EQUILIBAR PRECISION FLUID CONTROL

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Supercritical CO_2 research evaluates alternate method of using captured CO_2 emissions

Summary

Researchers from the ReActing System and Advanced Energy Laboratory (RASAER Lab) at the University of South Carolina in Columbia are using an Equilibar® Back Pressure Regulator (BPR) as well as an Equilibar® Electronic Pressure Regulator (EPR) to maintain stable pressure near the critical point of CO_2. The goal of this climate-based research is to study high-pressure electrical discharges and its effects in supercritical CO_2. Electrical breakdown in low-pressure CO_2 with a catalyst can cause CO_2 to split and produce CO, which can later be combined with Hydrogen to make synthetic fuels. This research attempts to explore the types of reactions that occur in supercritical CO_2 when there is an electrical discharge with no catalyst present. Since supercritical fluid is already in a state of high reactivity, there is reason to believe that a catalyst will not be needed to convert the CO_2 into CO.

Background

Many models attribute the average rising temperature of the earth's atmosphere to the increase of global CO_2 emissions. Achieving net-zero or near net-zero CO_2 emissions would be ideal for fighting the climate crisis. Direct-air capture is a method that has already been proven to remove CO_2 directly from the atmosphere. After CO_2 is captured, the next step is deciding what to do with it. Currently, it is common practice to bury the CO_2 deep within the earth.

But there is another promising alternative to burying the CO_2. Research conducted at Stanford University and the Technical University of Denmark has shown that electrical discharges in CO_2 with a cerium oxide catalyst can reduce CO_2 into CO with 100% selectivity and without producing solid carbon.[1] The addition of Hydrogen to CO can produce fuels like synthetic diesel fuels and the equivalent of jet fuel.

The Challenge

There is a clustering effect in molecules that occurs when a fluid approaches its critical point. This clustering effect allows for lower than usual breakdown voltages.[2] Precise pressure control is needed to keep the pressure of the system near the critical point and take advantage of the supercritical clustering effect. The critical point of CO_2 occurs at 87.8 °F and 1,070 psi.

In this setup, liquid CO_2 is boosted into the system at 1000 psi. It is then heated to the critical temperature, during which the pressure also increases. This method produces CO_2 at the critical temperature and above the critical pressure. Therefore, some CO_2 must be exhausted from the system to achieve the precise critical pressure.

Safety

High voltages and high pressures also make safety a top priority with these experiments. Therefore, a back pressure regulator that can be controlled remotely is needed for this setup.

The Solution

An Equilibar HT1 back pressure regulator was chosen for this experiment for its ability to control high pressure, high temperature, and mixed phase fluids. The HT1 in conjunction with an Equilibar® EPR3000 electronic pilot pressure regulator is used in the setup to exhaust excess CO_2 from the system and maintain pressure near the critical point. See the CAD drawing of the setup in Figure 1 on page 2.

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Figure 1: CAD Drawing of the supercritical CO_2 plasma reactor using an Equilibar HT1 with an EPR3000 pilot regulator for pressure control

The Equilibar BPR is a dome-loaded pressure regulator with pilot operation. This means that gas or air is fed into the top (dome) area of the regulator to provide the pressure setpoint for the process. The pressure of the gas in the dome is set by a secondary pressure regulator called a pilot regulator. In this case, an EPR3000 was used as the pilot regulator for automated control.

Because the BPR is dome-loaded, the pilot regulator can be located away from the BPR with gas lines running from the pilot controller to the dome of the BPR. This allows for the system to be remotely controlled and monitored. In this experiment, the supercritical CO2 plasma setup used Nitrogen for the pilot gas due to the high pressure required. The EPR3000 was controlled and monitored via LabVIEW® using 4-20 mA input and output controls. The HT1 ensured that the system would not over-pressurize when being heated.

Figure 2 shows the LabVIEW® user interface used to control and monitor the system remotely. This snapshot shows the setpoint pressure of the EPR and displays the actual pressure at the back pressure regulator and that of the system pressure.

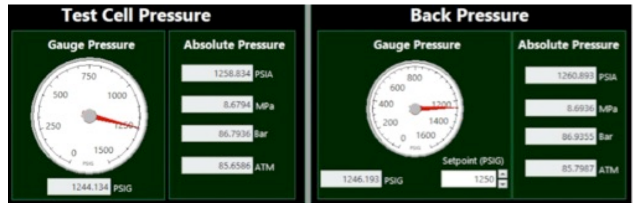

Figure 2: Pressure control and monitoring via LabVIEW®

The LabVIEW® data indicates that the Equilibar HT1 in combination with the EPR3000 pilot regulator maintained the system pressure to within 0.5% of the setpoint. This high precision allowed the system to maintain the critical point of the CO_2 for this research.

Considerations

Equilibar offers a series of supercritical back pressure regulators designed to reduce the Joule-Thomson effect of supercritical process fluids passing through the BPR. This effect causes a temperature drop which can lead to ice formation which could potentially block the internal passages of the BPR. Replacing the HT1 BPR with a supercritical back pressure regulator may increase the lifetime and functionality of the back pressure regulator in this process.

After several experimental runs of the plasma reactor, a slight leak was observed. Upon inspection, contaminants were found in the BPR, likely causing the leak. Equilibar recommends adding filters upstream of the back pressure regulator to ensure the sealing surfaces remain clean for the BPR to operate properly.

References

[1] Stanford University. "New route to carbon-neutral fuels from carbon dioxide." ScienceDaily. ScienceDaily, 16 September 2019. <www.sciencedaily.com/releases/2019/09/190916110602.htm>.

[2] Zhang, C. H., et al. "Generation of DC corona discharge in supercritical CO/sub 2/for environment protection purpose." Fortieth IAS Annual Meeting. Conference Record of the 2005 Industry Applications Conference, 2005. Vol. 3. IEEE, 2005.

About RASAER Lab

RASAER Lab is primarily dedicated to investigating both fundamental and applied aspects of Plasma, Combustion and Advanced Thermofluids. Their work consists of modelling, simulations and experiments to understand important aspects of these research topics.

Contact Equilibar

Equilibar is a provider of unique and innovative pressure control solutions based near Asheville North Carolina. Equilibar's patented pressure regulator technology is used in a wide array of processes including catalyst, petrochemical, sanitary, supercritical and other industrial applications. For more information please contact an Equilibar applications engineer at inquiry@equilibar.com or 828-650-6590.

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