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New Back Pressure Regulator Enables Carbon Sequestration Research

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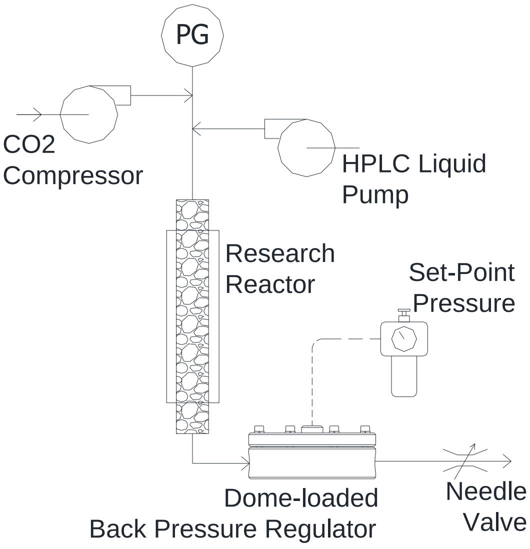
Supercritical carbon dioxide (CO2) is the subject of many new energy research programs around the world. The fluid possesses a unique mixture of both liquid and gas properties, and its impressive solvent ability and low toxicity have earned it the label of "green solvent." A growing number of university and energy company research programs are focusing on the role of supercritical CO2 in carbon sequestration, which is the process of capturing CO2 from combustion and preventing its introduction into the atmosphere, either by locking it underground in geological structures or by causing it to react with alkaline minerals to form stable mineral carbonates.

Equilibar® EB1ULF1 precision back pressure regulator provides stable reactor control at ultra-low flow rates in supercritical CO2 research

Jason Mann, a doctoral candidate at the University of Sydney, is focusing on carbon sequestration research. Like many others in this field, he is actively studying the sequestration of CO2 using geological routes. Probing such processes requires using pressures and temperatures similar to those observed in current CO2 enhanced upstream petroleum exploration but with the additional challenges of ultra-low flow rates and tight pressure control that are faced when operating at research scale.



Mann's research with supercritical CO2 involved feeding a reactor with both gaseous and liquid components. The back pressure regulator is key to maintaining control of the reactor conditions.

Back pressure regulators (BPRs) are similar to traditional pressure regulators, but control their inlet pressure instead of the outlet pressure. BPRs are often used to maintain a steady pressure in research reactors, but present a unique challenge for supercritical projects at this scale. The formation of solid CO2 associated with the adiabatic pressure reduction across the regulator can result in significant blockages in conventional needle valve systems at low Cv values and high pressures. This can result in poor pressure control with a high likelihood of catastrophic pressure letdown and subsequent damage to sensitive research equipment.

Mann's research confirmed that needle valve pressure regulators did not adequately address his demanding application conditions so he contacted Equilibar to find a solution. Equilibar® BPRs use a special dome-loaded design that incorporates direct sealing diaphragms. The direct diaphragm-to-orifice seal avoids this blockage issue by avoiding the use of needles, seats, and stems altogether. Unlike conventional needle valve systems, the pressure drop across the Equilibar design significantly reduces the likelihood of blockages via solid CO2 formation. In addition, Equilibar's unique flexible diaphragm approach provides for highly stable inlet pressures across widely varying flow rates (up to 10,000:1 flow ratios).

Equilibar supplied Mann with the Ultra Low Flow back pressure regulator (EB1ULF1) and proprietary PTFE/Glass composite diaphragm to meet the challenges of Cv values ranging from 10^{-4} to 10^{-5} and back pressures up to 1470 psig. Unlike competitive dome-loaded designs, Equilibar's proprietary supple diaphragm technology provides a dynamic system that can quickly adjust to the large volume change associated with the CO2 pressure reduction. Comparison of these diaphragm materials by Mann indicated that the standard PTFE diaphragm as similarly supplied in completive designs resulted in poor pressure control with catastrophic pressure blowouts down to the CO2 saturation pressure (830 psig).

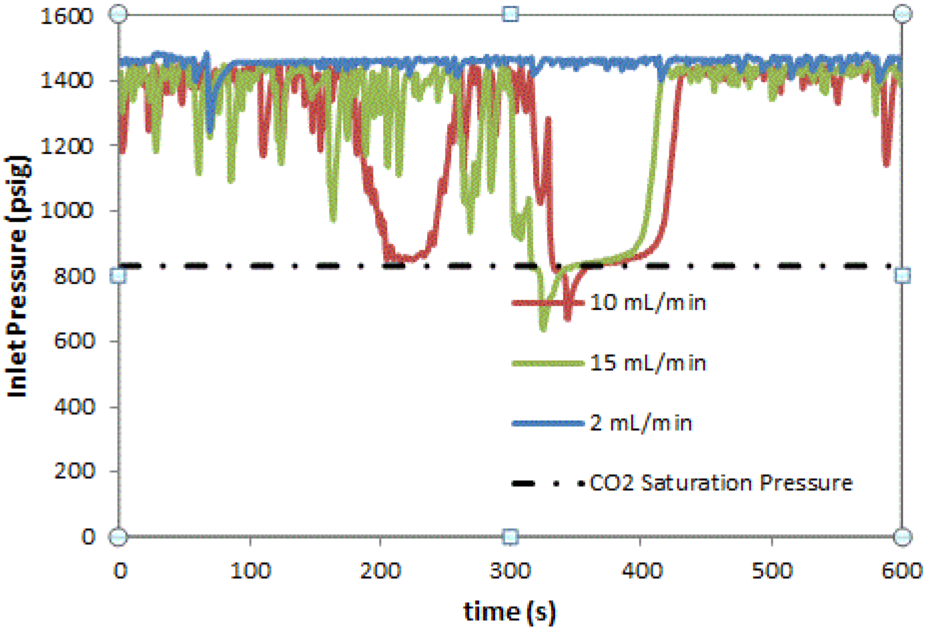


Figure 1. Upstream pressure fluctuations over time for high pressure CO_2 control with PTFE diaphragm.

In contrast, results from Equilibar's proprietary PTFE/Glass composite provided extremely stable pressure control within the CO2 supply pump specification (±2%). This allowed for reliable performance to satisfactorily meet the needs of Mann's application.

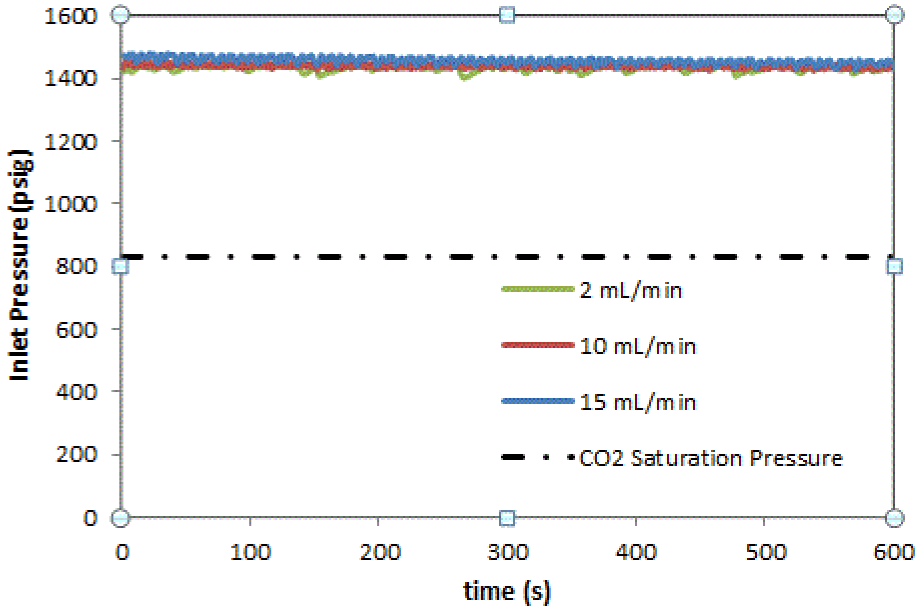


Figure 2. Upstream pressure fluctuations over time for high pressure CO_2 control using PTFE/Glass composite diaphragm.

Another common problem for research applications is o-ring integrity due to the exceptional solvent properties of supercritical CO2. When high pressure is reduced suddenly, explosive decompression can damage many o-ring materials when the dissolved fluid expands violently. To compensate, many researchers use specialty explosive-resistant Shore A90 FKM or expensive FFKM o-rings for these applications.

The stable pressure control provided by the BPR with the PTFE/Glass diaphragm allowed Mann to perform his studies using standard FKM o-rings. He demonstrated that either a secondary needle valve or capillary installed downstream of the BPR provided a slow depressurization of the system using the PTFE/Glass composite diaphragm, to avoid the damage to the FKM o-rings. This significantly reduced operational and downtime costs.

The success of the trials at University of Sydney will provide scientists and engineers working in the area of research scale supercritical/high pressure CO2 applications tighter control and more reliability in both pressure control and overall system performance.

Learn more about Equilibar's precision back pressure regulators
For more about the University of Sydney's School of Chemical and Biomolecular Engineering, visit http://sydney.edu.au/engineering/chemical/cecps/index.shtml