AN EXPERIMENTAL STUDY ON THE GAS PRODUCTION FROM GAS HYDRATE RESERVOIR BY DEPRESSURIZATION SCHEME

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Contents

Introduction

Introduction

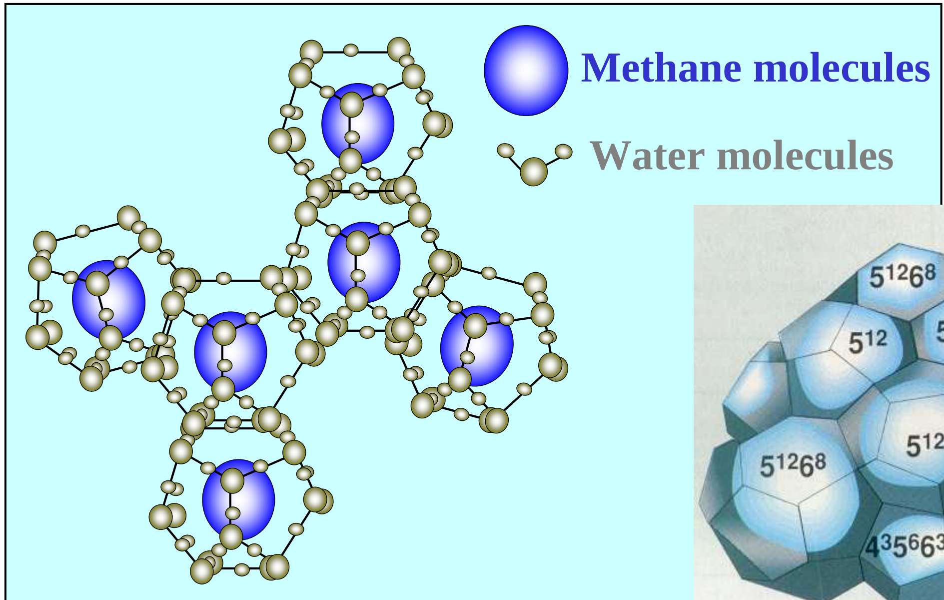
- Natural gas hydrate is one of the new energy resources for the future that can replace fossil energy such as coal and petroleum.
- It is believed that natural gas hydrate exists in the seabed of East Sea within the declared Korean territory.
- A ten-year national project was established in 2005 with the sponsorship of the Ministry of Commerce, Industry and Energy (MOCIE) of Korea and the 1st step including 2D, 3D exploration, drilling and so forth is going on at present.
- This study was performed as one of the project.

Objective

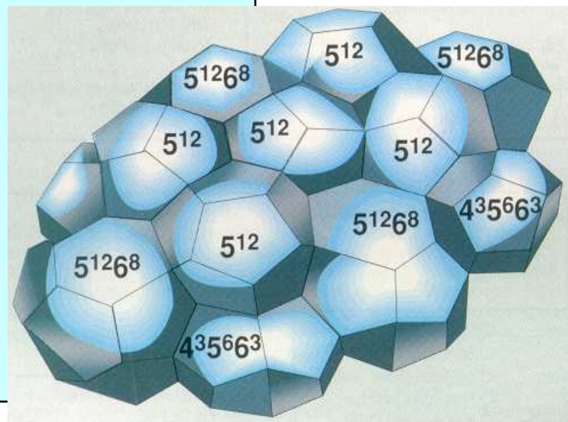
- Finding out the hydrate dissociation phenomena and a production behavior of the dissociated gas during a depressurization.

Background (1)

- Gas hydrates are solids resembling ice in appearance.
- Gas hydrates are about twice the amount of carbon held in all fossil fuels on earth.
  (10,000 gigatons)
- Hydrates have been considered as a future energy resource.



Structures



<Gas hydrate from deep sea>

Background (2)

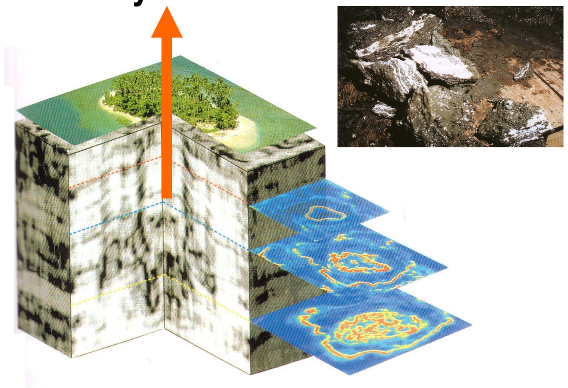
- Gas Hydrate Recovery Process defined as the process which can convert the gas hydrate existing in solid state in the reservoir to natural gas using several methods to produce.
- A little is known about the technology required to produce the gas from hydrate reservoir.


1249C-2H-1,108-140 cm


1249C-4H-5,63-86 cm

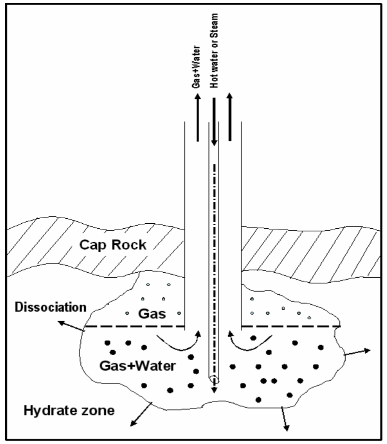

1249C-2H-2, 90-136

Gas Hydrate Production



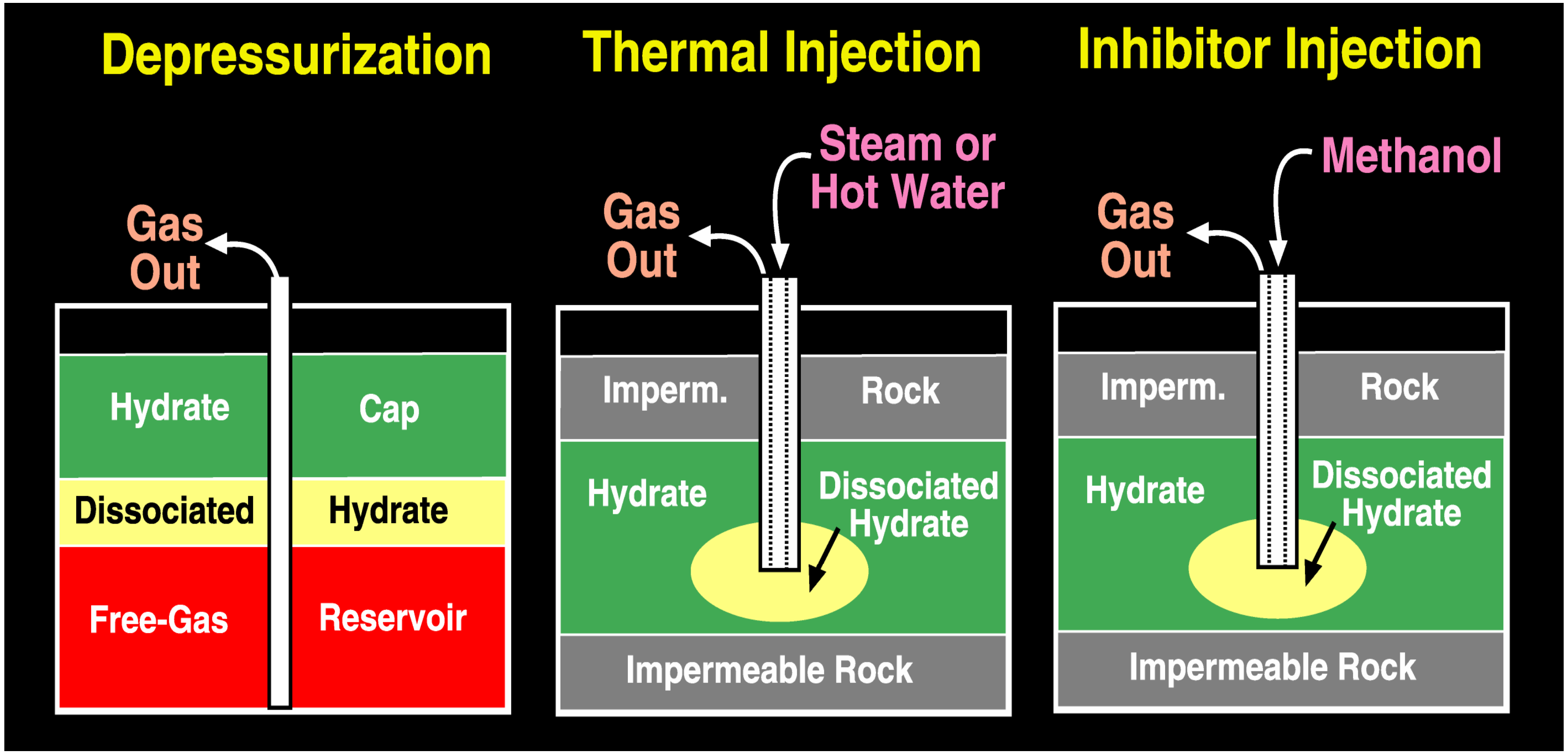

1249F-1H-1


1249F-1H-CC



<schematic diagram for gas hydrate production>

Gas Hydrate Production Methods



Change the reservoir temperature or pressure below equilibrium condition in order to dissociate hydrates.

R&D Actives in Korea

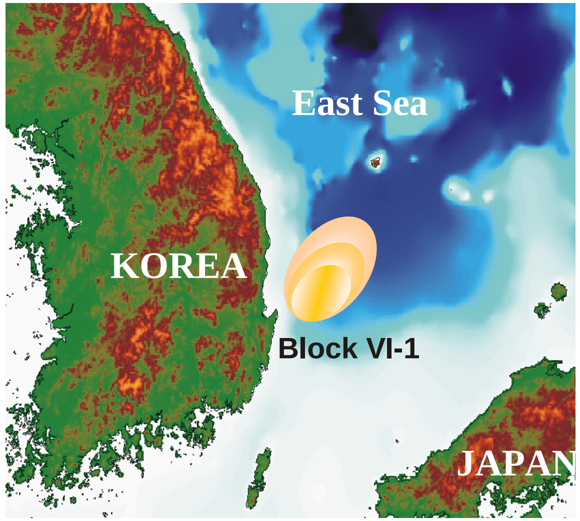
Gas Hydrate Survey in Offshore

- Preliminary survey on East Sea area by the joint project of KOGAS, KIGAM and KNOC
  - Period : 5 years (2000~2004)
  - Content : regional geophysical survey on deep sea area (about 12,000 L-km)
  - Investment : 4 million dollars
- A three-year 1st step project including 2D, 3D exploration and drilling on promising I area
  - Period : 3 years (2005~2007)
  - Investment : 67 million dollars

Research Vessel, Tamhae II

Interpretation Results

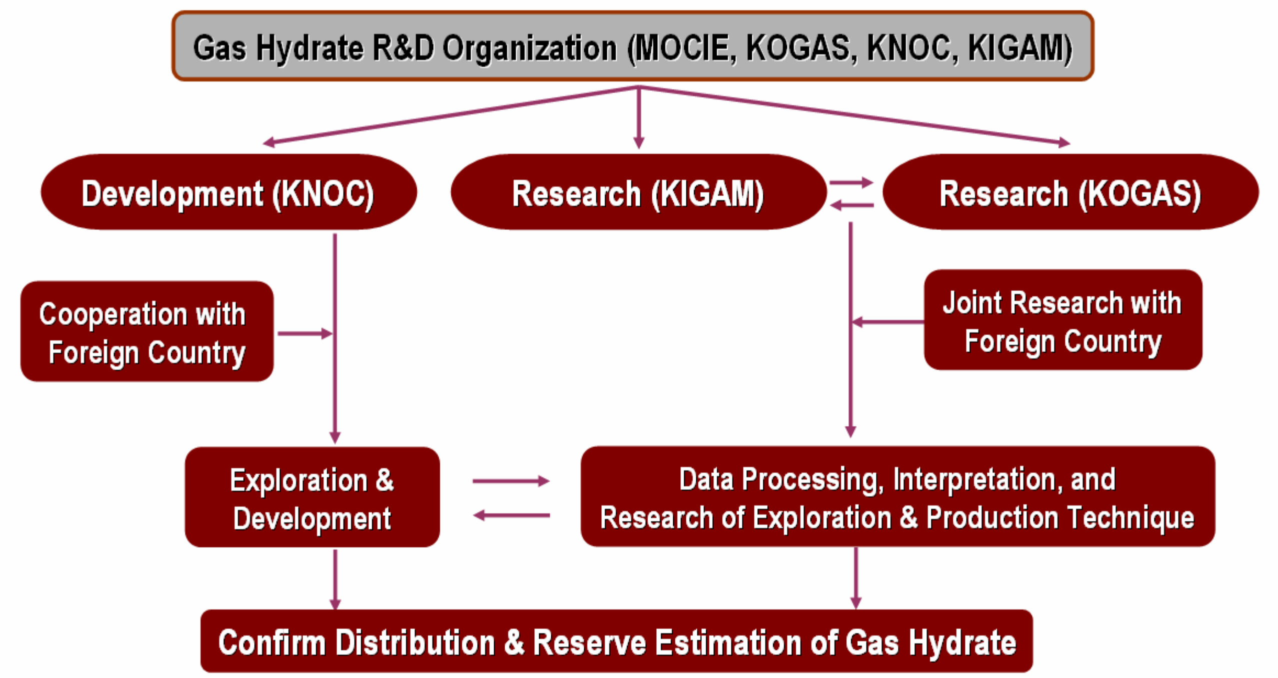
- Confirmed BSR distribution area : about 8,000 ~ 10,000 km^2
- Preliminary estimation of Gas Hydrate deposit : 600 million ton (corresponds to 30 year's of Korea's gas consumption)



Survey Area

Overview of National Project

- Period : 10 years (2005~2014)
- Chief organization : MOCIE (The Ministry of Commerce, Industry and Energy)
- Participation :
  - KOGAS (Korea Gas Corporation)
  - KNOC (Korea National Oil Corporation)
  - KIGAM (Korea Institute of Geoscience & Mineral Resources)
- Budget : 225 million dollars



Long Term Plan for Gas Hydrate in Korea

Execution of the project by phase with the target of commercial production in 2015

Field	preliminary step (2000~2004)	1st phase (2005~2007)	2nd phase (2008~2011)	3rd phase (2012~2014)
1. Regional Seismic Survey & Basic R&D				
2. Prospect I Survey & Drilling (Component research)				
3. Prospect II Survey & Drilling (Base technology for production)				
4. Test Production & Confirmation of production method				

Experiments

KOGAS KOREA GAS CORPORATION

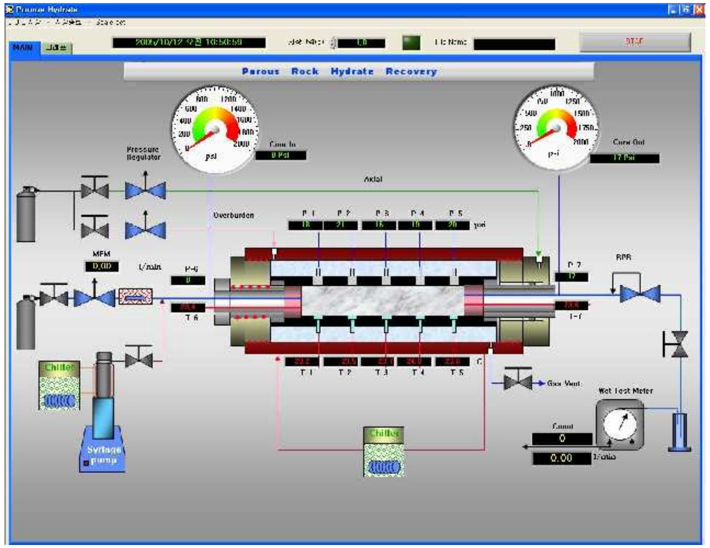
Experimental Study

- **Finding out the hydrate dissociation phenomena and a production behavior of the dissociated gas during a depressurization**
  - **Formation of methane hydrates in a porous rock**
  - **Measurements of the dissociation rate and volume of produced gas**
  - **Observation of the progress of the dissociation front**

Experimental Apparatus

- Porous rock hydrate recovery system

< Photography of experimental apparatus >

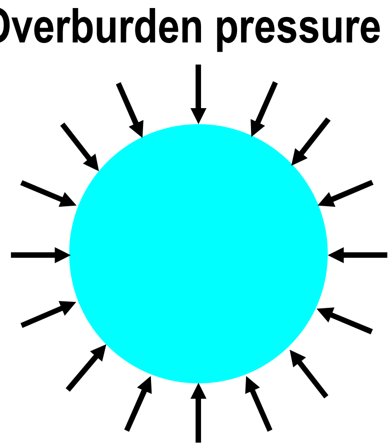


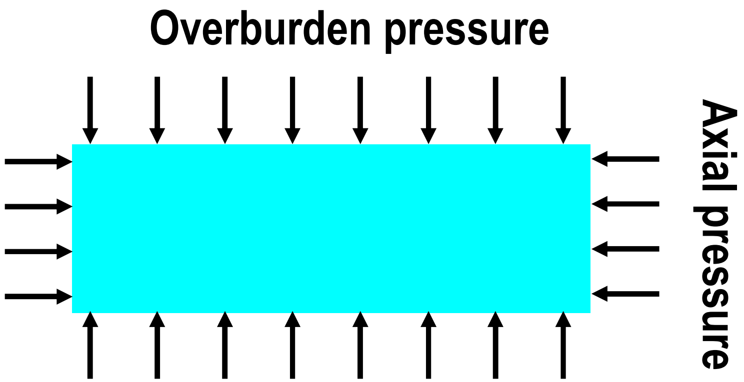
<Data display window>

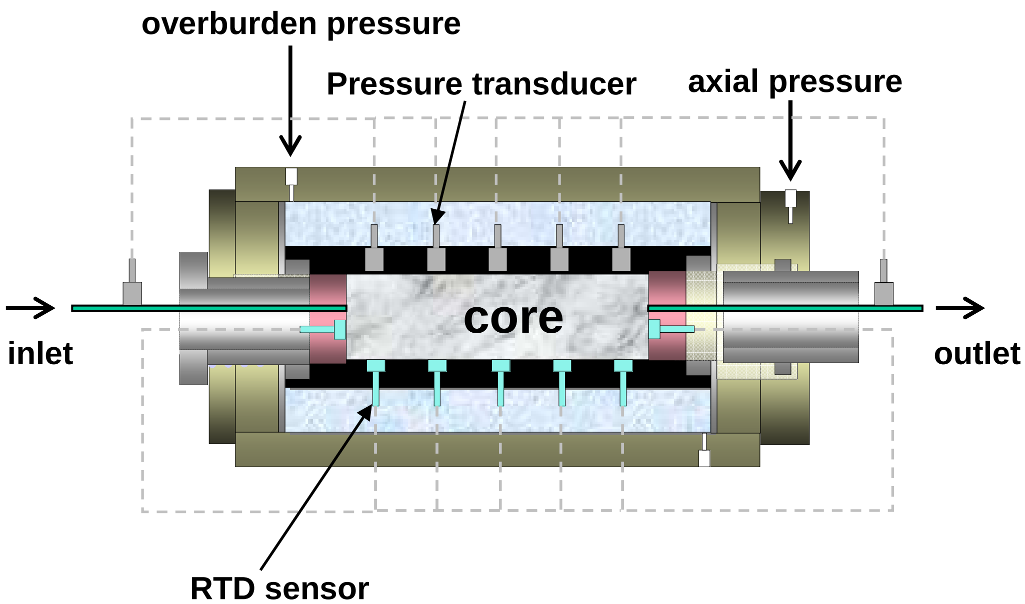
<Berea sand stone core sample>

Sedimentary Condition in Deep Sea

- Overburden pressure : water pressure at a depth of about 1,000 meters
- Axial pressure : lateral pressure by stratum







Descriptions

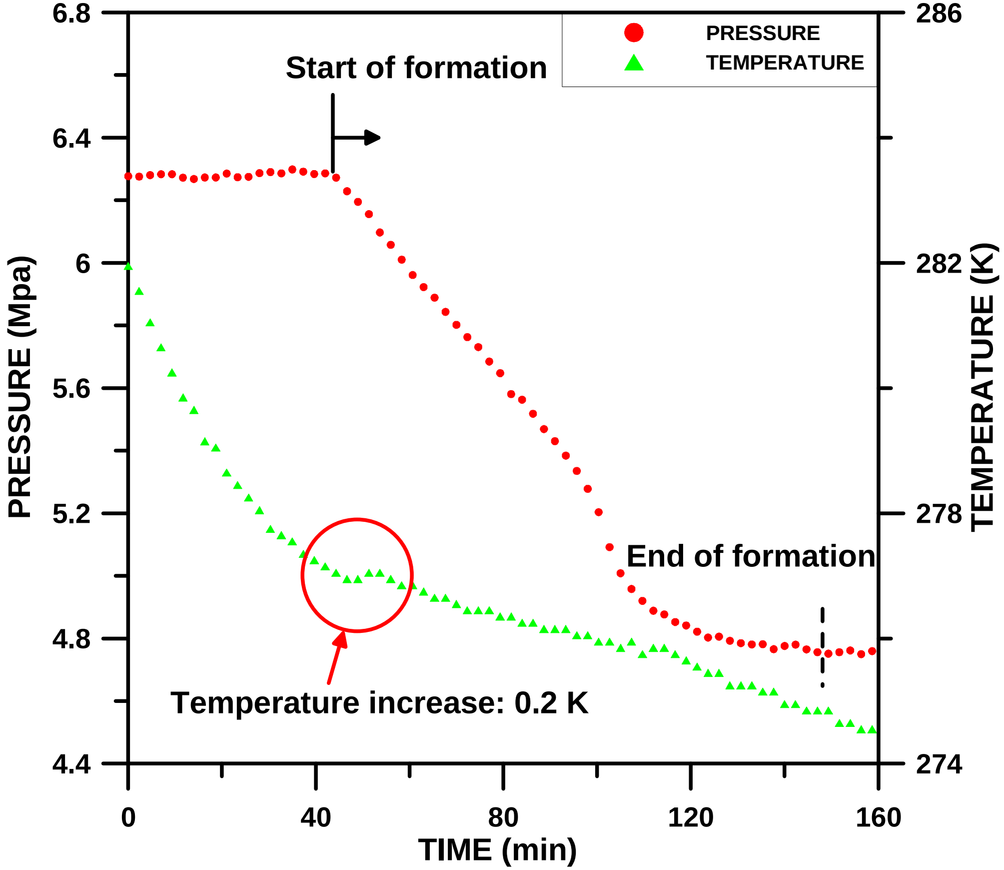
- Length: 60 cm, O. D. : 20 cm
- Glycol Jacket cooling type
- 7 PT & 7 RTD sensor
- Automatic data recording system (16 bit-256 channel)

Gas Hydrate Formation in Porous Rock

Sample core properties

- Porosity : 31%
- Permeability : 329 md
- Water Saturation : 80%

- Pressure decreases to 4.75 MPa from the injection pressure of 6.27 MPa
- Exothermic temperature increases 0.2 K during hydrate formation.

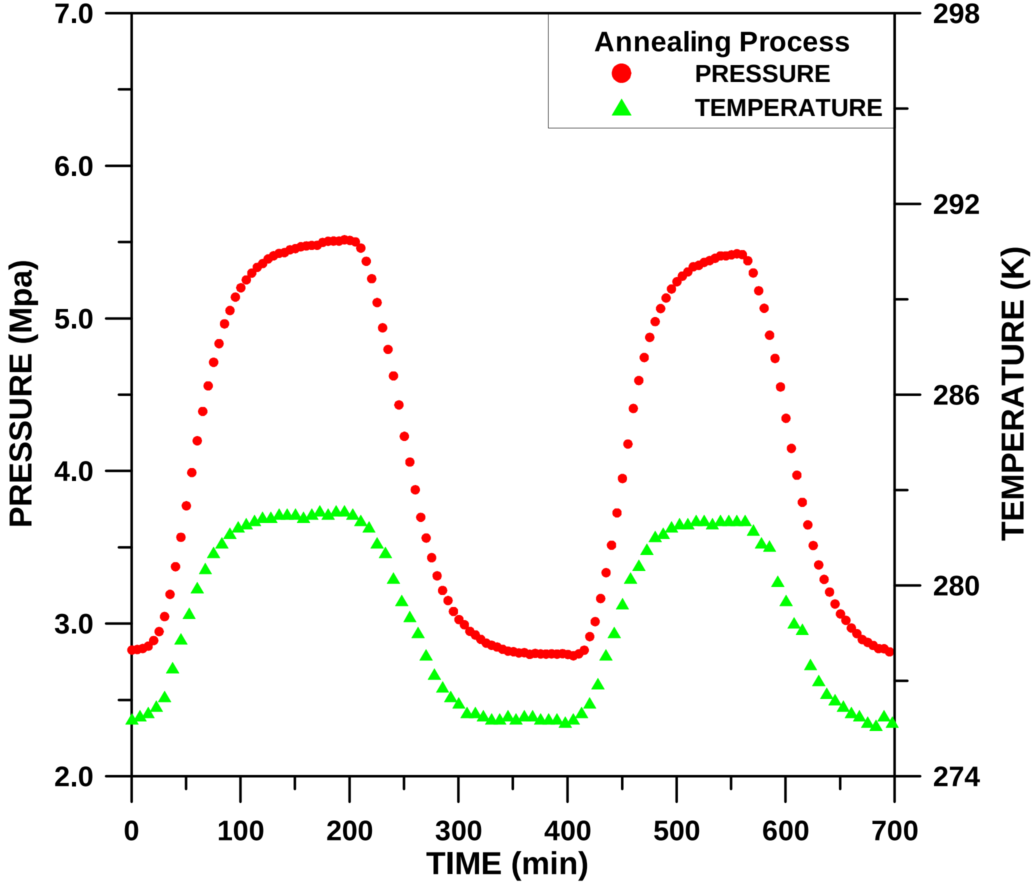


Pressure and temperature curve during hydrate formation

Annealing Process

Reflection of sedimentary condition in nature

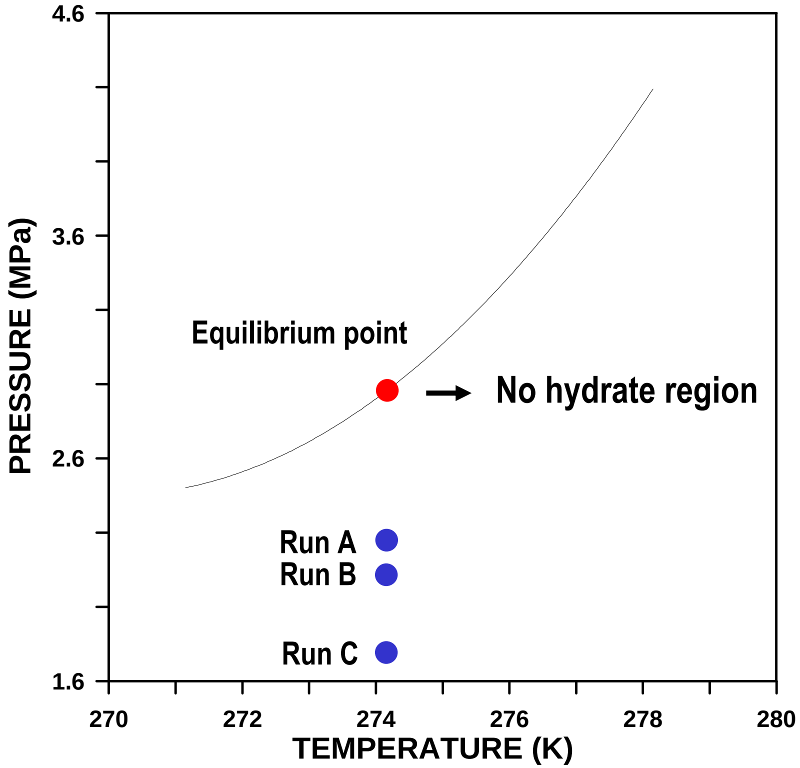
- To form hydrate sufficiently by increasing gas-water contact and to make uniform hydrate distribution along the core.
- Pressure is the almost same before and after the annealing process, which indicates no more additional formation and redistribution of hydrate.
- Annealing process may also have occurred in nature through an extremely slow climate cycle.



Pressure and temperature behaviour during annealing process

Experimental Condition

■ **Temperature: 274.15 K / Equilibrium pressure: 2.9 MPa**

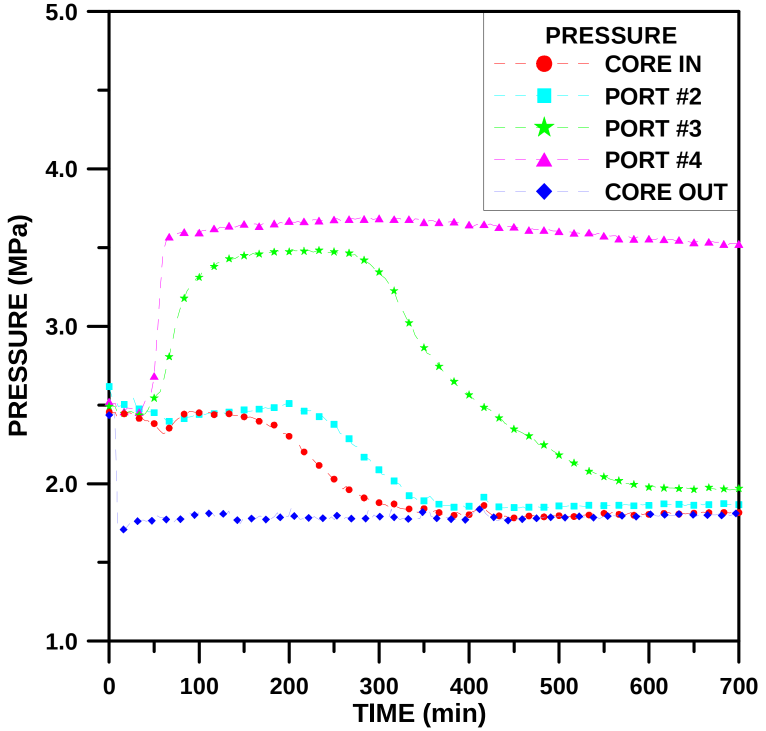


- These experiments were performed under isothermal condition of 274.15 K.
- Dissociation was conducted at 1.72 MPa (Run A), 2.07 MPa (Run B) and 2.21 MPa (Run C) respectively.

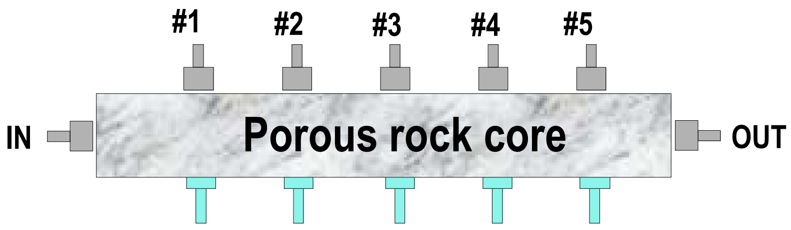
Equilibrium curve (Calculated by CSMHYD program)

Dissociation by Depressurization (Run A)

Run A (1.72 MPa=250 psi)



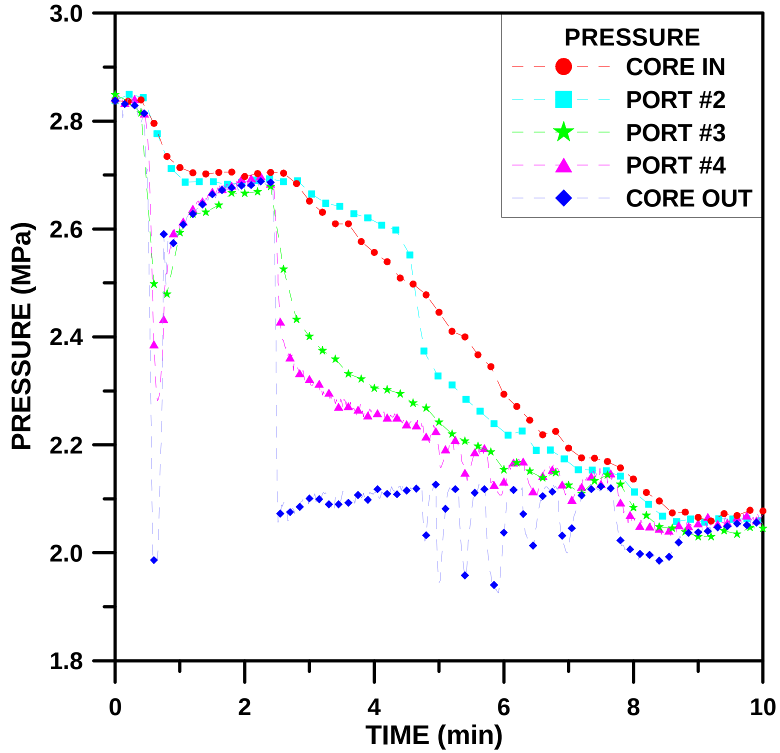
Pressure behavior with time during hydrate dissociation for Run A.



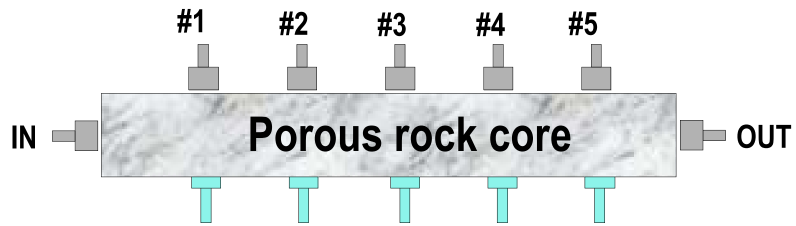
- Pores around #3 and #4 presure ports are plugged by hydrate regeneration due to abrupt pressure change.
- Since dissociation process is an endothermic, it causes a rapid dissociation with temperature decrease if the pressure difference between equilibrium and outlet is high. Also, it causes a reformation of hydrate by Jouls-Thompson effect with sudden gas expansion.

Dissociation by Depressurization (Run B)

Run B (2.07 MPa=300 psi)



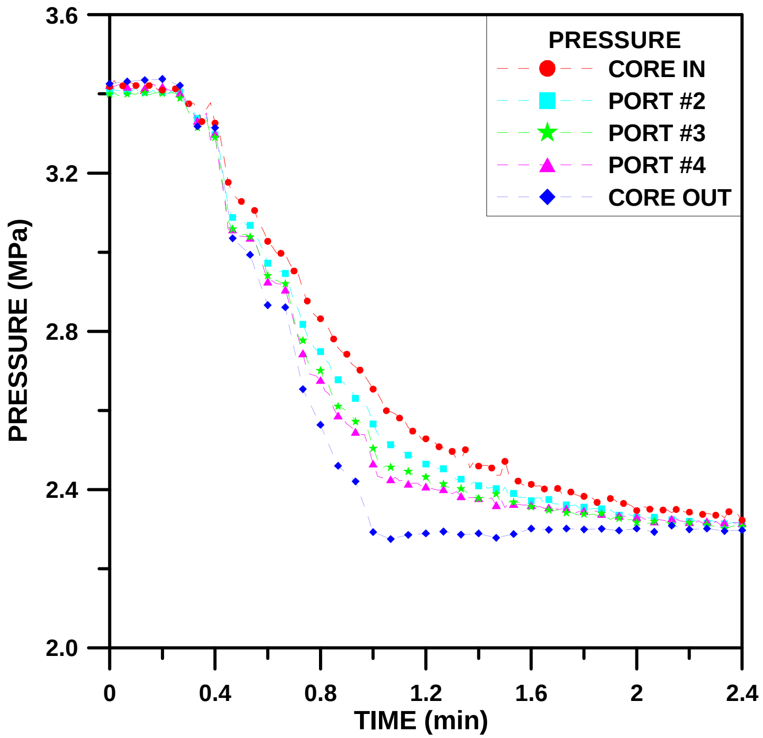
Pressure behavior with time during hydrate dissociation for Run B



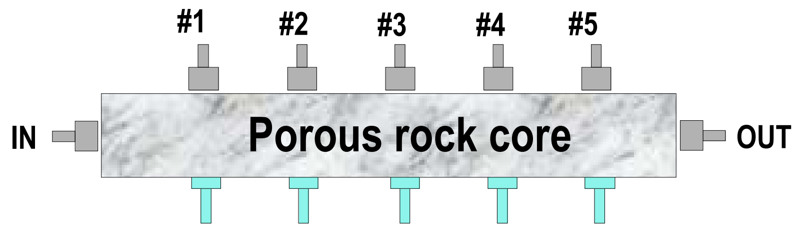
- Outlet pressure behaves like pulse type.
- With dissociation, the amount of dissociated water is greater than that of gas and hence relative permeability to gas decreases not to be flowing of gas.
- As dissociation continues, gas is mobile whenever gas saturation is over the critical limit.

Dissociation by Depressurization (Run C)

Run C (2.21 MPa=320 psi)



Pressure behavior with time during hydrate dissociation for Run C

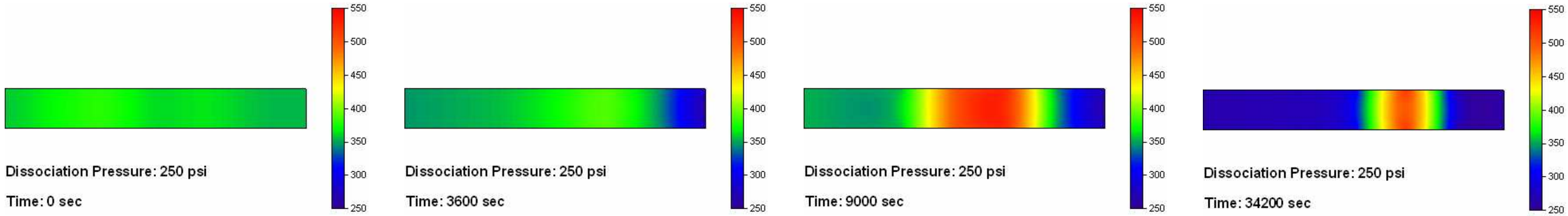


- All the pressures decline to set pressure without showing pluggings of pores or pulse type behavior.
- The time of depressurization when coinciding with all the pressure takes much shorter than those of Run B.

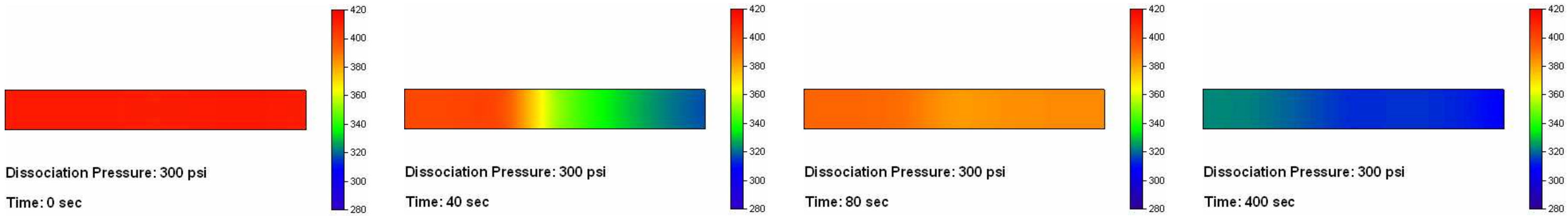
Pressure Distribution

Run A (1.72 MPa)

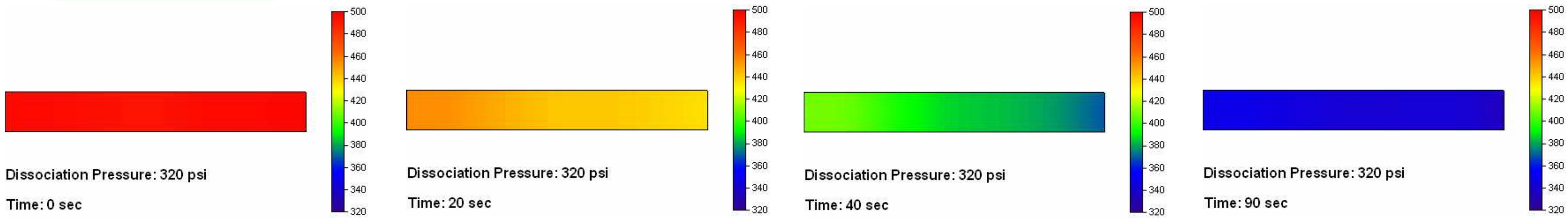
CORE IN CORE OUT



Run B (2.07 MPa)

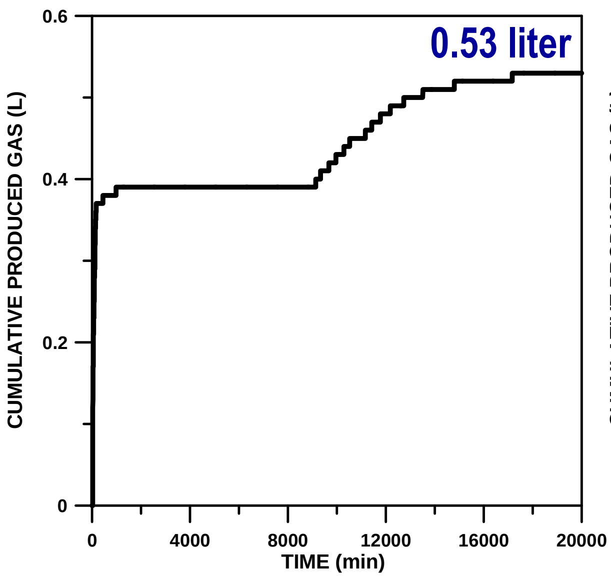


Run C (2.21 MPa)

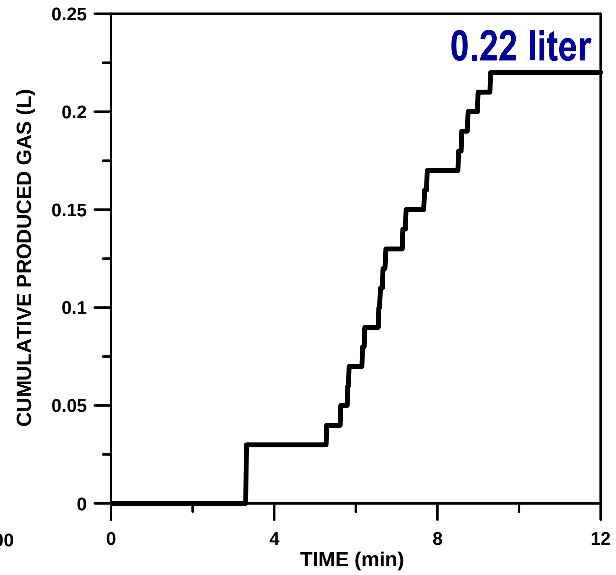


Cumulative Gas Production

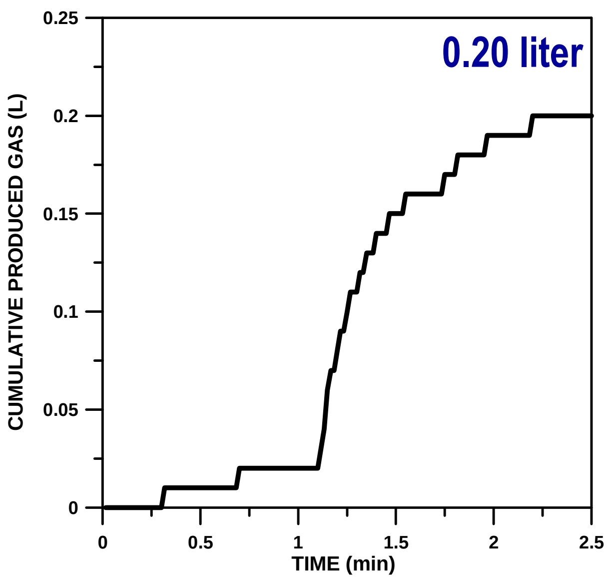
Run A (1.72 MPa=250 psi)



Run B (2.07 MPa=300 psi)

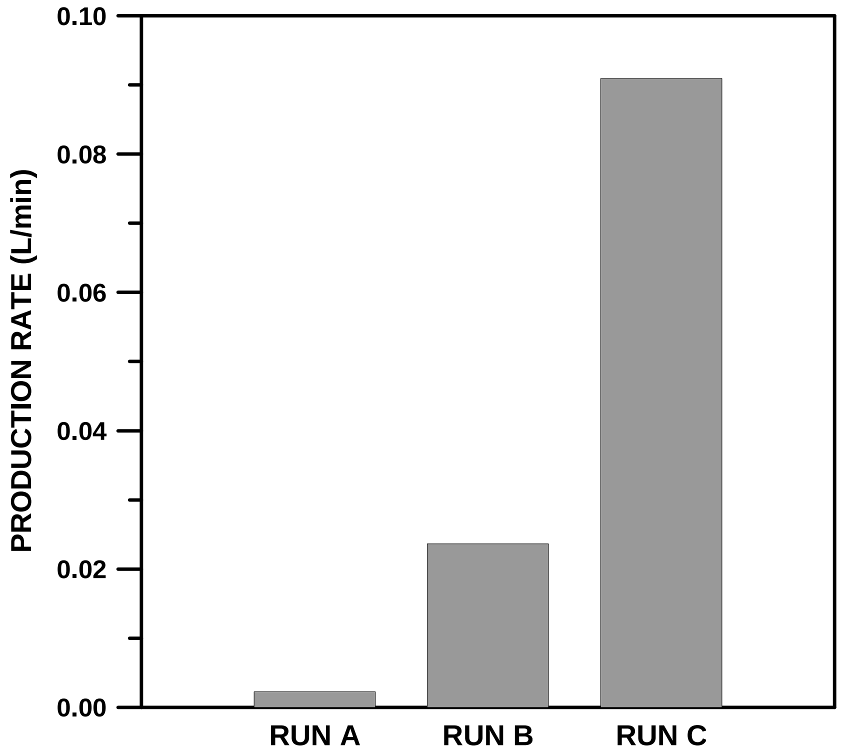


Run C (2.21 MPa=320 psi)



- Cumulative gas production is large but dissociation time is very longer than that of other cases.
- Gas dose not flow until 3.3 min because the pores are plugged by hydrate. As hydrate is dissociated, the dissociated gas are flowing due to increasing of the permeability.
- Gas production behavior is similar to Run B but dissociation time is four times shorter than Run B.

Comparison of Gas Production Rate



Comparative results of gas production rate for each case

- The gas production rate of Run C is much higher than others.
- As the outlet pressure is closer to equilibrium pressure, dissociation is faster and hence the productivity becomes higher.

Conclusions

1. In the formation process, when hydrate starts forming, the pressure falls rapidly and the temperature increases. Especially, exothermic temperature increases 0.2 K during hydrate formation.
2. Annealing process has been run to ascertain whether hydrate is formed all over the core. All the pressure including inlet is almost the same as outlet pressure in the processes of formation and dissociation of hydrate. That is, hydrate is formed all over the core before the dissociating step.
3. From the dissociating results with depressurization scheme, if the pressure difference between equilibrium and outlet is high, the pores are plugged by hydrate regeneration, and total productivity is decreased. So, the pressure difference between equilibrium and outlet should be kept low to preserve the isothermal condition by dissociating slowly.
4. The dissociating time takes shorter and the productivity becomes higher as the outlet pressure is closer to equilibrium pressure. From the results, it was experimentally verified that pressure decrease in depressurization scheme should be considered as significant factor affected on the gas production rate in a hydrate reservoir.

Thank You !

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