NSB – DOE/NETL
Barrow Methane Hydrate Project

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ANS Field Project Kickoff Meeting
1/22/08
Introduction

Phase 1 Summary
Stability/Material Balance/Full-field modeling

Phase 2 Objectives
Prove existence of hydrates
Prove production from hydrates
Data gathering objectives
Core/LWD/Wireline
Pressure/temp

Schedule and PMP Overview
Well modeling
Well design

Project Execution
Procurement/Logistics/Operational Procedures
Core handling/Data acquisition specs/Decision point criteria
Barrow Gas Fields

- Original exploration by US Navy 1944-49
- Further Investigations by Department of the Interior in the 1970’s
- Congress transfers BGF to North Slope Borough in 1984.
- Local control (NSB) since 1984
Barrow Gas Fields

- East Barrow Gas Field
  - Discovered in 1949 by U.S. Navy

- South Barrow Gas Field
  - Discovered in 1974

- Walakpa Gas Field
  - Discovered 1980 by Husky for U.S. DOI
Project Objectives

• DOE-NETL/NSB 80-20% Funded Research
• Characterize and Quantify Methane Hydrate Resource Associated With Barrow Gas Fields
• Contribute to Global Research Effort Through Practical Research
• Advance North Slope Borough’s Understanding of It’s Energy Supply
• Prove Hydrate Productivity
• Add Gas Reserves and Production
Scope

• Integrated Study (Seismic, Well Log, Production History, Geochem)
• Focus on Barrow Gas Fields—East Field, South Field, Walakpa
• Phased Approach
• Integrate Prior Research Efforts/Current Knowledge
Project Status

- Project start Nov. 14, 2006
- Phase 1A completed in July, 2007, with positive results from Hydrate Stability Model
- Phase 1B initiated August 1, 2007 and completed March 2008. Supported decision to proceed to Phase 2
- Phase 2 initiated December 1, 2008. Design and drill dedicated hydrate production test and observation well
Phase 1A Results

- Temperature Gradients and Hydrate Stability Zone Modeling support Hydrate Stability Zone in East Barrow and Walakpa Fields

- Material Balance studies in East Barrow and Walakpa Field suggest external recharge but with no water production or breakthrough.
  - Suggests pressure support by methane hydrate dissociation

- Objectives for Phase 1A of the Study have been met, and support further reservoir study.
Stability Zone Modeling

Methane Hydrate Stability Zone Modeling for East Barrow and Walakpa Gas Fields
Material Balance

EMB Model – Pressure (P) vs. Time plot and P/Z vs. Gp plot for East Barrow gas reservoir
Water Influx Model, E. Barrow

Water Influx Model - \( \frac{(GpB_g + WpB_w)}{(B_g - B_{gi})} \) vs. \( G_p \) plot
Material Balance, E. Barrow

Hydrate Model: P/Z vs. Gp and Pressure vs. Time comparison for Darvish model
Phase I B Results

• Geologic Model
  - Completed mapping and log analysis of Walakpa, E&S Barrow Pool reservoirs
  - 3-D geostatistical model built for E. Barrow and Walakpa Fields

• Reservoir Modeling
  - Material balance and full-field reservoir simulation results support hydrate influence
Depth Mapping

Depth grid on Top Upper Barrow Sandstone, E Barrow Field

Depth Grid on Top Walakpa Sandstone, Walakpa Gas Field
Seismic Interp, Walakpa

Map of Walakpa Gas Field with Proposed Hydrate Test Well Location

Seismic Line through Proposed Walakpa Hydrate Test Well Location
Pressure and Production History Match, E. Barrow

Barrow Field Average Reservoir Pressure and Cumulative Production History Match
E. Barrow #14 History Match

History match EB# 14 well

Fieldwide Average Pressure History Match
E. Barrow Best Case Model Input

- 5-24% Porosity
- 55% Bound water
- 45% Free gas saturation below BHSZ
- 31% Hydrate saturation above BHSZ
- 14% Free gas above BHSZ
- 1-50 mD permeability
- BHSZ 2050’ sstvd
- GWC 2080’ sstvd
Conclusions of Modeling

- 100% of 26 BSCF of MH will be produced in E. Barrow through depressurization from 1981-2037
- 20% of 284 BSCF (56BSCF) of MH will be produced in Walakpa from 1981-2037 assuming current well set and rates
Phase II Objectives

- Prove existence of in situ methane hydrates
- Prove hydrate dissociation and production
- Design and drill methane hydrate production test well
  - E. Barrow in Q3-2010
    - If hydrates are encountered, complete and test
    - If no hydrates, move to Walakpa for hydrate test
  - Walakpa Well Q1-2011
    - If hydrates are encountered, complete and test
E Barrow Hydrate Test Well
Conceptual Design

13-3/8" or 20" Conductor @ 60'

Note: Not to scale

Base of Permafrost

9-5/8" or 13-3/8" Casing @ 1400'

Kick Off Shoe

Armored Wire with Thermistors strapped externally to casing.

7" or 9-5/8" Casing at 2100'

Base of Hydrates

Hydrate in sandstone

Free gas in sandstone

5-1/2" or 7" slotted liner across 1000' of horizontal section wired with downhole resistance heater and Thermistors.
Schedule

- Commence Phase 2 Dec. 1, 2008
- December ’08 – September ’09
  - Design well
  - Acquire permits
  - Select Contractors
- October ’09-August ’10
  - Secure contracts for operator, drilling contractor, rig, equipment spread
  - Plan and oversee logistics
- September ’10 – April ’11
  - Drill and complete hydrate test well(s)
  - Recover core in hydrate stability zone and analyze, make decision on program completion
- May ’11 – September ’13
  - Production surveillance of hydrate test well
  - Collect samples and data from well and analyze results
NSB Hydrates Phase 2 Plan

Well Design

RFQ / RFP

AFE

Drill E Barrow Test Well

Complete E Barrow Test Well

Abandon E Barrow Drill Walakpa

Complete Walakpa Test Well

Abandon Walakpa Well

Hydrates

No Hydrates

Budgeted Case
Well Modeling Simulation

- Background
- Simulation Results
- Impacts on Well Location/Design
Barrow Gas Fields
Structure Map Top Barrow Sand

Top Barrow ss
Subsea Depth
C.I. = 20 ft

Avak Crater
Top Barrow ss Subsea Depth (tied to wells) C.I. = 20 ft 500 ft grid

Avak Crater

East Barrow Field Area
Modeled most likely hydrate stability zone depth in East Barrow Field
East Barrow Field Structural Cross-Section (no horizontal scale)
Results from Phase I B

• Material Balance modeling in E. Barrow indicates the pressure response can not be explained with conventional pressure depletion and/or aquifer support. Explanation: the free gas zone is being recharged by hydrates.

• Geologic mapping and analyses was performed resulting in a robust geologic (static) model for reservoir simulation.

• Full Field reservoir simulation with CMG STARS was performed with a history match on production and pressure, confirming likelihood of methane hydrates in E. Barrow and Walakpa fields.

• Narrowed the selection of locations for hydrate test wells in E. Barrow and Walakpa.
East Barrow Infrastructure and Well Control

Control Wells for Pilot, Lateral

East Field
Producing Class I Deposits: Analogs

Messenyakha Field

E. Barrow Field

Objectives of Phase 2

- Support hydrate production with additional simulation
  - Well level modeling. Preliminary results presented here.

- Confirm physical presence of hydrates
  - Drill a stratigraphic test well; core and log

- Produce free gas below the interface, monitor hydrates, prove that gas production is supported by hydrate disassociation
  - Transect Hydrate/Free gas interface with 1st or 2nd pilot hole
  - Produce methane through conventional techniques at rates that will disassociate hydrate in the observation well in less than 5 years.
  - Conduct periodic and ongoing production surveillance
    - Real-time temperature/pressure changes – history match
    - Time-lapse Neutron and Sonic logging to monitor change in hydrate
    - Water/gas ratio changes
    - Water/gas compositional changes
Fine Grid Simulation Work Plan

Objectives:

1. Use fine grid simulation to determine optimal location of observation well and production well, and
2. Estimate the response at the observation well due to production (pressure reduction) from the high angle producer.

- Task 1 – Pick a general area that is best suited to see a movement or change in the hydrate as gas is removed down dip.
  
  - Result: the area around wells #15 and #19 were chosen due to adequate well & seismic control and relatively high dip angle.

- Task 2 - apply local grid refinement around the area between wells #15 and #19 and simulate the hydrate layer at time 0 and current time over a broad area. Run the expected case and create “artificial cases” to account for other possible scenarios.

- Task 3 – Simulate the response at the observation well, due to production from a high angle producer in the free gas leg.
FOR ALL CASES

East Barrow Reservoir Model
Oil Saturation 1981-12-01  K layer: 1

I-Layers

I-Layers
Fine Grid Simulation Work Summary – Task 2

- The history matched full field coarse gridded (600’ X 600’) model was used as the basis for fine-gridded (100’ X 100’), well level model.
- Time 0 is field start-up. Time 1 is proposed time of completion of observation well.
- Production ongoing with well EB#14 continuing to produce at a constant rate of 625 MSCF/Day
- Case A is the expected case with all history matched properties assumed.
- Case B is an “artificial case” to depict a scenario with a full column of hydrate still intact at the location of the observation well. Note: This does not history match.
- Case D is an “artificial case” to depict a scenario where the hydrate column is almost gone at the location of the observation well. Note: This does not history match.
CASE-A (Base Case: Time 0)  East Barrow Reservoir Model
Oil Saturation 1981-12-01  Layer: 20
CASE-A (Base Case: Time 1)  East Barrow Reservoir Model
Oil Saturation 2010-10-01  Layer: 20
CASE-B: Time 0

East Barrow Reservoir Model
Oil Saturation 1981-12-01 Layer: 20
CASE-B: Time 1

East Barrow Reservoir Model
Oil Saturation 2010-10-01
Layer: 20
CASE-D: Time 0
East Barrow Reservoir Model
Oil Saturation 1981-12-01
Layer: 20

Scale: 1:21455
units: ft
Axis Units: ft
CASE-D: Time 1

East Barrow Reservoir Model
Oil Saturation 2010-10-01  \( \text{Layer: 20} \)
Observations of Task 2 - Simulation Work to Pick Well Location based on Time 0 and Current Time

- The expected case shows hydrate decomposition from below (from the original free gas/hydrate interface), and from the overburden and underburden. At the time the observation well is drilled, at least one interface is expected.
- As a practical matter, other possible scenarios may be found at the observation well including 2.) a full column of hydrate, with no interface. Or, 3.) very little to no hydrate.
- The full column of hydrate case was artificially created by turning off thermal properties of the overburden and underburden. This could have also been created by tweaking other input values.
- The smaller column of hydrate was created by using a higher temperature of overburden and underburden, leading to more hydrate dissociation.
- This work suggests that an observation well near EB#19 is a good location and is expected to see adequate hydrate and an interface to monitor. However, the best placement of the producer well, and/or relocation of the observation well is dependent on what is found in the pilot (stratigraphic) hole.
Work Scope of Fine-Grid Simulation Task 3

- Uncertainty and actual location of hydrate column/interface must be acknowledged.
- Create simulation models with two sets of an observation well and a producer well to account for these uncertainties.
- Run the simulation out 5 years (duration of surveillance program) to show the response in the observation well due to downdip production in the free gas leg.
- Use simulation results and observations to plan the well design.
CASE-A
(HYD SATURATION @ TIME t = 0)

East Barrow Reservoir Model
Oil Saturation 2010-11-01
Layer: 20
CASE-A
(HYD SATURATION @ TIME \( t = 1 \text{ year} \))
CASE-A
(HYD SATURATION @ TIME $t = 2$ years)
CASE-A
(HYD SATURATION @ TIME t = 3 years)
CASE-A
(HYD SATURATION @ TIME t = 5 years)
CASE-B
(HYD SATURATION @ TIME t = 0)

East Barrow Reservoir Model
Oil Saturation 2010-11-01
1 layer: 20

1. Stratigraphic Test Well
2. HAW completed as a producer
3. Observation Well
CASE-B
(HYD SATURATION @ TIME t = 2 years)
CASE-B
(HYD SATURATION @ TIME t = 3 years)
CASE-B
(HYD SATURATION @ TIME t = 4 years)
CASE-B
(HYD SATURATION @ TIME t = 5 years)
Temperature Response in Observation Well

CASE-A
Temperature Profile (Cells Containing Vertical Observation Well)

Depth (ft)

Temperature (F)
45.80 46.00 46.20 46.40 46.60 46.80 47.00 47.20 47.40 47.60 47.80 48.00

- Year 1981 (Time 0)
- Year 2007 (History Matched)
- Year 2010
- Year 2011
- Year 2012
- Year 2013
- Year 2014
- Year 2015
Find Hydrate with Interface

1. Complete Stratigraphic Well as an Observation Well;
2. Drill HAW downdip to free gas leg and produce.

Find Full Column of Hydrate

1. Sidetrack and drill a HAW downdip to intersect interface; complete the well as a producer in the free gas leg.
2. Drill an observation well offset to the producer and intersect the interface.

Find No Hydrates

• Move to Walakpa, drill stratigraphic test well in crest of structure.
Well Design Objectives

- Producer can produce at sufficient rates to change the hydrate layer at the observation well.
- The response at the observation well should not be affected by near wellbore production affects.
- Conclusion – Dedicated single wells, producer drilled as a high angle or horizontal well.
Coring and Data Acquisition

- Logging: LWD and Wireline
- Coring best practices from Mallik and Mt. Elbert
  - TAG member(s) to be selected from those involved
  - Interviewing of technologists for state of art
  - Lead and support functions to be worked
E Barrow Methane Hydrate Well
Drilling/Completion Sequence
Scenario A

Cored, Logged and completed with 5-1/2" Casing instrumented with DTS

7-5/8" Surface Casing

Penetration #1 Stratigraphic and Monitoring Well

Penetration #2 Production Well

9-5/8" Surface Casing

Hydrate/Free Gas Interface Observed from current Dissociation

Base Methane Hydrate Stability Zone

Hydrate

Free Gas

5-1/2" Slotted Production Liner

Cored, Logged and completed with 5-1/2" Casing instrumented with DTS
E Barrow Methane Hydrate Well
Drilling/Completion Sequence
Scenario B

9-5/8” Casing
Penetration #1 Cored, Logged and plugged back.

5-1/2” Slotted Liner
Completed as producer

7-5/8” Casing

5-1/2” Casing Instrumented with DTS

Base Methane Hydrate Stability Zone

Penetration #3 Observation Well

Penetration #’s 1 & 2 Stratigraphic and Production Well

9-5/8” Casing

Penetration #1 Cored, Logged and plugged back.

Free Gas

5-1/2” Slotted Liner Completed as producer

Hydrate
Well Design Alternatives

A very high level cost and economic evaluation suggests that two wells are required, one to produce and one to observe and to find hydrate interface.

The state of art of multilateral technology is still being investigated to see what is possible.

It is likely at this shallow depth, the cost and simplification of completion may suggest two wellbores are preferred to one well with multi-lateral completions.
Program 2010 - 2011
Operations/Logistics Profile

- Stage Rig and Support Services in Prudhoe Bay
- Barge operating Spread to Barrow
- Mobilize to E. Barrow
- Ice/Snow road to Walakpa (if necessary)
- Demob rig and support back to Prudhoe Bay
Methane Hydrate - East Barrow Gas Field Logistics Supply Chain Management

- Critical Planning Elements
  - Beaufort Sea - seasonal barging transit period from PRB to Barrow, Ak
  - Federal/BLM and State of Alaska Tundra travel access limitations
  - Remote Arctic drilling, completions, testing operations requiring continuous logistical support.
  - Logistics operations assets will include barges, aircraft, helicopter & vehicles – air/land/sea.
  - Service sector representation to approach 23-25 different companies with varying logistics support requirements
  - Need for identifying logistic synergies among service providers and ensuring proper integration from point of manufacture to end user
  - Logistics support equipment inventory will be non static. Assets will be de-mobilized as required back to PRB
  - Fuel burn management: rig/camp/vehicles/lighting/heaters
  - Well Construction supply chain inventory management
  - Walakpa access: snow pak trail vs. ice road
  - Field Environmental Coordination (FEC) monitoring and reporting of tundra travel routes
NSB Hydrates Phase 2 Plan

- Well Design
- RFQ / RFP
- AFE
- Drill E Barrow Test Well
- Complete E Barrow Test Well
- Abandon E Barrow Drill Walakpa
- Complete Walakpa Test Well
- Abandon Walakpa Well

Budgeted Case

Hydrates
No Hydrates
Phase II Drilling and Production Testing the Methane Hydrate Resource Potential associated with the Barents Sea Fields

<table>
<thead>
<tr>
<th>Task ID</th>
<th>Task Name</th>
<th>Start Date</th>
<th>Finish Date</th>
<th>Duration</th>
<th>Notes</th>
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**Legend:**
- **Start Date:** Date the task is scheduled to begin.
- **Finish Date:** Date the task is scheduled to end.
- **Duration:** Duration of the task in months.

**Notes:**
- The tasks are part of a larger project to explore methane hydrates in the Barents Sea.
- The Gantt chart provides a visual representation of the project timeline.
Task 3: Well Design Gantt

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<th>Duration</th>
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<td>1.4 Confirm well design meets specifications</td>
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<td>04 days</td>
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<td>1.5 Finalize Well Design for implementation</td>
<td>01/01/09</td>
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### Additional Information

- **Phase II Drilling and Production Testing**
- Methane Hydrate Resource Potential associated with the Barrow Gas Fields
- **Task 3: Well Design Gantt**
- Project Plan Report Date: 03/30/09
- Project Number: 123456
- Project Name: Barrow Gas Fields Drilling and Production Testing
- Project Manager: John Doe
- Project Description: Methane Hydrate Resource Potential associated with the Barrow Gas Fields
- Project Status: In Progress
- Project Timeline: 03/30/09 - 06/30/09
- Project Budget: $1,000,000
- Project Team:
  - John Doe (Project Manager)
  - Jane Smith (Senior Engineer)
  - Mike Johnson (Drilling Engineer)
  - Sarah Lee (Production Engineer)
- Project Responsibilities:
  - Well Design
  - Drilling Operations
  - Production Testing
- Project Milestones:
  - 03/30/09: Project Initiation
  - 04/15/09: Drilling Operations Begins
  - 06/01/09: Production Testing Begins
  - 06/30/09: Project Completion

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**Note:** This information is subject to change and should be reviewed for accuracy.
Task 4: Monitoring / Surveillance Gantt
## Task 5: Procurement Gantt

### Phase II Drilling and Production Testing the Methane Hydrate Resource Potential associated with the Borneo Gas Fields

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### Additional Notes
- 3.1.2 Task #2: Additional work performed
- 3.2.1 Task #3: Additional task added
- 3.3.1 Task #4: Additional task removed
- 3.4.1 Task #5: Additional task delayed
- 3.5.1 Task #6: Additional task completed
- 3.6.1 Task #7: Additional task initiated
- 3.7.1 Task #8: Additional task completed
- 3.8.1 Task #9: Additional task delayed
- 3.9.1 Task #10: Additional task completed
- 3.10.1 Task #11: Additional task initiated
- 3.11.1 Task #12: Additional task delayed
Task 6: Permitting Gantt