Installation of a vertical pressure cell at the Priddis Geophysical Observatory

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ABSTRACT

Carbon Management Canada and CREWES have installed a vertical pressure cell in Testhole 4 at the Priddis Geophysical Observatory for the purpose of testing downhole equipment. Thus far, steel coil tubing with a cap welded onto the bottom has been inserted into the well, and a bell nipple with threads for a flange has been welded onto the top of the coil tubing. The coil tubing has been sealed at the top with access ports for CO_2 and test instrument tubing, allowing the pressure to be taken up to 35 MPa, thereby simulating various reservoir depths. By releasing CO_2 bubbles into the bottom of the coil tubing, the new sensors can be tested and calibrated. The pressure cell was completed November 20 2014.

INTRODUCTION

Testhole 4 at the Priddis Geophysical Observatory was drilled in 2007 and cased to a depth of 127 m with PVC casing grouted with bentonite (Figure 1) (Wong et al.). The well was used for instructing students in well logging methods for several years as part of the Geophysical Field School at the University of Calgary. More recently seismic data quality obtained in the well has appeared to deteriorate in quality, possibly due to the bentonite being washed away by ground water. This made it a good candidate for the installation of a vertical pressure cell.

One of the projects supported by Carbon Management Canada was the development of an optical fiber based sensor for detecting concentrations on CO2 in a well bore. This project has produced a prototype sensor, and there was a need to field test this under the various pressure regimes that it will be expected to operate in. Since Well 4 at the Priddis Geophysical Observatory was somewhat degraded from loss of coupling to the surrounding material, it was decided to build a pressure cell in this well for testing the optical sensor, or any other system that would benefit from this type of test facility. The construction was done during the year, with 2.875 inch steel coil tubing being run into the well in July, and the rest of the structure finished in November. The main limitation of the cell is the internal diameter restriction of the coil tubing used. This is approximately 2.5 inches, so with the requirement of inserting a tube to the bottom of the cell for gas injection, the sensor is limited to a diameter of 2 inches.

The first test of the cell without the top structure installed was November 18 to 20 2014 when the prototype sensor from the University of Victoria was deployed at Priddis. This first test was simply to ensure that the sensor could dfifferentiate between fluid types – in this case nitrogen bubbles in the water column. This test was carried out without any added pressure beyond the hydrostatic depth of the well.

FIG 1. Well 4 before the installation of the coil tubing. The bentonite grout between the PVC casing and the steel conductor casing is visible

THE INSTALLATION

Steel coil tubing with a cap welded onto the bottom was inserted into the well (Figure 2) in July 2014 by Sanjel Corporation. The tubing has a 0.188 inch wall thickness, as well as a welded seam on the inside which protrudes into the interior of the tubing by the wall thickness. This results in the restriction to the internal diameter available for tools of approximately 2.5 inches or less. A centralizer was installed in early November (Figure 3), and a bell nipple with threads for a flange was been welded onto the top of the coil tubing (Figures 4 and 5).

The well head structure was designed and constructed by Select Energy Systems and installed on the well November 20 by Select Energy (Figure 6). All components of the structure are certified for pressures well above the expected operating pressure of the cell (35 MPa). The structure has six ports on the side for control of the water levels and pressure in the tubing, and five ports on the top which can accommodate Conax fittings for sealing tubes entering the well. These top fittings are aligned with the well bore so that the tubes entering this way can continue straight down the hole without being subjected to bending stress. All ports are standard ½ inch NPT threads for maximum flexibility. The top fitting is secured in place by a “knock-on” thread to prevent any twisting of the tubes inserted through it.

FIG 2. The coil tubing being inserted into Well 4.

FIG 3. The centralizer in place on the coil tubing.

FIG 4. The bell nipple being welded onto the top of the coil tubing.

FIG 5. The finished coil tubing ready for the wellhead equipment to be installed.

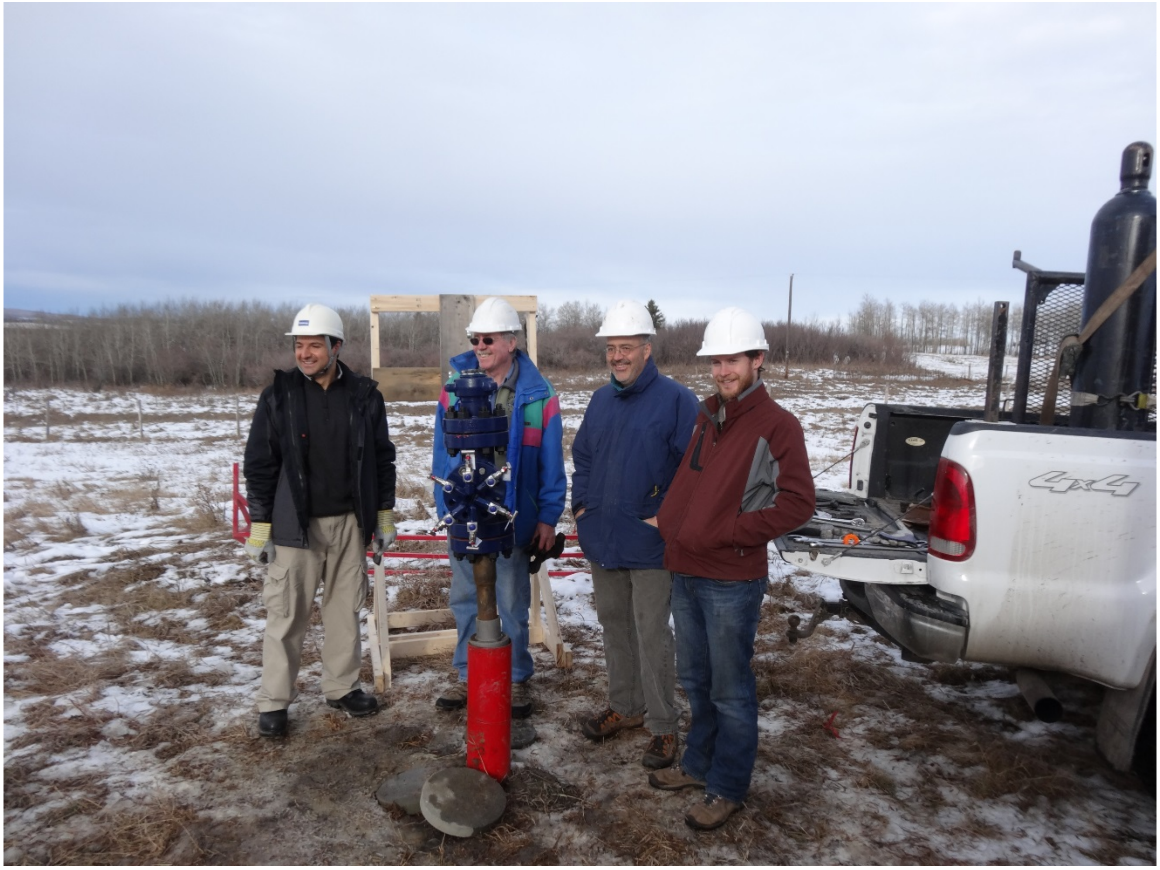

FIG 6. The completed wellhead structure on Well 4 at the Priddis Geophysical Observatory

THE COMPLETED WELL HEAD

The wellhead structure is shown in Figure 7. The shut off valves on the left are for fluid control and will be used:

a) to control the level of water in the well to ensure that there is minimal head space above the water requiring pressurizing,

b) for nitrogen (or other gas) injection to create the desired pressure regime and

c) for a precision pressure relief bleed valve that will maintain the pressure in the well as carbon dioxide (or other gas) is injected into the bottom of the water column.

There are six valves available of which 4 will be used for the above purposes, leaving two for future use.

On the top of the well head is a knock-on cap with 5 ports for Conax fittings which can accommodate tubing of 0.125 to 0.375 inches. These fittings are rated to 10,000 psi. The unused ports are sealed with plugs.

FIG 7. Detail of the well head

THE FIRST TEST OF THE PRESSURE CELL

The first test using the pressure cell was completed November 20 and used the cell as an open pipe before the well head structure was installed. This test was of the optical fiber sensor developed by the University of Victoria (Figures 8 and 9) (Burton et al.).

FIG 8. The internal structure of the sensor.

FIG 9. The assembled probe ready to be deployed.

The first measurement was to test the sensor as a bubble detector to ensure that it could differentiate between different fluids. For this test the sensor was set at various depths up to 25 metres, and a 0.25 inch stainless steel tube was inserted to a depth of about 40 metres and used to bubble nitrogen into the water column (Figures 10 and 11). The flow rate was adjusted to various settings to test the sensor.

FIG 10. The nitrogen bottle and flow meter / regulator used for this test.

FIG 11. Bubbles coming to surface in the coil tubing.

Figure 12 shows the winch used for this test setup. The yellow cable is a two core fiber line connecting to the sensor. This cable also acts as the support for deploying and recovering the sensor from the well. The 0.25 inch stainless steel tubing for the nitrogen bubbles is visible curving in from the upper right.

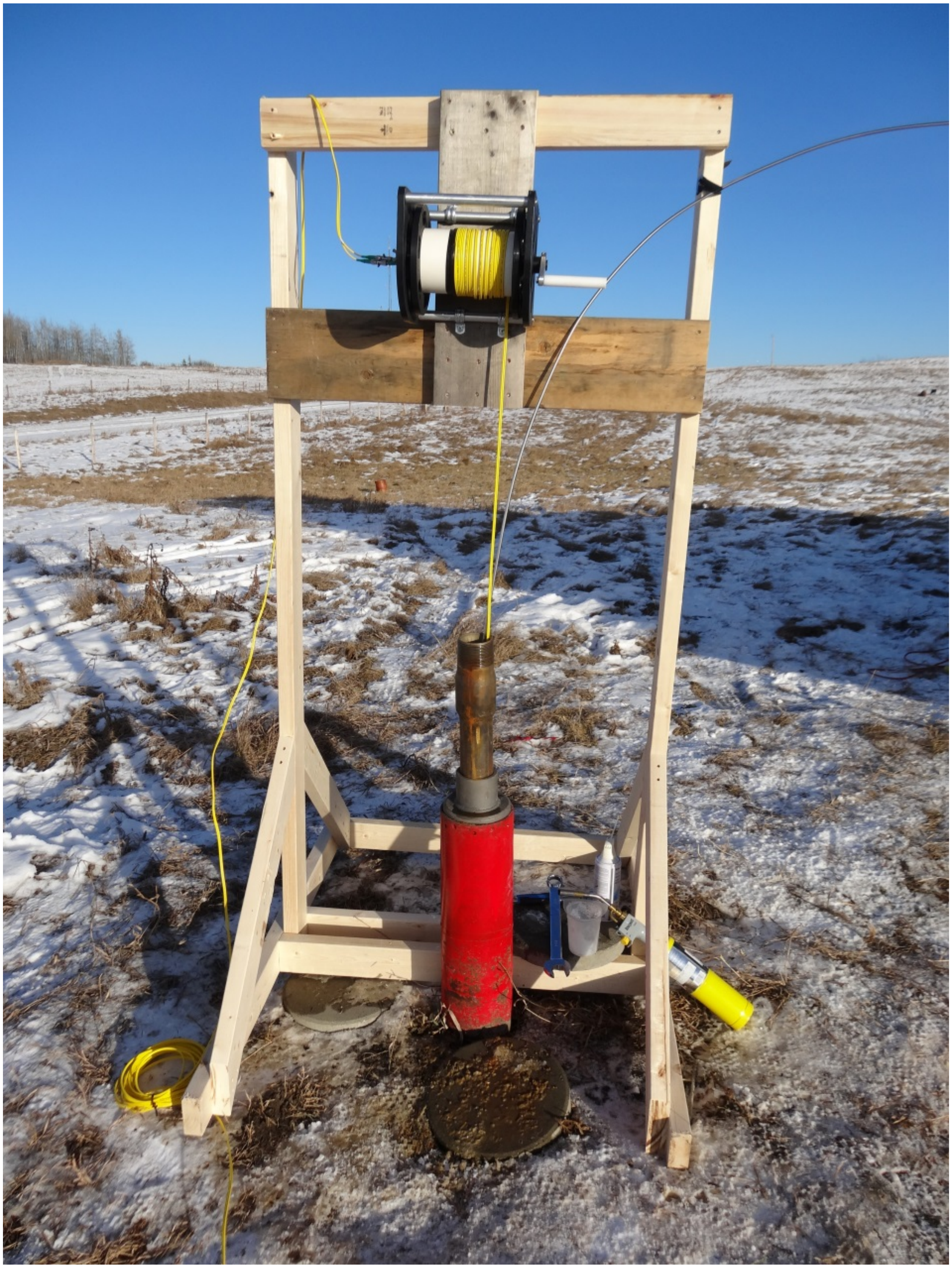

FIG 12. The gantry and winch for deploying the sensor in the well.

Figure 13 shows the electronics, laser source and interface for the sensor, and Figure 14 two screen shots of different bubble counts. The sensor has two independent fibers internally, one which acts as a horizontal sensor, the other vertical.

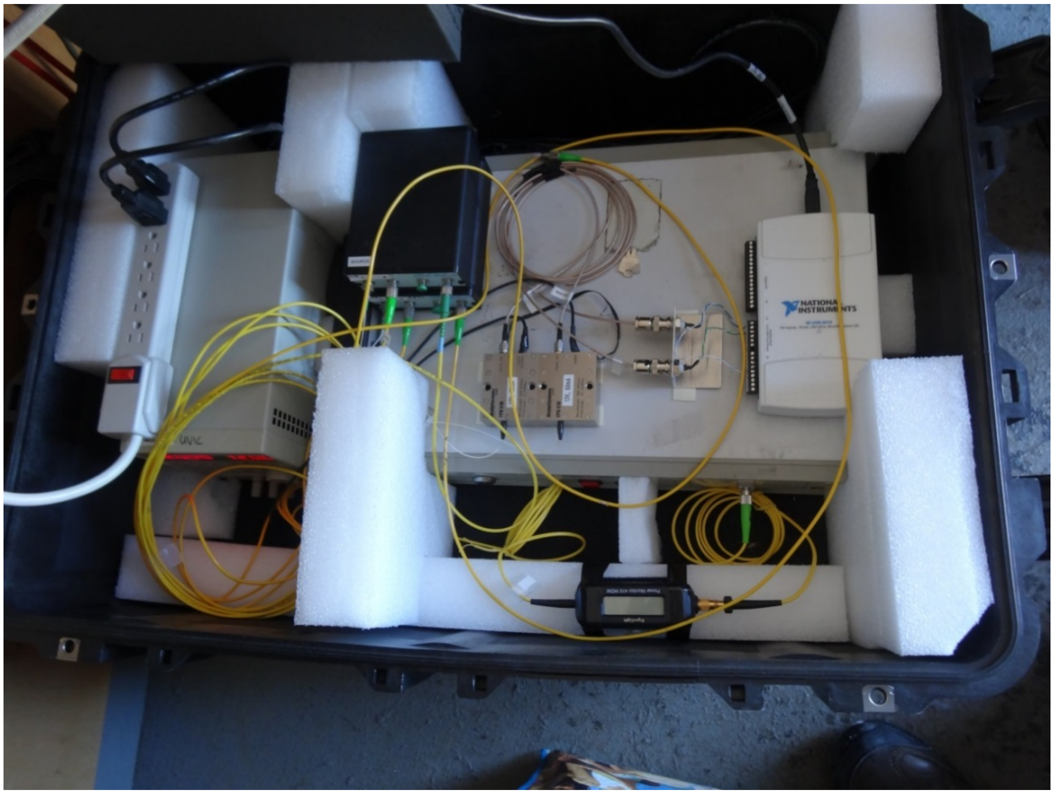

FIG 13. The control electronics package for the optical sensor.

Two screenshots of the output from the sensor are shown in Figure 14. The two sensors are plotted with different colours, one red, one white. The red plot is hard to distinguish on screen as the white is plotted overlaying it.

This first test of the pressure cell was completely successful, and has provided much data for analysis, which was ongoing at the time of this publication.

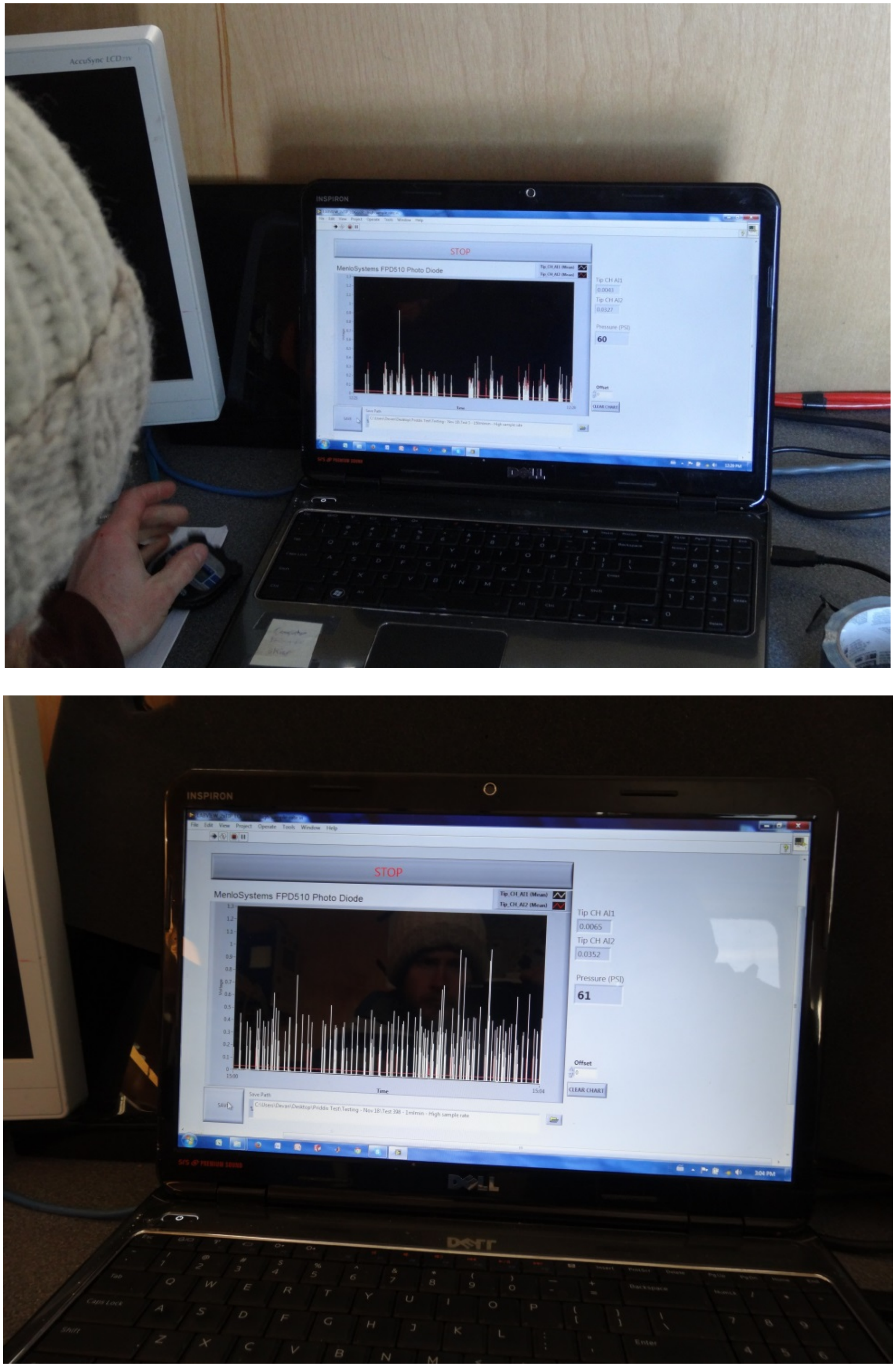

FIG 14. Two screenshots of the bubble detector output at different flow rates. There are two sensors in the probe, one vertical and one horizontal. The two are shown in different colours, white and red on screen.

FUTURE WORK

The next procedure to be carried out on site is to pressure test the cell to make sure that there are no leaks. This will be done by using either compressed air or nitrogen to bring the pressure up in stages to the expected maximum operating pressure, with a lengthy pause at each stage to monitor for pressure loss anywhere in the system. When at maximum pressure, the cell will be held at this for enough time to monitor for pressure changes due to other factors such as ambient temperature changes.

ACKNOWLEDGEMENTS

This system was designed and installed with the assistance of many people.

- Sanjel Corporation provided the coil tubing and the services to install it in the well
- Select Energy Systems Inc. designed, built and installed the well head equipment
- CREWES provided staff to monitor equipment installation and other logistics
- Carbon Management Canada provided funding for the pressure cell
- University of Victoria provided the optical sensor and personnel for the first test of the cell (unpressurized)

REFERENCES

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