Facilities & Capabilities

CO_2 CAPTURE SYSTEM DEVELOPER

Adsorbent Structure Knowledge Hub

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inventys

21,000
sq.ft facility

29
performance & durability testing platforms

68
days to manufacture adsorbent sheets to fill 600-tpd plant

At Inventys, we're dedicated to solving difficult gas separation challenges—like liberating CO_2 from flue gas. We intend to dramatically reduce the cost of carbon capture so that it can be deployed worldwide, create a viable carbon-using economy, and preserve our planet for future generations.

Essential to this goal is our 21,000-square-foot Inventys Adsorption Structure Knowledge (iASK) Hub, one of the largest adsorption development centres in the world. It houses advanced, custom-designed equipment for evaluating the effectiveness of the smallest samples of adsorbents and sophisticated manufacturing equipment to take the breakthrough concepts from the lab to working CO_2 capture plants in the field.

Our engineering teams have successfully accomplished many complex gas separation research and commercial projects. Their unique experiences created and refined the innovative adsorption characterization techniques that encompass all phases of the technology development.

They rely on an established methodology that's created through the alignment and synergy between testing and demonstration stations, manufacturing and technical expertise. Each component brings a unique and needed capability to the system, and combining these assets offers competencies and efficiencies rarely found in a commercial setting.

Perhaps Stephen Covey, American educator, author, businessman, and keynote speaker, said it best, "Synergy is what happens when one plus one equals ten or a hundred or even a thousand!"

From validating and synthesizing active adsorbent materials to process plant design and integration, Inventys remains uniquely qualified to serve in the roles of revolutionizing adsorption capture technologies and pioneering gas separation processes, including the difficult separation of CO_2 from flue gas.

RAPID DELIVERY

Relying on this interdisciplinary approach coupled with a cohesive team of chemical, mechanical, and process researchers and engineers offers advantages not possible with stand-alone facilities.

Rigorous assessment is less complex and faster because the research, testing, and manufacturing equipment are designed and managed as an integrated system and the team's expertise is specific to the development of adsorbent structures. This translates to a more efficient evaluation and development methodology where lost time is minimal and cost savings are high.

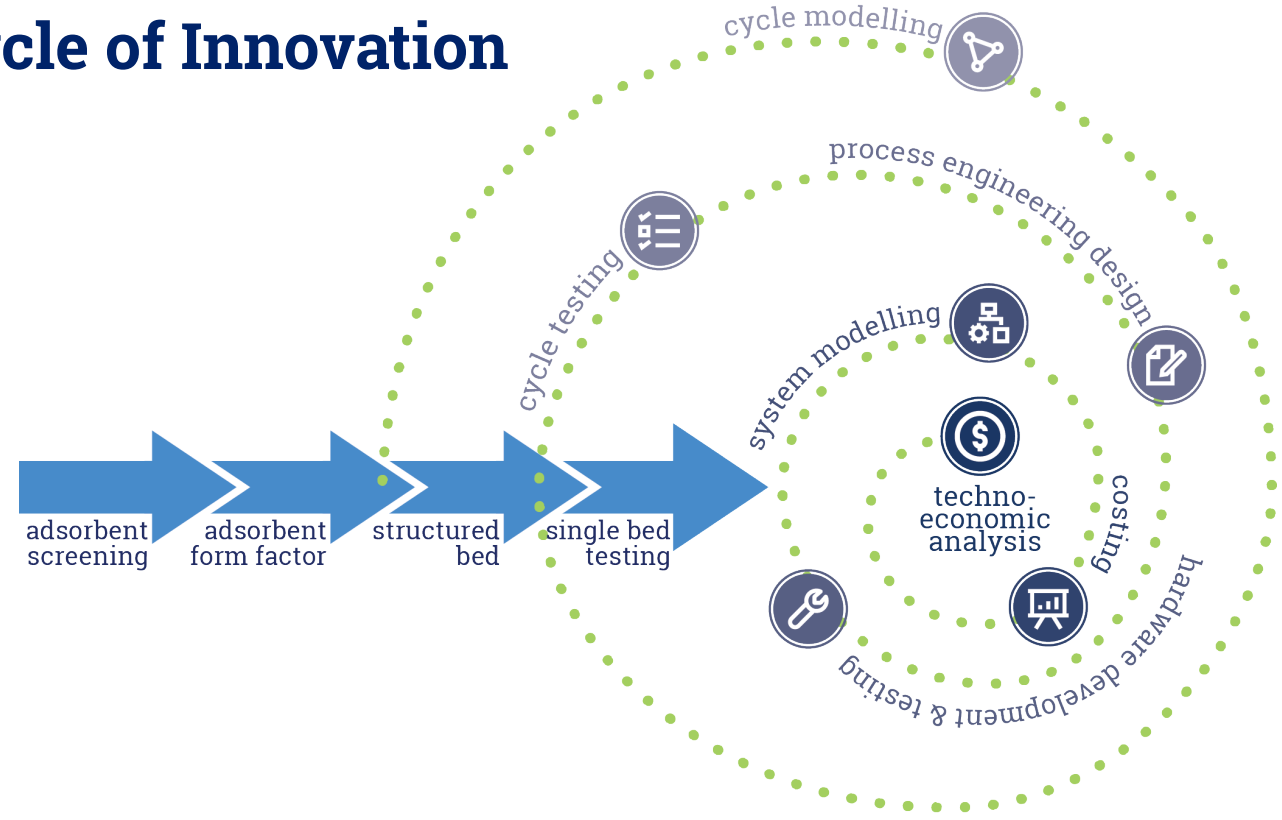
Parameters such as selectivity, pore distribution, working capacity, and stability, for example, can be rapidly measured. The data gathered in the lab influences the process modelling, which in turn affects the adsorbent structure development and the bed and process testing. Because the results from one centre can be seamlessly fed into another, or even back to the engineering department, if necessary, Inventys creates a continuous cycle of innovation.

This innovation cycle makes it possible to quickly and accurately predict plant performance and economics as the raw adsorption material is transformed from a powder form into an adsorbent structure that fits into an industrial machine and CO_2-capture plant.

$2 Million

State-of-the-Art Adsorption Development and Synthesis Laboratory

Cycle of Innovation



iASK HUB

The Inventys Adsorbent Structure Knowledge (iASK) Hub is a network of assessment and verification stations, each with its own custom-designed equipment and established methodology.

The iASK Hub is home to teams of chemical, mechanicial, and process researchers and engineers. Their expertise in adsorption processes provides the ability to connect the characteristics of the smallest sample of adsorbent material to the field performance of a large plant without any capital investment.

This facility can simultaneously support a variety of advanced, highly integrated assessments throughout all stages of the structured adsorbent development program:

- Adsorbent Materials Screening and Synthesis
- Adsorbent Structure Formation and Manufacturing
- Capture Plant Process Modelling
- Testing and Performance Validation
- Process Plant Design and Integration

The Hub is specifically designed to provide a rigorous evaluation environment and rapid delivery of data to guide development progress through each stage.

Adsorbent Materials Screening & Synthesis

The $2 million state-of-the-art adsorption development and synthesis laboratory plays a key role in the development process.

Home to an experienced team of scientists and chemical engineers, Inventys' adsorption development and synthesis laboratory provides a full complement of instruments needed to produce and screen materials and thoroughly assess the interactions between adsorbent materials, water, CO_2, and contaminants.

The data gathered in the lab influences the advancement of the adsorbent material through each of the following phases and it also enables rapid problem solving during the development process.

The characterization and development of promising adsorbent structures starts here with immediate screening of in-house materials and to verify the claims from the materials' manufacturers.

All the instruments in the lab contribute toward understanding the interactions of gas adsorption, vapor adsorption, kinetic, and equilibrium at a fundamental level.

While many of the instruments start as off-the-shelf purchases, the researchers have added additional instrumentation to enhance the basic tool's capability in both static and cyclic testing. And, each instrument is designed to

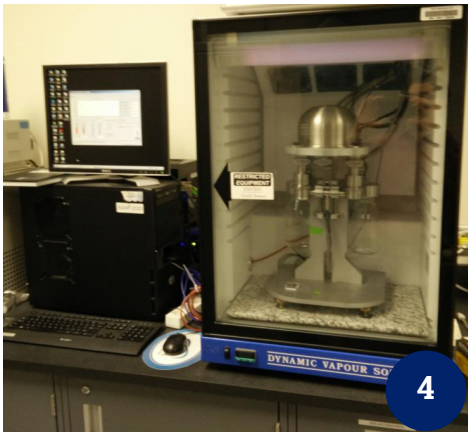
work together to enhance the ability of each other creating a very dynamic process.

The adsorption development laboratory provides the following data:

- Water isotherm from -20°C up to 120°C
- Surface area and porosimetry
- Stability and loss of CO_2 adsorption capacity
- Adsorption kinetics
- Water capacity
- Diffusion rate
- Adsorbent density
- Equilibrium point
- Wet CO_2 capacity

The goal is to gain a complete understanding of the physical, chemical, and mechanical properties of the smallest adsorbent material samples (<5mg) under a variety of conditions, including different temperatures and exposures to different vapours.

Additional instrumentation enhances the capability of each piece of equipment



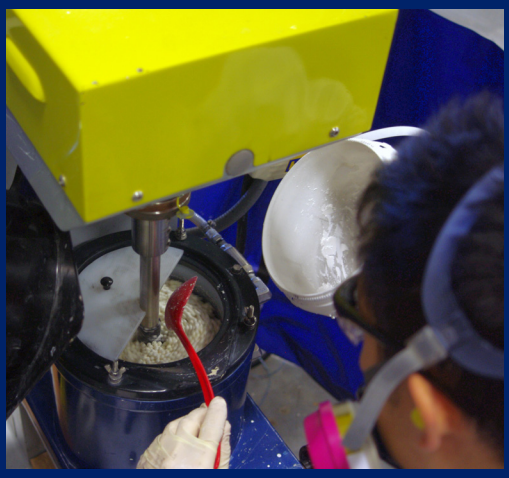
Four of the 21 lab instruments :

1. **VSTAR:**
   This custom-designed instrument can measure water isotherm as low as -20°C to as warm as 120°C.
2. **ZLC:**
   Capable of providing kinetics of adsorption from the smallest samples, 5-15mg.
3. **ASAP:**
   Provides accurate and precise surface area and porosimetry measurements.
4. **DVS:**
   Measures wet CO_2 capacity of the adsorbents and provides cyclic testing in the presence of air or inert gas.

TOUR THE iASK HUB: A CLOSER

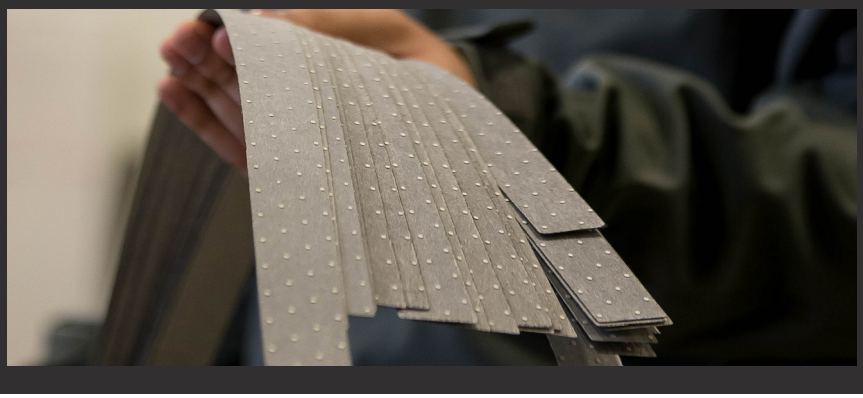
RAW ADSORBENTS

It starts with the preparation and synthesis of novel adsorbent materials with efficient adsorption performance.



IMPROVED FORMULATIONS & OPTIMAL CONSISTENCY

Creating the right formulation to successfully tranform a raw adsorbent material into an effective and stable adsorbent structure requires unique knowledge. Through years of experience and extensive testing, our scientists have created the perfect blends that have the necessary properties for structure development while retaining adsorption capability.



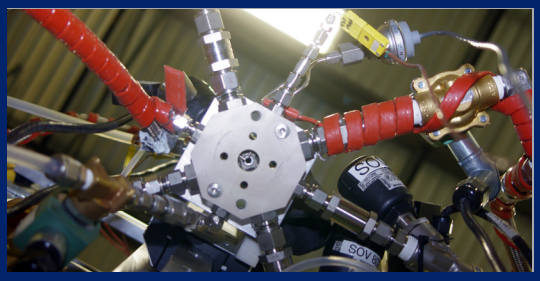
ADSORBENT SHEETS

The custom-formulated slurry is then used to fabricate adsorbent sheets with a prescribed thickness to provide a favourable balance between hydraulic and transport properties. This technology makes adsorbent materials perform better.

BUILDING ADSORBENT BEDS

Single test beds are built by hand because quantity is small. A full manufacturing line, can produce 20 metres/minute, and includes a robotic assembly machine to build the adsorbent beds.

LOOK AT INNOVATION AT WORK

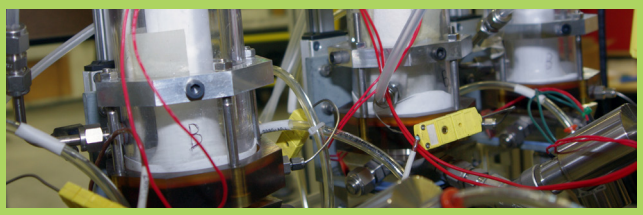


VELOXOTHERM™ TEST STATION

Theories developed in the lab are thoroughly tested on the VTS, where cycle timing, flow, temperature, pressure, and gas composition can be quickly and easily altered with a few simple mouse clicks. Shown here is where a single bed would be mounted during the testing procedures.

PDU

The 24-bed rotating process demonstration unit simulates a real carbon capture system.



PROVEN DURABILITY

The beds are thoroughly tested with an accelerated process to assess for strength and erosion. Through invention, design, and continued innovation, the reliability of our adsorbent beds is proven for long-term use.

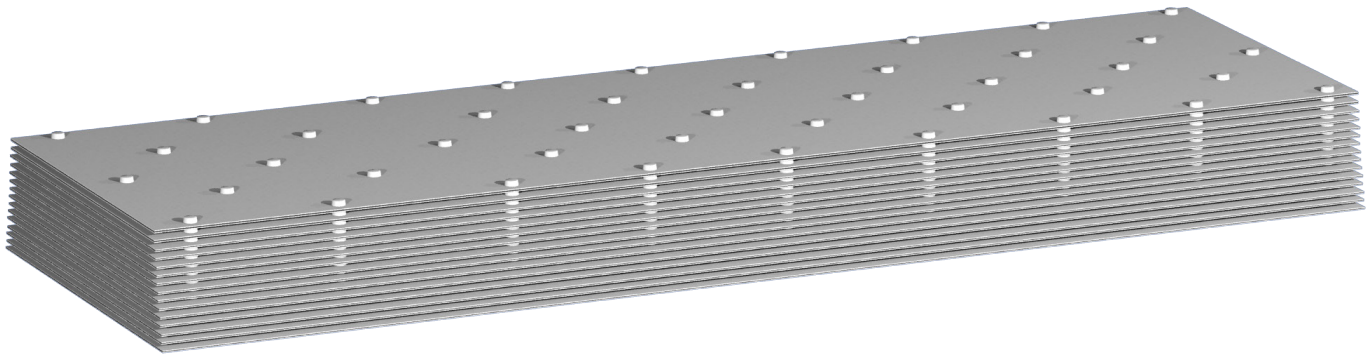
DEMO PLANT

The VeloxoTherm Field Demo Plant is used as a a platform for rapid development of the new adsorbent structures. It is currently situated at its latest field location, Husky Energy's Pikes Peak South site in Saskatchewan, Canada.

REAL FLUE GAS

A once-through steam generator and a coal-fired burner provide real flue gas for testing of the complete carbon capture process and related hardware. This arrangement provides field-like conditions in an easily accessible environment.

Adsorbent Structure Formation & Manufacturing



Data gathered in the adsorption development lab contributes toward the rapid shift of an adsorbent material into a new adsorbent structure.

The scientists, who through decades of experience inherently understand the compatibility of the materials involved, focus on minimizing the loss of adsorption capacity as they transform the powder into a slurry and then through a proprietary coating process to create an adsorbent sheet.

Supported by the uniqueness of the lab instruments, adsorbent mixing machines, and slurry preparation equipment, Inventys' lead scientist claims he can coat any adsorbent on Earth. While a bold claim made in jest, it does demonstrate his passion and enthusiasm for this exclusive expertise as well as the capacity of the equipment to coat things others may deem impossible.

The coating line precisely deposits adsorbent slurry onto a substrate and then dries the sheets with a controlled temperature oven.

Our exclusivity is keeping the integrity of the powder and forming it into a sheet-like material that can be used in an industrial process

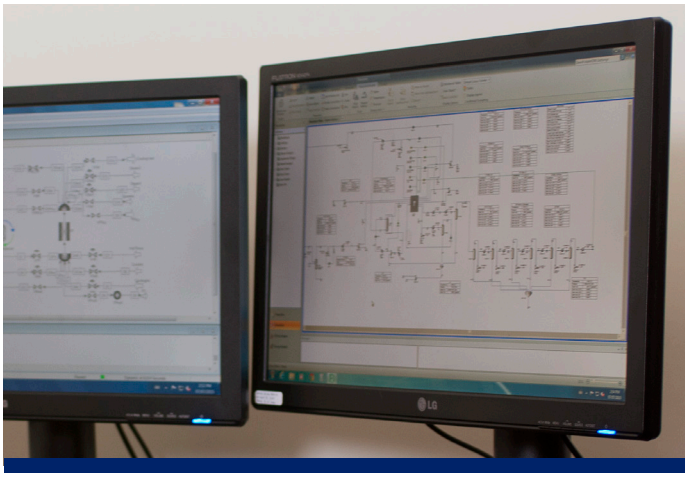
Adsorbent structure development is a multi-step process supported by a one-of-a-kind industrial-sized coating and drying line, rotary screen printer, and sheeting equipment. Each of the steps is influenced

by the data gathered in the lab and the process modelling parameters.

Even working with the most delicate materials, the coating line is able to produce 600 metres of adsorbent sheet per day, which is enough material to support fabrication of CO_2-capture pilot plants and even pioneer commercial plants.

Capture Plant Process Modelling

In-house proprietary simulation models simultaneously solve energy balances in combination with mass and momentum balances in cyclic adsorption processes.



Inventys' process modelling software not only plays a key role in both the bed design and process design stages but also in projecting the performance of the actual carbon capture unit.

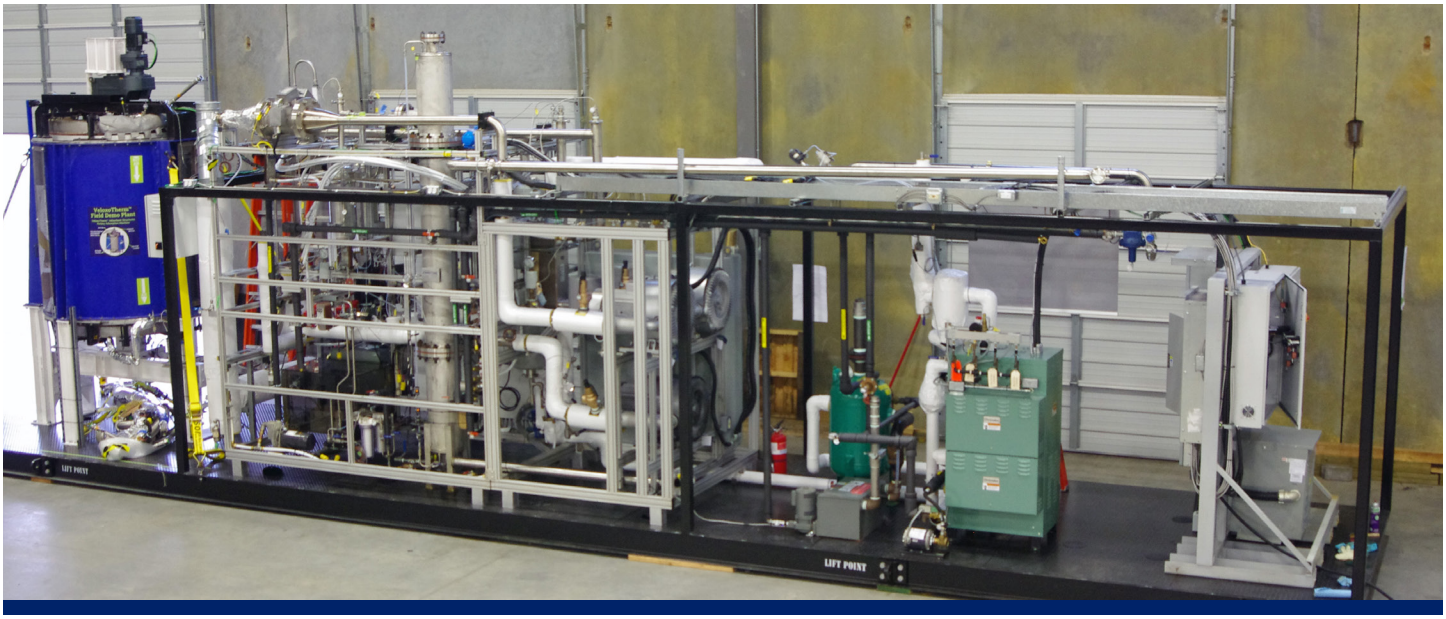
The initial data gathered from the lab that is used to qualify the material is applied to start the process cycle development. The capability to fully characterize the materials in-house and input that detailed information into the model improves the accuracy of the preliminary modelling.

Another cyclic process, the model then guides the adsorbent bed design, sheet thickness, and spacer size as well as the testing cycles.

A reiterative process, the discrepancies between model projections and test results can affect either the bed development or the model design, or both, as the team closes the gap between the model and reality.

The seamless transfer of information and the collaborative engagement between the teams ensures all aspects mesh together.

Testing & Performance Validation



We have developed a unique architecture of testing stations that have been designed to aggressively assess, quantify, qualify, and/or dismiss adsorbent materials and structures.

Testing begins once the process model is refined and an adsorbent structure is crafted. The structure's strength and integrity can be instantly evaluated.

Structures are initially tested for:

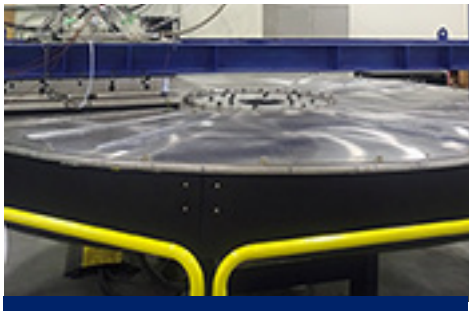
- Flexural strength
- Tensile strength
- Compression strength

The adsorbent structure is then fitted into the VeloxoTherm Test Station (VTS) where it undergoes faster and more strenuous adsorption and regeneration cycles than in traditional processes.

The VTS is a single-bed test station that simulates the cycle, which allows for greater flexibility of the testing parameters. Because of its size and design, the cycle reaches a steady state quickly, allowing for more testing in a predetermined time frame.

A cycle takes 60-120 seconds to complete. The VTS usually runs for six hours of active testing per day. And, each week, two adsorbent beds are tested. The sequence and timing of the cycles, which can be modified on the fly, are customized based on the characterization of the adsorbent structure and the control conditions.

The VTS is the workhorse in the Hub. It makes it easy to measure process conditions such as temperature, flow rate, and pressure,



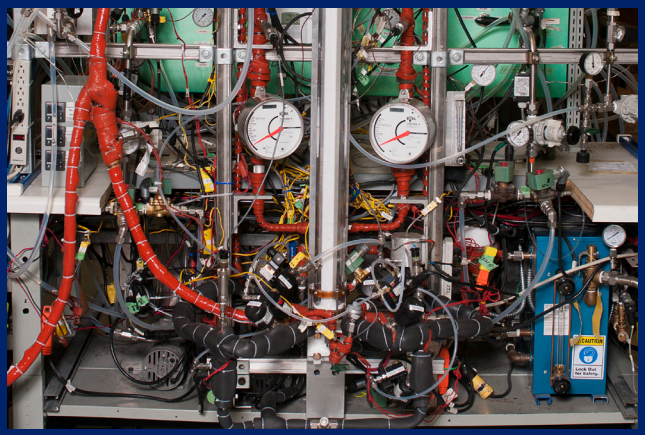
in real time. And to see how the stream composition changes during the process based on each step.

Results gathered from the VTS may affect the process modelling and/or bed design, where the performance validation would then be repeated.

Once the process model and bed design are verified and a high level of certainty is gained, testing is advanced to the process demonstration unit (PDU). The PDU provides a high-fidelity demonstration using multiple beds in a continuously rotating embodiment. This delivers a second level of assurance as the performance of the structure adsorbent beds are assessed using the same sensitivity testing as the VTS within a fixed cycle.

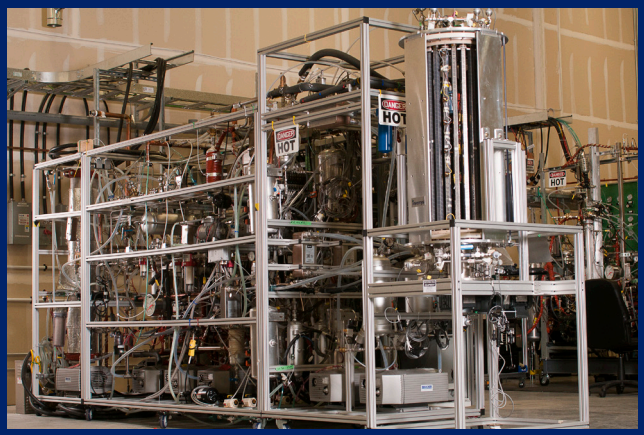
While some elements remain unchanged at scale, a prototype of the VeloxoTherm™ System, including the Rotating Adsorption Machine (RAM) offers a testing platform that includes the balance of plant, necessary systems, and supporting equipment for fully unattended field operation. Built by one of the world's largest manufacturers of rotary air preheaters, the VeloxoTherm 0.5 TPD CO2 capture plant, demonstrates aspects such as structured bed performance, seal design, flow distribution, mechanical operation, and long-term operability on real flue gas supplied by a natural gas boiler or a coal-fired power slipstream.

Designed as a platform for rapid development of the thermal swing adsorption technology on real-world sites, it is currently fashioned to capture one half to two tonnes of CO_2 per day. This is large enough to provide meaningful data, yet small enough to have the adsorbent beds swapped out as part of materials and structure testing.



VELOXOTHERM TEST STATION (VTS)

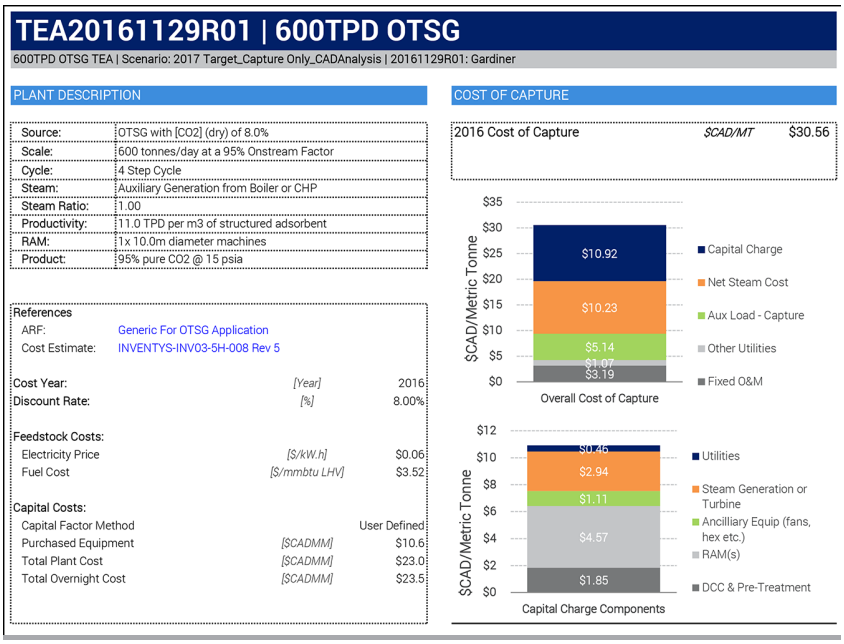
Single bed testing that simulates a multi-bed process allows for quick development, easy changes in a short amount of time. Also allows condition changes without interrupting or delaying testing.



PROCESS DEMONSTRATION UNIT (PDU)

Once a level of certainty is achieved at the VTS, 24 beds are developed and installed in the PDU. A rotating, multi-bed unit, the PDU increases the level of certainty while doing the same sensitivity testing as the VTS.

Process Plant Design & Integration



This is where the synergy is on its finest display.

With the multidisciplinary team focused on a single objective, the mechanical group, and the process and the bed manufacture teams collaborate to develop a supportive rotary model, seal design, and structured adsorbent bed package.

Using each other as a resource and the data garnered up to this point, the plant team takes a systematic approach to refining the plant's performance and economics. Developing is very iterative; moving between requirements, detailed concepts, and prototypes.

From here, the refined process model and the practical plant design meet to deliver an accurate techno-economic analysis of a full scale capture plant for the intended application.

THE INVENTYS ADVANTAGE

Combining these facility assets with technical expertise and breakthrough equipment that can run harder than anything in the field provides a premier research and testing organization for validating and deploying structured adsorbent carbon capture technology, as well as other gas separation technologies. Partnering with Inventys provides access to a world-class workforce with adsorbent structure expertise plus unrivaled research, testing, and manufacturing facilities.

Inventys understands how the fundamental parameters of the adsorbent and structured beds affect the cost of capture in a real world environment. This deep knowledge of the active material properties and the chemical process right through to the metal on the ground guides Inventys' laser focus on achieving breakthrough CO_2-capture economics.

"Inventys is developing technical advances that should dramatically reduce the cost of carbon capture so that it can be deployed worldwide. If successful, our technology could revolutionize carbon capture."

— Inventys Board Member Dr. Steven Chu, former US Energy Secretary and Nobel Laureate

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