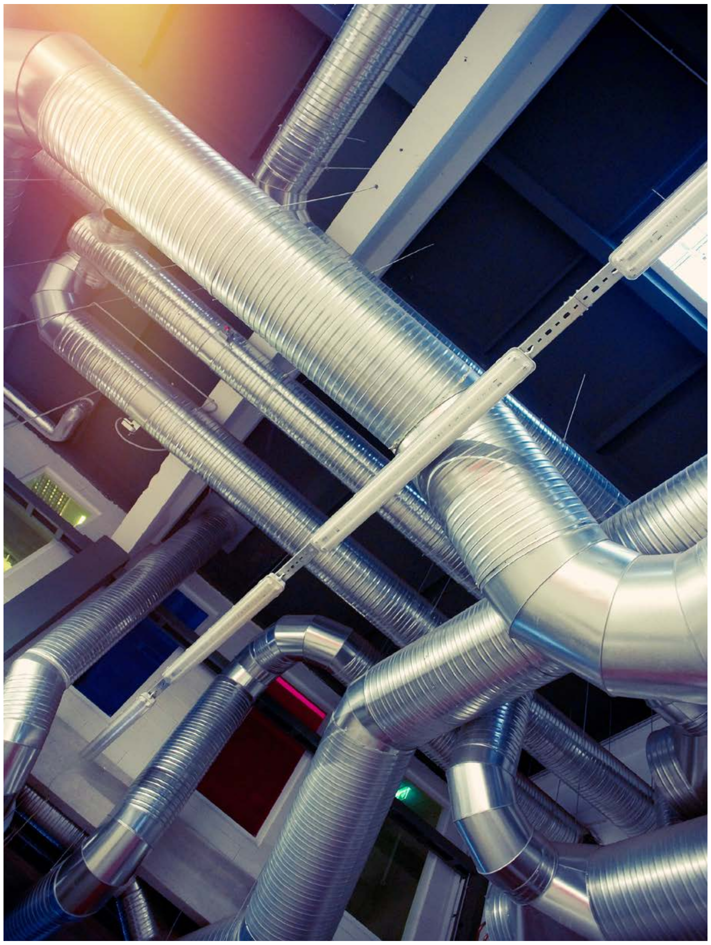
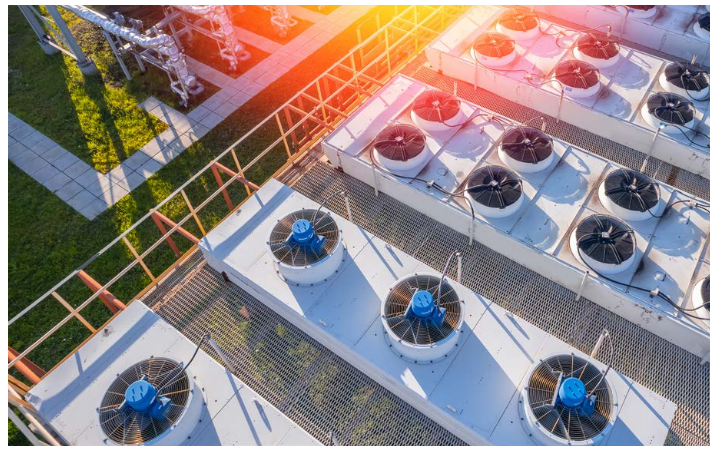




Profile of Dr. Chris Seeton: How CVI's technology helps to transition the refrigerant and natural gas industries toward a cleaner future

The history of equipment specifically created for refrigeration goes back centuries – as early as the 17th century, when people began to notice that a salt and water mixture had cooling properties. The concept of artificial refrigeration was invented by William Cullen at the University of Glasgow in 1748, and was patented by Thomas Moore in America in 1793. In 1931, Thomas Midgley, Jr. developed Freon-12, a safe, powerful, non-flammable refrigerant – and for the next 50 years, chlorofluorocarbons were used in air conditioners and refrigerators around the world.

Until, in 1985, an ozone hole was found above Antarctica. By 1987, the world was on a mission to stop the ozone hole from becoming larger by reducing CFC consumption by 50% over the next 10 years.

Just a few years later, a young man named Chris Seeton graduated from Georgia Institute of Technology in 1995 with a BS in mechanical engineering, and started his career at a small refrigerant chemistry house started by Dr. Hans Spauschus, where, he says, they were "six people big and a powerhouse in compatibility of refrigerants, lubricants, and refrigeration systems – particularly the changeover from CFCs and HFCs." It was at this company that Seeton was first introduced to viscometers and high-pressure viscometrics, and used his first Cambridge Viscosity viscometer for refrigerant testing.

Since those early years, Chris Seeton has become an expert in the compressor/refrigerant industry. Today, he has the notable distinction of being the person who won the first battle that allows new low global warming refrigerant regulations to come into effect by serving as the Global Technology Leader at Honeywell and leading the industry's effort to replace R134a with R1234yf which came to fruition in 2015 (an EPA CAFÉ credit of 13.8 gCO_2/mile or ~3 mpg per vehicle by just changing the refrigerant). Even today, he continues to drive change in the industry by leading two cooperative research project groups through SAE on developing new heat pump systems for electric vehicles.

Cambridge Viscosity

Profile of Dr. Chris Seeton

"Introducing any refrigerant," Seeton said, "requires you to understand that it's not about the chemical, it's about how the system works. And the system isn't just geared around the refrigerant. You also have heat exchangers that need to be designed correctly, compressors that need to be efficient over wide operation ranges, and controls that need to be smart enough to work in Minnesota defrost/defog conditions while providing AC in the event the owner wishes to drive through Death Valley in the summertime. A critical part to figuring all of this out is knowing what characteristics we need from the lubricant to maximize compressor efficiency and lifetime. That's why knowing the measured viscosity over a very wide range of temperatures and pressures is so vitally important and the Cambridge viscometer designs allow for these measurements."

It was in the early 2000s, while Seeton was working on his Ph.D. thesis at the University of Illinois Urbana-Champaign where he first developed what he refers to as "the system," which is designed to measure the thermophysical properties of refrigerant-lubricant mixtures. The entire system operates on a recirculation method utilizing a vibrating-tube densimeter for mixture density measurements, a Cambridge Viscosity oscillating piston viscometer for mixture viscosity measurements, platinum RTDs for temperature measurements, and a precision strain-gauge pressure transducer for solubility measurements.

What is novel about Seeton's system is that he can analyze the complete refrigerant/lubricant combination's operating range (normally from -40˚ to 130˚C and pressures up to 350 bar (5000 psi) in a week's time, while a traditional analysis could take months. By being able to automate the measuring metrics, Seeton not only completes the analysis faster, but he can also more accurately control and interpret the data.

While the ViscoPro in his original test system used a 571 sensor, over the years, he's come to prefer the 372 sensor, due to its ability to work in extended pressures up to 5000 psi.

Seeton said, "The form factor of the 372 sensor really lends itself to a flow-through design. I currently have three running in parallel at the same time. It's one of my secrets to how I'm able to measure from 2000 centistokes, down to half a centistoke, just by offsetting the three different viscometer ranges in a single temperature sweep."

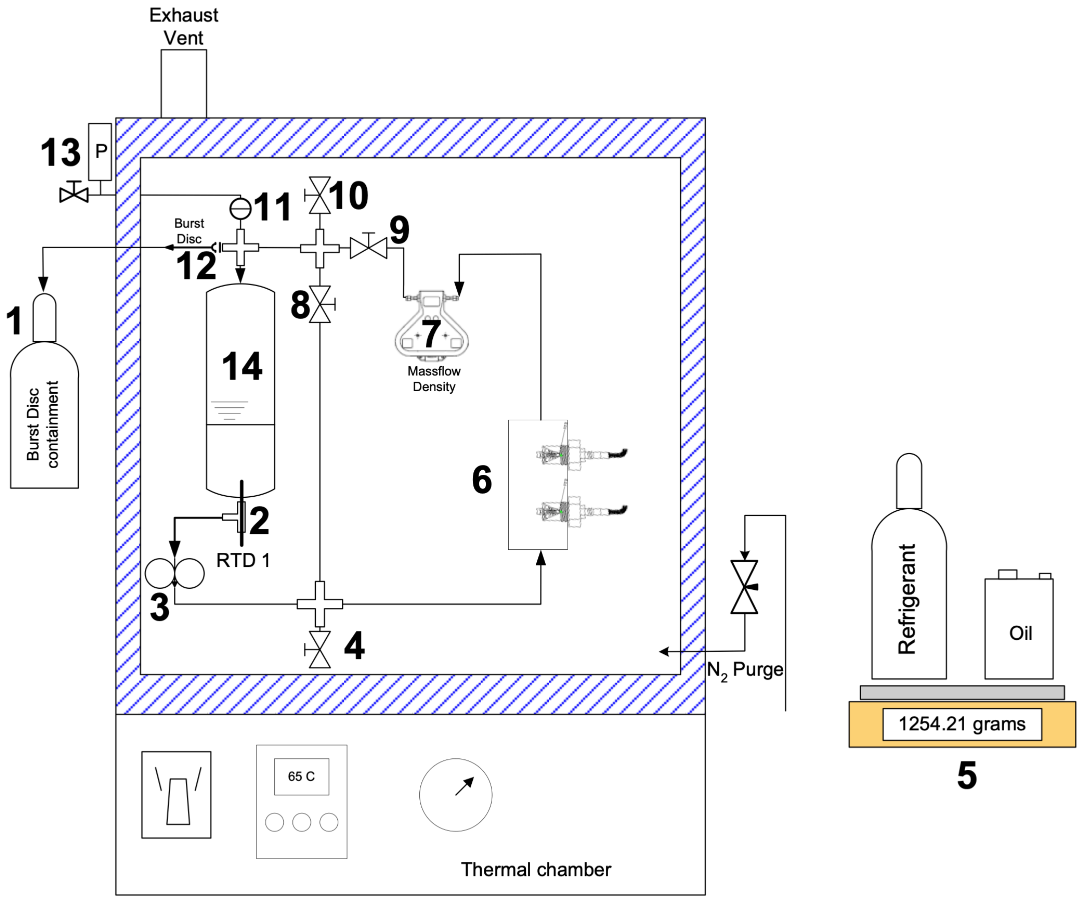
In the beginning," he mentioned, "when I could only afford one viscometer, I'd have to charge the system and get the high viscosity measurements. Then I'd have to clean it all out, put in the other piston, run the medium viscosity points, take it out, clean it, and run the low points, so it took a lot of time. Today, by running three units in parallel, I can do all the measurements in one go."

Seeton has a funny story about why he began to use viscometers in his research and development work. While working on his thesis for his PhD, he had a small lab set up in the basement, which just happened to be under his new baby's bedroom. Through the course of his experiments, the glass density cell he was using exploded when he was testing high-pressure CO_2 at ~2000 psi – and woke the baby. His wife, understandably, told him to find a different experiment that wasn't prone to exploding in their house. He ended up with the flow loop using the flow through 372 Cambridge Viscosity's viscometer design coupled with a Micro Motion density meter.

"And I owe it all to my wife," said Seeton, "who challenged me to find a different method to get the data I needed and do it safer."

"The great thing about this method and the ViscoPro 2100 viscometer with a 372 sensor in particular," Seeton continued "is that the data that is produced is actually useful for engineers. It gives the data at the right accuracy level, in the right timing, and at the right cost required by the industry to make decisions to go forward in design and testing."

What it comes down to, according to Seeton, is identifying the "why of a problem". "Why" is a system behaving the way it is, and what corrective actions need to be done to solve the problem. And that's exactly what his system does – by quickly experimentally testing the lubricant with the gases of interest at the operating parameters one can understand "why" a compressor or plant may be malfunctioning and how to proceed to fix it. "After all," Seeton said, "while many seem to believe lubricants are magic, that is simply not the case when the mysteries are understood."



Thermophysical Property Test System Schematic from Seeton's thesis. 1. Burst disc containment vessel; 2. Bulk fluid RTD; 3. Variable speed gear pump; 4. Liquid filling valve; 5. Balance; 6. Oscillating piston liquid viscometers; 7. Vibrating tube densitometer/massflow meter; 8. Circulation valve; 9. Circulation valve; 10. Gas filling valve; 11. Pressure diaphragm seal; 12. Burst disc; 13. Pressure transducer; 14 Bulk fluid reservoir

Seeton's method has saved companies tremendously. For example, on a fracking operation, where all calibers of hydrocarbons make it topside and to a heater treater to seperate the water and crude oil from the gases – methane, propane, ethane, butanes, pentanes, all the way up to octane and light gasoline routinely cause damage first stage compressors. Before these NGL streams were recognized to have significant value, teams once referred to these hydrocarbons as trash gas because they would actually trash the equipment as mineral oil lubricants were used. One small company in particular had a $3M annual budget for compressor replacement as they were using mineral oils in a high NGL/BTU gas stream. With his system, Seeton could help them identify the right lubrication oil for their equipment and application, which keeps the compressors from failing and needing to be replaced.

"And, that company with the $3M compressor budget," Seeton circled back, "hasn't had to replace a compressor since switching to a proper lubricant after we completed the viscosity testing."

If you'd like more information on Cambridge Viscosity sensors, or the proven system Dr. Chris Seeton has developed over the past 15 years, visit the Cambridge Viscosity website at **https://cambridgeviscosity.com**.