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Whole Value Chain CCUS Conference Week

CO2 Sequestration in Hydrates with Associated Carbon Neutral Methane Gas Production

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Prof. Arne Graue
Dept. of Physics and Technology
University of Bergen, NORWAY

Whole Value Chain CCUS Conference Week, Sept. 22nd–26th, 2025, Golden, CO, USA.

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18 – 20 February 2025
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IPTC-25104-EA

Net Zero CO2 Emission Utilizing Energy from Gas Hydrates - Carbon Neutral Methane Production with CO2 Storage and Conversion to Hydrogen

Arne Graue[1] and Geir Ersland[1]

[1]Department of Physics and Technology, University of Bergen, Bergen Norway

Sponsoring Societies

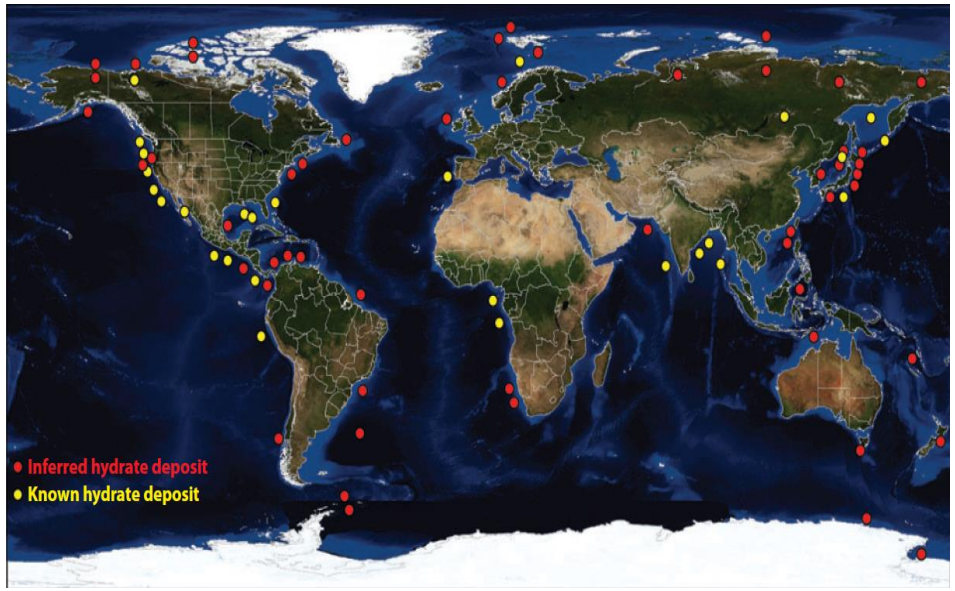
AAPG Advancing the World of Petroleum Geosciences™
EAGE European Association of Geoscientists & Engineers
SEG Society of Exploration Geophysicists
SPE International

CO_2 Storage in Hydrate Reservoirs with Associated Spontaneous Natural Gas Production

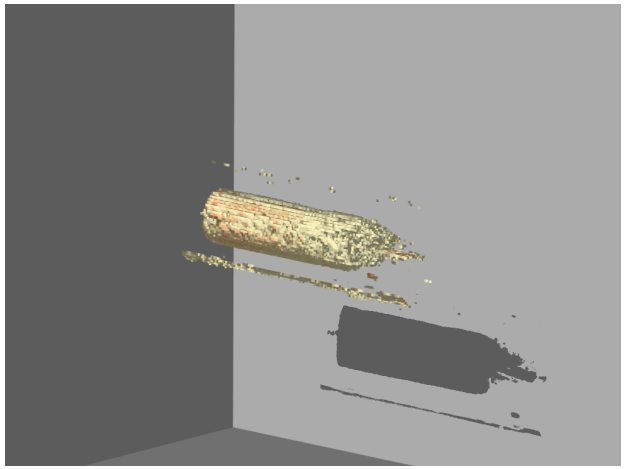
Presentation Overview:

Lab Verification Upscaled to Field Pilot Demonstration of Spontaneous Methane Production When Hydrate is Exposed to CO2. This technology provides Net Zero CO_2 Emission when Utilizing Energy from Gas Hydrates in Carbon Neutral Methane Production with CO_2 Storage.

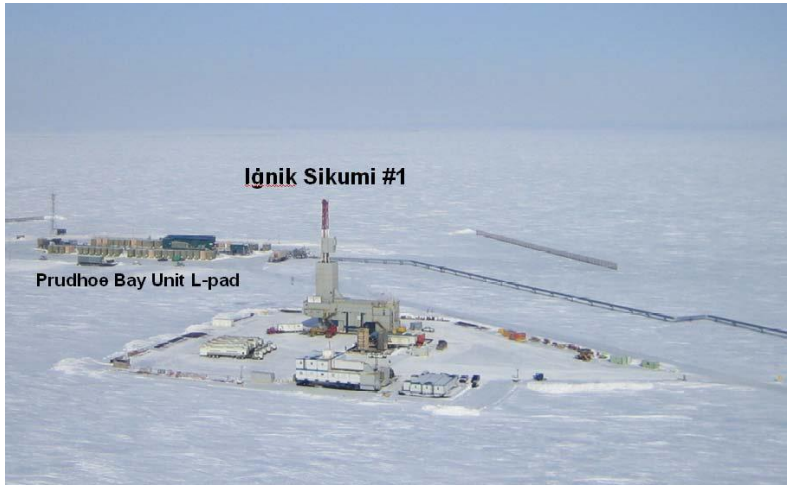
Methane hydrate reservoirs



***In-Situ* imaging (MRI) of hydrate formation**

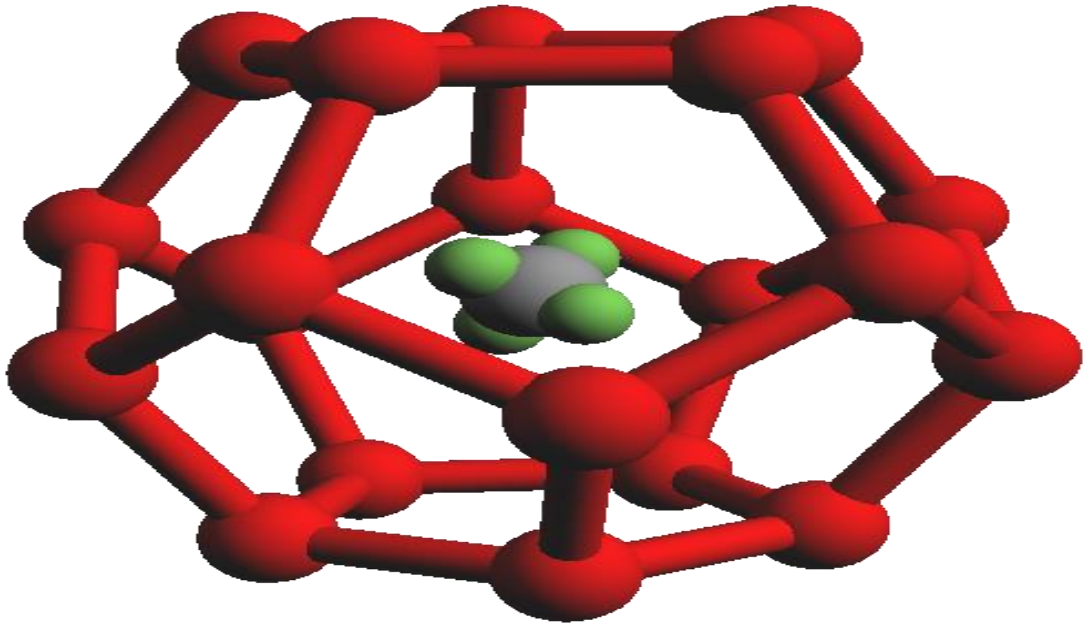


Methane production by CO_2 injection in field test in Alaska 2012



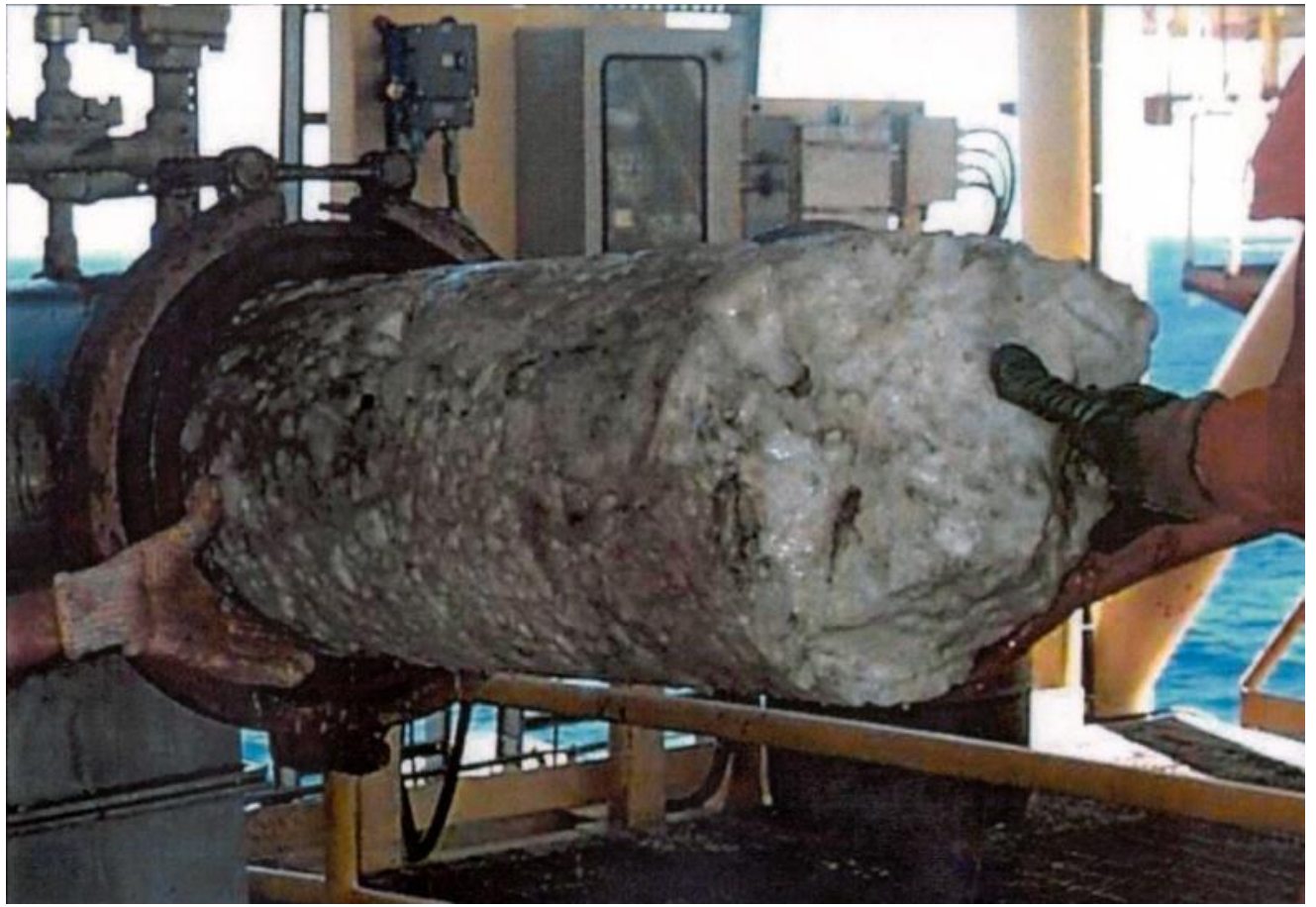
GAS HYDRATES

- Solid state of gas and water where the water molecules form a cavity that encapsulates the guest molecule.



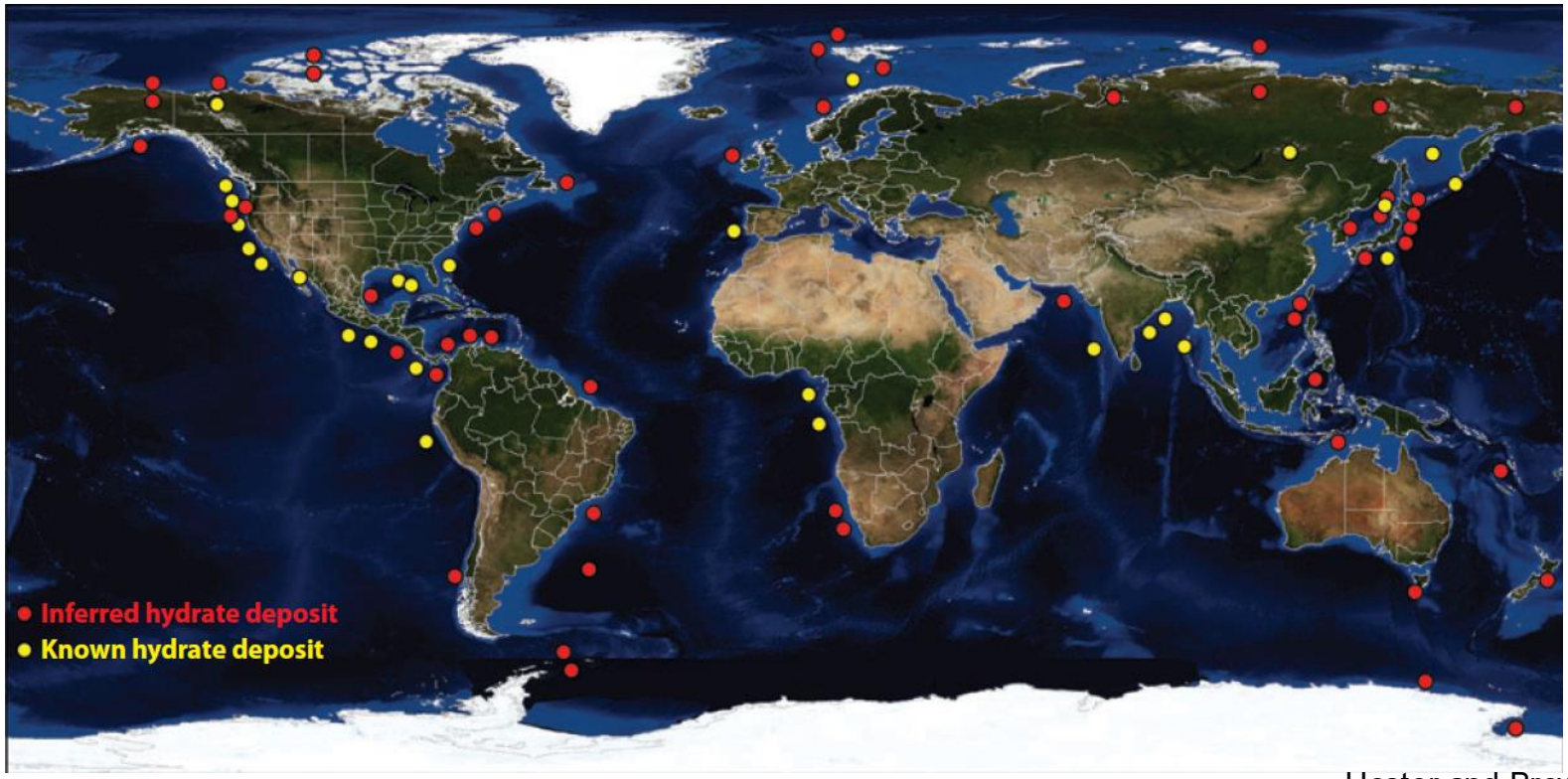
Why are hydrates of interest?

- Initial interest as a curiosity
- Plugging of production and transportation pipelines



Renewed interest

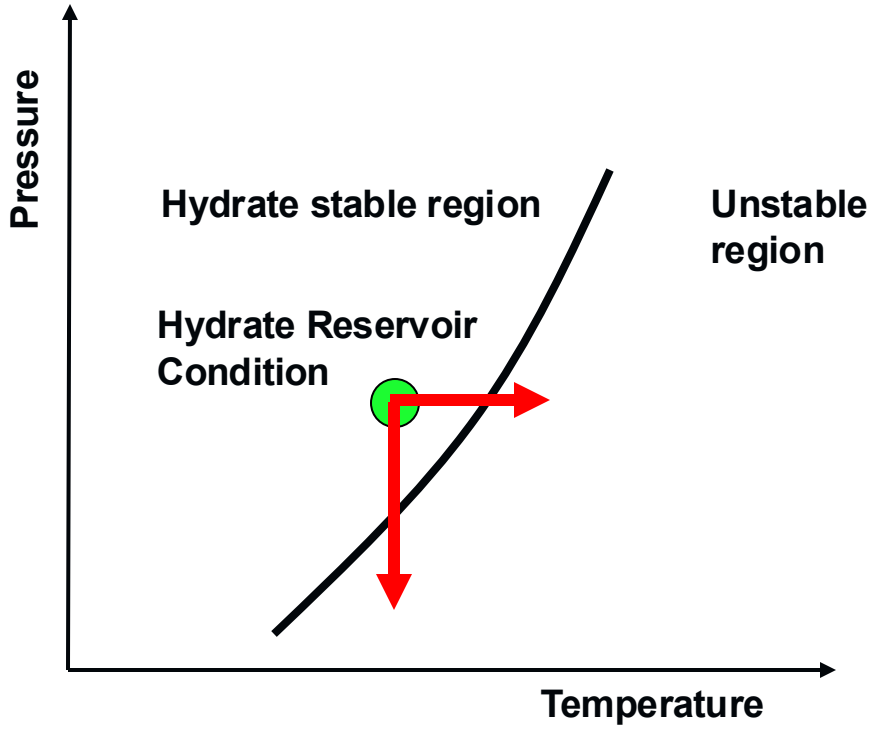
- Significant amount of energy
  - Permafrost regions
  - Marine environments (high water column)



Hester and Brewer, 2009

GAS HYDRATE PRODUCTION METHODS

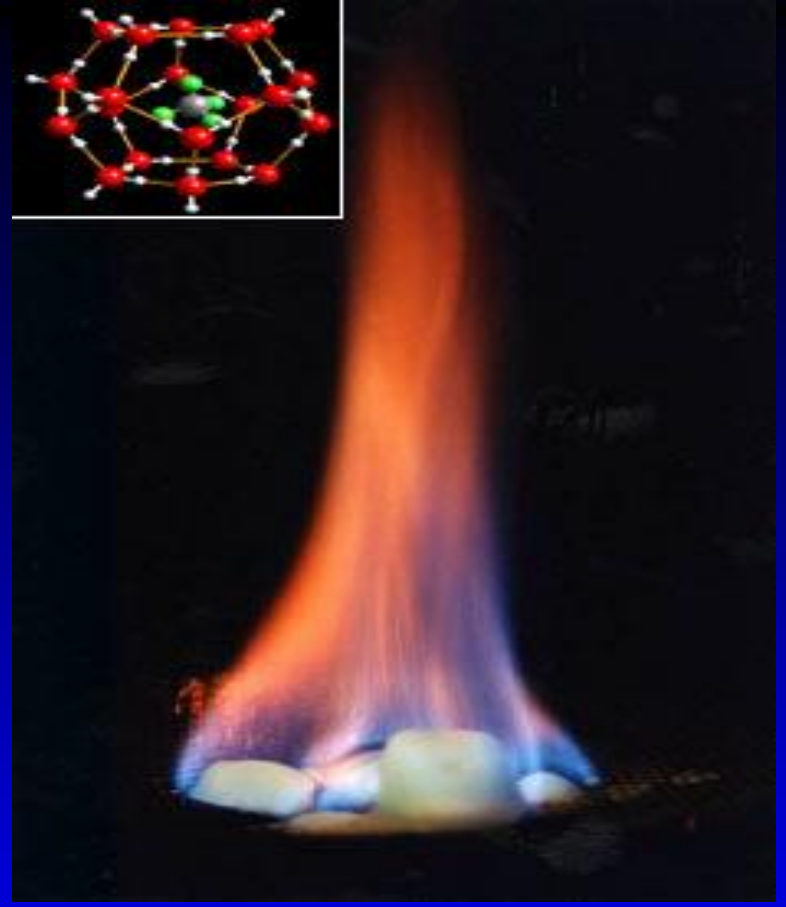
- **Move the gas hydrate outside its stability region**
  - **Depressurization**
  - **Thermal stimulation**
  - **Hydrate inhibitors**
- **CO2 exchange**



CO2 Exchange: Project Motivation

- **The amount of energy bound in hydrates may be more than twice the world's total energy resources in conventional hydrocarbon reservoirs; i.e. oil-, gas- and coal reserves**
- **Simultaneous CO_2 Sequestration**
- **Win-win situation for gas production**
- **Need no hydrate melting or heat stimulation**
- **Spontaneous process**
- **No associated water production**
- **Formation integrity**

CO2 storage in hydrates with associated methane gas production



Challenge:

Determine exchange mechanisms during potential sequestration of CO_2 to produce methane from hydrates

Three component Phase Field Theory

$$F = \int d\underline{r}\left\{\frac{\varepsilon^2 T}{2}(\nabla\phi)^2 + \sum_{i,j=1}^{3}\frac{\varepsilon_{i,j}{}^2 T}{4}\left(c_i\nabla c_j - c_j\nabla c_i\right)^2 + f_{bulk}(\phi, c_1, c_2, c_3, T)\right\}$$

$$f_{bulk} = wTg(\phi) + [1 - p(\phi)]f_S(c_1, c_2, c_3, T) + p(\phi)f_L(c_1, c_2, c_3, T)$$

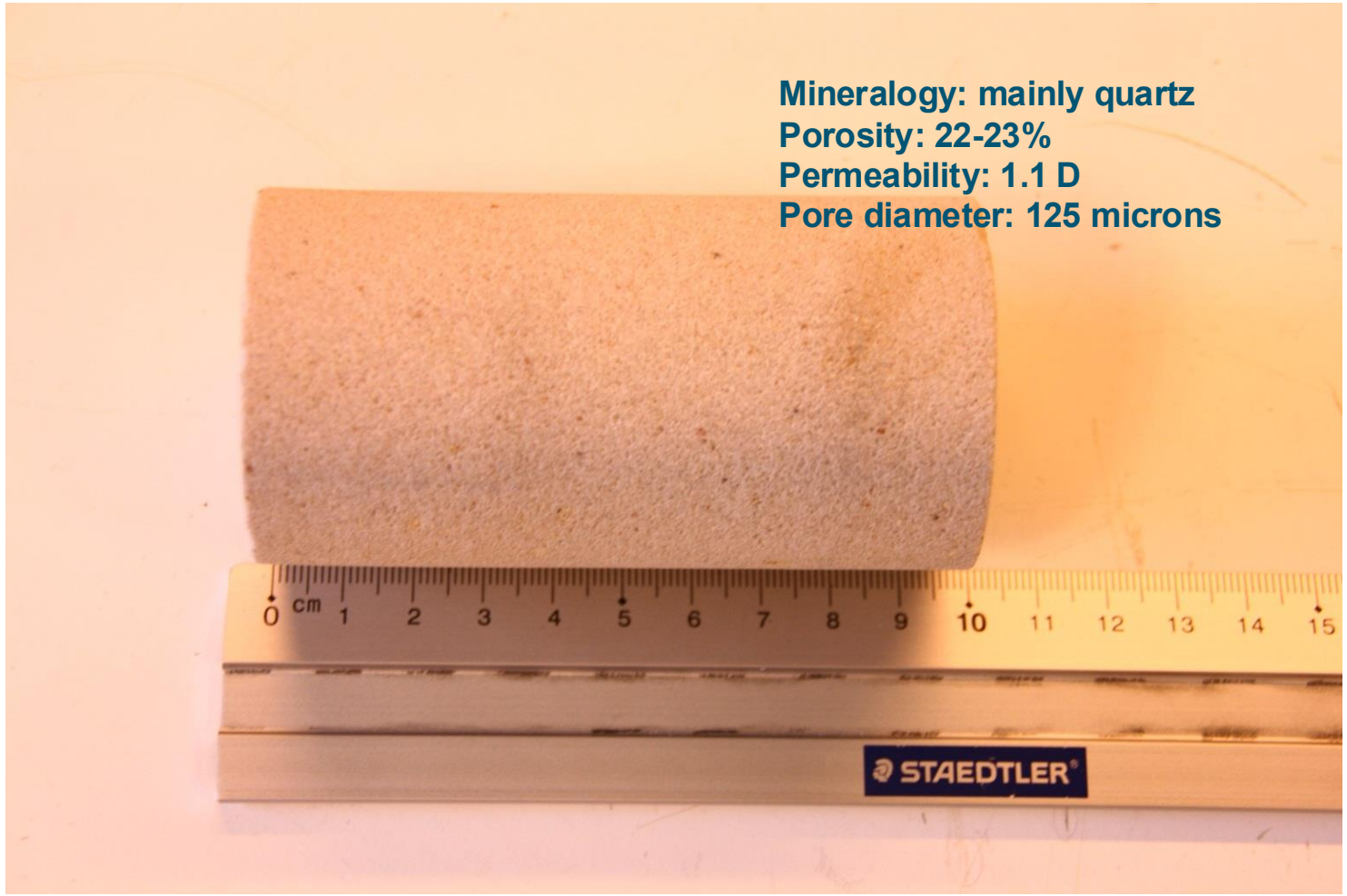
$$\dot{\phi} = -M_\phi\frac{\delta F}{\delta c} + \zeta_\phi$$

$$\sum_{i=1}^{3} c_i = 1$$

$$\dot{c}_i = \nabla M_{ci}(c_1, c_2, c_3)\nabla\left(\frac{\delta F}{\delta c_i} - \zeta_i\right)$$

Parameters ε and w can be fixed from the interface thickness and interface free energy. ε ij set equal to ε

- **Hydrate reservoirs are often found in porous media**
  - **Sedimentary rock**

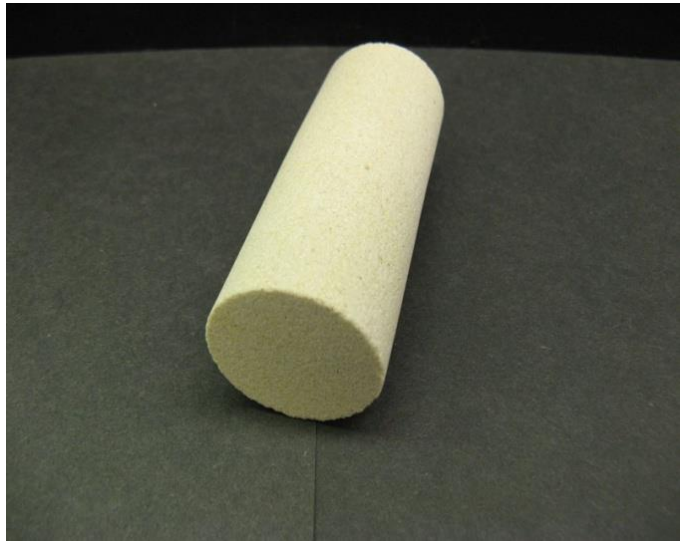


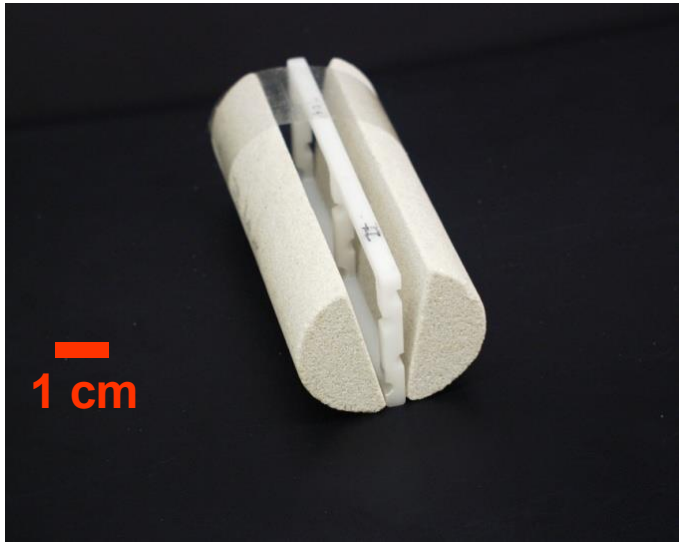
Core Sample Design

Bentheim Sandstone

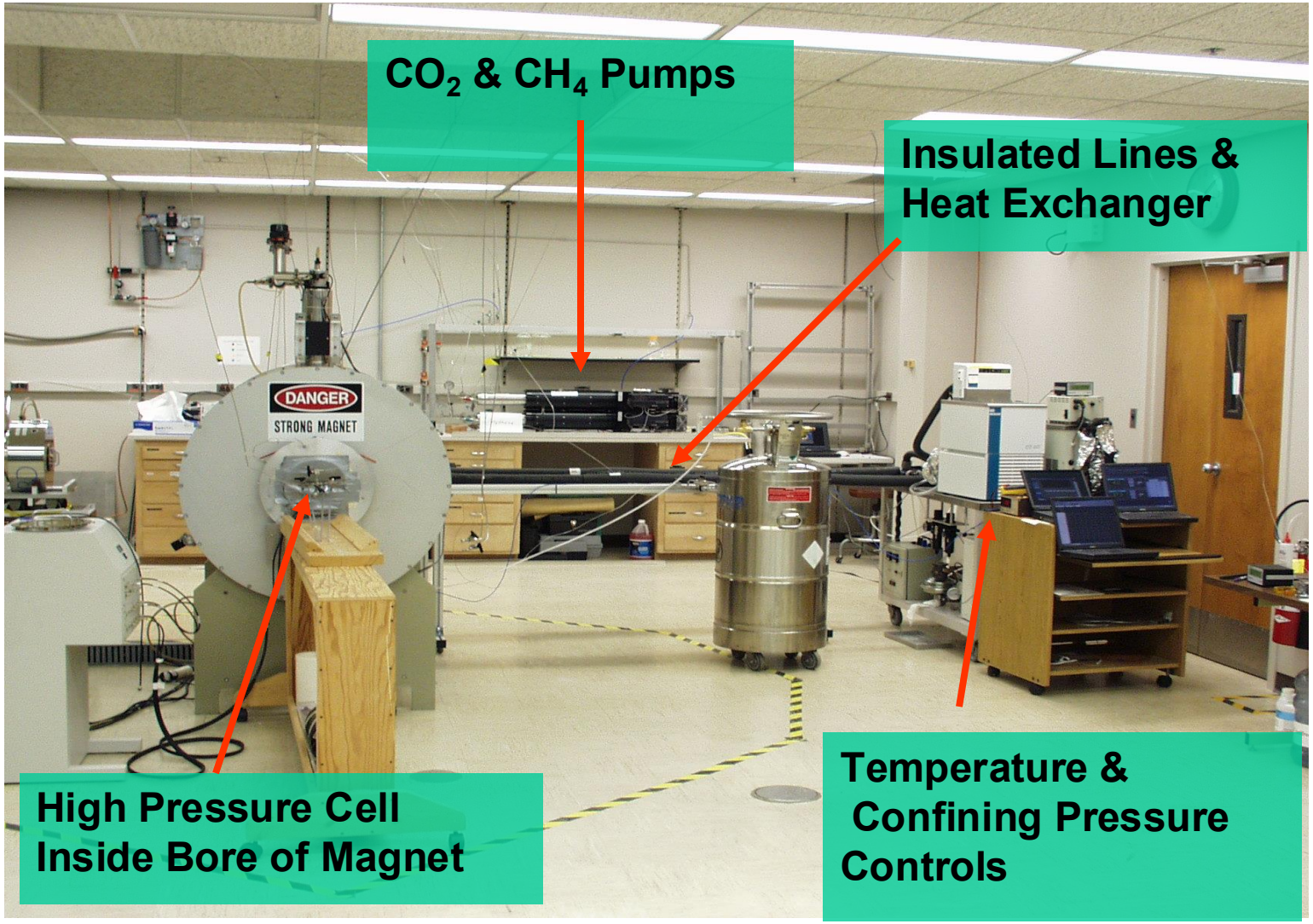
20-25% porosity, ~1.1 D Perm

- Whole Core
- Longitudinal Cut With Machined Spacer to Simulate Open Fracture.

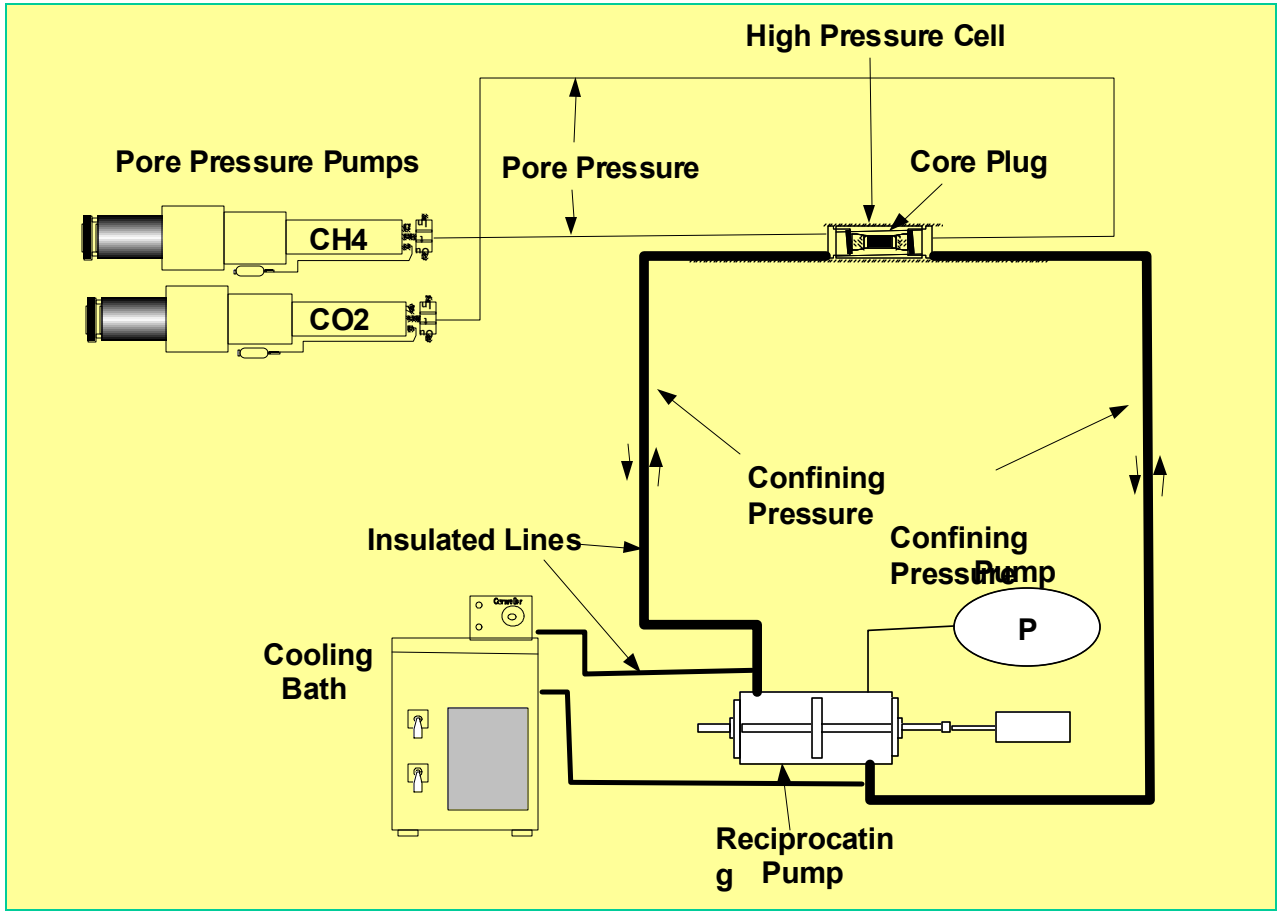




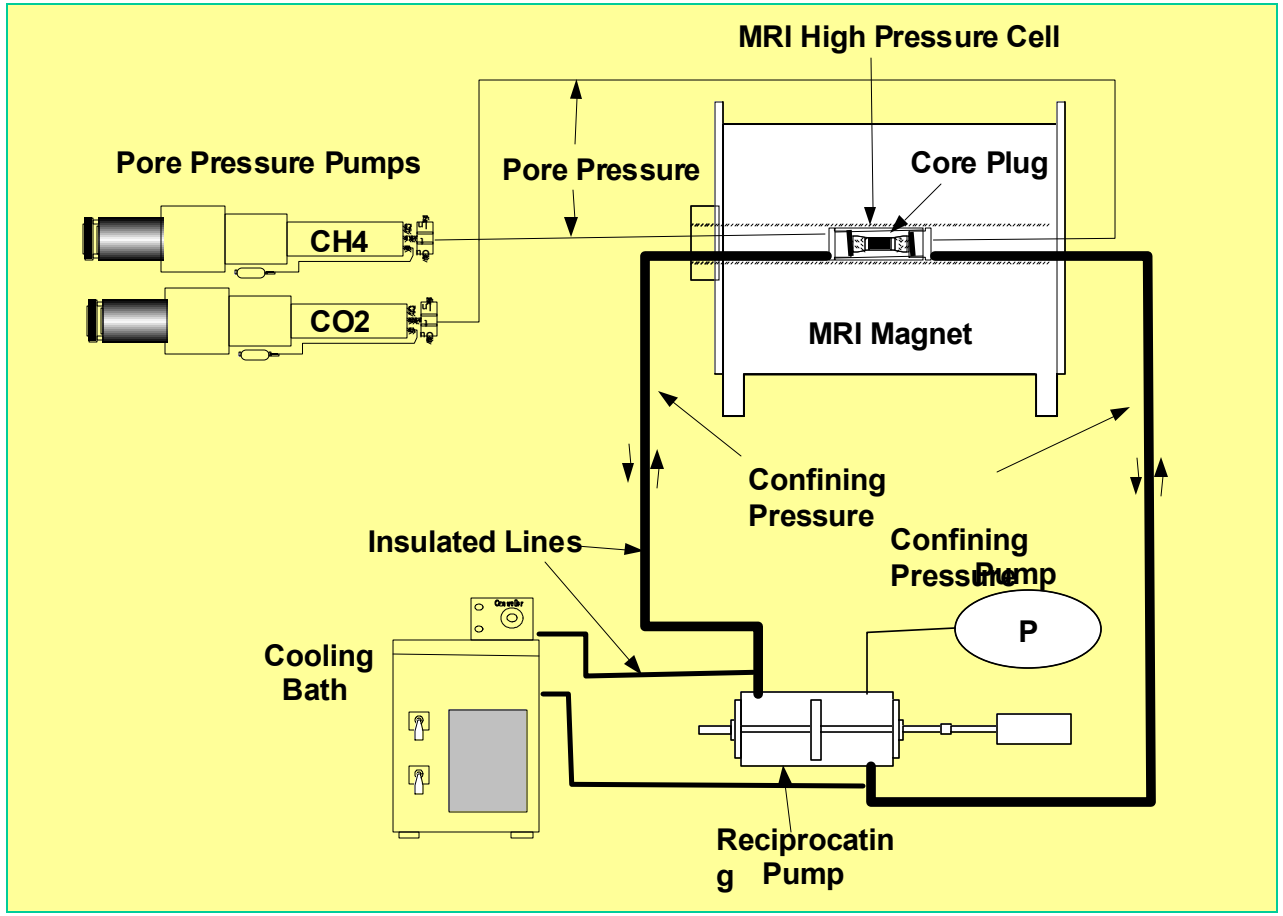
Experimental Setup



Experimental Setup



Experimental Setup

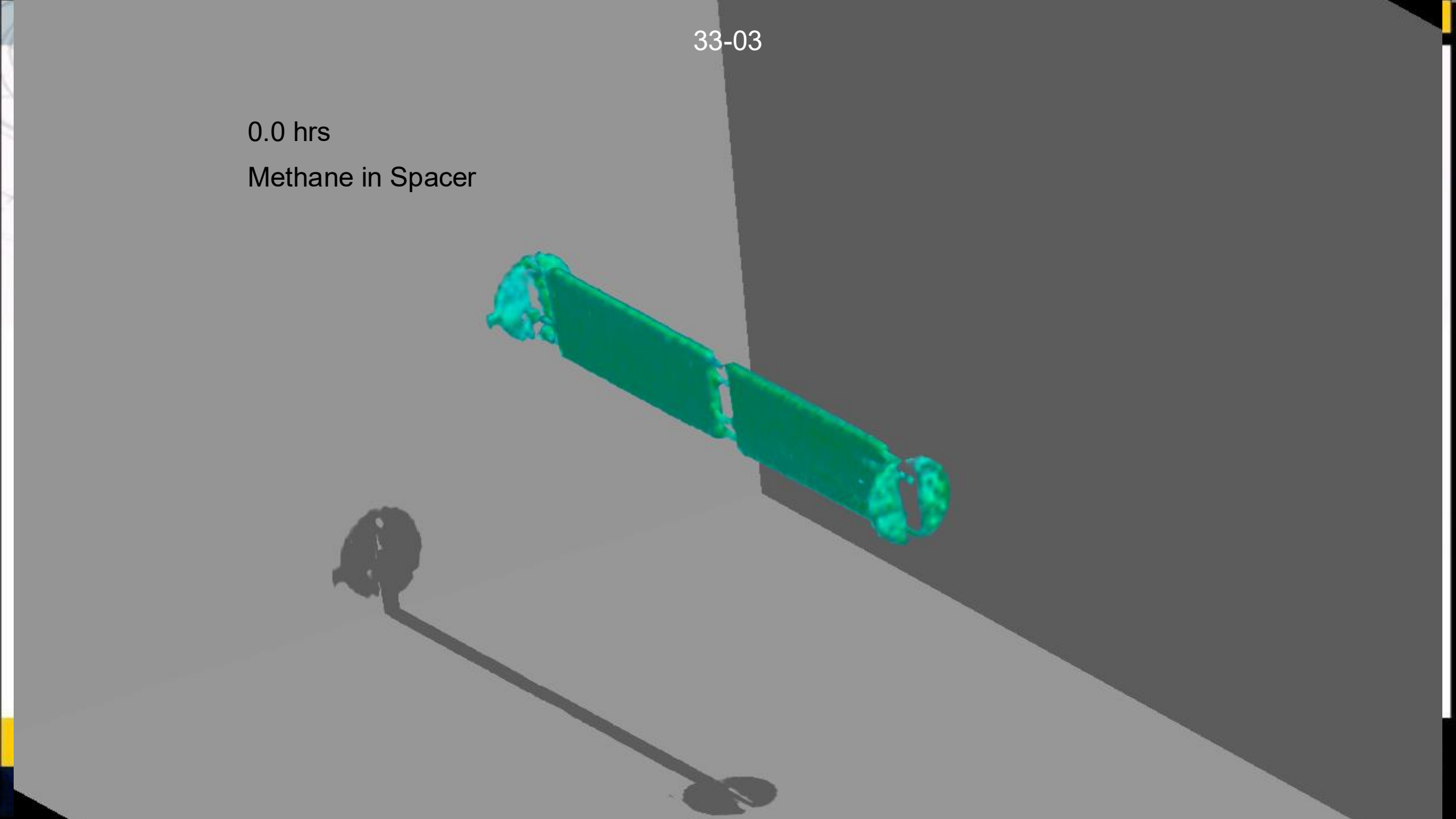


Monitor P-V-T and MRI Intensity

During Hydrate Formation

0.0 hrs

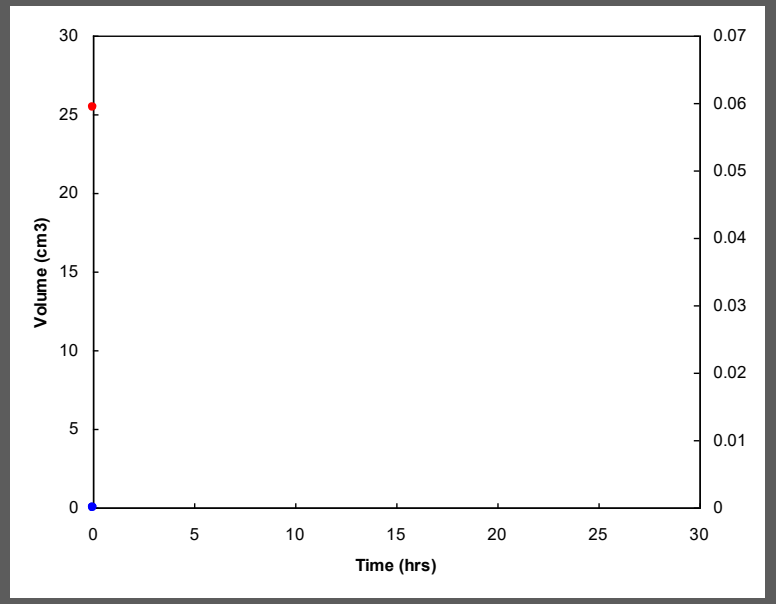
Methane in Spacer



33-07

0.0 hrs

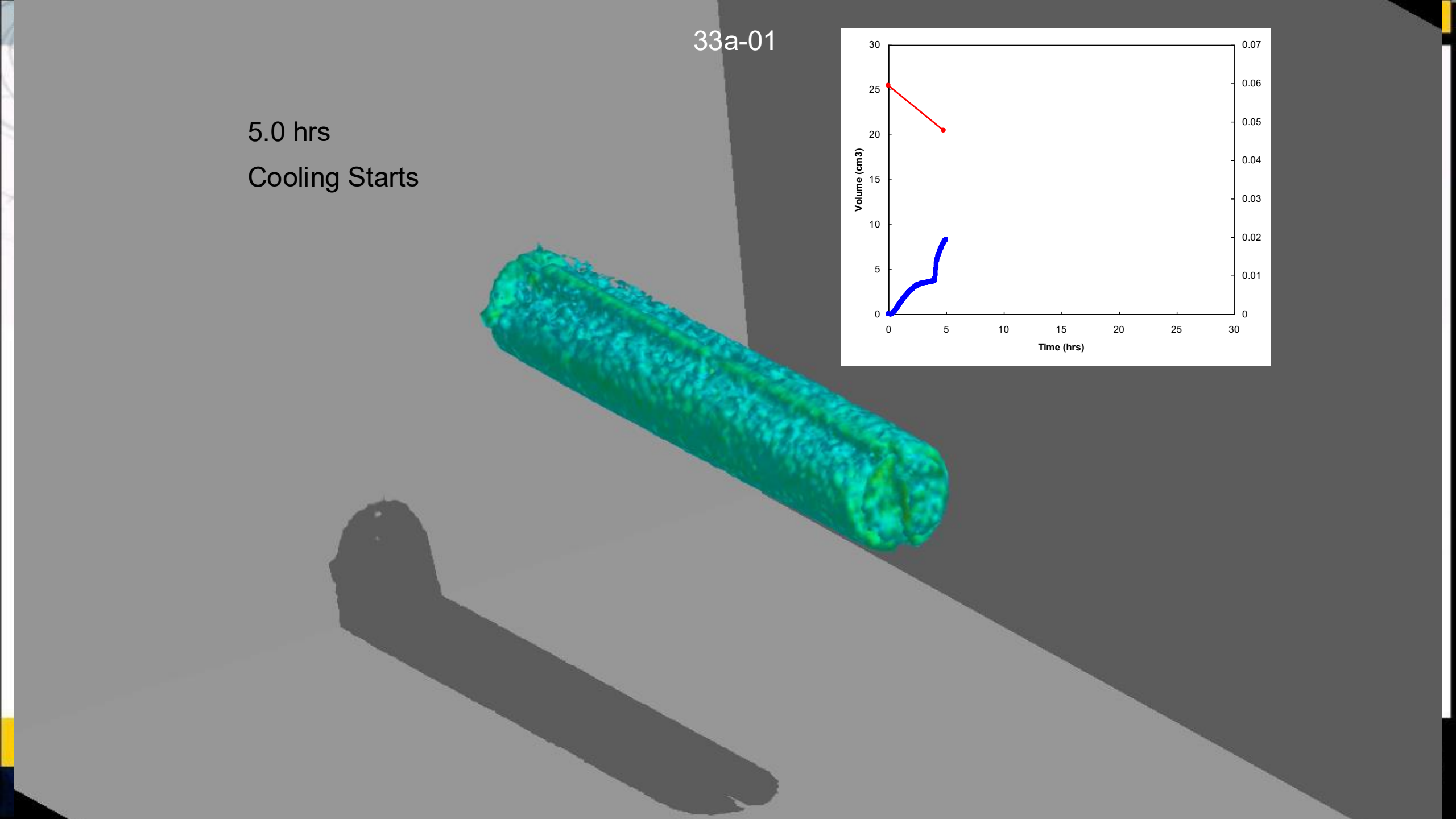
Sw=0.5 + Methane



33a-01

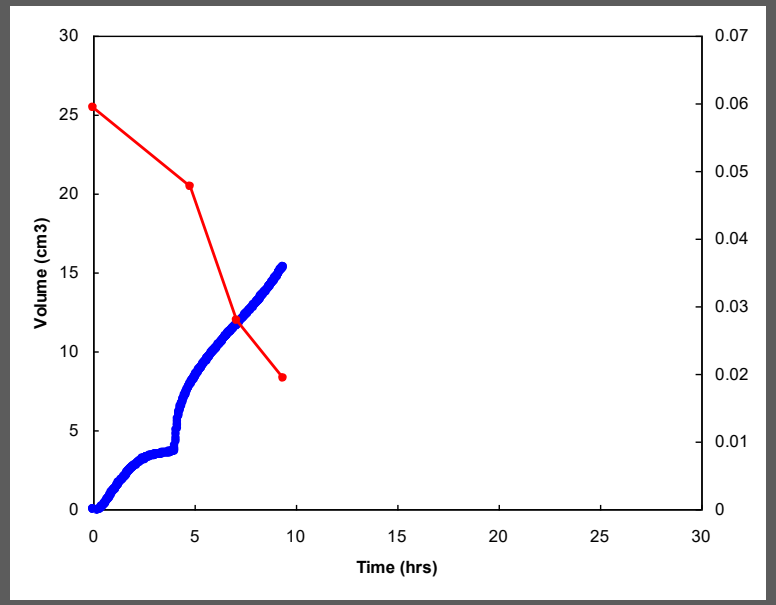
5.0 hrs

Cooling Starts



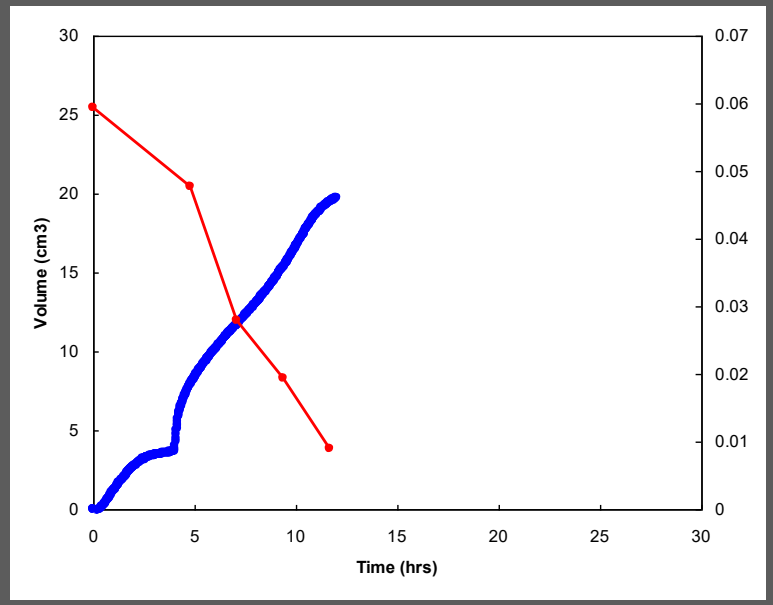
33c-02

9.4 hrs


30
25
20
15
10
5
0
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Volume (cm3)
0
5
10
15
20
25
30
Time (hrs)

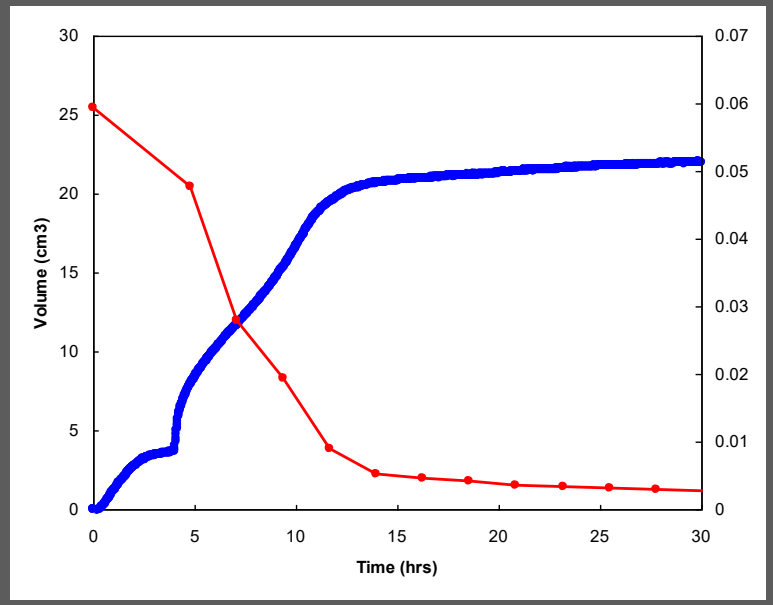
33c-03

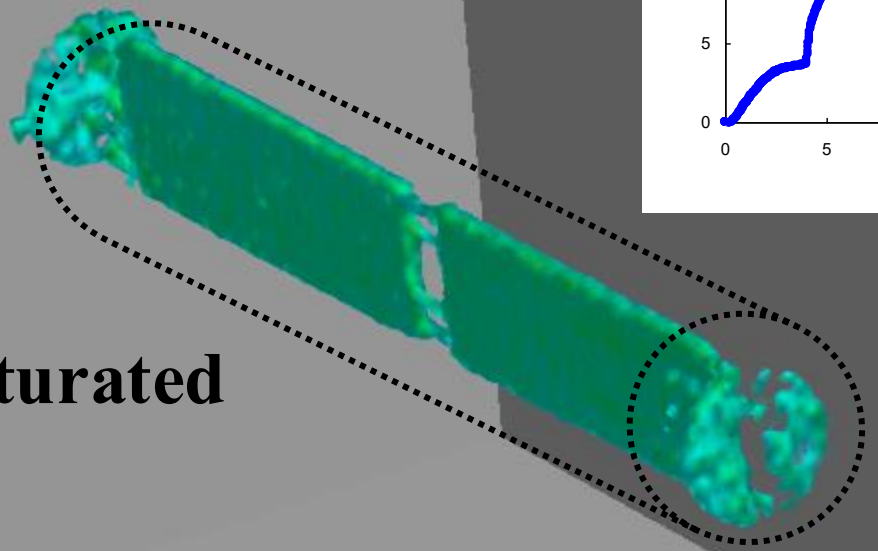
12.0 hrs



33c-11

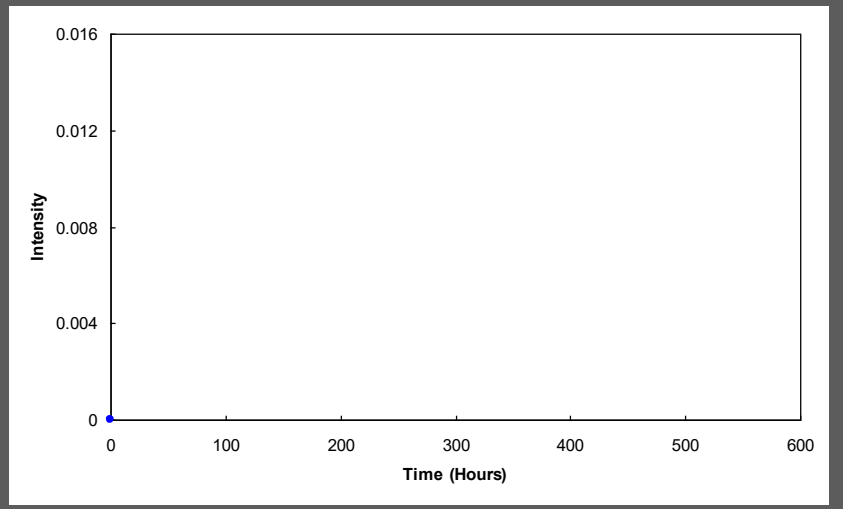
30.0 hrs





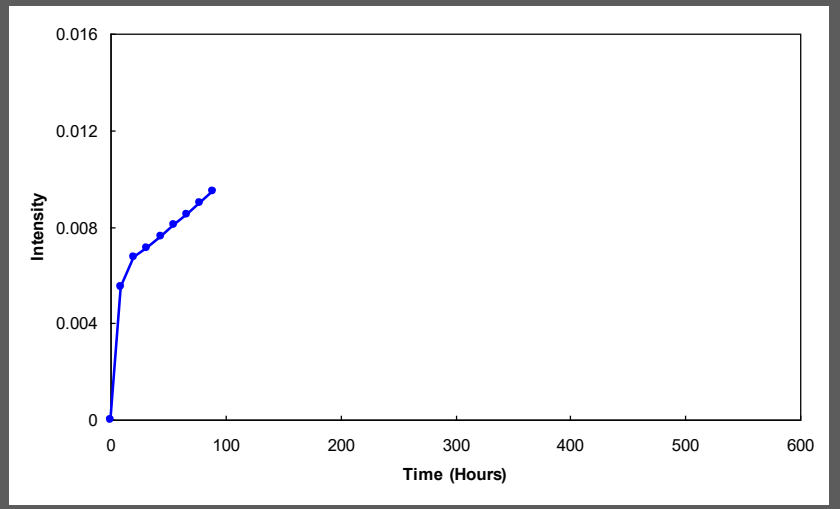
Core Halves Saturated with hydrate

0.0 hrs


0.016
0.012
0.008
0.004
0
Intensity
0
100
200
300
400
500
600
Time (Hours)

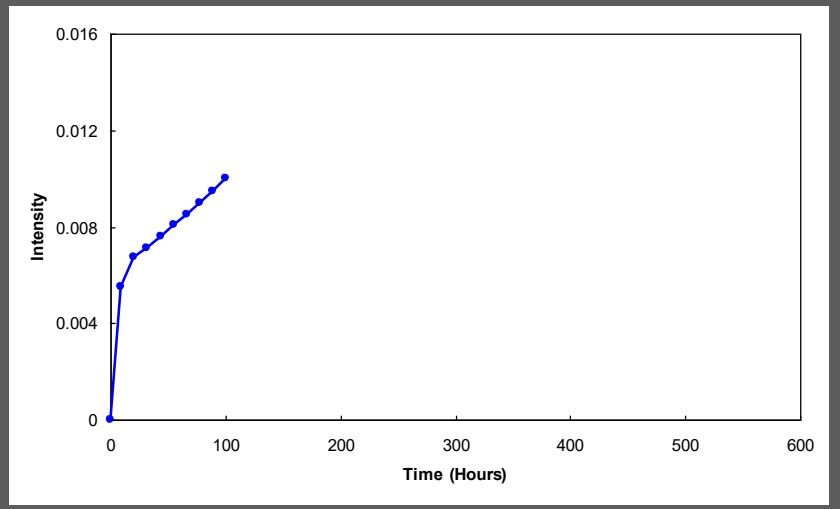
34b-07

89.2 hrs



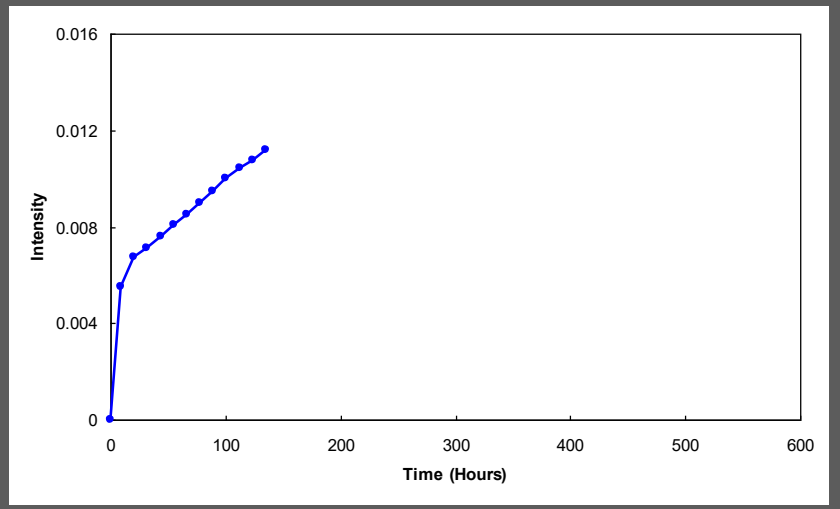
34b-08

100.6 hrs



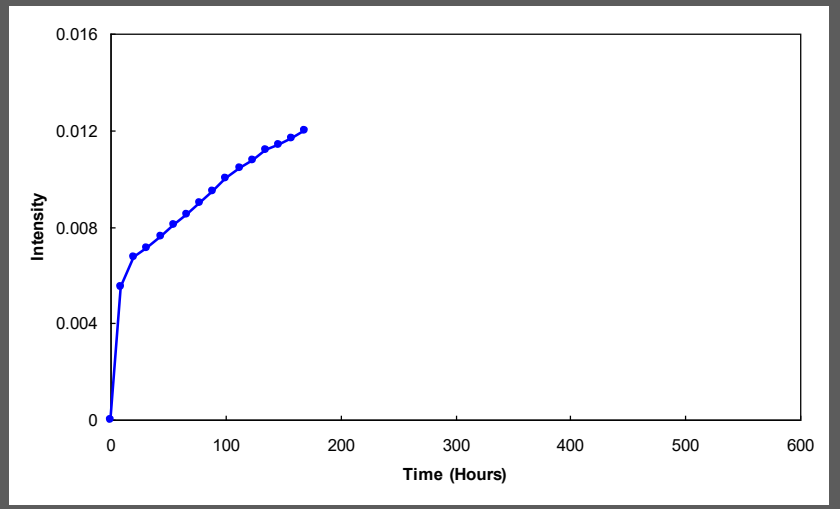
34b-11

135.0 hrs



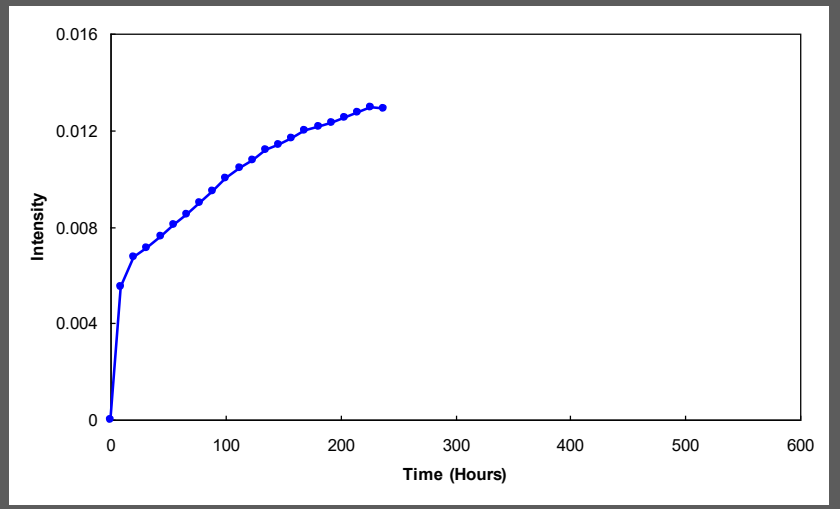
34b-14

169.3 hrs



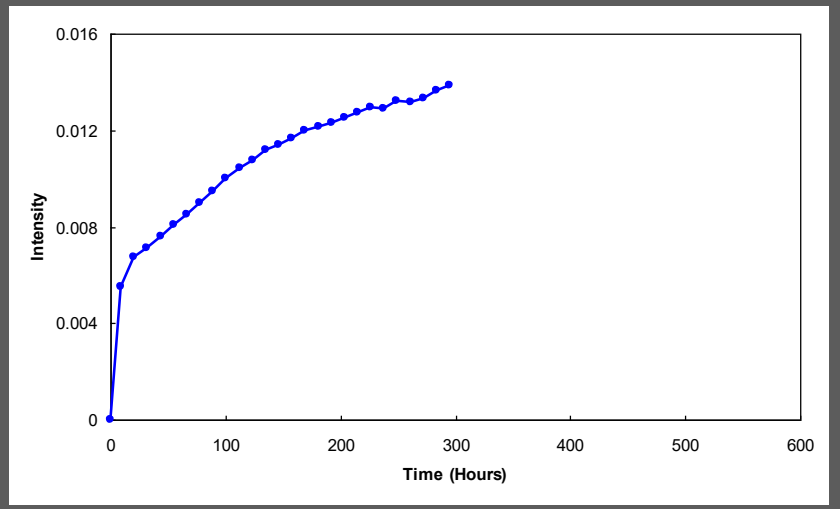
34b-20

237.9 hrs



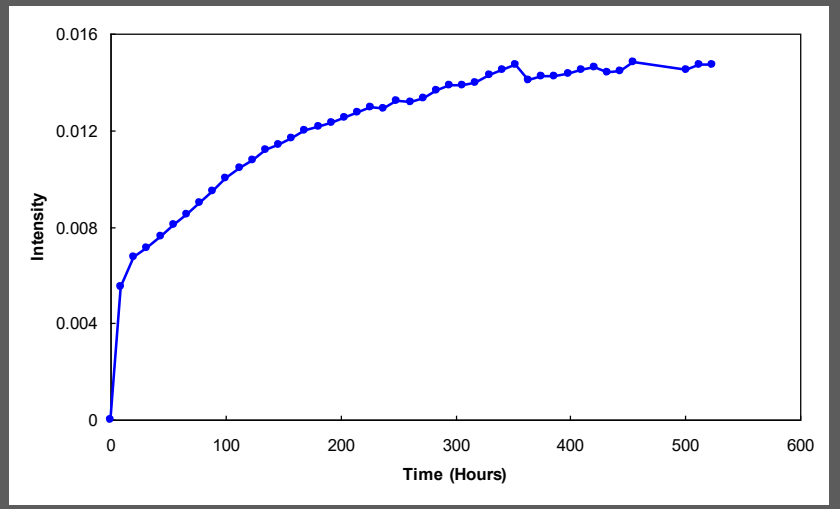
34b-25

295.1 hrs



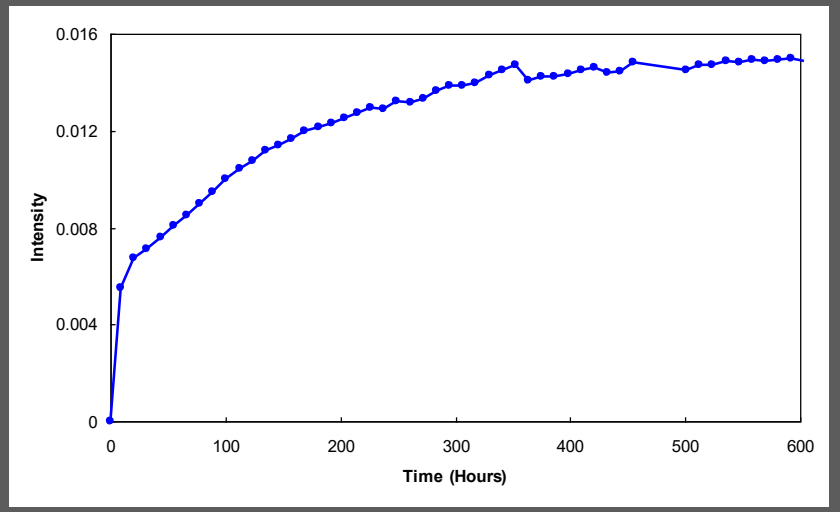
34b-45

523.8 hrs

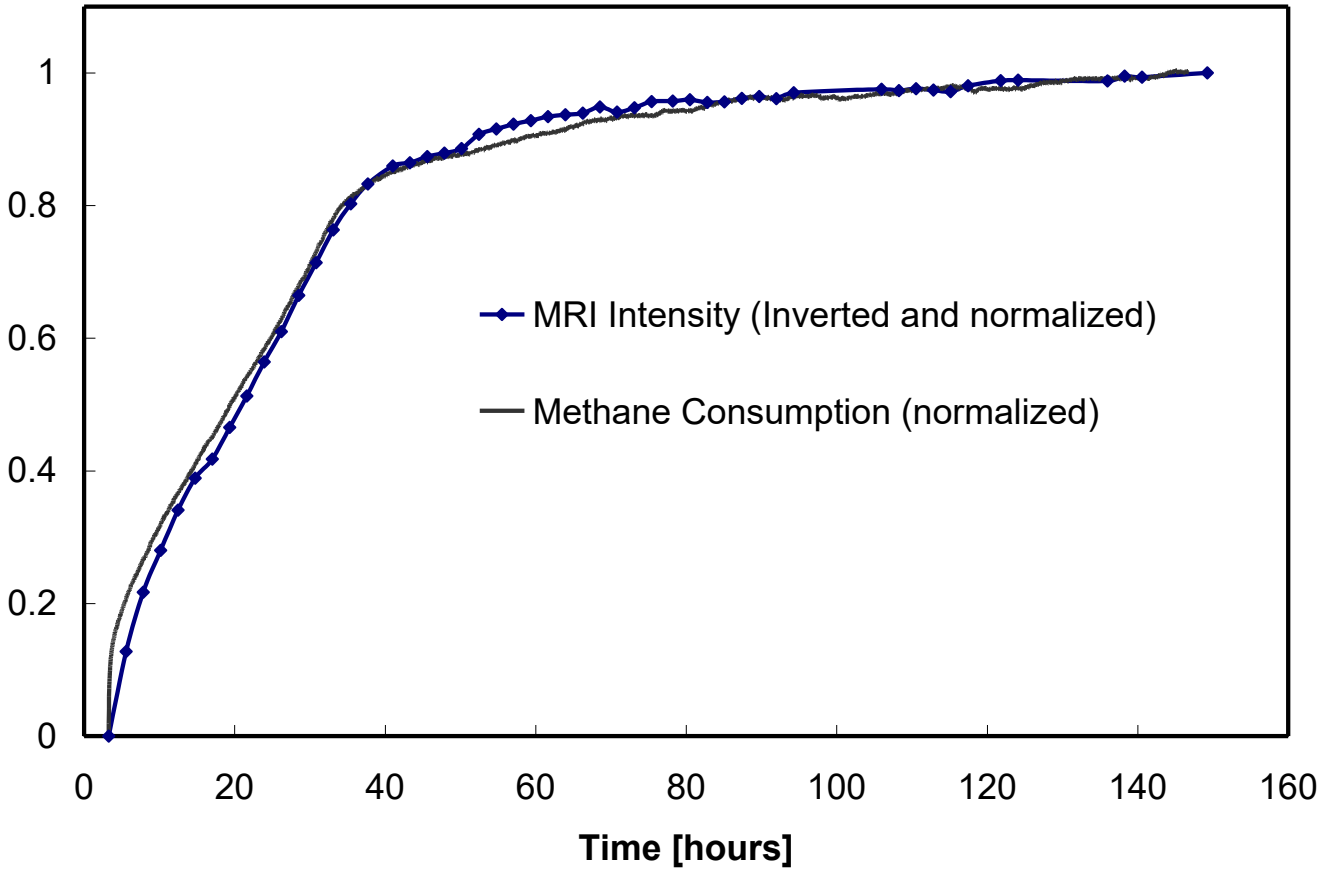


34b-52

603.9 hrs



Volumetrics and MRI Results



MRI Intensity in Core and CH_4 Volume Consumption

Scientific Conclusions

- MRI Provides Unique Dynamic Data of Hydrate Formation and Production Consistent with Conventional Results.
- CO_2 Exchange for CH_4 in Hydrates Is Rapid and Efficient.
- No Free Water Observed During Exchange Process.
- Sufficient Permeability Remains During Hydrate Formation and Subsequent Production.