Hydrogen Transport Behavior in Coal: Implication for Hydrogen Geo-storage

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INTRODUCTION
Industrial decarbonization is an imperative undertaking in the fight against climate change, and clean hydrogen and carbon dioxide capture, utilization, and storage (CCUS) technologies present transformative solutions to achieve this goal. In November 2021, the United States took a historic stride towards a more sustainable future by passing the Infrastructure Investment and Jobs Act. A monumental piece of legislation, this act authorizes a substantial $62 billion investment in the U.S. Department of Energy (DOE), with a remarkable $9.5 billion dedicated to the advancement of clean hydrogen technologies. Emphasis is placed on promoting the deployment of cutting-edge clean hydrogen technologies and driving decarbonization across high-priority sectors with limited alternatives by using CCUS technologies. Nevertheless, hydrogen is difficult to store due to the high diffusivity, the high cost, and the low storage efficacy. In the pursuit of sustainable energy solutions, coal has emerged as a compelling candidate for clean hydrogen storage and utilization. The permeability of hydrogen in coal is a crucial aspect that warrants in-depth exploration, as it holds the promise of unlocking vast potential for clean energy storage and utilization.

OBJECTIVES
- Apparatus design and build up for hydrogen permeability measurement
- Measurement of hydrogen permeability in coal under replicated in situ conditions
- Comparisons between helium (non-sorbing gas) permeability and hydrogen permeability
- Evaluate the potential of hydrogen storage in coal from transport perspective

MATERIALS AND METHODS
Apparatus design and sample preparations

Calculation method

Steady-State Flow Method

\[ Q = - \frac{kA(P_b - P_a)}{\mu L} \]

- \( Q \) - total discharge in \( m^3/s \)
- \( k \) - soil coefficient of permeability in \( m^2 \)
- \( P_b \) - upstream pressure in Pa
- \( P_a \) - downstream pressure in Pa
- \( \mu \) - viscosity in Pa*s
- \( L \) - Length in m

Experimental procedure
The experimental procedure entailed simultaneous injection of two phases into the test core at constant rates and pressures. To ensure accuracy, the coal sample was carefully sealed and loaded into the test cell. Vertical stress of 3000 psi and horizontal stress of 2000 psi were applied to hold the sample at reservoir conditions, simulating real-world geological scenarios.

To achieve steady state, close monitoring of the pressure drop across the core was performed until it stabilized. Upon reaching steady state, precise measurements of the outlet flow rate of each phase and the pressure drop were conducted. Subsequently, these measured values were utilized in Darcy’s Law to calculate the effective permeability of the fluid at the given pressure level.

RESULTS AND DISCUSSION

- The permeability of hydrogen increases exponentially with pressure. When the pressure reaches 935 psi, the permeability is 2.8789 \( \mu \)D.
- Helium, being a non-absorptive gas, exhibits no expansion of coal as it traverses through it. Due to the similar permeability of hydrogen and helium, hydrogen is also less inclined to adsorb onto coal seams.
- In future research, it would be beneficial to explore the inclusion of mixed gases or water in permeability tests for a better simulation of the real-world geological environments. This experiment serves as a valuable reference and lays the groundwork for further investigations in this direction. The incorporation of additional variables may provide deeper insights into hydrogen permeability in coal and its potential implications for clean energy storage and utilization in practical applications.

References

ACKNOWLEDGEMENTS
With Special guidance From
- Dr. Shimin Liu
- Dr. Ang Liu
- Kunming Zhang

Leone Family
Department of Energy and Mineral Engineering
Penn State College of Earth and Mineral Sciences