Directional Drilling Technology for HLW Disposal - Long Term Monitoring in the Borehole – 16079

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ABSTRACT

Central Research Institute of Electric Power Industry (CRIEPI) has been conducting a project for the directional drilling and measurement/logging technologies to survey hydro-geological condition at the stage of the preliminary investigation (PI) of site selection for the deep geological disposal of HLW. 1000m length borehole which intersects the Omagari fault was drilled by directional drilling technology in order to verify the drilling technology in Hokkaido. Long term monitoring to clarify pore water pressure and water chemistry in the drilled borehole was also developed.

We set measurement intervals on a hanging wall side of a main fracture and started the measurement of pore water pressure in February 2014.

We assume that long term monitoring for several boreholes will be achieved in vast areas where power supply and/or communication networks are not available at the PI stage. Thus, we have been developing an automatic data acquisition system for long term monitoring, which enables us to access data remotely. The monitoring system, which was set in Horonobe-town in Hokkaido, is an automatic data acquisition system that performs long term monitoring of pore water pressure.

This paper provides an overview of the development of monitoring technologies of pore water pressure measurement in the borehole as well as the automatic data acquisition system.

INTRODUCTION

In Japan, there are three stages of site-selection for the deep geological disposal of HLW. Literature surveys, followed by preliminary investigations (PIs) and finally, detailed investigations (DIs) are carried out in successive selection stages. Underground survey facilities are constructed in the final selection stage. Geological, environmental and radiological conditions might be affected by the construction of these underground survey facilities and the final depository. It is necessary to obtain the initial-state conditions of pore water pressure and water chemistry through long term monitoring of boreholes during the PIs in order to estimate the influence on geological, environmental and radiological conditions by the construction of underground facilities and the final depository [1].

Since 2000, CRIEPI has been conducting a project on the development of directional drilling and measurement/logging technologies [2]. In FY2006, we began applying these technologies to the Omagari fault, distributed at the Kami-Horonobe area in Horonobe-town, Hokkaido (site no. HCD-3). After drilling the borehole of length 1000 m, a steel pipe was inserted to support the borehole wall. In FY2013, considering the hydro-geological conditions along the borehole, a Standpipe Multi Packer (SPMP)-type monitoring system was installed in the borehole and we began to measure the pore water pressure at three measurement intervals. The data recorded on data loggers were collected every 3-4 months on site and the batteries were replaced at the same time.

At the PI stage, we assume that long term monitoring for several boreholes will be achieved in vast areas where power supply and/or communication networks are not available. Thus, we are developing an automatic data acquisition system for long term monitoring, which enables us to access the data remotely.

DEVELOPMENT OF MONITORING TECHNOLOGIES

For soft sedimentary rocks, a casing pipe protects the borehole wall and the annulus is filled with cement; hence, the casing pipe must be perforated such that pore water pressure measurement intervals can be set. The measurement intervals are set by installing packers in the casing pipe; then, the monitoring devices are set in the perforated casing so that the measurement process can be started. This is a general measuring method for long-term monitoring of pore water pressure in the soft sedimentary rocks [3].

As the borehole bored by using the directional drilling technology at the Kami-Horonobe area is relatively stable, Kiho et al developed another method for measuring the pore water pressure of the borehole at the site. The outline of the devices of the system (Standpipe Multi Packer System) is shown in TABLE I. Measurement intervals are established by cutting and moving the casing pipe upwards. Since the packers are installed directly on the borehole wall between the casing pipes, the measurement intervals have no annulus. Thus, it is possible to ignore the effect of cement included in the annulus on the groundwater quality.

TABLE I. Outline of Standpipe Multi Packer System (SPMP)

System	Standpipe Multi Packer System (SPMP)
Measurement Intervals	5 (maximum)
Diameter of Devices	Casing : 76.1mm/70.9mm(outer/inner) Packer : 180mm/110mm(inflation/deflation) Standpipe:23mm/21mm(outer/inner) Number of standpipes: 5(maximum)
Pressure Gauge (for pore water pressure)	Sensor technology: Piezoresistive Working pressure range: 0-10 x 10^5 Pa Linearity: 0.025%FS, Resolution: 0.002%FS Size: ϕ16mm, length 120mm
Measurement Items	Pore water pressure In situ groundwater chemistry by sampling

The Standpipe Multi Packer (SPMP) system, which is easy to maintain during the monitoring, has been proven to perform satisfactorily for an inclined borehole. Kiho et al improved SPMP partially such that it was compatible with the processed casing pipe and devised a groundwater sampler that could pass through a standpipe with an inner diameter of 21 mm [4], and an improved SPMP was installed at HCD-3.

Setting Measurement Intervals and Monitoring Devices

The maximum expanded diameter of the packer of SPMP is set as 180mm to a drilling diameter 152mm with some borehole expansion. A preliminary survey of caliper logging was carried out in boreholes of lengths 200-235 m, 295-345 m, and 405-455 m, depending on the geological conditions. Measurement intervals in the borehole were set on the hanging wall side of main fracture at lengths of 249.45-257.45 m (interval 1), 210.95-215.95 m (interval 2), and 208.45-209.95 m (interval 3), where the packers could work in the maximum expansion 180 mm. And monitoring devices were set up at each interval.

Interval 1 is in the intact Wakkanai formation and interval 3 is in the permeable fracture. Drilling confirmed the occurrence of lost circulation at interval 3. Results of the permeability test near interval 3 show a 3-4 order higher permeability of 2×10^{-6}m/s compared to other test results. Results of pore water pressure measurement conducted during controlled drilling show that three intervals are confined, so mini-packers are set 10 m from the top of the standpipes to prevent yield of groundwater. Pressure gauges are installed under the mini-packers to measure the pore water pressure at each interval, as shown in Fig. 1.

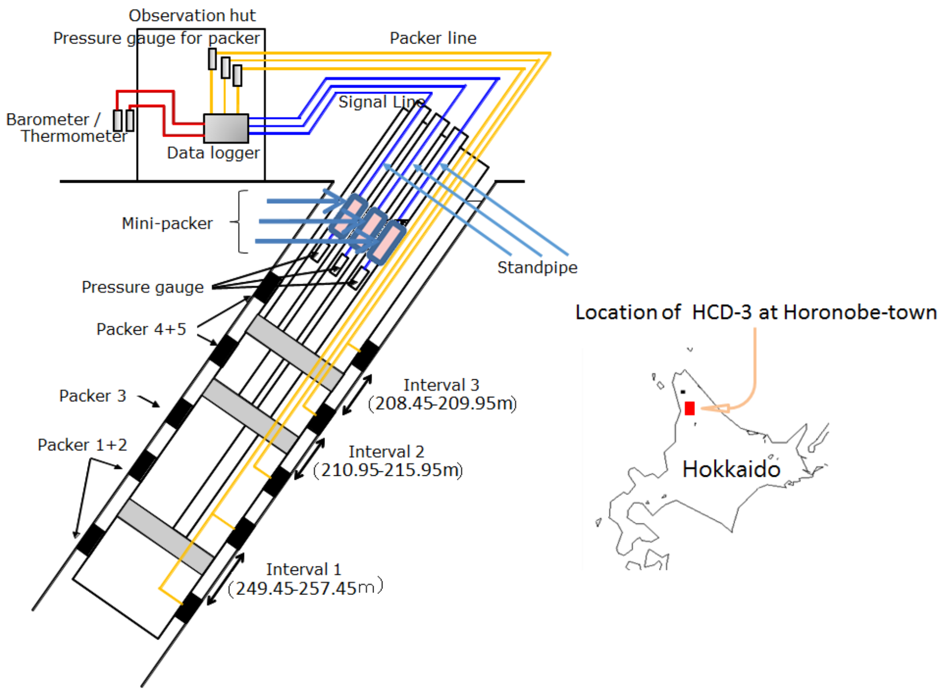

Fig. 1. Standpipe Multi Packer (SPMP) monitoring system for HCD-3

Pore Water Pressure in the Borehole

SPMP was installed on February 22, 2014 at HCD-3, and we started the measurement of pore water pressure of three intervals. Fig. 2 shows the measurement results until March 2015. Because the measurement process was interrupted by the removal of the drilling equipment and the mini-packer did not operate correctly, the quality of data cannot be ensured, however, the pore water pressure of interval 3 was higher than that of other intervals.

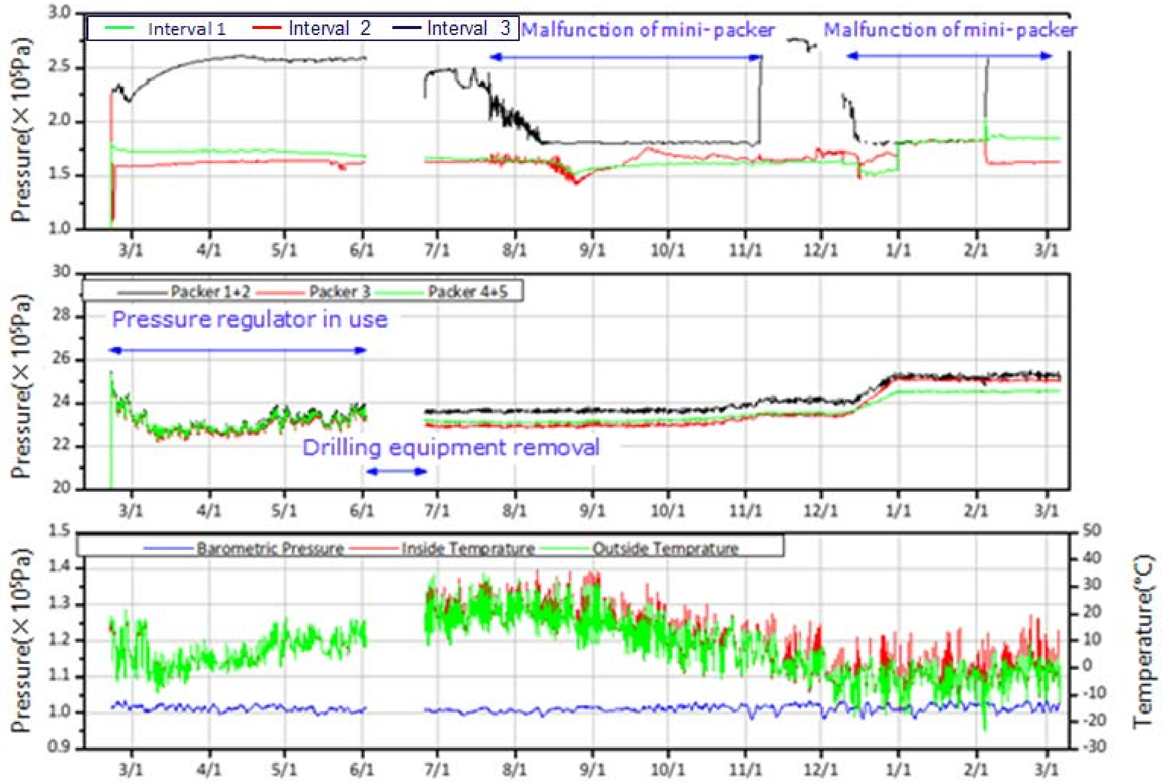

Fig. 2. Measurement results at HCD-3

AUTOMATIC DATA ACQUISITION SYSTEM FOR LONG TERM MONITORING

There is a possibility that infrastructure for electricity and/or communication is not available at the monitoring site during the PI stage. Thus, we designed a data acquisition system that automatically saves the measured data and communicates with the monitoring center for a long period of time [5].

Not only pore water pressure of three measurement intervals but also three sets of packer pressure, mini-packer pressure, atmospheric pressure and temperature are measured at HCD-3. Based on the environmental and weather information affecting the functioning of the data acquisition system at the Kami-Horonobe area, specifications of the power supply and data communication necessary for the maintenance of the system are clarified. As for this system, the power is supplied by solar photovoltaic generation and wind power generation. Data communication is secured through a satellite line depending on a local commercial communication network service. The environmental information such as wind direction, wind speed, solar radiation, rainfall and snowfall, as well as the information about the peripheral equipment such as battery voltage and ambient image, are to be measured or monitored. Real-time continuous monitoring is remotely possible when a geological event such as a massive earthquake occurs. The basic configuration of stand-alone data acquisition system is shown in Fig. 3.

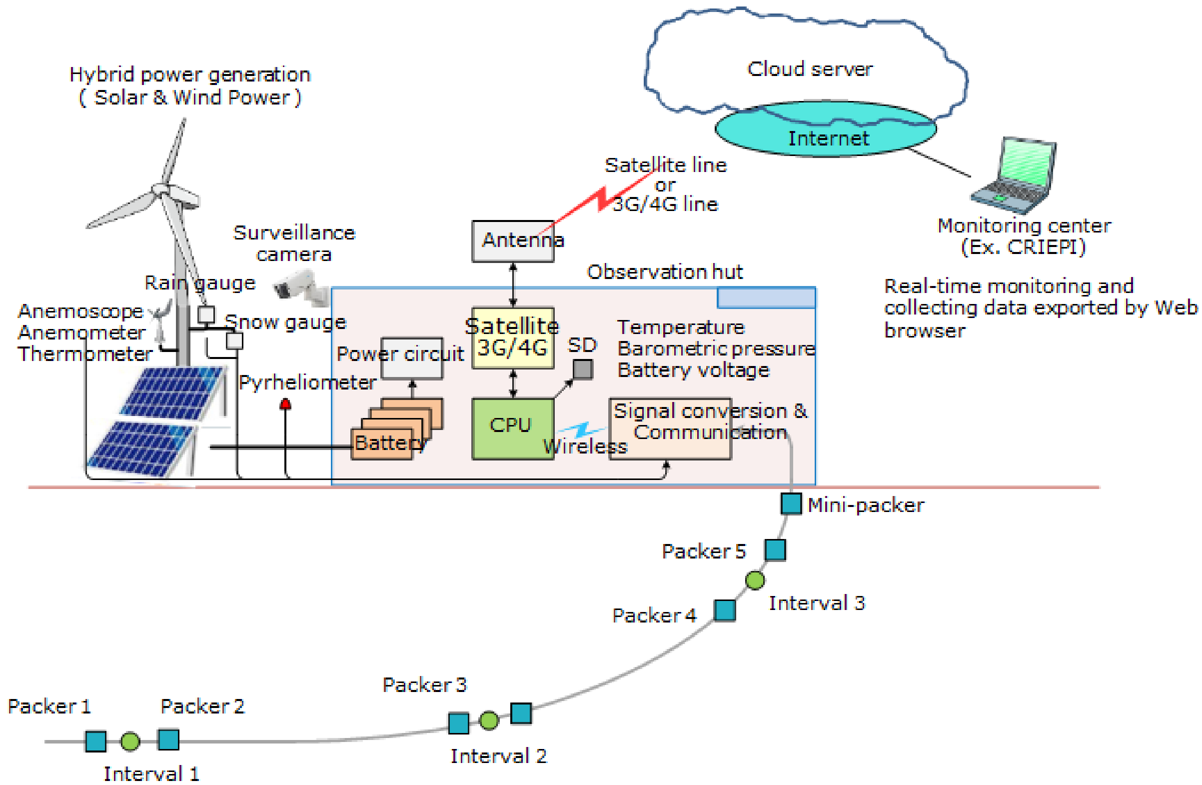

Fig. 3. Stand-alone data acquisition system

We considered power supply capacity of the site in accordance with local environmental conditions and power saving of the monitoring system in the basic design. Data communication capability with the site and the monitoring center was also considered. So the automatic data acquisition system for HCD-3 was installed in Oct. 2015 (see Fig. 4 and TABLE II).

Fig. 4. Automatic Data Acquisition System at HCD-3

TABLE II. Equipment of Automatic Data Acquisition System for HCD-3

EQUIPMENT	REQUIREMENTS	PRODUCT MODEL (Manufacturer)
Network Computer	・Stability as host device driver and control unit device ・Low power consumption ・System extensibility for multiple survey points ・Flexible customization capabilities	openATOMS (SHIKOKU RESEARCH INSTITUTE)
Data Loggers	・Low power consumption ・Control of the operation modes ・Correspondence to the number of measurement points	MAGIC BEE (TOYO ELECTRIC)
Satellite communications equipment	・Stable communication ・Low power consumption	NTT DOCOMO Widestar Ⅱ (MUTSUBISHI ELECTRIC)
Communication satellite antenna	・Compatibility to the satellite communication equipment	AAD68096 (MUTSUBISHI ELECTRIC)
Mobile router	・Environmental capability for severe weather condition ・General purpose router for 3G/4G communication	HSPA-450C (GENETEC)
Surveillance camera	・Stability for severe weather condition ・General purpose camera for surveillance	BB-SW175A (PANASONIC)
Wind turbine	・Power generation capacity required for the system ・Stability for severe weather condition	WTR-91012 12V Diameter of Rotor: 910mm Rated output: 72W(10m/sec) (MARLEC)
Solar battery	・Power generation capacity required for the system ・Stability for severe weather condition	KC-32T-02 Size:517×512mm Rated output: 32W (KYOCERA)
Battery	・Storage capacity ・Stability for severe weather condition	SEB-50 Storage capacity: 12V 50Ah (GS YUASA)

The system is a standard stand-alone data acquisition system; however, simultaneous monitoring is also possible by creating local wireless network for each borehole in a PI area having severe weather conditions such as less sunlight and without adequate infrastructure of power supply and/or communication networks. When measuring or monitoring more than one survey point, the system can easily be changed to an adaptable system by adding observation stations without cable laying, as shown in Fig. 5.

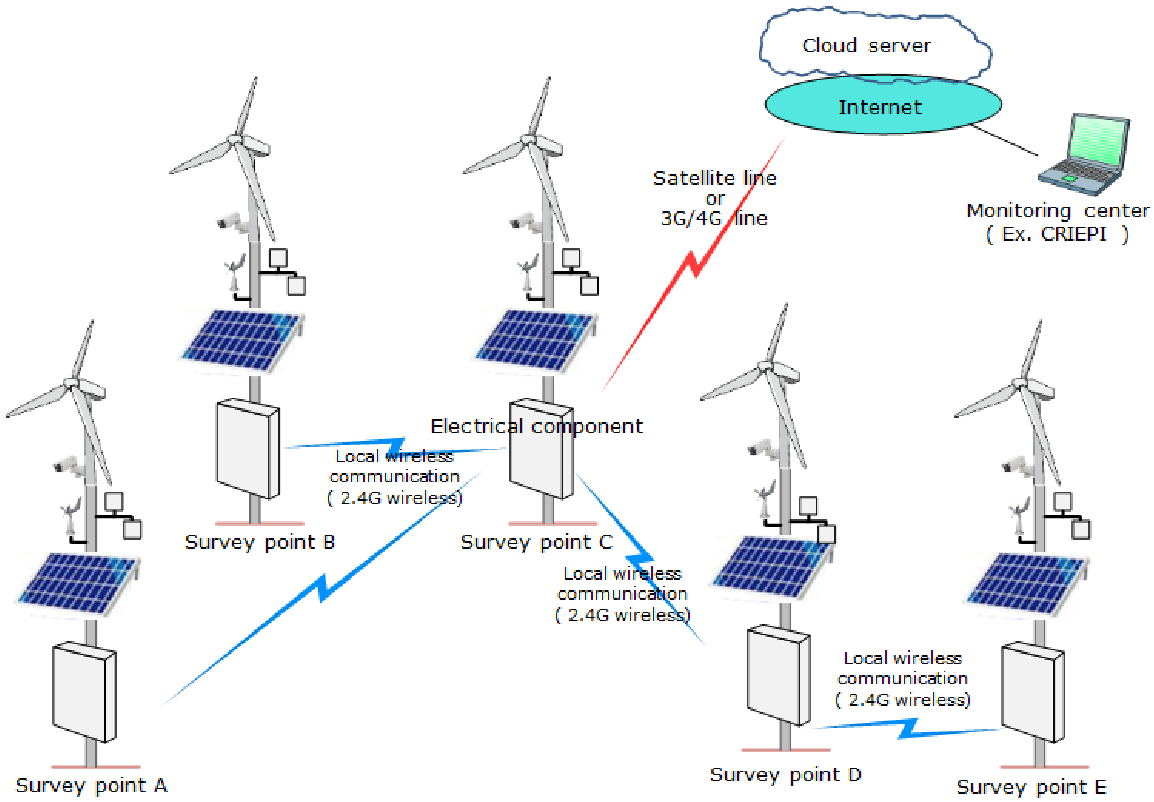

Fig. 5. Simultaneous monitoring system for multiple boreholes

DISCUSSION

As part of the installation work and pore water pressure measurement of SPMP at HCD-3, the following results were obtained.

・Mini-packers are to be inflated independently;
As mini-packers are installed in three intervals, inflated by nitrogen gas of one system at a time, we have to deflate all the mini-packers when we are working at one interval (standpipe) or replacing the faulty mini-packer.
It is necessary to separate the gas system for the expansion.

・Recording the local weather data is recommended;
External factors such as precipitation, atmospheric pressure and earth tide might affect the pore water pressure. So it is preferable to record the local weather data near the site by referring to the AMeDAS (Automated Meteorological Data Acquisition System of Japan Meteorological Agency) data. This will improve reliability of the data analysis.

・Packer having a large inflation diameter should be developed;
Measurement intervals should be set by considering the geological environment characteristics obtained by studying the conditions in the borehole. However, in this case, the monitoring interval setting was constrained by the expansion capability of the packer. It is necessary to develop a packer that inflates to an

expanded borehole.

OUTLOOK

While addressing the issues revealed in the demonstration so far, long-term monitoring of the pore water pressure will be continued in 2016. Water sampling and water quality analysis also require to be performed to understand the baseline of water chemistry. We will obtain the knowledge required for the systematization of the directional drilling and measurement/logging technologies used in boreholes.

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