EQUILIBAR
PRECISION PRESSURE CONTROL

Demanding Supercritical CO2 Service: Equilibar Back Pressure Regulator maintains stability in Porous Media Research

Background

International concerns about climate change have increased interest in carbon sequestration, specifically the storage of CO2 in underground aquifers to isolate it from the atmosphere. Loughborough University in Leicestershire, England is engaged in research to determine the stability of CO2 after injection into saline aquifers at depths where the underground pressure would retain CO2 in its supercritical state (at or below 1000 meter). To assess the risks of leakage, the University is studying dissolution of supercritical CO2 (scCO2) into brine, displacement of brine by scCO2, mineral precipitation of the host rock by reaction with CO2 and acidified brine/water, viscous fingering as a result of difference in viscosities of the two fluids and other processes related to the fluid-fluid-porous media interactions.

Research Interest

The Loughborough project requires characterizing the two-phase flow system involving scCO2 and brine/water, especially the displacement of water by scCO2. To meet this goal, the laboratory system must be maintained at a pressure and temperature that will ensure the scCO2 and brine are in conditions similar to the geological conditions where the actual sequestration will take place.

A supercritical fluid pump was used to inject CO2 at the desired conditions into the porous media (unconsolidated sand) that was previously saturated with brine or water. As a result, scCO2 displaces the brine/water out of the porous medium. The displaced water was collected in the beaker (outflow bottle) on the electronic weighing balance under atmospheric conditions, as shown in Figure 1.

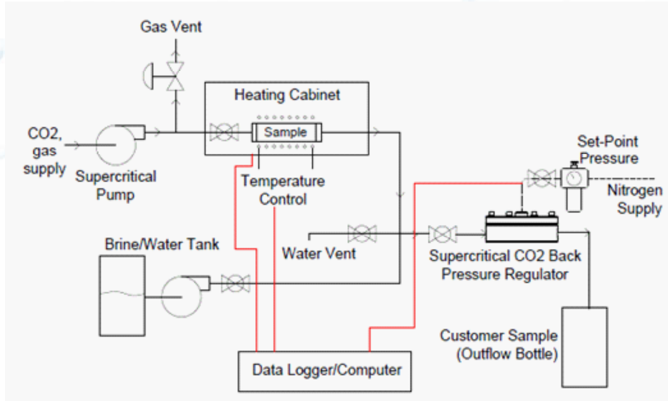

Figure 1: Experimental Schematic showing the path of the CO2 displacement of brine through the Back Pressure Regulator

Pressure Control Problem

Initially, the back pressure on the cell (sample holder containing the unconsolidated sand) was controlled by throttling the outflow with a solenoid valve in conjunction with a ball valve. As the displacement progressed, the pressure of the supercritical fluid pump dropped below the 80 bar set-point and continued until failure of the experiment. The research team tried replacing the ball valve with a metering valve to maintain back pressure. While this solution provided some improvement in stability, the pressure decline continued, as shown in Figure 2.

Solution with Equilibar® Back Pressure Regulator

Researchers at Loughborough conducted an online search to find a suitable back pressure regulator (BPR) for their demanding supercritical service. They contacted Equilibar (Fletcher, NC, USA), which has a series of high precision BPRs for demanding research environments such as this one. The Equilibar® BPR uses a simple design – instead of a spring it uses a 1:1 nitrogen pilot pressure to communicate the desired set-point to a diaphragm, which directly seals on the outlet ports.

Key advantages included both affordability and ease of installation and operation.

Equilibar engineers recommended a 1/8" ULF1 Research Series back pressure regulator made of SS316L with a PTFE/Glass diaphragm and FKM o-rings. Once the Equilibar was installed, researchers saw an immediate improvement in pressure cell stability, as is shown in Figure 2. The robust pressure control required much less time and attention devoted to the everyday operation of the experiment.

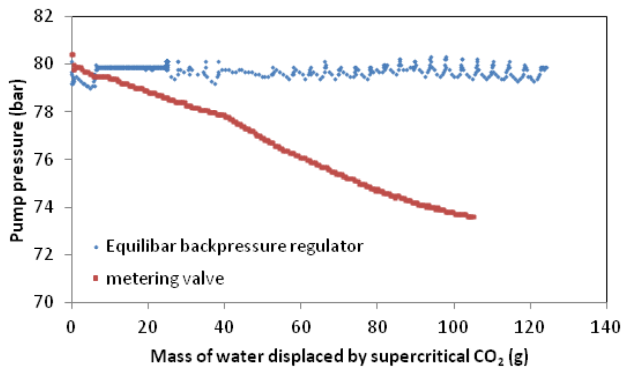

Figure 2: Behaviors of the supercritical fluid pump pressure with and without backpressure regulator at 80 bar.

Diaphragm Refinement

After approximately two months service, the PTFE/Glass diaphragm initially used with the Equilibar developed a hole at the small control orifice. The failure repeated with a replacement PTFE/Glass diaphragm after another two months. The research team worked with Equilibar engineers to select a harder PEEK (Polyether Ether Ketone) polymer diaphragm. This more-durable material has been in place for over four months with no difficulties or instabilities in the system.

Solution for Supercritical Applications Worldwide

A variety of supercritical fluid applications around the world requires reliable and robust pressure control. In many applications, aggressive chemicals, fuels, or solvents are mixed with the supercritical CO2. Other applications, such as supercritical CO2 extraction, also have viscous oil or other dissolved solids that can precipitate with the phase change of the fluid. Traditional pressure regulators, which use conical seats similar to metering valves, are often blocked by the formation of dry ice (due to Joules Thompson cooling), viscous oils, or the precipitated solids.
Equilibar's dome-loaded design is proving itself capable of handling many of these demanding scCO2 applications where traditional valve seat designs fail.

Contact Equilibar's application engineers to select the optimum diaphragm material and trim design for your custom requirements.

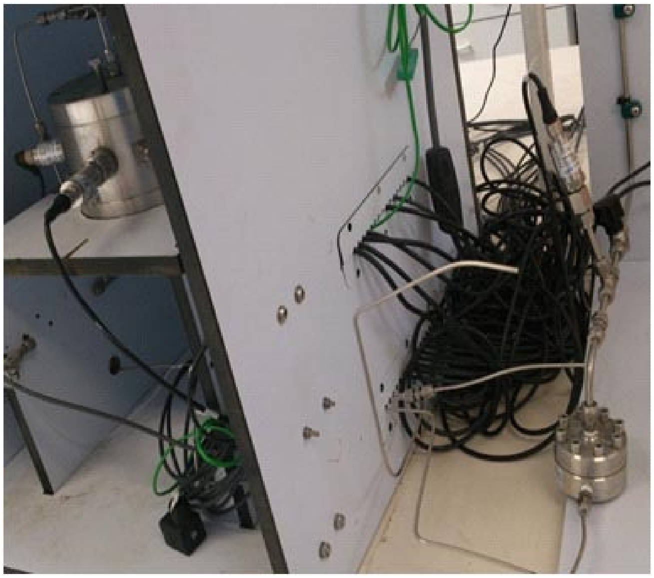

Figure 3: High-pressure Experimental Rig for Supercritical CO2 and Water System (Equilibar Back Pressure Regulator at the bottom right)

References

Abidoye, L.K., Das, D.B., and Khudaida, K. (2014). Geological carbon sequestration in the context of two-phase flow in porous media: A review. Critical Reviews in Environmental Science and Technology. https://dspace.lboro.ac.uk/2134/14567

Benson, S. M., and Cole, D. R. (2008). CO2 sequestration in deep sedimentary formations. Elements, 4(5), 325–331.

Berg, S., and Ott, H. (2012). Stability of CO2–brine immiscible displacement. International Journal of Greenhouse Gas Control, 11, 188–203. doi:10.1016/j.ijggc.2012.07.001

Kopp, A., Class, H., and Helmig, R. (2009). Investigations on CO2 storage capacity in saline aquifers: Part 1. Dimensional analysis of flow processes and reservoir characteristics. International Journal of Greenhouse Gas Control, 3(3), 263–276.

Morris, J. P., Detwiler, R. L., Friedmann, S. J., Vorobiev, O. Y., and Hao, Y. (2011). The large-scale geomechanical and hydrogeological effects of multiple CO2 injection sites on formation stability. International Journal of Greenhouse Gas Control, 5(1), 69–74.

Ott, H., Berg, S., and Oedai, S. (2011). Displacement and mass transfer of CO2 / brine in sandstone, 1–12.

Taku Ide, S., Jessen, K., and Orr Jr, F. M. (2007). Storage of CO2 in saline aquifers: Effects of gravity, viscous, and capillary forces on amount and timing of trapping. International Journal of Greenhouse Gas Control, 1(4), 481–491.

Luqman K. Abidoye
Chemical Engineering Department, Loughborough University, Loughborough, Leicestershire, United Kingdom
L.K.Abidoye@lboro.ac.uk, kluqman2002@yahoo.co.uk. +447774437875

Tony Tang is a Senior Engineer at Equilibar, LLC, a provider of high precision pressure control solutions. He has worked as an applications and development engineer for 4 years. Prior to Equilibar he received his M.S. and B.S. from North Carolina State University. Mr. Tang can be reached at tonytang@equilibar.com or 828-650-6590.