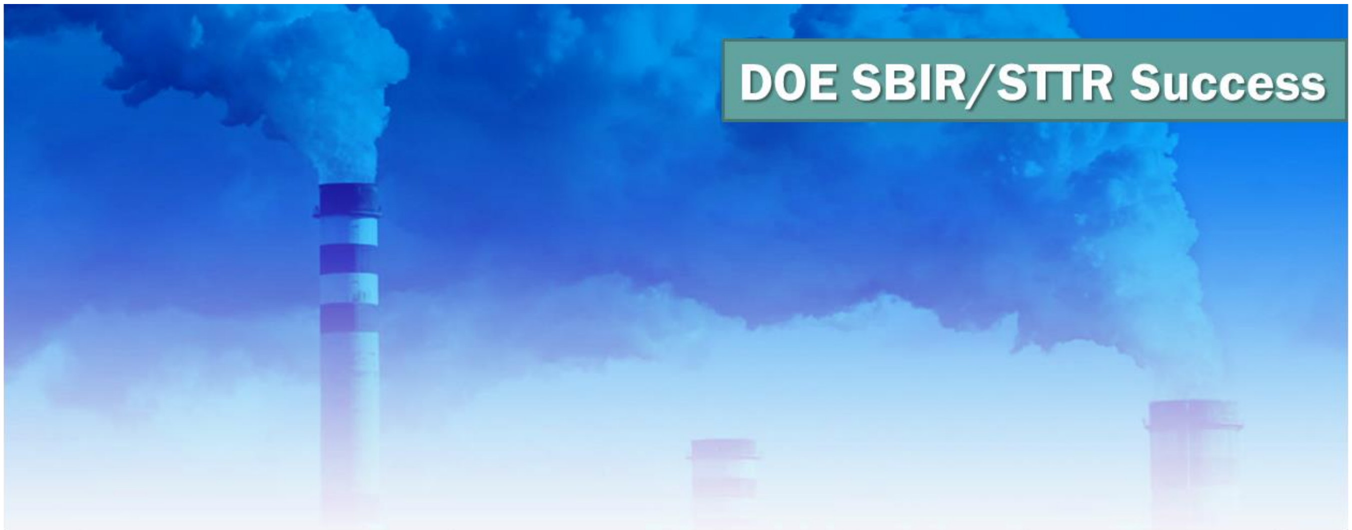
SBIR·STTR
America's Seed Fund

U.S. DEPARTMENT OF ENERGY | SBIR/STTR Programs Office



ION ENGINEERING LLC.

ION Engineering (ION) was formed in 2008 following an unexpected encounter between Dr. Alfred "Buz" Brown, an entrepreneur with years of experience in leading early-stage technology companies, and a team of postdocs at the University of Colorado, Boulder, CO. The team of scientists, led by Dr. Jason Bara, had developed an idea about how to drastically improve the removal of carbon dioxide (CO_2) from industrial sources. Dr. Brown's business experience with startups and technical aptitude for identifying transformational technologies, combined with commitments from Dr. Bara and his technical team, resulted in the formation of ION in 2008. From its initial beginnings, ION's mission has been to develop novel, proprietary liquid solvent technologies for the capture of CO_2 from power plants, refineries, and other industrial sources more efficiently and at lower costs than commercial alternatives.

FACTS

PHASE III SUCCESS
ION secured a $2.6M Phase III project from the U.S. Department of Energy's Carbon Capture Program implemented at the National Energy Technology Laboratory. The required 20% matching funds were provided by ION's industrial partners.

IMPACT
Based on additive manufacturing (AM) or 3D printing technologies, ION's innovation is expected to drive large scale deployment of post-combustion carbon capture by making it cost-competitive.

DOE OFFICE/PROGRAM
Office of Fossil Energy (FE), Carbon Capture Program.

www.ion-engineering.com
3052 Sterling Circle, Boulder, CO 80301-2338

Dr. Brown and his team also recognized early on that carbon capture was not a developed market in the U.S. and that industrial commercialization at an industrial scale that would be sufficient to impact greenhouse gas emissions globally would require significant involvement from the U.S. DOE. The team also recognized that in order to create commercial opportunities, as well as to secure government funding, strong industrial collaborations with both end users as well as service providers would be required. To date, ION's collaboration partnerships have included industry leaders such as Chevron, BP, and Shell, utility operators such as Nebraska Public Power District and Tri-State Generation and Transmission Association, and others. As Dr. Brown explains, "collaboration partnerships have provided ION access to multi-disciplinary expertise in the chemical engineering, energy, plant design, construction, and simulation modeling fields to develop our proprietary CO_2 capture solvent technology." With the assistance of its collaboration partners, ION has successfully tested its solvent technology at increasing scales at the University of North Dakota Environmental and Energy Research Center (EERC) and the National Carbon Capture Center (NCCC), in the U.S., and has most recently completed testing at the Technology Centre Mongstad, an existing 12 MWe test facility in Norway as part of a joint U.S. DOE and Norwegian-funded collaboration.

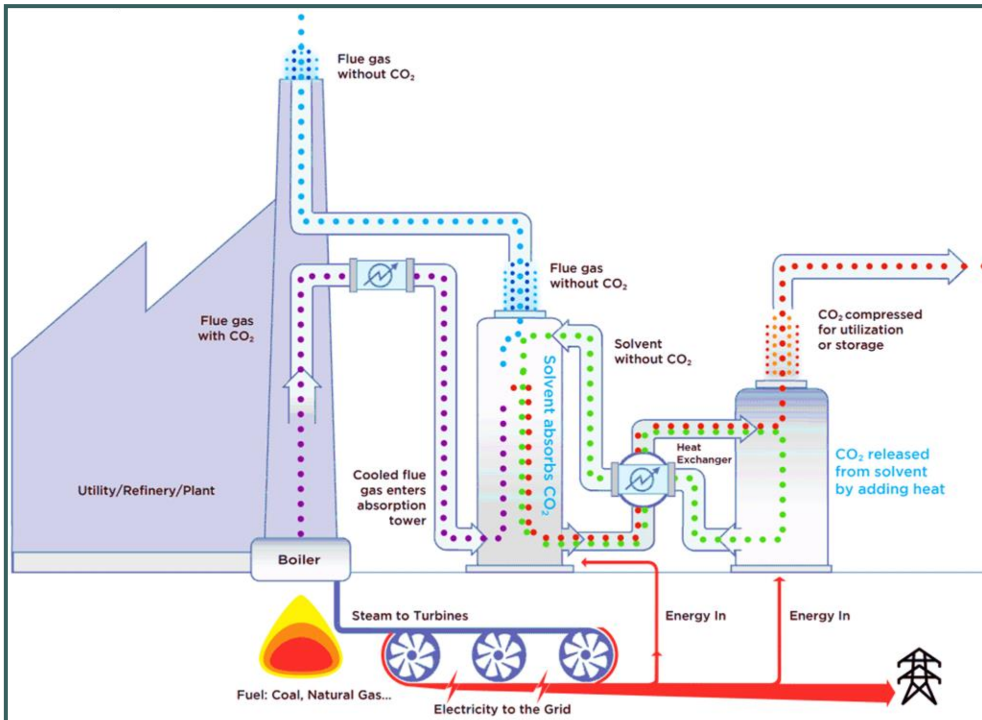
During the development and testing of its solvent, ION recognized the urgent need to develop additional new enabling and process intensification technologies to further reduce the cost of carbon capture. One of ION's initiatives in these areas is their innovative absorber column packing technology, which was developed through a 2016 DOE SBIR Phase II award entitled "*Rapid Design and Testing of Novel Gas-Liquid Contacting Devices for Post-Combustion CO_2 Capture via 3D Printing."* The grant was funded by the Office of Fossil Energy (FE) and overseen by Program Manager Isaac Aurelio. ION's innovation, which is known as it's Modular Adaptive Packing or MAP, involves a novel packing material for *in-situ* cooling, which is designed and manufactured using advanced computing and 3D printing of advanced materials. In post-combustion solvent capture processes, CO_2 absorption occurs when the exhaust gas (also known as flue gas) mixes with a liquid solvent in an absorption column, which utilizes high-surface-area packing materials to facilitate gas/liquid interaction. The solvent can be thought of as a liquid filter. The liquid's molecules bond to the CO_2 molecules, separating them from the combustion gas as it travels up the absorber column. For this absorption process to be efficient, a steel scaffolding resembling steel wool is typically placed inside the column and the liquid solvent flows downward as the combustion gas rises from the bottom of the column. Currently, the use of high-grade steel is required, due to the corrosive nature of many CO_2 capture solvents, thereby driving up capital costs. The solvent can later be heated to separate a concentrated stream of CO_2 from the solvent with the CO_2 "lean" solvent being returned to the absorber in a continuous process. Post-combustion carbon capture is a very effective process with typically 90% or more of CO_2 being removed from the flue gas in a single pass. However, the process is also energy intensive. Chemical CO_2 absorption is an exothermic reaction and excess heat needs to be removed to avoid consequent CO_2 desorption, which would defeat the CO_2 capturing purpose. To avoid desorption, the solvent can be continuously driven through external heat exchangers before being brought back into the absorber column (see diagram below). This additional cooling and streaming of the liquids translates into considerable amounts of electrical energy spent to operate the various pumps and keep the solvent at optimal temperatures.

ION's MAP technology addresses the energy-intensive processes described above, and significantly reduces the overall cost of carbon capture, which will consequently drive market broader acceptance. This is achieved by replacing traditional packing material with a proprietary packing design that includes circulation of cooling liquids throughout the packing resulting in continuous temperature management during the CO2/solvent interaction process, and without the need to force solvent through expensive external heat exchangers. When coupled with ION's solvent chemistry, the new packing material could be manufactured using a lower grade steel, or other less costly materials, thereby further reducing costs.

The innovative geometric design of ION's packing material is achieved by 3D printing, which can rapidly implement unique structural designs resulting from complicated mathematical models, and can be customized for today's more advanced low-aqueous (and "non-aqueous") solvents. Due to ION's proprietary design, the new packing material is also far more efficient, allowing for the absorber column to be smaller. This means smaller and fewer pumps and less solvent, all of which improves functionalities of the system and significantly reduces capital and operating costs.

ION's collaborative development program has also created new competencies, alliances, and research infrastructure in the U.S. to enhance U.S. dominance for application of process technology and advanced manufacturing in future projects beyond carbon capture. Industrial applications beyond carbon capture include many thermally-regulated chemical separations such as protein, peptide, or nucleic acid separations, which can all benefit from controlling the exothermic reaction. Application of ION's MAP technology is initially envisioned on a smaller scale, research pilot separations for CO_2 capture and commercial scale in the pharmaceutical industry, with subsequent extension to the oil and gas industry.

During ION's Phase II project carried out in 2016 and 2017, ION produced engineering plastic and metal packing prototypes using 3D printing techniques by a major 3D printing firm, and has tested the new column packing systems utilizing ION's CO_2 capture pilot facilities in Boulder, CO. The SBIR Phase I and Phase II achievements have resulted in ION securing a $ 2.6 M Phase III project from DOE's Carbon Capture program. The Phase III project currently underway is an ION-led advanced manufacturing development effort that will result in a 3D printed commercial prototype of a gas-liquid contacting device, which is being positioned by a major U.S. industrial partner to meet the needs of global markets.



Flue gas rich in CO_2 (purple dots) is directed into the absorption tower. ION's advanced solvent contacts the flue gas and absorbs the CO_2 (red dots). Flue gas, now free of CO_2 (blue dots), is returned to the stack and safely and cleanly released into the atmosphere. Solvent loaded with CO_2 (green and red dots) is directed to the regeneration section of the process.

Written By Claudia Cantoni, Commercialization Program Manager, DOE SBIR/STTR, December 2017.