For immediate release: **July 15, 2018**

Zhengzhou University, China, uses Equilibar Back Pressure Regulator for Direct Synthesis of Hydrogen Peroxide

Hydrogen Peroxide (H2O2) is widely used in the chemical industry as an environmentally friendly oxidizing agent. In a weaker form, it is also popular as a household cleaner. The most common method for large scale hydrogen peroxide production uses a process called anthraquinone oxidation (AO). The AO process is a multistep method that requires significant energy consumption. In addition, it generates waste, which brings its sustainability into question.

Background

Direct synthesis is a new process being explored as an effective alternative to AO. Direct synthesis could produce H2O2 more cost effectively and sustainably than the traditional anthraquinone oxidation, enabling broader use of H2O2 for industrial oxidations. This direct synthesis reaction is usually carried out on supported catalysts in liquid solvent at temperatures ranging between 263 K to 293 K, and pressures ranging from atmosphere to 10 MPa. To date, although significant research has taken place, several aspects of direct synthesis remain unclear, including the reaction pathway, identity of active sites, and their catalytic consequences during O2 hydrogenation to H2O2. Dr. Weifeng Tu and his research team at China's Zhengzhou University are studying these topics.

The Challenge

The reactivity of O2 hydrogenation and the selectivity toward H2O2 formation on supported metal catalysts are a function of the individual pressure of the reactants (H2 and O2) and of the total pressure. One of the goals of the research is to measure changes in the selectivity of the reaction toward the formation of H2O2. Unstable total pressure of the reaction may cause significant noise in rate and selectivity measurements. Therefore, precise and consistent pressure control are extremely important to the research.

Dr. Tu's research team was using a traditional spring-loaded back pressure regulator in the process, but with this regulator in operation, the upstream pressure would always increase slowly with increasing flow rate of gas reactants. Additionally, with this type of regulator, the liquid solvent caused significant noise in the pressure of the reaction, resulting in imprecise data.

The Solution

Equilibar application engineers recommended a stainless steel LF1 regulator with Kalrez® O-rings and stainless steel diaphragm for Dr. Tu's reactor. The LF1 is part of Equilibar's Research Series back pressure regulators which are specifically designed for a variety of gas, liquid and mixed phase applications where precision performance is key, especially during wide variations in flow rates.

Figure 1:Equilibar LF1 back pressure regulator

Equilibar Research Series back pressure regulators are used in applications that involve low flow rates, extremely high pressures and other challenging laboratory scenarios.

By using unique combinations of diaphragm and O-ring materials, Equilibar regulators are able to perform with high accuracy even in the harshest environments, including those with high temperatures and aggressive chemicals.

Customer Feedback

The Equilibar® back pressure regulator, with its dome-loaded multiple orifice design and sensitive diaphragm, can maintain constant reaction pressure no matter how the flow rate of gas reactants or the liquid solvent are changing. The Equilibar's unique operation allows the unit to control over a wide Cv range, making it an ideal solution for mixed phase applications and varying flow rates. (See graph below).

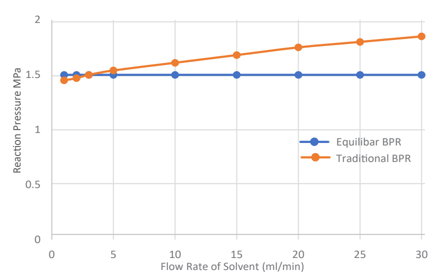

Figure 2: Graph of reactor pressure control at various flow rates with an Equilibar back pressure regulator versus a traditional unit

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The reaction of H2O2 formation was carried at pressure set-point of 1.50 MPa. As the flow rate of the solvent increased from 0.1 ml/min to 30 ml/min, the Equilibar LF1 unit provided a relatively stable pressure at 1.5 MPa with an error less than ±0.1%. By contrast, the traditional spring-loaded back pressure regulator caused the pressure in the reactor to increase from 1.45 MPa to 1.88 MPa over the same flow rate.

The schematic and photo below show the direct synthesis reactor system configuration. Reactant gas mixtures (H2, O2, and Ar) are introduced into the reaction system by mass flow controllers (MFC). The reaction solvent (DI water) is introduced to the system by using a high pressure liquid pump and mixed with the gas mixtures ahead of the packed-bed reactor.

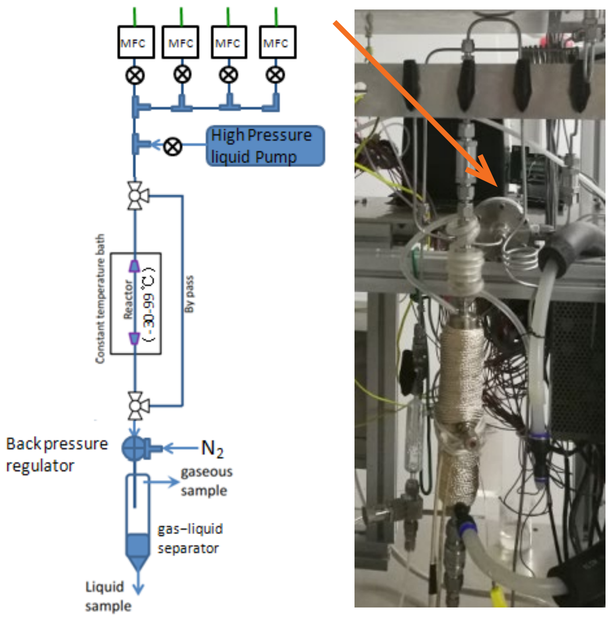

Figure 3: Direct synthesis reactor schematic and photo with an Equilibar LF1 back pressure regulator indicated by arrow.

The gas and liquid streams converge and mix within 120 cm of 1 mm I.D. tubing before flowing through the catalyst bed in an upflow configuration. The reactor pressure (0.1–5.0 MPa) is controlled using an Equilibar® LF1 back pressure regulator equipped with a stainless steel diaphragm. The entire system is shown below.

Figure 4: Equilibar unit installed in lab

About The Heterogeneous Catalysis and Engineering Research Center

The Heterogeneous Catalysis and Engineering Research Center at Zhengzhou University, China, studies rational design and controllable preparation of industrial catalysts. For more information visit www5.zzu.edu.cn/catalysis/.

Contact Equilibar

Equilibar is a provider of unique and innovative pressure control solutions based near Asheville, North Carolina. The patented back pressure technology is used in a wide array of processes including catalyst, petrochemical, supercritical and other industrial applications. For more information contact an Equilibar application specialist at *inquiry@equilibar.com* or call 828.650.6590.

About the Authors

Dr. Weifeng Tu is an Associate Professor at The School of Chemical Engineering, Zhengzhou University, China. Dr. Tu's research focuses on providing molecular solutions to develop catalytic conversion technology for meeting the challenges in the fields of environment and energy. Dr. Tu specializes in developing microchemical technology for water treatment, emission control, fuel processing, and heat generation. Specifically, he applies a multidisciplinary strategy that integrates materials synthesis, spectroscopy, electronic structure theory, and kinetic and isotopic assessments to deepen the fundamental understanding of physical and chemical events at molecular scale in chemical transformations, such as hydrogen peroxide formation, CO hydrogenation, alkanes oxidation or reforming, and more. For more information visit www5.zzu.edu.cn/catalysis/.

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