Pumps for CO_2 Sequestration and Supercritical CO_2 Research

Application Note

The Application

Geologic carbon storage and supercritical CO_2 research depend on injecting carbon dioxide into rock under carefully controlled pressure and temperature. In the laboratory, this work is done by flooding CO_2 — often together with brine — through a core sample held at reservoir conditions, then measuring how the CO_2 displaces the resident fluid, how much is trapped, and how the rock and pore fluids respond. The results feed directly into estimates of storage capacity, injectivity, and the long-term security of sequestered CO_2.

These experiments share much with conventional core flooding, but CO_2 adds challenges of its own. Carbon dioxide is highly compressible, it must be kept liquid or supercritical to behave like a reservoir fluid, and in the presence of brine it forms carbonic acid that attacks standard wetted materials. The pump is central to all of it:

- **CO_2 must stay liquid or supercritical.** Above its critical point (about 1,071 psi and 31 °C), CO_2 has the density of a liquid and the mobility of a gas. Holding the fluid in that state — and pre-cooling it for clean, bubble-free fills — requires both pressure and temperature control at the pump.
- **Compressibility demands a stable pump.** Because CO_2 changes volume sharply with small pressure changes, any pulsation or flow instability in the pump shows up directly in the differential-pressure record that the experiment is trying to measure.
- **Precise pressure, often near a phase boundary.** Storage conditions sit at high pressure, and many experiments run close to the critical point or sweep through it, so pressure must be held and changed with fine resolution.
- **Depletion and exsolution cycles.** Studies of trapping and leakage deliberately raise and lower pressure — depletion, imbibition, repressurization — and the pump must follow those profiles smoothly, in both directions.
- **Corrosive by nature.** CO_2 saturated brine is acidic, and CO_2-brine-rock reactions are part of what is being studied, so wetted materials must stand up to carbonic acid.

Why Vindum Pumps

For CO_2 work, the VIPR-Series syringe pump is the right tool. Its long syringe stroke and dedicated liquefied-gas seal give it the volume capacity and sealing needed to handle a highly compressible fluid like CO_2 — something a short-stroke metering pump is not designed to do well. (Our VP-Series metering pumps excel with liquids in other applications, but their shorter stroke and seal design make them a poor fit for compressible CO_2.) The VIPR-Series has been used in CO_2, reservoir, and energy research by major oil companies, national laboratories, and universities.

- **Purpose-built for CO_2 and liquefied gases.** The VIPR-Series carries an extra O-ring piston seal specifically for pumping liquefied gases such as CO_2, and an optional temperature-control jacket circulates cooled or heated fluid around the cylinder to pre-

cool incoming CO_2 and minimize phase changes during filling — the most common source of trouble when metering CO_2.

- **Continuous, pulse-free flow.** Vindum's patented constant-volume valves eliminate pulses at cylinder switchover. For continuous CO_2 injection, two VIPR-Series pumps are paired and run as a single dual-cylinder system: while one delivers, the other refills and pre-pressurizes, so flow continues pulse-free for days or months without stopping — essential when a single injection step can run for hours or longer and the differential-pressure signal must stay clean throughout.
- **Precision pressure control through the critical region.** A high-accuracy transducer (0.1% error) and 0.1 psi servo control let you hold pressure precisely and move through the CO_2 phase boundary in fine, programmable steps, at pressures up to 10,000 psi on the VIPR-Series.
- **Bi-directional pressure control for depletion cycles.** In addition to constant-pressure delivery and receipt, a pressure-bi-directional mode automatically switches between delivering and receiving CO_2 — without stopping — to hold a target pressure as the system pressurizes or relaxes. This is well suited to the depletion, imbibition, and repressurization cycles used in trapping and exsolution studies.
- **Automatic confining-pressure control (master/follower).** CO_2 core floods use one pump to set the pore (injection) pressure and another to hold the confining pressure around the core. VPware's master/follower feature ties the two together: designate the injection pump as master and the confining pump as follower, then set the confining pressure as a fixed differential or a percentage of the pore pressure, and the follower tracks it automatically as conditions change.
- **Built for carbonic acid and brine.** Optional Hastelloy C-276 wetted parts — backed by matching Hastelloy needle valves and Hastelloy C-276 tubing — stand up to the acidic, CO_2 saturated brines these experiments produce. For concentrated brines at low flow rates, the VIPR-Series built-in vacuum-driven wash system draws distilled water into the cylinder barrel below the piston to help prevent salt deposits from forming on the cylinder surface.
- **Relative permeability and capillary measurements.** Our optional Recirculation software add-on is used to determine relative permeability curves, including 2-phase (CO_2-brine) and 3-phase systems — central quantities for predicting CO_2 migration and trapping. Recirculation is sold separately from the included control software.
- **Data you can trust.** VPware logs any pump parameter at intervals as fast as 50 milliseconds, with real-time graphing and full data export, so the injection record lines up with your CT, NMR, or saturation measurements.
- **Designed to fit the bench.** Vindum pumps have an unusually compact footprint for continuous-flow pumps, which matters on crowded CO_2 core-flood rigs that already carry core holders, back-pressure regulators, heaters, and imaging equipment.

Recommended Configuration

A typical CO_2 sequestration core flood uses a pair of VIPR-Series pumps for continuous CO_2 injection, a brine pump (a VP-Series metering pump works well here), a confining-pressure

pump, and back-pressure control — all held at reservoir temperature. Vindum pumps cover each of these roles.

Need	Recommended Vindum solution
Continuous CO_2 or supercritical CO_2 injection	A pair of VIPR-Series syringe pumps (two are required for continuous, pulse-free delivery of compressible fluids)
Keeping CO_2 liquid for clean, repeatable fills	VIPR liquefied-gas piston seal plus temperature-control jacket to pre-cool and stabilize the cylinder
Holding reservoir pressure above the CO_2 critical point	Constant-pressure mode with 0.1 psi servo control; VIPR-Series models to 10,000 psi
Depletion / exsolution and repressurization cycles	Pressure-bi-directional mode — the pump delivers or receives automatically to hold pressure through the cycle
Reservoir-temperature (HPHT) conditions	HT versions of the VIPR-Series (CO_2) and VP-Series (brine) operate with fluids to 160 °C; VIPR temperature-control jacket pre-cools or stabilizes incoming CO_2
Brine, carbonic acid, and CO_2-brine-rock corrosion	Hastelloy C-276 wetted parts, Hastelloy needle valves, and Hastelloy C-276 tubing
Concentrated brines at low flow rates	VIPR-Series built-in vacuum-driven wash system, to prevent salt buildup on the cylinder
CO_2 / brine relative permeability and capillary curves	Optional Recirculation software add-on (2- and 3-phase)
Automatic confining (overburden) pressure	VPware master/follower control, with confining pressure set as a differential or percentage of pore pressure

VPware and all of our pump-control software — including Modbus, DDE, a DLL, and a LabVIEW Instrument Driver — are provided free with every pump. The same VPware software controls up to 16 Vindum pumps from a single PC (VIPR-Series for the CO_2 side, with VP-Series metering pumps available for liquid duties such as brine), and the pumps also support OPC UA and analog/digital control at no extra charge. The pumps communicate over USB and RS232, and the RS232 port can be placed on an Ethernet network using a serial-to-Ethernet converter, so they integrate cleanly into custom and automated CO_2 core-flood and high-pressure systems.

In the Field

Researchers studying CO_2 storage, supercritical CO_2 flooding, and reservoir behavior have relied on Vindum pumps for their combination of pulseless flow, precise pressure control through the critical region, liquefied-gas capability, and small footprint. The pumps are in service at national user facilities, major oil and petrochemical companies, and university research labs worldwide — a track record that spans more than thirty years.

> *"I work in oil and gas, with a recent focus on carbon capture … where we need very high accuracy at low flow rates."* — Quinton Gill, Research Technologist. Read the testimonial

Talk to Us About Your CO_2 Setup

Every CO_2 rig is a little different. Tell us your pressure and temperature range, whether you are working below or above the critical point, your flow rates, your fluids, and how you'd like to control the system, and we'll help you select the right pump configuration — and, where available, arrange a loaner pump so you can evaluate Vindum performance in your own lab.

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