EGU General Assembly 2020

CHUNGBUK NATIONAL UNIVERSITY

Soaking effects on CH_4-CO_2 replacement efficiency in gas hydrates

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2020.05.06

2020-2581

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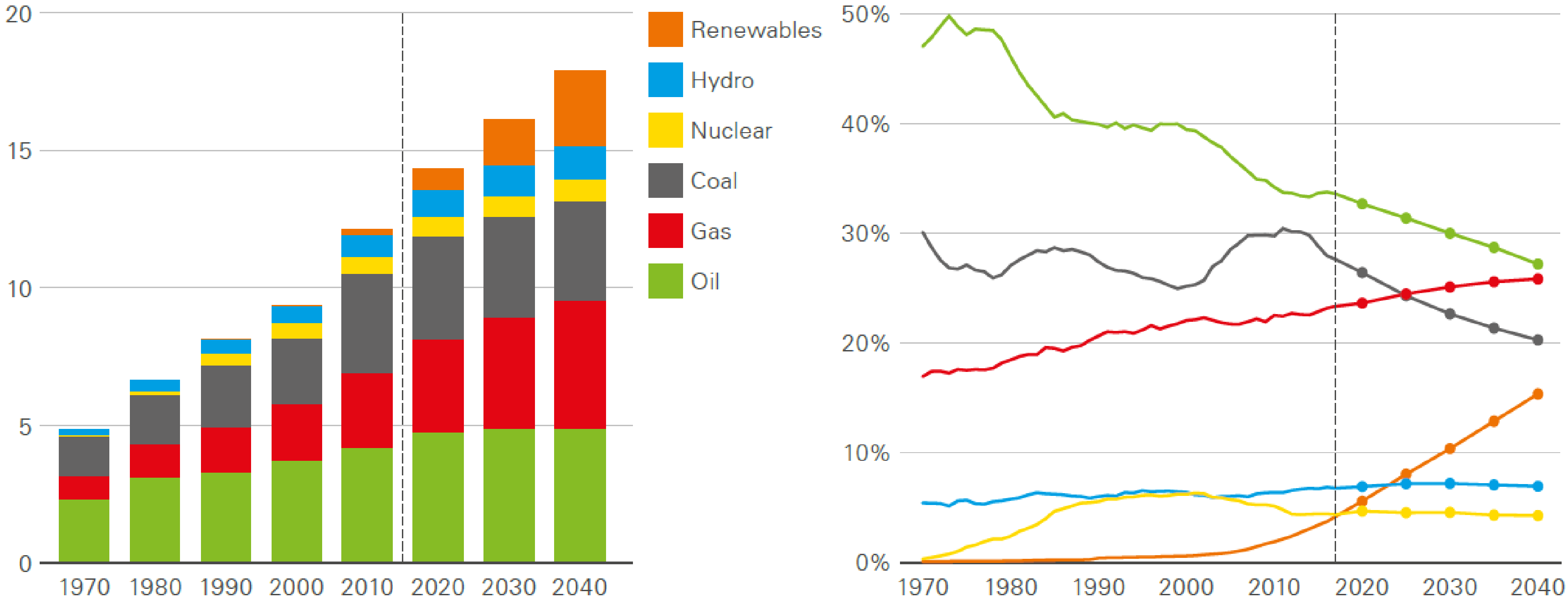
Ⅰ. Introduction

Energy consumption

In 1970, the consumption of coal reached 30% and the consumption of oil reached 50%, but over time, the consumption of oil and coal is decreasing due to environmental problems and energy exhaustion. It is also predicted that the consumption of oil and coal will decrease further in the future. Therefore, it is necessary to pay attention to next-generation energy sources such as renewable energy and gas energy.



Unit: 1 trillion TOE

Energy consumption worldwide

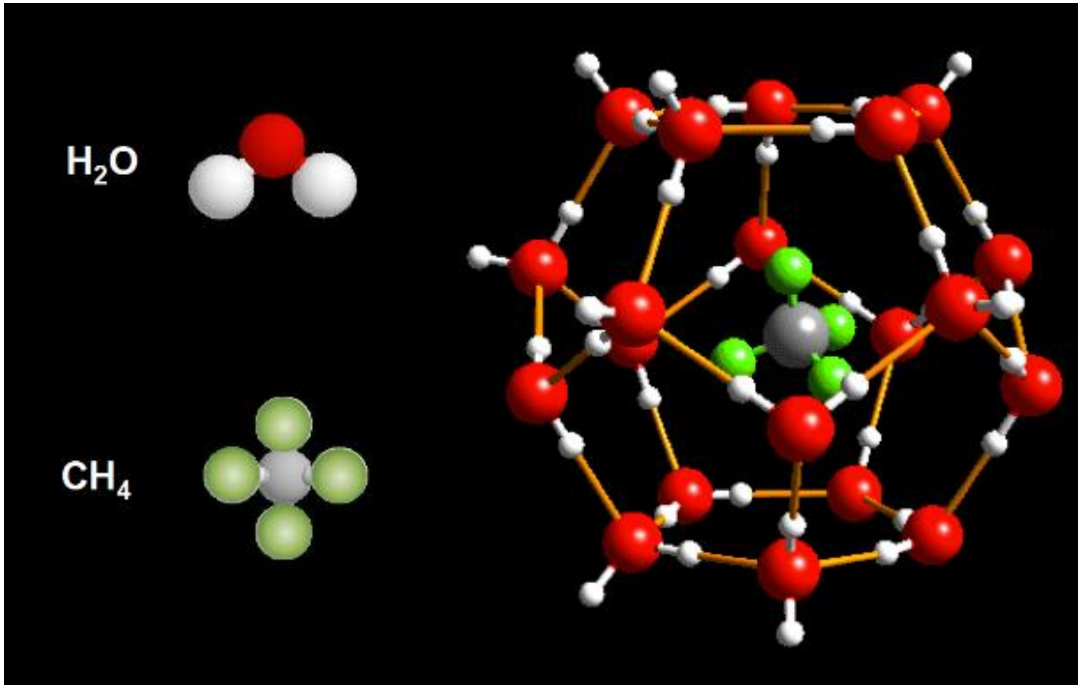
(BP Energy outlook, 2019)

Ⅰ. Introduction

Gas hydrates

Gas hydrates are solid energy resources in deep sea and permafrost, called “Fire ice." Gas hydrates have different properties depending on the type of molecule trapped in the lattice.

Fire ice



Structure of gas hydrate

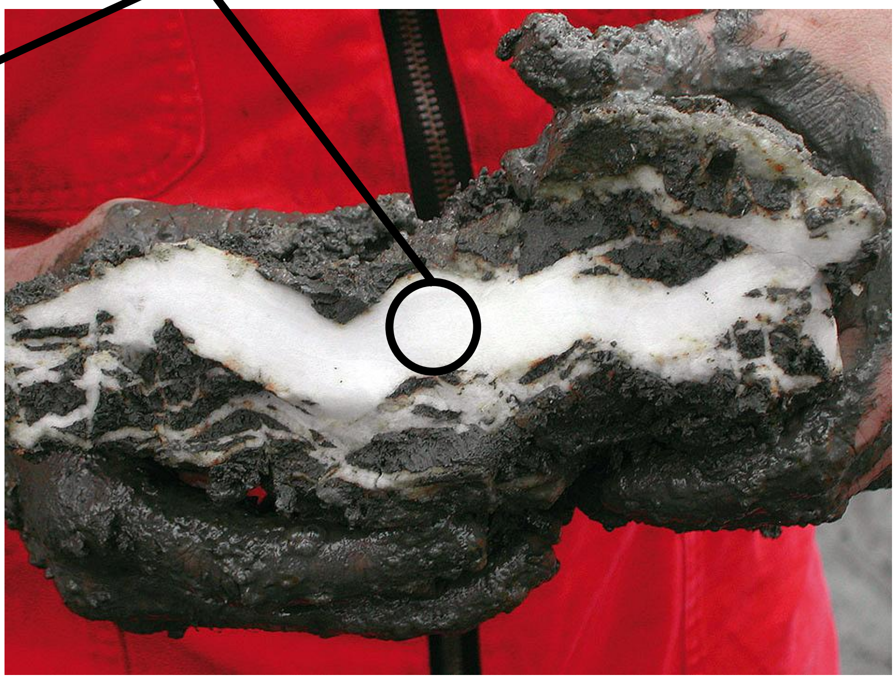
(Jones, 2017; UIB, 2010)

Ⅰ. Introduction

Hydrate-bearing sediments

Gas hydrates present in the permafrost and deep sea sediments. Therefore, it was called hydrate-bearing sediments. The actual gas hydrates are shown in the photo below.

Hydrate bearing sediments



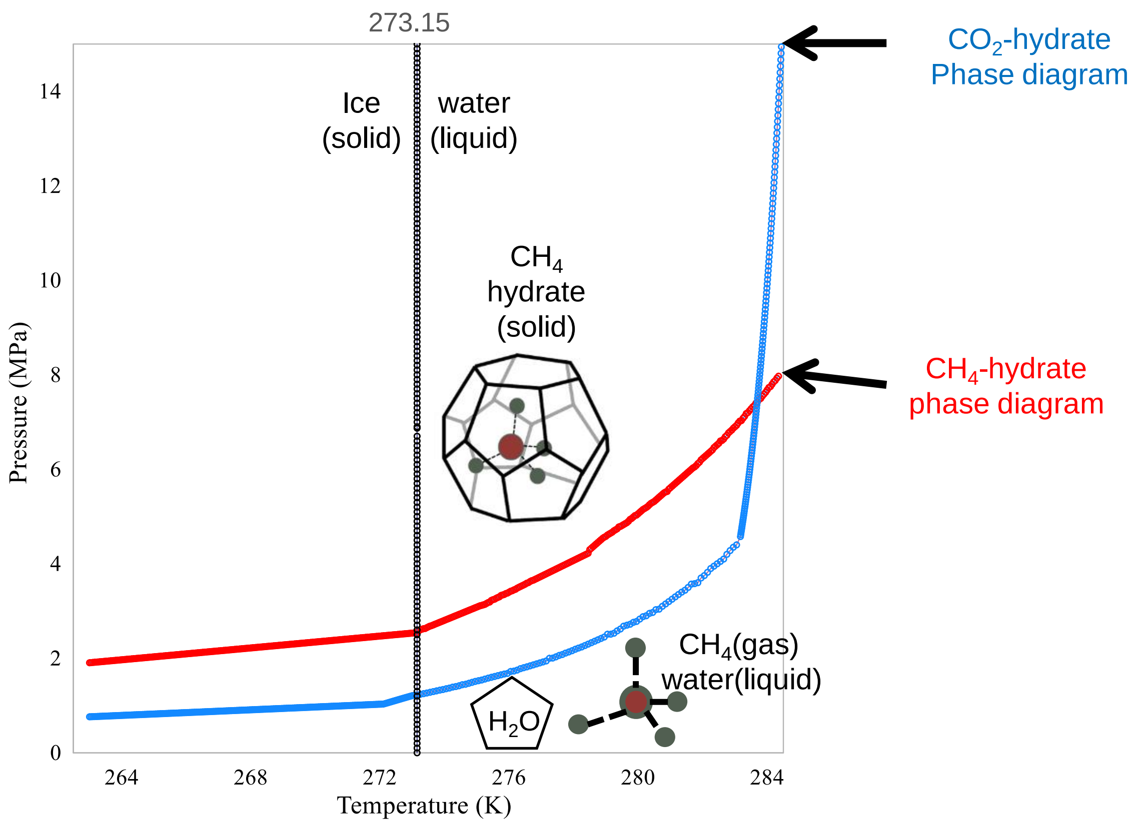
Gas hydrates collected on site

("Gas Hydrates in Marine Sediments off the Oregon Coast“, 2002)

Ⅰ. Introduction

Phase diagram of gas hydrate

Gas hydrates are phase change material such as water and the phase diagram is as follows. The blue marker below means the phase equilibrium of CO_2-hydrate, and the red marker means the phase equilibrium of CH_4-hydrate. In phase equilibrium, the hydrate retains the solid phase in the upper region and the hydrate dissociates into the liquid and gas phases in the lower region. Therefore, the gas extraction technique is divided into a dissociating method and non dissociating.

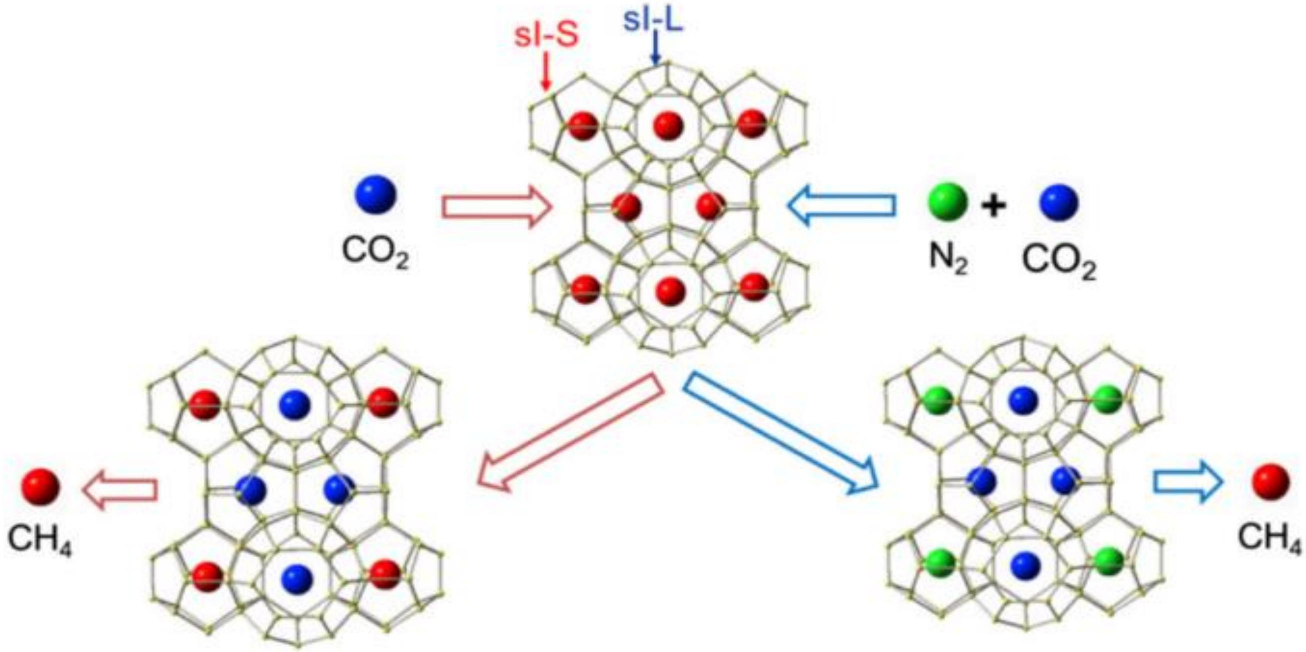


(Perry, 1984; Seo, 2001; Sloan, 2007)

Ⅰ. Introduction

CH_4-CO_2 Replacement

The replacement method is non-dissociating method of extracting CH_4(gas) in the cage by replacing the cage occupied by CH_4 gas in the hydrate with another injected gas. CO_2 is generally used as the gas to be injected. It is a one-pounding method that can extract CH_4 gas at the same time as sequestering carbon dioxide existing in the atmosphere when CO_2 is used. Also, the non-dissociating technique promotes the stability of the ground rather than the dissociation technique such as depressurization, thermal injection technique.

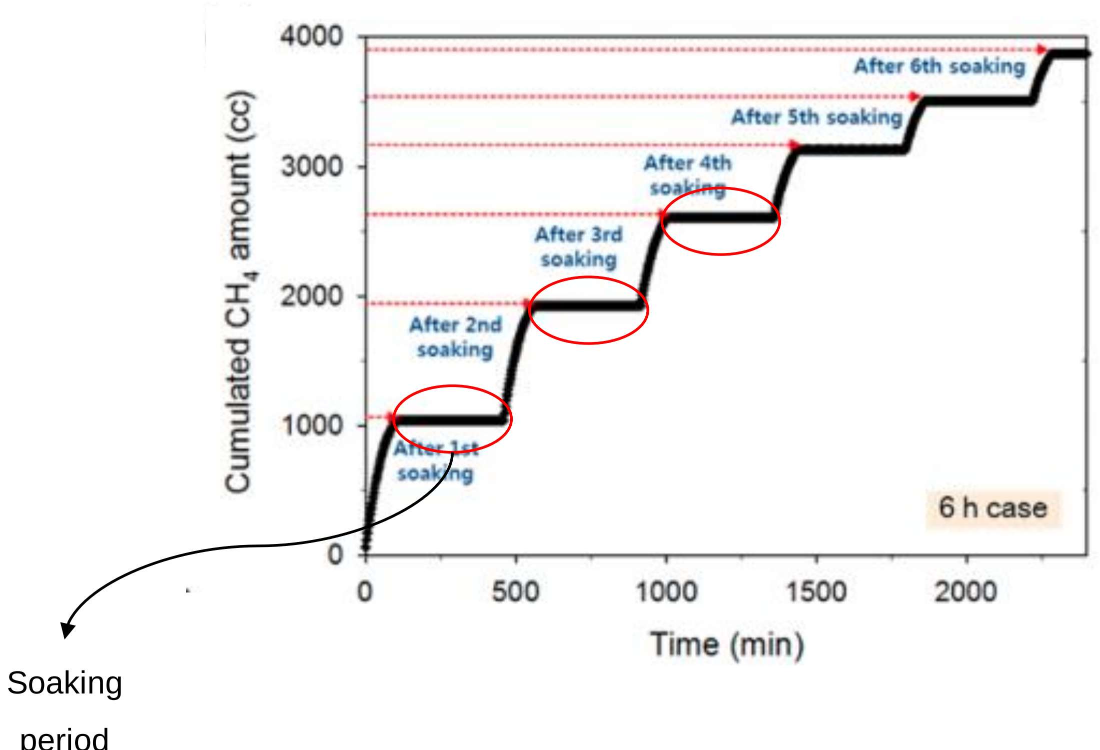


("Production of gas from methane hydrate", 2010)

Ⅰ. Introduction

Soaking process

Soaking means that when carbon dioxide is injected into CH_4-hyd, CH_4(gas) is extracted and then no longer extracted. At this time, the cell is locked to increase the reaction time of CH_4-CO_2. It was discovered by Seo(2015) and it has been reported that the replacement efficiency increases when a soaking process is introduced. As a further study, this study researched changes in replacement efficiency due to soaking time and changes in replacement efficiency by permeability.

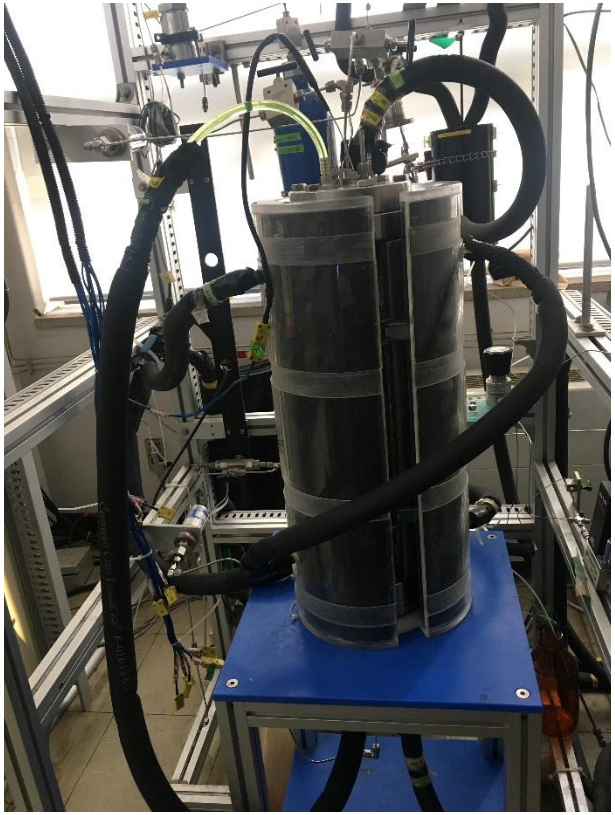


(Seo et al., 2015;"Production of gas from methane hydrate", 2010)

Ⅱ. Experimental section

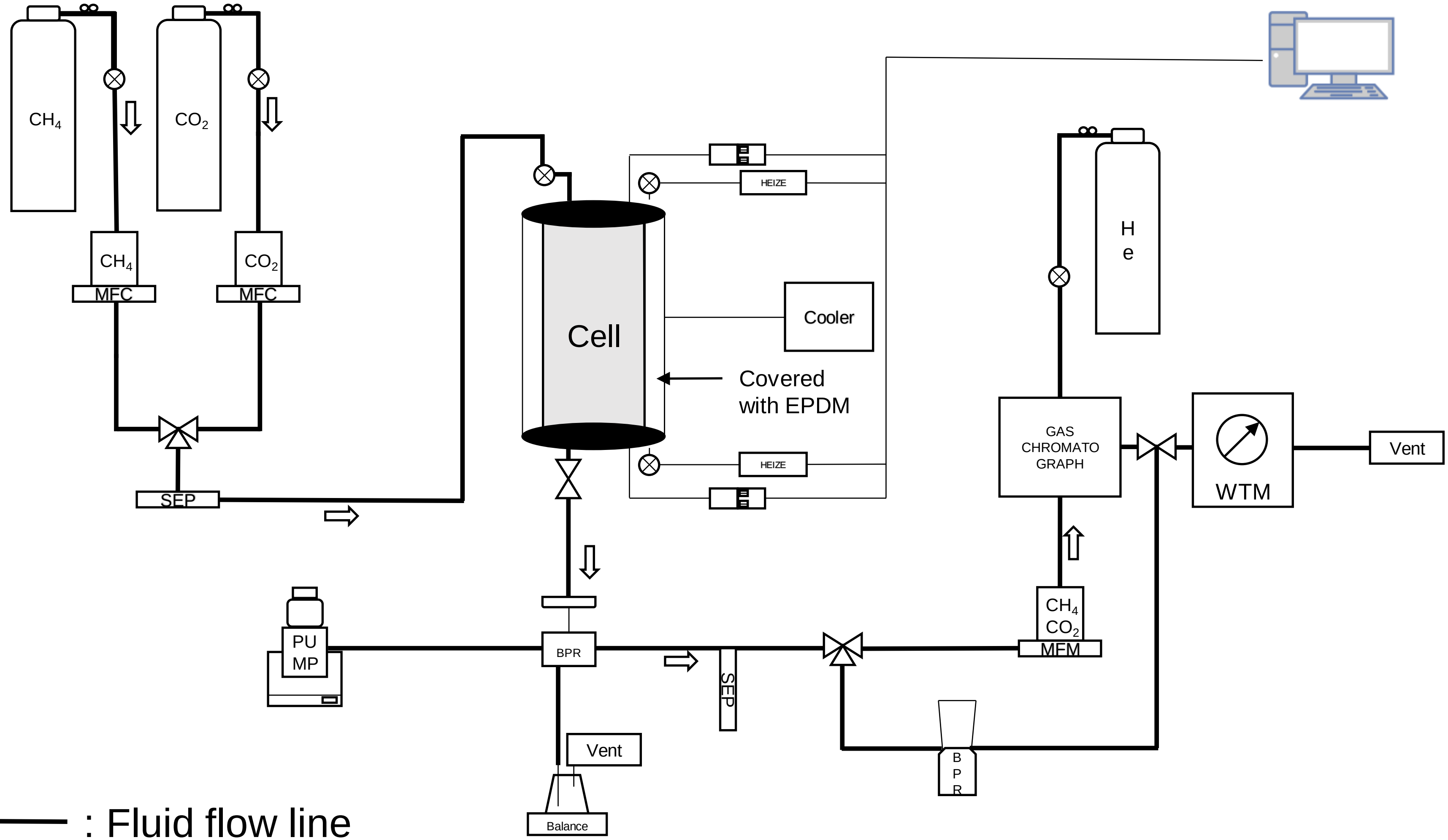
Experimental apparatus

The equipment used for the CH_4-CO_2 replacement experiment was as follows, and the experiment was conducted at Korea Institute of Geoscience and Mineral Resources.



Ⅱ. Experimental section

Schematic diagram of experimental apparatus

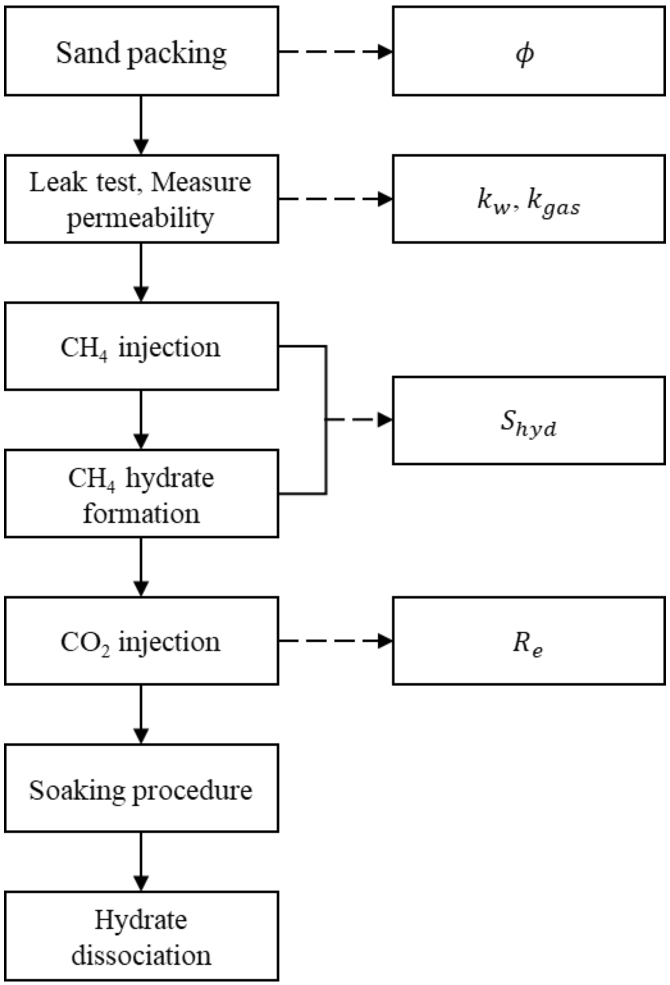


: Fluid flow line

: Thermostat line, pressure line

Ⅱ. Experimental section

Experimental procedure



1. Sand packing

: The cell was filled with sand through vibration compaction, and the porosity was calculated.

2. Measure permeability

: The flow of water and gas was generated to calculate absolute water permeability and absolute gas permeability.

3. CH_4 hydrate formation

: After injecting methane gas into the saturated cell, the temperature was lowered to form CH_4-hydrate, and the hydrate saturation was calculated.

4. CH_4-CO_2 replacement

: The CH_4-hydrate was replaced by injecting CO_2 into the formed CH_4-hydrate, and the soaking time was given by locking the cell when no methane gas was discharged.

5. Hydrate dissociation

: When the methane gas was finally discharged, the hydrate was dissociated to terminate the experiment.

Ⅱ. Experimental section

Experimental condition

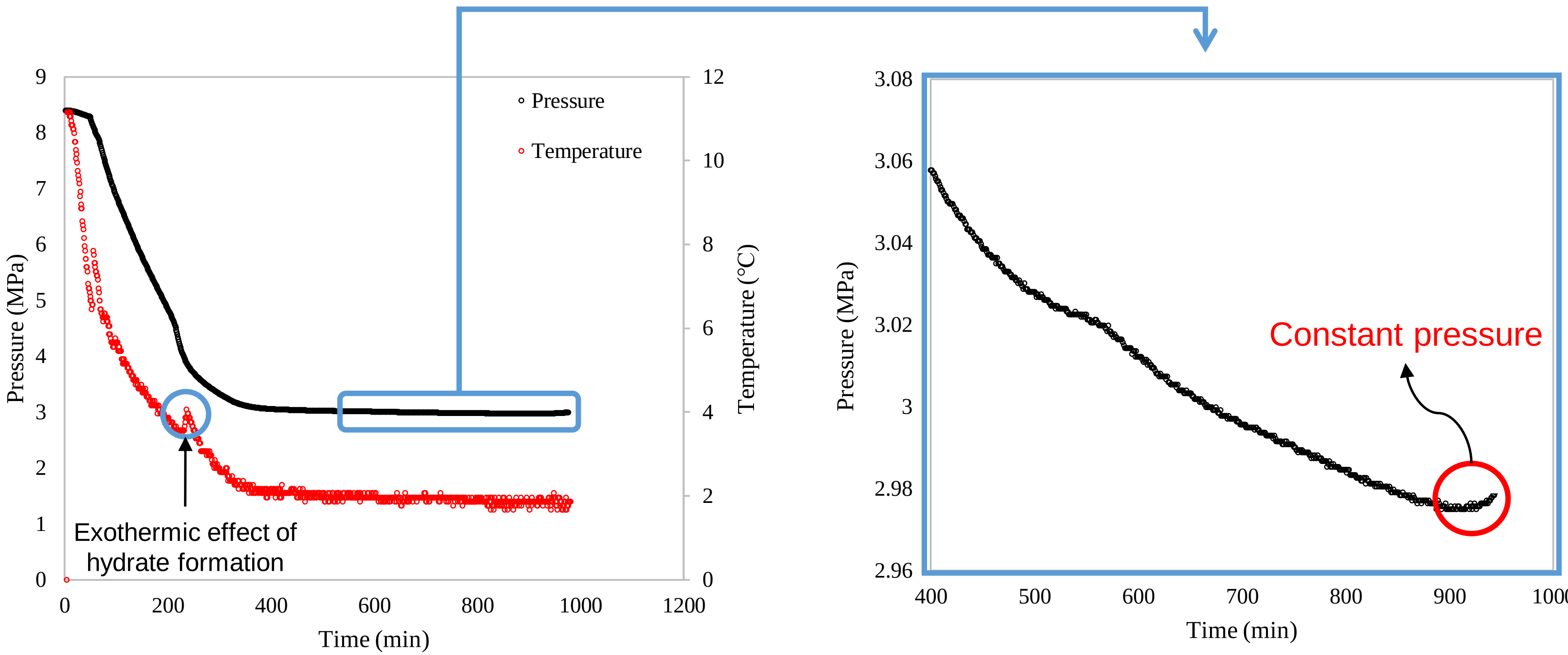
The operating pressure of the experiment was maintained at 4.01 MPa, and the temperature was 275.15K. In addition, the injection flow rate of CH_4 (gas) is 800cm^3/min, and CO_2 (gas) is 200cm^3/min. Based on the five experimental conditions, test 1, 2 and 3 examined changes in the replacement efficiency due to soaking time, and test 4 and 5 examined the change in replacement efficiency according to permeability.

Set	Sample	Grain size (㎛)	Porosity (%)	Residual water sat (%)	S_{hyd} (%)	Soaking time (h)
1	Hama #6 (sand)	485	42.7	27.22	23.69	2
2				28.43	24.77	6
3				27.79	24.26	12
4				37.24	33.13	6
5	Hama #8 (sand)	106	42.09	38.42	32.81	6

Ⅲ. Results and Discussion

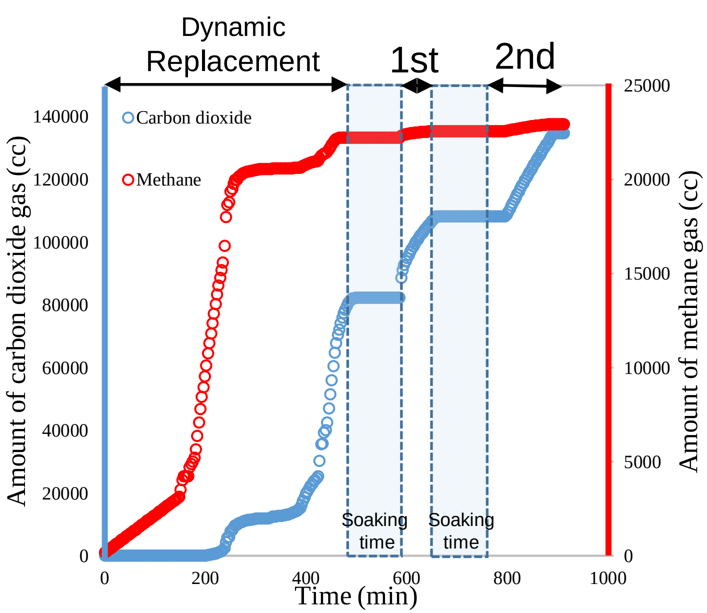
Hydrate formation

After the injection of methane gas, the temperature of the cell was lowered from 8.5MPa to 3.2MPa by lowering the temperature, and it was indicated that CH_4-hydrate was formed due to the exothermic reaction.

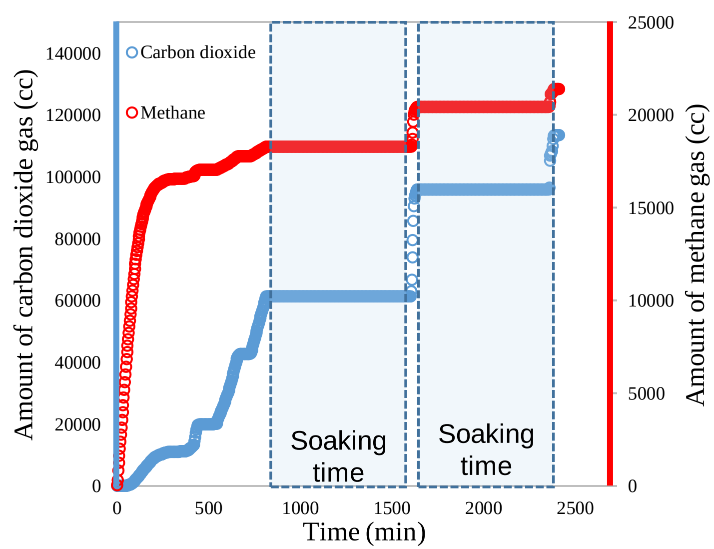


Soaking effect

The following figure shows the amount of methane gas and carbon dioxide gas discharged over time, and the soaking time is 2 hours and 12 hours. When the soaking time was 2 hours, the amount of methane gas that could be additionally recovered even by introducing the soaking process was about 2000 cc, but when the soaking time was 12 hours, additional 15,000 cc of methane could be recovered by the soaking process. In addition, the more the soaking time was introduced, the more the replacement ratio was decreased.



soaking time = 2h

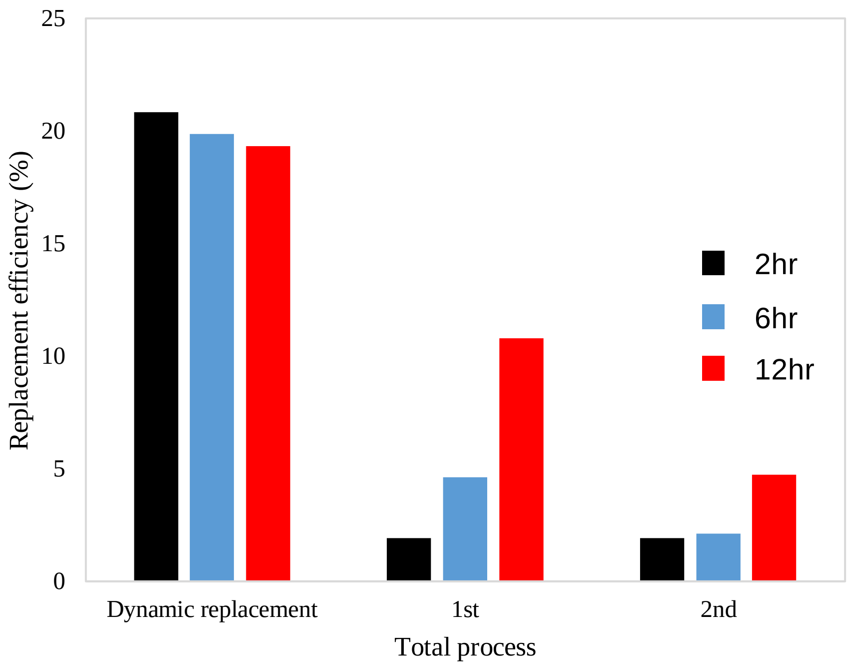


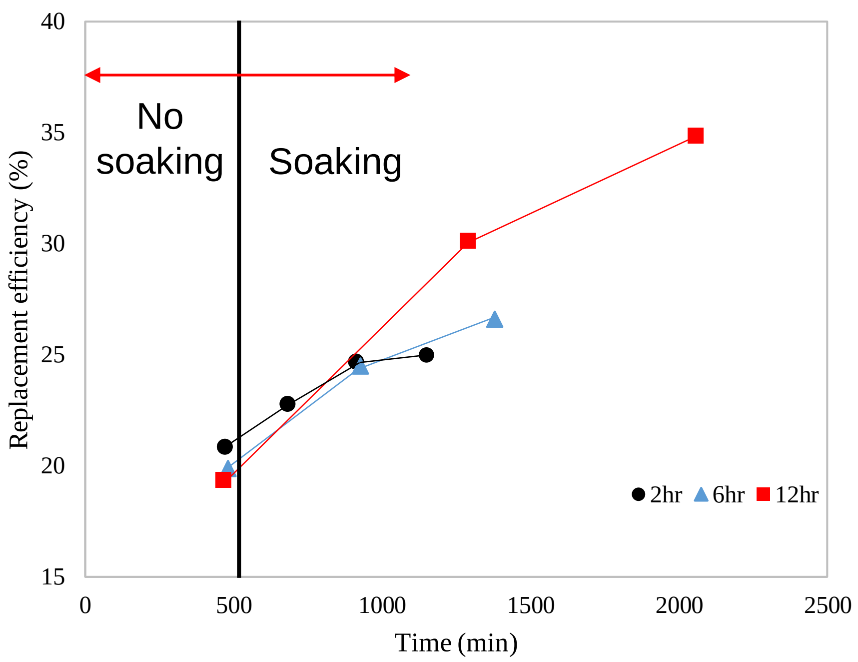
soaking time = 12h

Ⅲ. Results and Discussion

Soaking effect

The following shows the results for the periodic replacement efficiency, and the soaking time is 2 hours, 6 hours and 12 hours. In all three cases, the replacement efficiency in the dynamic replacement was the highest, and as the soaking time increased, the replacement efficiency increased by the soaking process increased. Also, When the soaking time was 12 hours, replacement efficiency increased about 16% before introduce of soaking process.

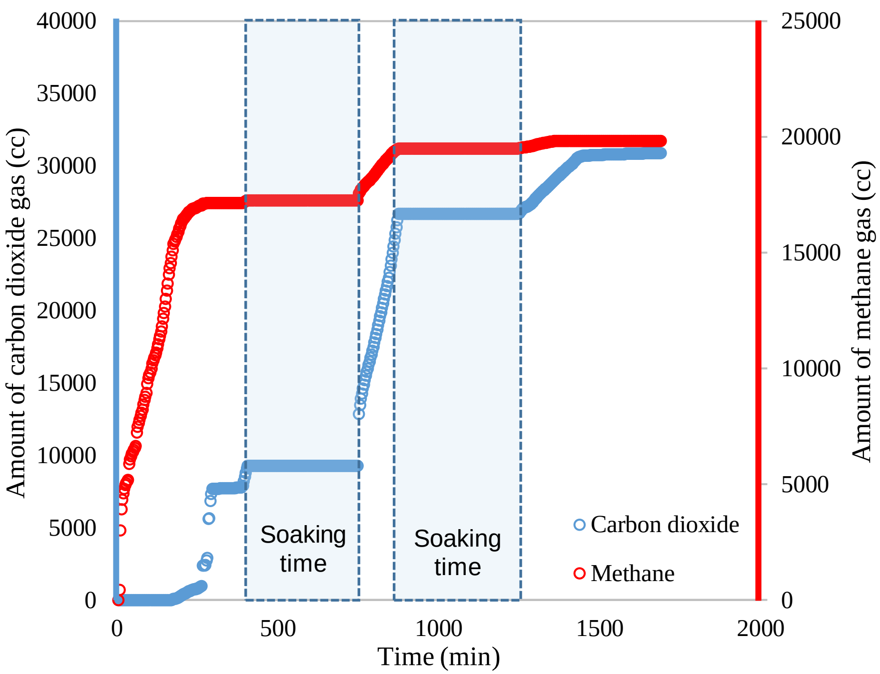




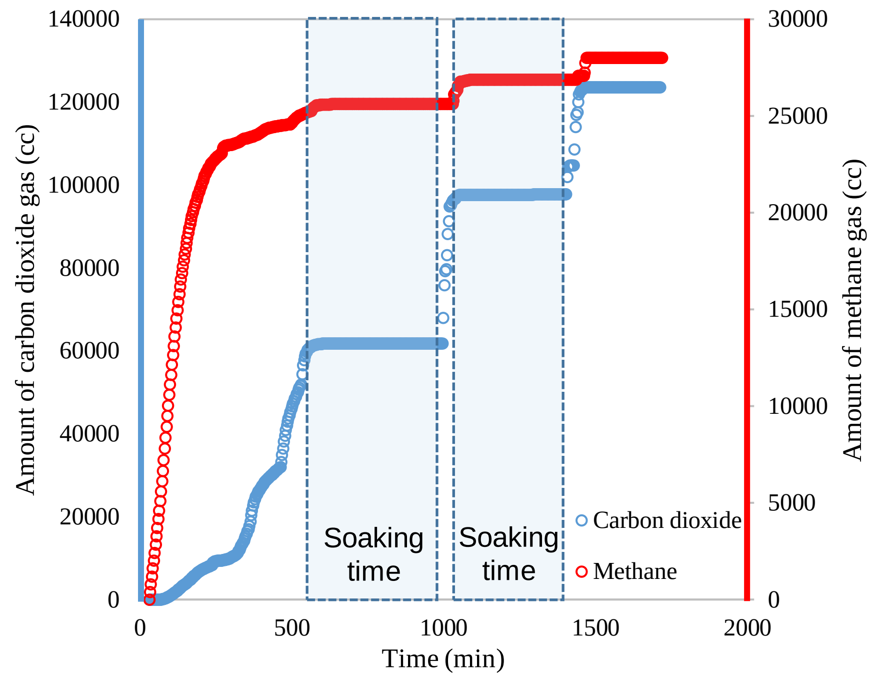
Ⅲ. Results and Discussion

Absolute gas permeability effect

The following figure shows the amount of methane gas and carbon dioxide gas discharged over time, different permeability. Under the same conditions, when the perm was low, about 5000cc of additional methane gas was recovered due to the one-cycle soaking process, but when the perm was high, 3500cc was recovered.



Abs gas perm: 386.5(mD)

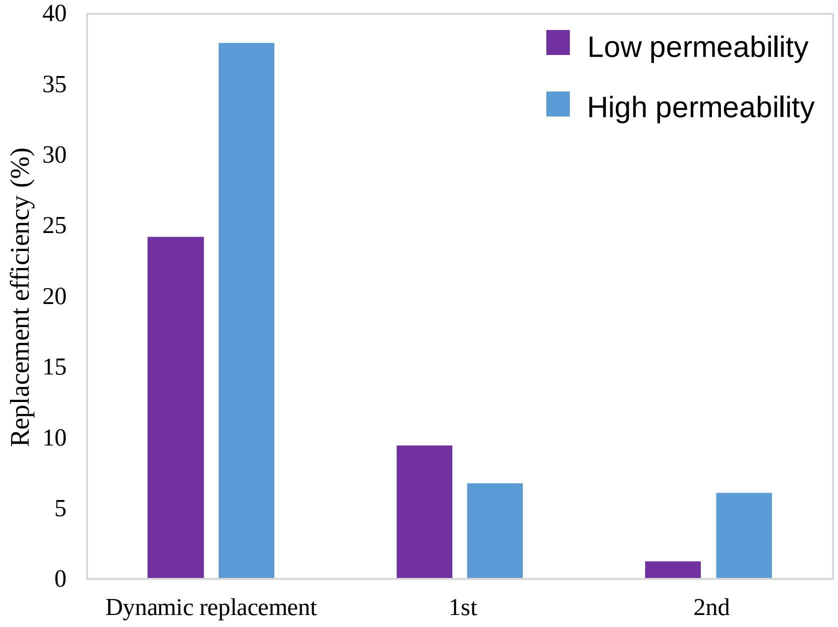


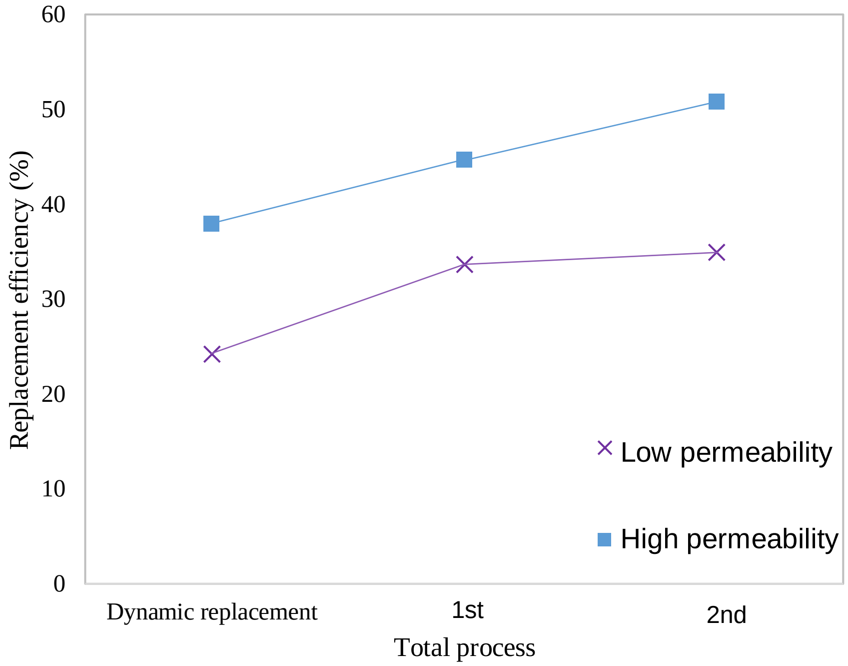
Abs gas perm : 16352(mD)

Ⅲ. Results and Discussion

Absolute gas permeability effect

The following shows the results for the periodic replacement efficiency and the perm is low and high. In both cases, the substitution rate in the dynamic replacement was the highest, and the effect of the soaking process was higher when the perm was lower than when the perm was high.





IV. Conclusions

The replacement efficiency according to the change in soaking time and the change in the initial gas permeability was studied. The conclusion is as follows.

- When soaking time was given for 2, 6, and 12 hours, the substitution rate increased by 5, 7, and 17%, respectively. Therefore, The effect of soaking time increased with replacement efficiency.
- The lower the gas permeability, the smaller the soaking effect, and the higher the soaking effect.
- It is considered that the replacement efficiency can be increased if the actual gas hydrate collection site is selected and the permeability of the initial filed is considered, and the soaking time is given in consideration of economic efficiency and gas hydrate production.

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Acknowledgement

- This work is supported by the Korea Agency for Infrastructure Technology Advancement(KAIA) grant funded by the Ministry of Land, Infrastructure and Transport (Grant 20CTAP-C152100-02).
- Also, it is supported by partial funding from NPRP grant # NPRP8-594-2-244 from the Qatar national research fund (a member of Qatar Foundation) and the Ministry of Trade, Industry.
- Energy (MOTIE) through the Project “Gas Hydrate Exploration and Production Study (20-1143)” under the management of the Gas Hydrate Research and Development Organization (GHDO) of Korea and the Korea Institute of Geoscience and Mineral Resources (KIGAM).

Thank you !!