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Research Paper

# Pressure retaining method based on phase change for coring of gas hydrate-bearing sediments in offshore drilling

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## HIGHLIGHTS

- Pressure corer based on phase-changing of situ drilling fluid has been proposed.
- Ice valve made from seawater mixed with 7% bentonite can sustain pressure up to 47 MPa.
- Long length and lower freezing temperature can improve ice valve pressure sustaining.

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## ABSTRACT

Coring of gas hydrate-bearing sediment with situ-pressure retained is significant for both geophysics and geochemistry. However, the core recovery of current pressure corers is relatively low, which is attributed to the sensitivity of mechanical valves to solid particles and drilling cuttings. To improve the core recovery of the pressure corers, the pressure retaining method based on the phase change of situ drilling fluid has been used to seal the core tube mouth. The pressure retaining capacity of the ice valves made from seawater mixed with different mass concentrations of bentonite was tested; the influence of the ice valve length and freezing temperature on the pressure retaining capacity was also studied. Results show that the ice valve made from pure seawater could not retain pressure for the fissures caused by stress because of the temperature difference and the incompletely freezing of the ice valve caused by the concentrated inorganic salts in the core of the ice valve. The ice valve made from seawater mixed with 7% mass concentration of bentonite can sustain pressures of up to 47 MPa. Both high ice valve length and low freezing temperature are beneficial for improving the pressure sustaining capacity of the ice valve. Results indicate that using the ice valve made from seawater mixed with bentonite to instead mechanical valves in the pressure corer can be a potential solution to improve the recovery of pressurized hydrate-bearing sediment core.



## 1. Introduction

Natural gas hydrate has been widely studied for its potential as energy resource as well as its important role in landslip and global warming [1]. Sufficient natural gas hydrate-bearing sediment cores in in-situ conditions are necessary for assessing the nature, distribution, and concentration of hydrate-bearing sediment [2]. However, gas hydrate dispersed in sediment will dissociate rapidly when retrieved without pressure; the physical and chemical properties of the hydrate-bearing sediment cores are then changed [3–5]. Cores retrieved and analyzed at full in-situ pressures are considered the "gold standard" for natural gas hydrate detection [6]. Furthermore, the data obtained by full in-situ pressure cores can be used to interpret and calibrate geophysical data; and pressure-coring systems for sampling gas hydrate-bearing sediments have been deployed in natural gas hydrate survey [7–11].

Several pressure corers have been developed and successfully deployed; these include the Pressure Coring Barrel developed by the Deep Sea Drilling Project, the Pressure Coring Sampler developed by the Ocean Drilling Program, and the Fugro Pressure Corer and the HYACE Rotary Corer developed by the European Union [12–15]. All such corers can be classified as two types: those based on ball valve mechanisms those based on flapper valves. Both types seal the pressure chambers by using mechanical valves. Japan and China also followed the DSDP and ODP; they developed pressure corers based on a ball valve mechanism. Recently, Japan has successfully retrieved pressure cores with the Hybrid-PCS, which is a

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system that is improved from the Pressure Temperature Coring System (PTCS) and the Non-cooled PTCS [16,17]. Although gas hydrates were found and successfully sampled in the marine and permafrost formations in China, no pressure cores that contain hydrate were retrieved by the pressure corer developed by the institutes in China [18].

Significant scientific achievements have been attained with the help of the developed pressure corers. However, the average core recovery for these pressure corers is less than 60% [19–24]. Such a percentage is relatively low and incongruent for the operation cost of natural gas hydrate survey. Sealing failure, which is caused by the erosion of both valves and seal ring, is the main reason for the failure of pressure coring. In addition, the drilling cutting blocking played an important role in these failures [19]. Although mechanical valves have been widely used in fluid power systems, solid particles mixed in the fluid represent the greatest threat to mechanical valves because of free movement, which can abrade both mating surfaces by a three-body abrasive wear mechanism. Furthermore, solid particles can become partially imbedded in one of the surfaces and act as a cutting tool that results in two-body abrasion of the other mating surface [25]. Therefore, a filtration system is an essential apparatus in fluid power system, and only the ball valve or flapper valve can guarantee a seal and reliable function in a system with solid particles. These valves can effectively keep the particles below an acceptable level. However, the ball valve or flapper valve built in a pressure corer works in the harsh environment of the drilled borehole, in which the drilling fluid is always laden with drilling cuttings and other added solid particles; these particles increase the possibility of leakage when mechanical valve based pressure corer are used, thereby causing lower core recovery. Therefore, finding an alternative solution that can avoid the problems encountered by a mechanical valve could be beneficial to significantly improve the performance of the next generation of pressure corers.

Popularly known as the pipe freezing technique, ice valves have been extensively studied and widely applied in the industry. A pipe with a maximum diameter of 813 mm has been frozen [26], and pressures of 132 MPa have been recorded in the vicinity [27]. Therefore, sealing the core tube by using the ice valve made from the drilling fluid has been proposed, and its pressure sustaining capacity has been validated.

Different from mechanical valves, the ice valve is formed from the phase changing of drilling fluid and can function as the mechanical valve when a section of ice is formed from the fluid in the tube, thereby sealing the tube mouth to keep in-situ pressure in the tube. Their advantages are as follows. First, no moving parts are needed. Therefore, abrasion or jamming cannot occur, thereby improving valve robustness. Second, high quality working surfaces are not need because ice can form and adhere to the rough surfaces. Third, no seals made of highly molecular materials are needed. These three advantages can be used to overcome the shortcomings of mechanical valves that operate under harsh borehole conditions.

Previous studies have shown that the ice-valve formed from the drilling fluid used in the Scientific Drilling Project of Gas Hydrate in the Qilian Mountains can sustain a pressure greater that is than

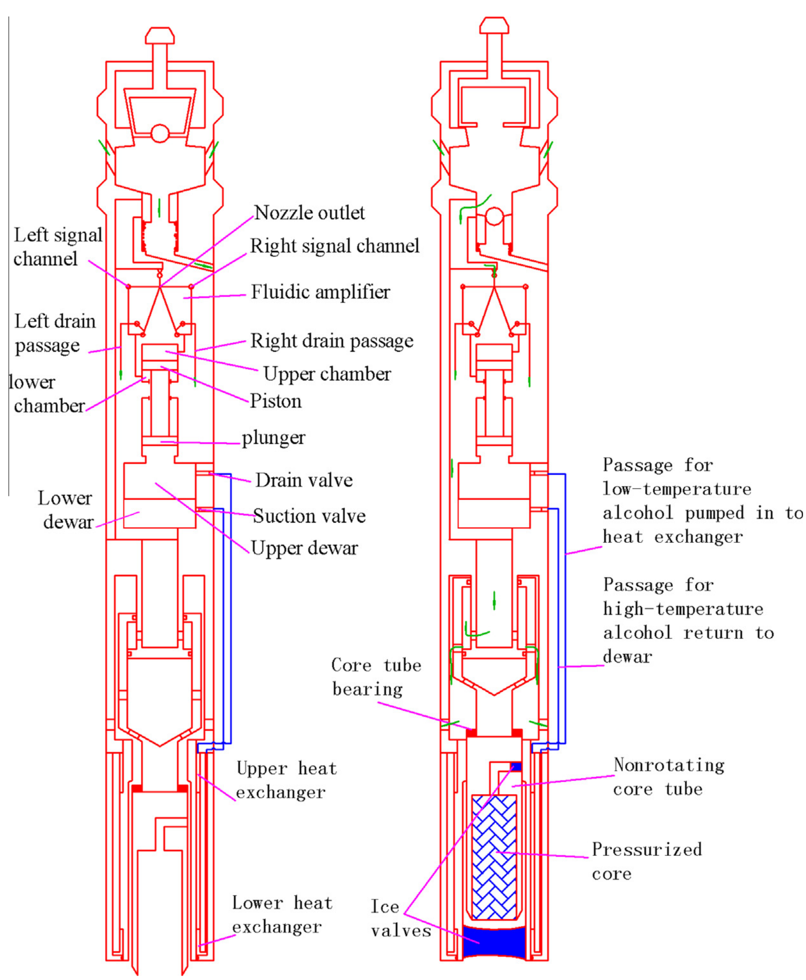


**Fig. 1.** Schematic of the wire line ice valve based pressure corer.