Institute of Oceanography, San Diego, CA,
  – Study hydrates in the northern Gulf of Mexico;

• Joint Oceanographic Institutions, Washington, D.C.,
  – Develop new tools for recovering and analyzing hydrate cores from ocean sediments;

• Chevron Petroleum Technology Co., Houston, TX,
  – Proposal includes drilling into hydrates in the Gulf of Mexico;

• Halliburton Energy Services Inc., Houston, TX,
  – Conduct laboratory experiments to develop reservoir models and simulators that can be used to predict the behavior of hydrate formations during gas production;

• Maurer Technology Inc., Houston, TX,
  – Concentrate on hydrates formed beneath the Arctic permafrost in Northern Alaska;

• BP Exploration Inc., Anchorage, AK,
  – Determine whether gas hydrates and associated gas resources on the Arctic North Slope offer future commercial prospects.
Conclusions

• Huge amount of gas trapped in hydrates - too enormous to ignore
• Much to be learned before methane hydrates can be considered a resource
• Governments and Industry will have to make investments
  – Japan, India, U.S., Canada, Germany have current programs
• Petroleum industry engineers, geologists, and scientists are the key to finding the technical and economic solutions
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Tim Collett - USGS
E. Dendy Sloan - CSM

Information source:
www.netl.doe.gov/scng/hydrate

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THANK YOU
Gas-Hydrate Reservoir Models

Model A
- Solids (matrix)
  - Quartz
  - Calcite
  - Clay
- Fluids
  - Free water
  - Gas hydrate

Model B
- Solids (matrix)
  - Quartz
  - Calcite
  - Clay
- Fluids
  - Bound water
  - Ice
  - Gas hydrate

Model C
- Solids (matrix)
  - Quartz
  - Calcite
  - Clay
- Fluids
  - Bound water
  - Free water
  - Gas hydrate

Model D
- Solids (matrix)
  - Quartz
  - Calcite
  - Clay
- Fluids
  - Bound water
  - Free gas
  - Gas hydrate

Figure 4a–Permafrost associated gas-hydrate reservoir model for conditions below the base of ice-bearing permafrost (Model A).

Figure 4b–Permafrost associated gas-hydrate reservoir model for conditions above the base of ice-bearing permafrost (Model B).

Figure 4c–Marine (clay-rich) gas-hydrate reservoir model (Model C).

Figure 4d–Free-gas- and gas-hydrate-bearing reservoir model (Model D).

Courtesy USGS
Messoyakha - Siberia

- Discovered in 1968
- Estimated 2.8 Tcf [79 million m³] - 1/3 in hydrates that overlie free gas
- 36% of gas produced attributed to dissociation of gas hydrates
Messoyakha, West Siberia - Production History

Five periods of production:
I. Production of free gas
II. Production of gas from free-gas zone and hydrate deposit
III. Production of gas from hydrate alone
IV. Shut in
V. Small amount of gas production from hydrate.

Oilfield Review Summer 2000
Why are hydrates important?

- Flow Assurance - pipeline plugging, etc.

Courtesy Petrobas