# Portfolio Hy Dinh

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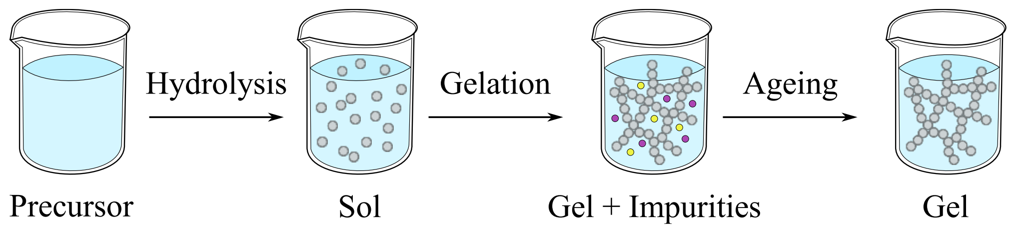
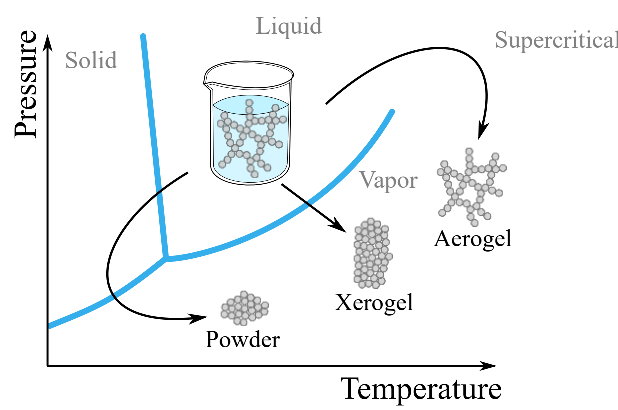
## Silica Aerogel

Aerogel is a versatile class of low-density, high surface area, adjustable surface chemistry, nanoporous material attractive for a wide range of applications, including thermal insulation, light-weighting of transportation, catalyst and use as an adsorption medium in environmental remediation.

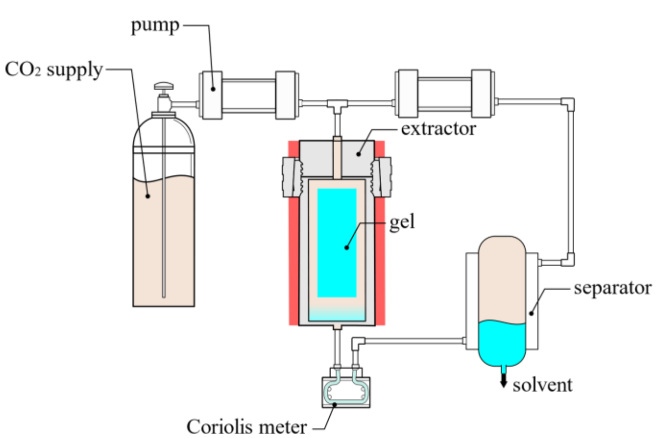



Aerogel synthesis: sol-gel method

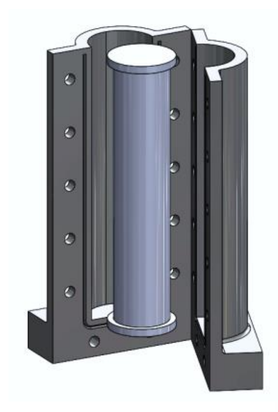
- Gelation: React silicon alkoxide, say, with water to form solid silica skeleton with alcohol-filled pores (alcogel).
- Aging: Increase alcogel strength by soaking at elevated temperature – continued hydrolysis and condensation, Ostwalt ripening and syneresis.
- Drying: Replace pore liquid with gas without damaging the silica structure.

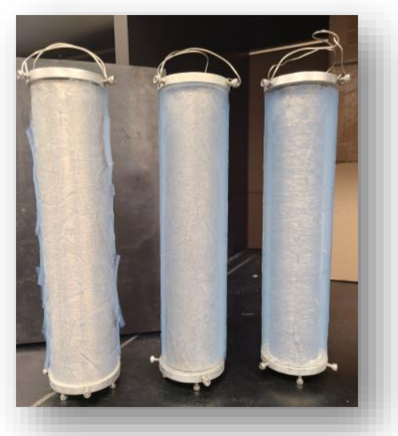



Aerogel drying methods




Simplified schematic of a representative SCCO2 extraction rig





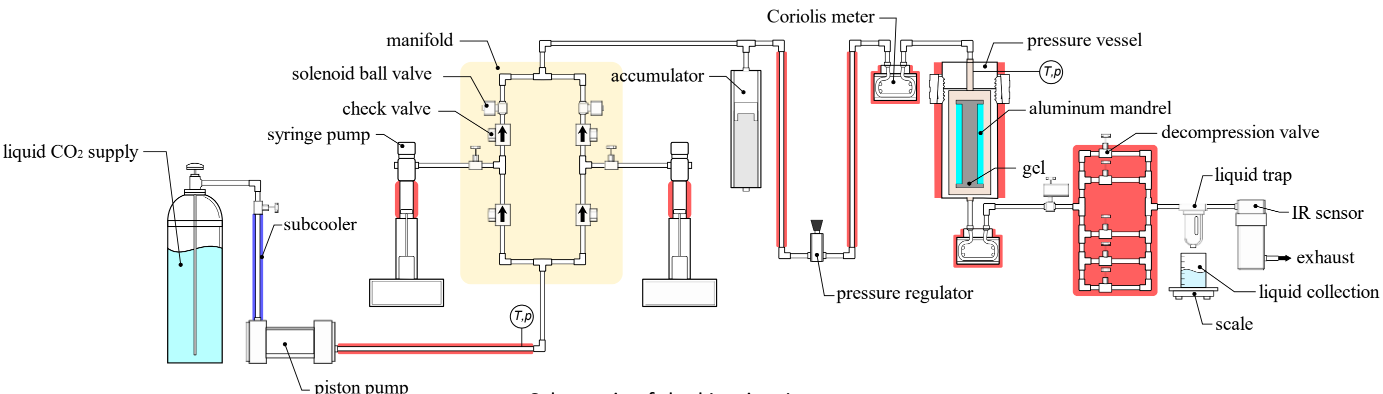
Gel mold and silica aerogels of various thicknesses

During aerogel manufacture, first, an alcogel, i.e., porous nanoskeleton filled with alcohol, is synthesized via a sol-gel process. The alcohol must be removed (i.e., the aerogel must be "dried") without damaging its delicate porous nanoskeleton via capillary forces to convert it into an aerogel. Slow, diffusion-limited mass transfer during drying is a key barrier to aerogel's widespread adoption. Development of cost- and energy-efficient aerogel manufacture requires an in-depth understanding of the underlying drying mechanisms.

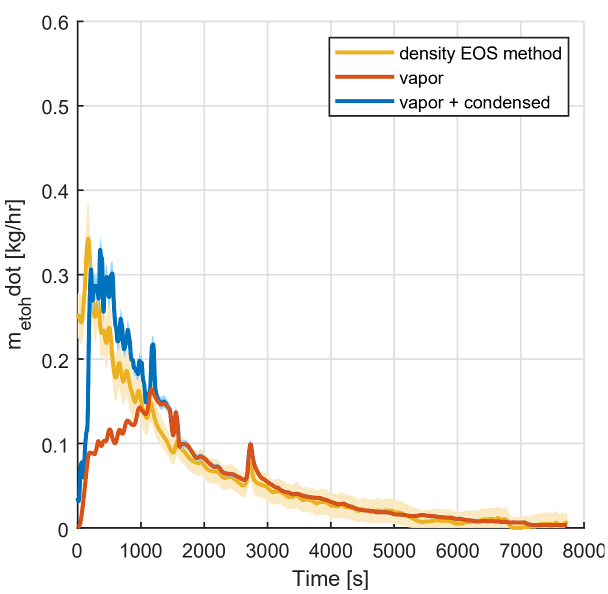
## Supercritical CO2 Drying

Designed and constructed an experimental apparatus (kinetics rig) to measure continuous rates of alcohol extraction from SCCO2 drying of aerogels using 2 independent methods:

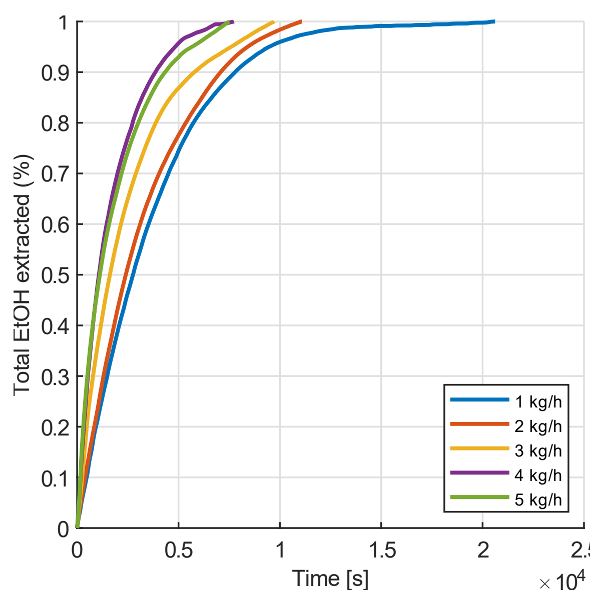
- Total mass flow rate of ($CO_2$ + EtOH) effluent ($\dot{m}$) measured by downstream Coriolis meter and, after decompression, liquid-component of two-phase mixture is continuously weighed on a scale and mass fraction of EtOH in vapor measured by infrared hydrocarbon sensor.
- Measure total effluent mass flow rate and mixture density ($\rho$) with downstream Coriolis meter and based on known equation-of-state $\rho(m_{\mathrm{EtOH}}, T, p)$ and measured $T$ and $p$, compute $m_{\mathrm{EtOH}}$ in effluent. Then, $\dot{m}_{\mathrm{EtOH}} = m_{\mathrm{EtOH}}\dot{m}$.




Schematic of the kinetics rig



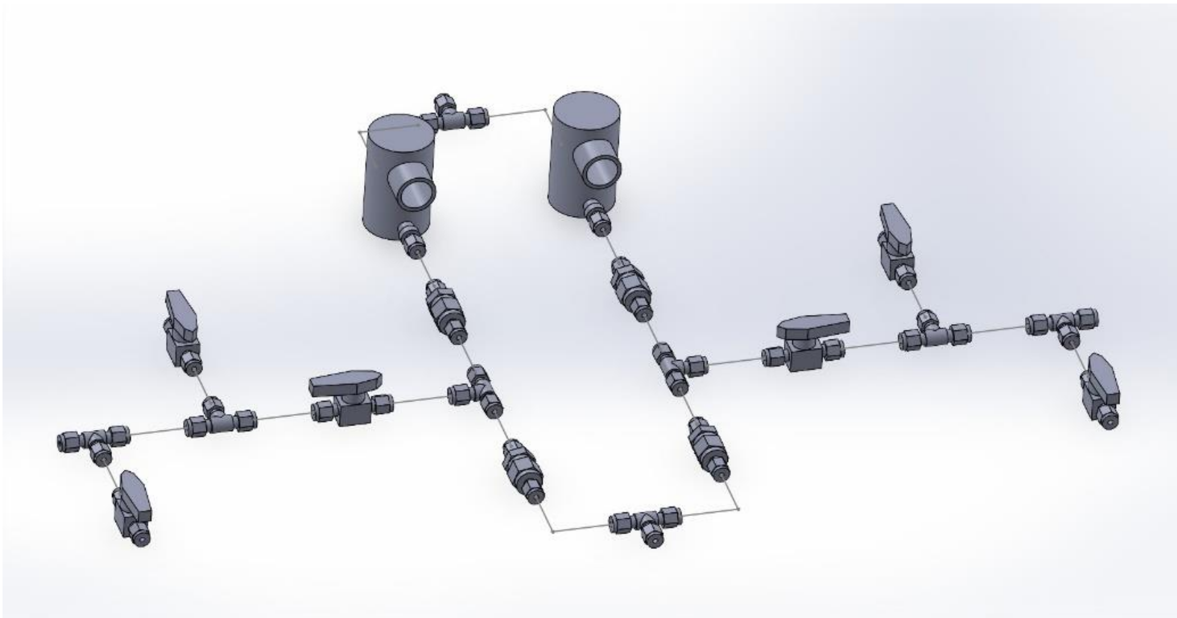

Extraction rates for 7.5 mm-thick annular gel at 4kg/h SCCO2 mass flow rate.




Extraction rates for 7.5 mm-thick annular gel at increasing mass flow rates.

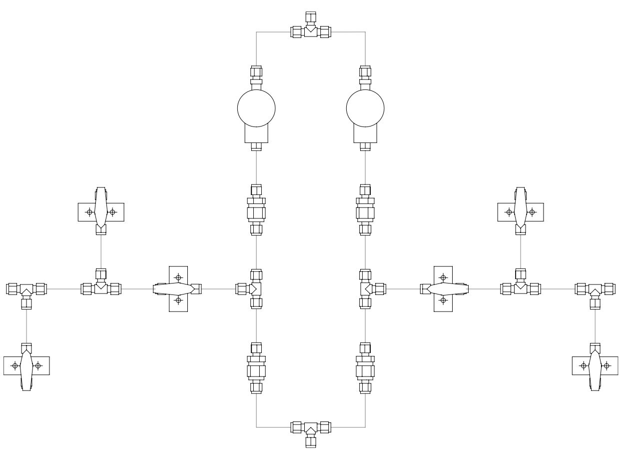
## Dual-pump Continuous Flow System

- Built an H-bridge valves manifold to enable continuous flow using 2 Teledyne ISCO syringe pumps
- Designed the manifold consisting of one-way valves, solenoid valves, ball valves, and fittings in SolidWorks



Manifold design in SolidWorks

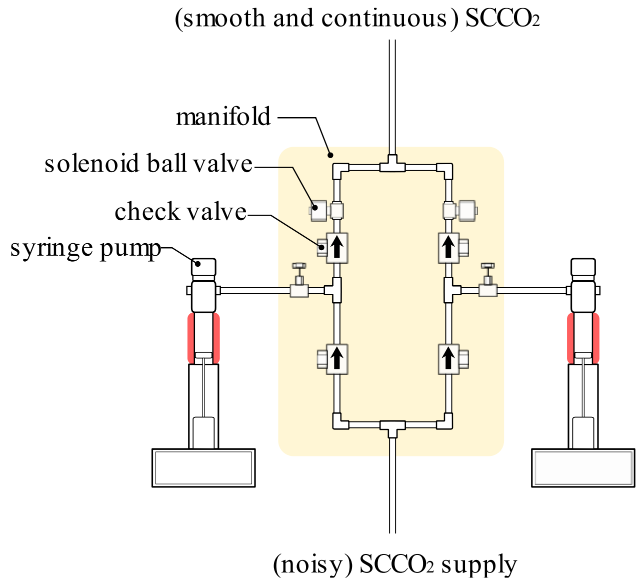
- Created a layout for the manifold assembly



Component layout as designed and pre-assembled

- Cut an aluminum base using a jump shear and machined fixtures for the valves and regulators
- Assembled and connected the manifold to the syringe pumps, finalizing the flow path

Assembled manifold




Schematic of the dual-pump system

- Programed a state machine in LabVIEW to control the pumps and manifold such that when a pump is running at a set pressure/flow rate, the other pump is set to refill and waits on stand-by until the first pump is empty. Then, the second pump switches over to provide a smooth and continuous flow.

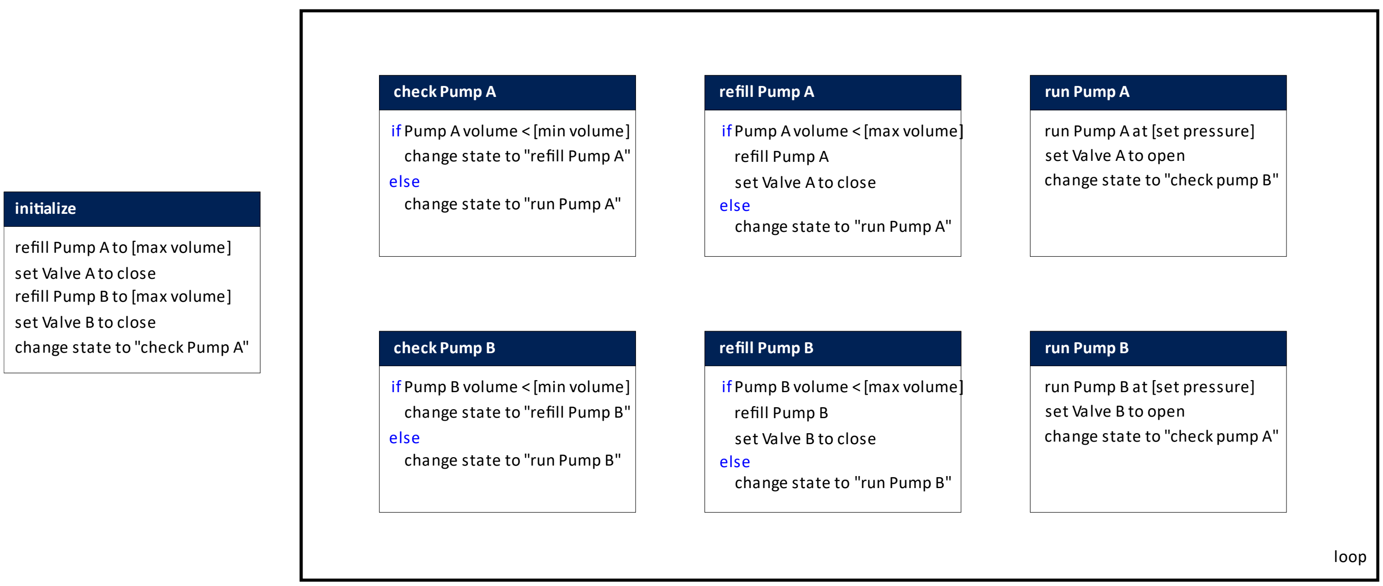
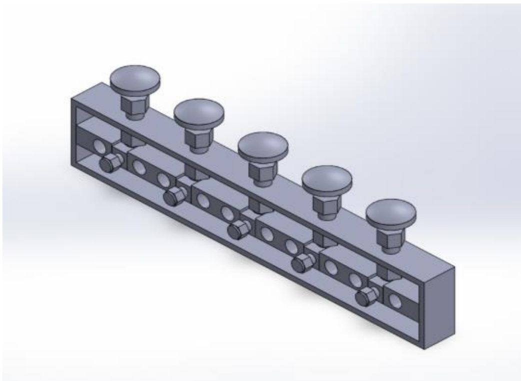
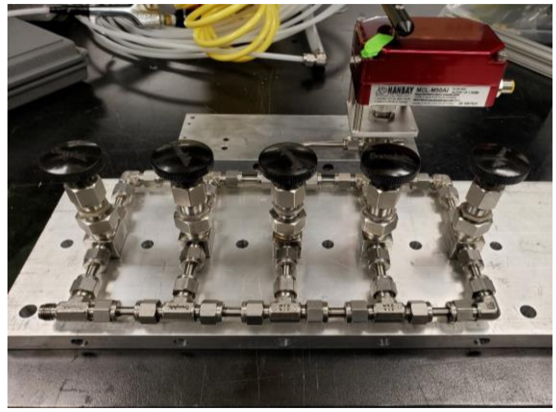



Diagram of the state machine

## Decompression Valves

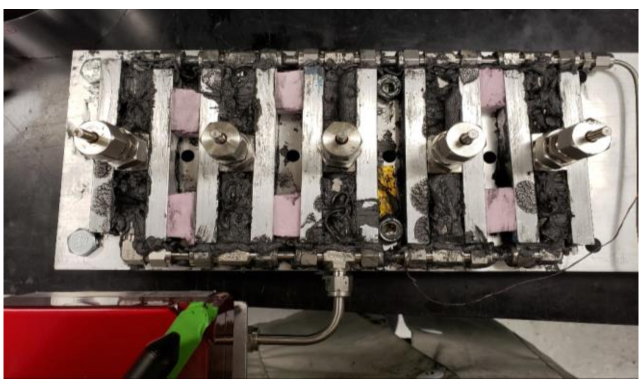
- Designed and constructed a heated and automated valve system to prevent decompression valves from freezing due to the Joule-Thomson effect when $CO_2$-ethanol solutions expand from 1800 psi to ambient pressure

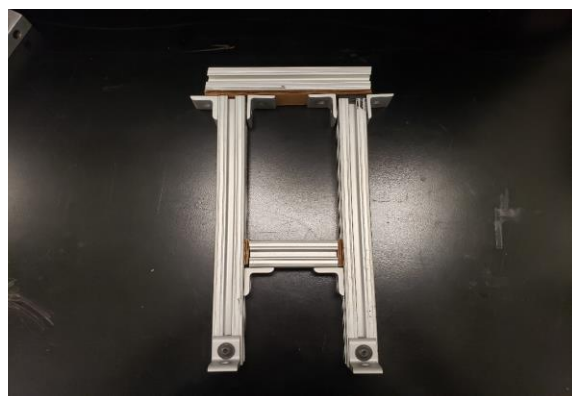
Initial design of the decompression valves in SolidWorks and actual photo

- Completed thermal testing of the initial design to adjust the appropriate thermal mass of the heater block and contact area to increase heat transfer

- Filled the gaps between the valves and heater block with thermal grease and assembled a mounting leg



Revised decompression valve assembly



Mounting leg

- Insert 5 cartridge heaters (1000 W in total) into the heater block and attached a thermocouple as the sensor of a closed loop temperature control

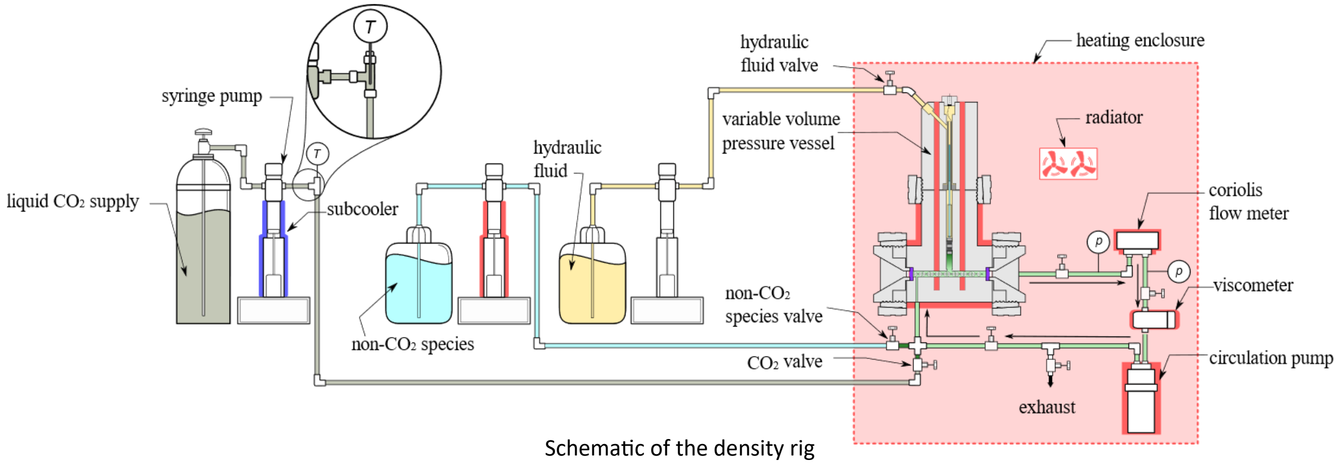
- Attached an automated (red) needle valve to regulate the CO2 mass flow rate (measured by a Coriolis meter)

- Eliminated freezing issue at highest operating flow rate (5 kg/h)

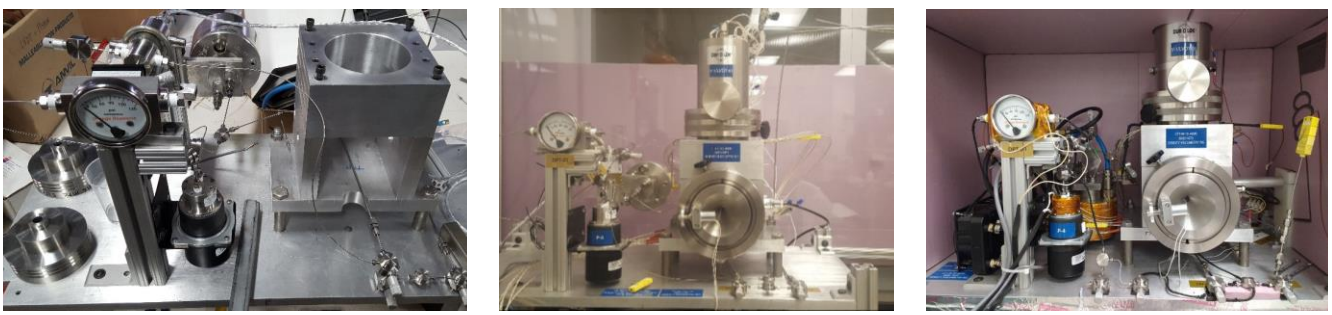
Assembled decompression valve system

## Density Rig

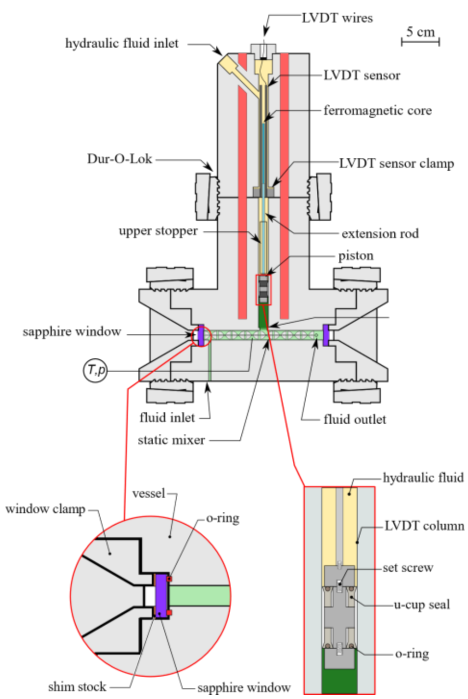
- Designed and constructed an apparatus (density rig) to measure thermophysical properties of binary (and higher order) fluid mixtures at up to 80 °C and 2500 psi.




Schematic of the density rig



Progression of the density rig: fixture + heater blocks (left), assembled vessel with circulation loop (middle), density rig inside heating enclosure (right)



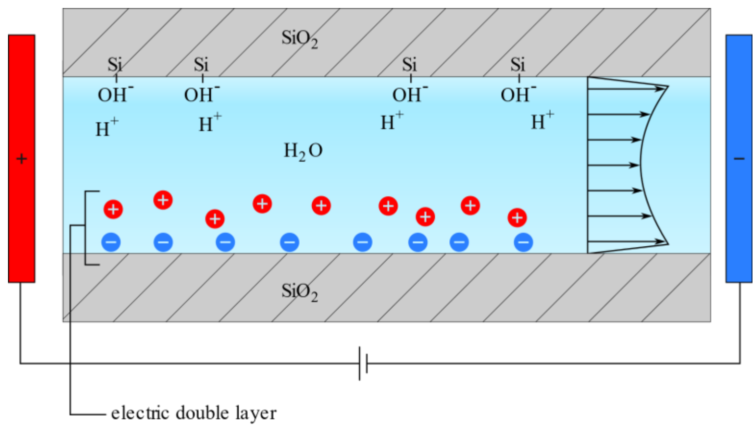

Schematic of the pressure vessel and seals

- The test section is pressure vessel with a piston traversing vertically to vary its volume.
- The piston has Teflon U-cup seals on its upper and lower ends to isolate the CO2-EtOH mixture from the hydraulic fluid.
- Optical access is enabled by sapphire windows (1 in diameter) at each end of the vessel. O-ring seals between the windows and the fluid side of the vessel are made from buna-N to minimize swelling and blistering observed with other seals upon decompression.

## Electroosmosis-enhanced Ageing of Aerogels

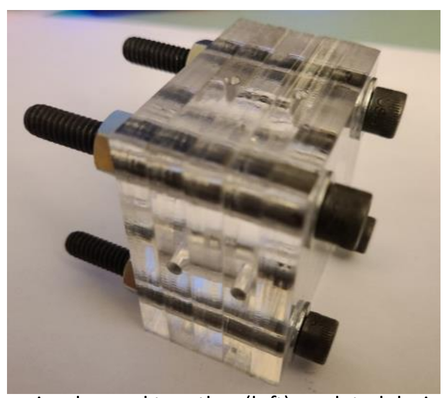
- An electric double layer naturally forms along the inner periphery of a polar-liquid-containing tube due to deprotonation of the surface silanol groups. The $OH^-$ ions in the water are pinned to the wall of the tube via interaction with the silica and the corresponding $H^+$ ions are mobile.

- The application of an electromotive force drags the positive ions in the direction shown. The external potential difference applied across the tube induces a Coulomb force on the mobile $H^+$ ions. They drag along the neutral water molecules in the middle section of the channel, resulting in a flow with the highest velocity near the wall the and, thus, a plug-like velocity profile as opposed to that of a pressure-driven flow, which is parabolic.



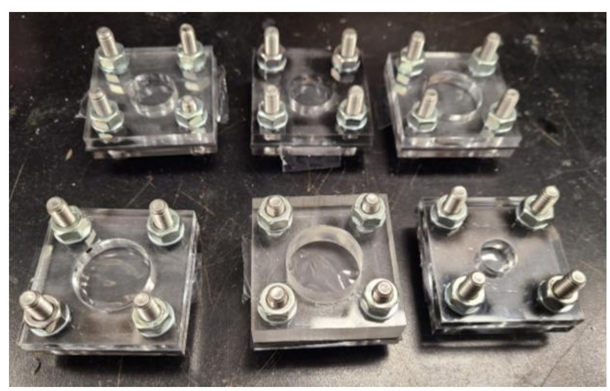

Representative diagram of electroosmotic flow

- An apparatus was designed and constructed to generate EO flow across an alcogel

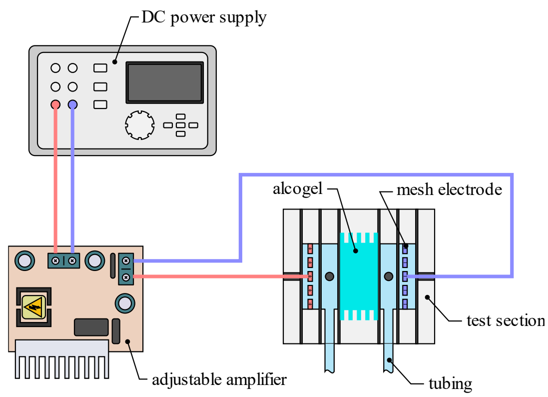




Progression of the apparatus: initial design with separated reservoirs clamped together (left), updated design with laser cut acrylic plates (middle), disassembled apparatus showing the electode (right)

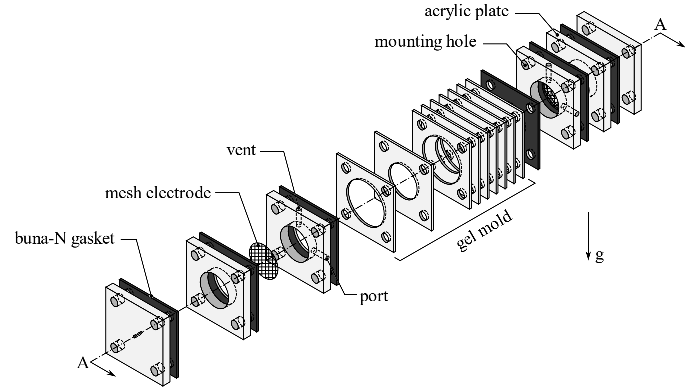
- The gel mold is comprised of nine 1/16 in acrylic plates with 1.3 in and 1 in center holes alternatively stacked and cemented together. When an alcogel is formed using this mold, a lip is created at each layer forming a hermetic seal between the gel and the mold.



Alcogel molds

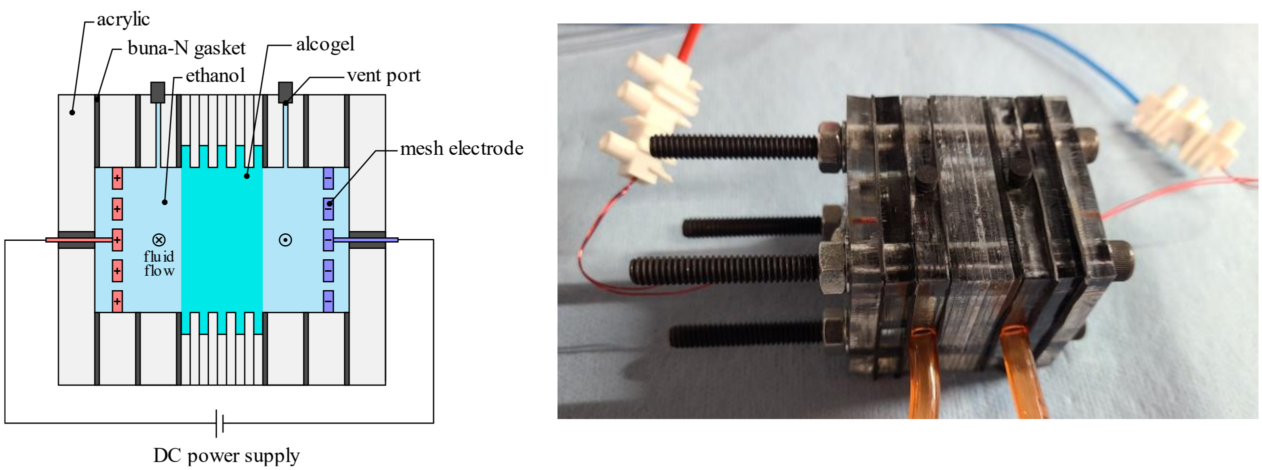



Schematic of the apparatus



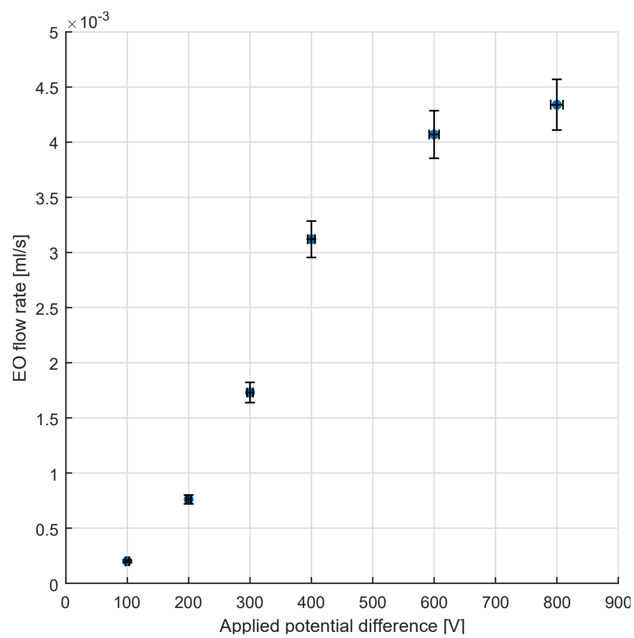

Exploded view of the test section

- Ethanol was charged inside the test section and residual air vented through the vent ports.
- Electroosmotic flow was generated at varying potential difference up to 800 V.




Schematic and photo of the test section

- An apparatus was constructed to successfully generate an electroosmotic flow through an alcogel. Experimental results indicate that new founded advection can significantly reduce the time-consuming diffusion-limited solvent exchange process to, potentially, minutes.




Measured EO flow rate vs. applied voltage