john crane
a smiths company

CCUS

Mission-Critical Sealing Considerations for CO_2 and sCO_2

Under the International Energy Agency's Sustainable Development Scenario, in which the energy industry's emissions fall to zero by 2070, nearly 15% of cumulative emissions reduction will stem from carbon capture, utilization and storage (CCUS). The IEA projects that CCUS' contribution to emissions reduction will only increase with time, driven in part by technological advances and reduced costs. Simply put, CCUS is a critical lever for decarbonization, especially for hard-to-abate sectors — and the number of such initiatives is on the rise.

Since January 2022, developers have announced 50 new capture facilities to be operational by 2030. Global capacity could reach NZE Scenario levels by 2030 if all announced CO_2 capture capacity projects are realized and the current growth trend continues. CCUS is experiencing an undeniable upward trajectory, and it leverages largely proven technology. Still, challenges persist. When it comes to CCUS sealing solutions, one of the most critical hurdles is carbon dioxide's supercritical phase (sCO_2). Beyond CCUS, supercritical CO_2 is also present in fertilizer plants and new CO_2 power cycles that harness the characteristics of sCO_2 to generate power with fewer emissions.

Luckily, market-ready dry gas sealing solutions are already helping CCUS operators navigate the unique properties of CO_2 and sCO_2. With a clear understanding of physical properties and the right proven partner, CCUS pioneers can accelerate their initiatives safely, reliably and sustainably.

CO_2 in the Atmosphere

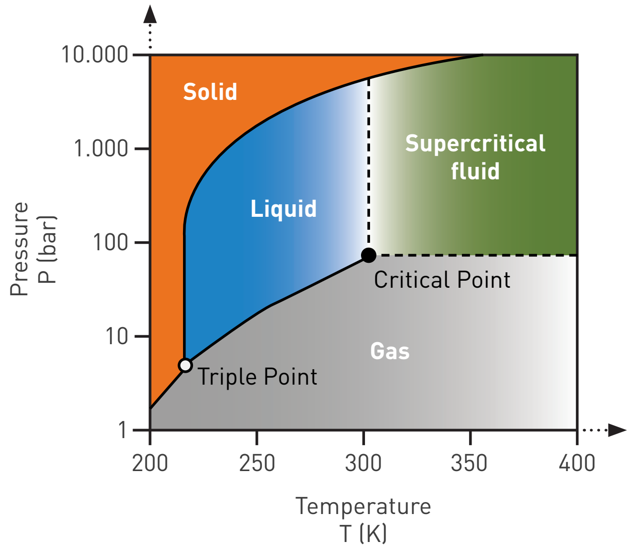
Carbon dioxide is well-known to us, but how does it relate to the air we breathe? Although CO_2 only represents a very small part of the Earth's atmosphere, data from the Mauna Loa Observatory shows that its concentration has increased 47% since the beginning of the Industrial Age — and 11% since 2000 alone.

Scientists know that this increase is caused primarily by human activities. Carbon produced by burning fossil fuels has a different ratio of heavy-to-light carbon atoms, which gives it a distinct measurable "footprint." Researchers have chronicled a decline in the amount of heavy carbon-13 isotopes in the atmosphere; this points to fossil fuel sources. Fossil fuels also deplete oxygen and lower the atmosphere's ratio of oxygen to nitrogen.

Physical Properties of CO_2 in its Supercritical Phase

As we learned all in chemistry class, there are three normal phases of matter: solid, liquid and gas. But CO_2 also has an extra phase — the supercritical or "dense" phase — in which there is no distinct definition between the liquid and gas phases. For sCO_2, the critical point between liquid and gas is approximately 74 bar at 31°C. The triple point, or the convergence of solid, liquid and gas, occurs around 5 bar at -57°C.

Gases have a lower density than liquids; in this sense, sCO_2 is more akin to liquid than gas. But from a viscosity perspective, this reverses, and the properties of sCO_2 more closely resemble a gas than a liquid. Navigating this dichotomy is critical to developing safe, reliable sCO_2 sealing solutions.



On a phase chart such as this one, you'll typically see dotted lines depicting a "breakpoint" among the different phases. However, these are purely theoretical. These sudden transitions do not exist, and numerous factors influence when and how a CO_2 phase change occurs.

Density

Supercritical CO_2 has a high density, but it maintains some compressibility. This makes it unique among dry gas seal applications. Operating near the critical point causes large variations in density with only minor changes in temperature or pressure. This dynamic is especially evident when comparing sCO_2 with an inert gas such as N_2, which is prevalent in dry gas seal applications and showcases less density variation when operating near 67°C.

Viscosity

Supercritical CO_2 has a high dynamic viscosity. As with density, its viscosity varies widely when operating near the critical point, with only minor changes in temperature or pressure.

When compared with N_2 near the critical point, CO_2 has a much lower kinematic viscosity — a viscosity measure that also accounts for density. Because of this, CO_2 would exhibit more leakage than N_2 through the same sealing gap. This is crucial when measuring seal performance. Another key consideration is viscous heating, which can pose a significant challenge in high-speed sCO_2 applications.

Churning Loss

Churning loss, essentially a power loss, is often overlooked in the quest for the ideal sealing solution. However, this is a critical consideration for seals involving high-speed, high-viscosity fluids such as sCO_2. When components rotate at speed with tight clearances, it generates a significant amount of heat in the seal. As the speed increases, so does the churning loss.

To address this challenge, John Crane has invested heavily in research that has helped our experts better understand the heat balance of the system that moves the dry gas seal, as well as its expected temperature differential.

Sealing Solutions for CO_2 and sCO_2

For nearly 30 years, John Crane has equipped CCUS operations with safe, reliable solutions. Our unrivaled track record includes a quarter-century of expertise in supercritical CO_2 sealing — one of the key barriers to scaling carbon capture deployment.

Our CCUS solutions include market-ready dry gas seal technologies that allow operators to seal CO_2 during its supercritical phase. These dry gas seals leverage our legacy of technology leadership, innovation and sustainability to address the complexities of sCO_2:

- It has a critical point of approximately 74 bar @ 31°C.
- It has a high density and viscosity but maintains some compressibility.
- When operating near critical point, minor changes in temperature and pressure can cause large variations in density and viscosity.
- Viscous heating is a key challenge for high-speed applications.
- Increased gas injection temperature can reduce the amount of heat generated. This is because increasing temperature reduces density, which means less effort is required to rotate the mass of fluid within the dry gas seal.
- Holding high pressures statically can lead to icing of the sealing interface, as expected sudden expansion of sCO_2 at the sealing interface inner diameter causes rapid cooling. This, in effect, has the potential of developing into a phase change for any water vapor present in the process gas.

For Process Fluid Close to the Vaporization Point: Type 28VL

Deployed mainly in pumps, the Type 28VL is utilized when process fluid is at, or close to, its point of vaporization. It harnesses the heat generated by the rotating machine shaft to "flash" the fluid as it passes the sealing interface. This changes the phase from liquid to gas, enabling the deployment of Type 28 non-contacting dry gas seal technology.

The Type 28VL delivers proven, market-ready performance, with hundreds of seals operating reliably in the field.

For the Gas or Supercritical Phase: Type 28AT, Type 28XP and Type 28EXP

These technologies are utilized when CO_2 is in either its gas or supercritical phase; the model deployed is based upon the pressure requirements of a given application. Used mostly in compressors, these technologies can operate at higher speeds than the Type 28VL.

Like the Type 28VL, the Type 28AT, Type 28XP and Type 28EXP are based on the Type 28 non-contacting dry gas seal technology and are performing reliably in operations worldwide.

Overcoming CO_2 Sealing Challenges With John Crane

John Crane was committed to sustainability long before net zero goals transformed our industry's approach to environmental impact. Today, we're continuing this legacy by helping operators around the world accelerate their CCUS progress. We're proud to provide market-ready sealing solutions that overcome the challenges posed by the unique properties of CO_2 in its supercritical phase.

Are you ready to navigate the energy transition with John Crane's CCUS pioneers? Get in touch with our experts. Together, we can shape a new energy reality.

john crane
a smiths company

smiths
bringing technology to life

North America	Europe	Latin America	Middle East & Africa	Asia Pacific
United States of America	United Kingdom	Brazil	United Arab Emirates	Singapore
Tel: 1-847-967-2400	Tel: 44-1753-224000	Tel: 55-11-3371-2500	Tel: 971-481-27800	Tel: 65-6518-1800