

tpgroup

TEST RESULTS FOR NEW NON-REGENERATIVE CARBON DIOXIDE SCRUBBERS

Jon Constable
TP Group
Senior Vice President

Tom Daley
Micropore US
Technical Manager

Innovative thought. Absolute trust. Critical technology.

/ Innovation in CO₂ removal systems

- Long history of providing CO₂ scrubbers to global navies
- Traditionally providing regenerative MEA based systems
- Partnered with Micropore USA to develop new technologies



Background

Current trends in submarine carbon dioxide control are driven by:

1. Manning levels above submarine baseline design due to additional riders, especially special forces or training compliment
2. Decreasing CO₂ levels to comply with national worker's safety requirements or risk of cognitive decline at elevated CO₂ concentration
3. The need to minimize hardware and consumable volume within the pressure hull.
4. The need for safe-3 and non-toxic adsorbents



CO₂RE Single Cube Scrubber

/ A new range of systems

Non-regenerative CO₂ removal systems using Micropore PowerCube®

Modular and can be scaled to suit application

Designed with AIP / Diesel Electric submarines in mind

Good for spot CO₂ removal e.g. single compartments

/ TP Group CO₂RE range of CO₂ scrubbers



CO₂RE
Single cube & sensors



CO₂RE
3 + 3 scrubber



CO₂RE 6XK
6 Cube with sensors

/ Straight 6 and V6 configurations

- A 6 cube arrangement badged as the STRAIGHT-6 CO₂RE
- This scrubber is intended for back-fit or new construction diesel electric submarines
- These scrubbers offer 6 cubes in either two banks with parallel flow or all 6 cubes in parallel
- Due to the low pressure drop, airflow can be provided by existing ventilation system or by a dedicated fan
- Very Good Performance test results

CO₂RE Straight 6



CO₂RE V6



/ Micropore USA



- Micropore is a 21 year old USA Corporation founded to exploit patented technology
- Micropore is uniquely qualified to encapsulate fine powders into solid sheet adsorbents
- Micropore technology produces solid sheet adsorbent with greater than 95% purity.

/ MICROPORE PRODUCTS

Military Diving:

- Diver Safety: 70% less caustic even after 5 minute flood
- Absorbent can be stored with rebreather instead of separately in bulk containers
- Platform Friendly- no caustic dust on metal surfaces
- Diver's breathing workload is reduced up to 15%
- Canister loads 5 times faster
- Reduces performance variability



/ MICROPORE PRODUCTS

Medical Anesthesia Adsorbents:

- Portable Patient Transport Life Support System (PPTLSS)
- Operating Room Anesthesia Machines



/ MICROPORE PRODUCTS

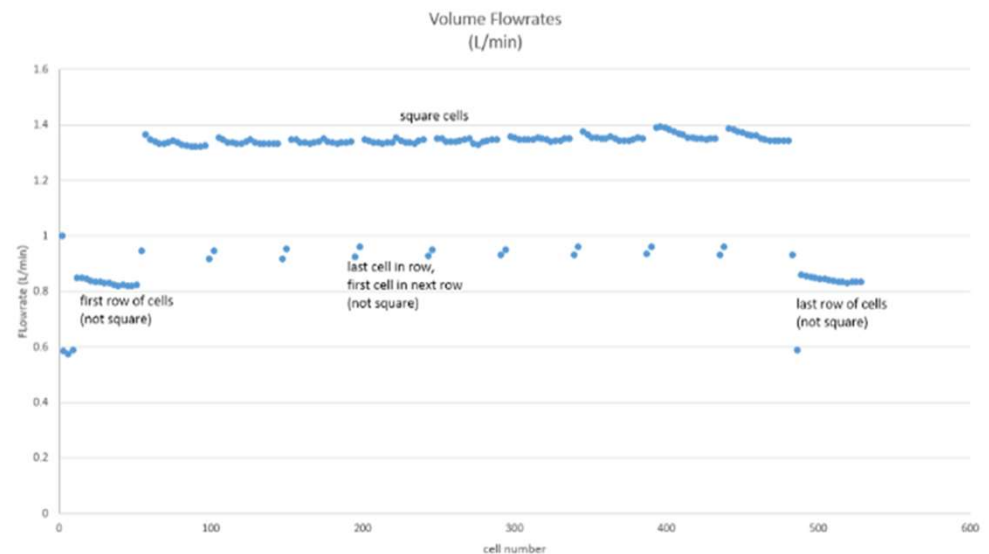
Submarine/Space Products:

- Emergency Life Support Curtains
- PowerCube® adsorbent blocks

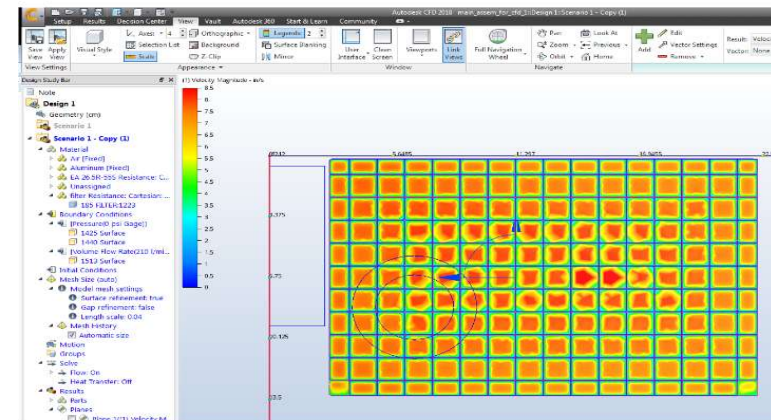
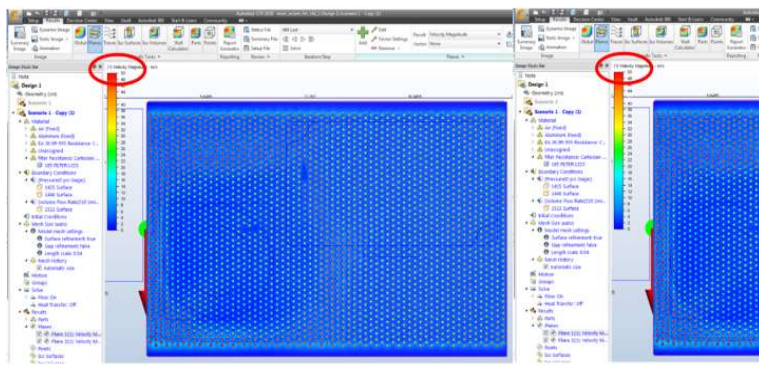
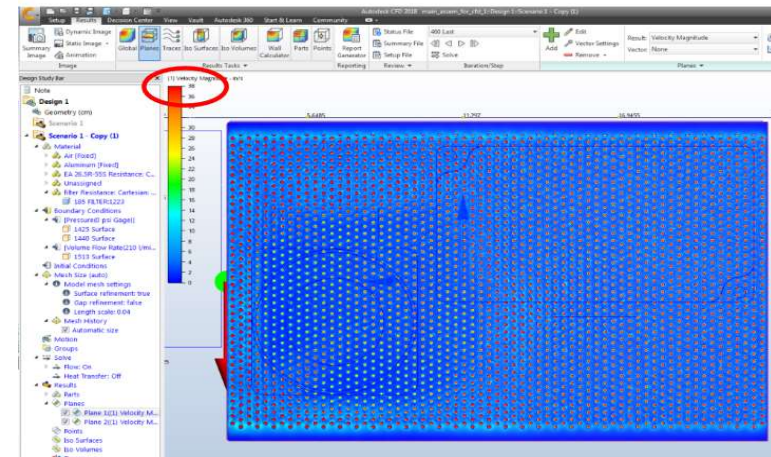
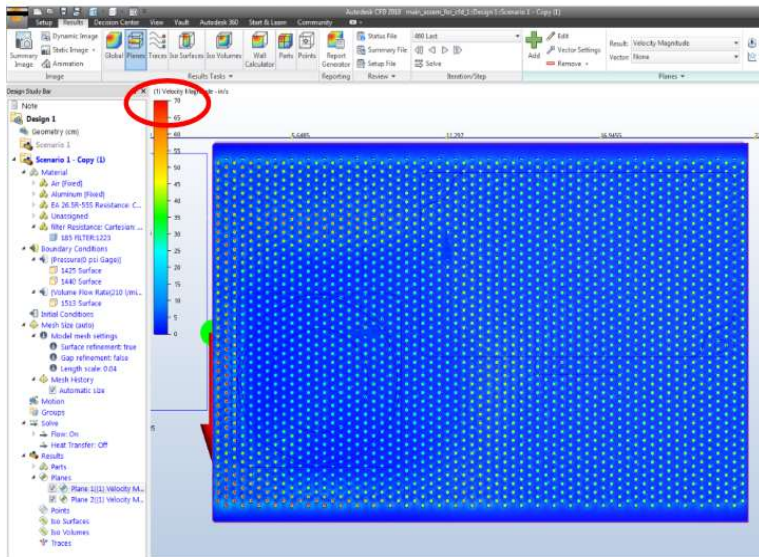


/ Single Cube Scrubber CfD analysis

- In addition to the test work carried out, flow modelling was completed to assure air distribution across the cube and optimal utilization of the cube
- Whilst for physical reasons the fan was offset, baffle plates and a plenum chamber allowed air distribution across the face of the cube
- Looking end on to the individual channels through the cube the colour is fairly consistent indicating even flow distribution

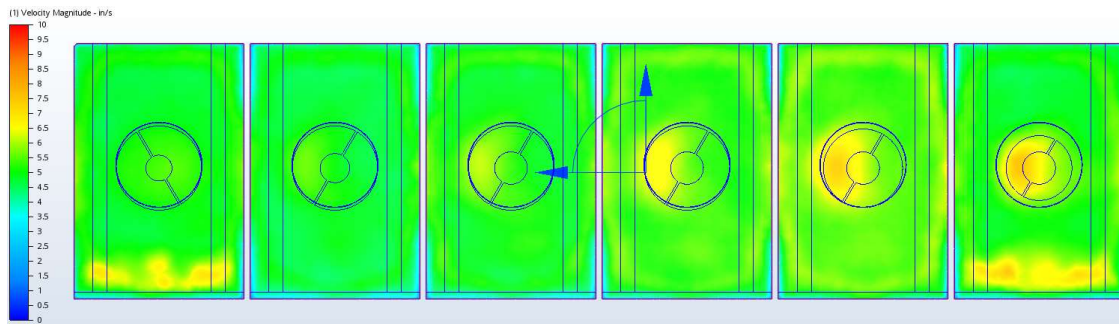
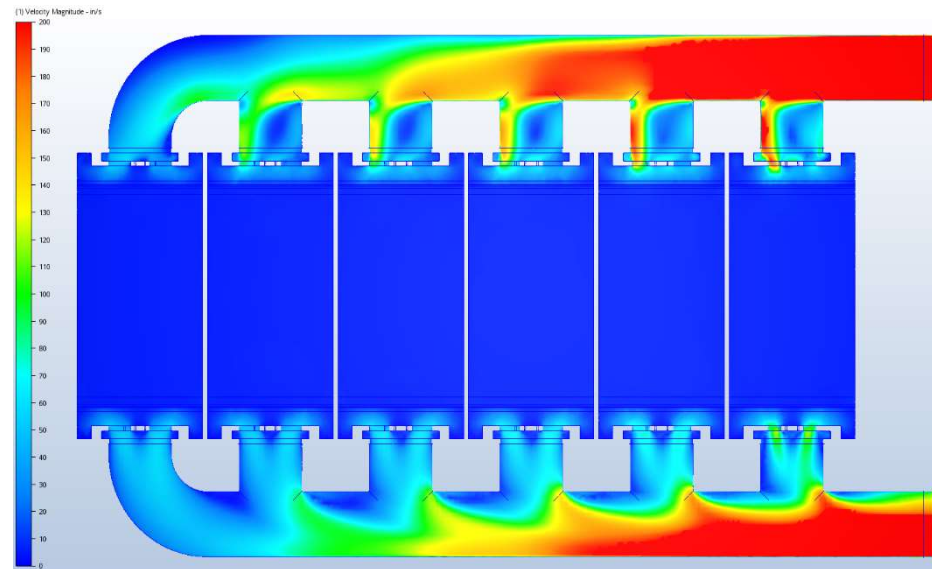


CO₂RE Scrubber Computational Fluid Dynamics



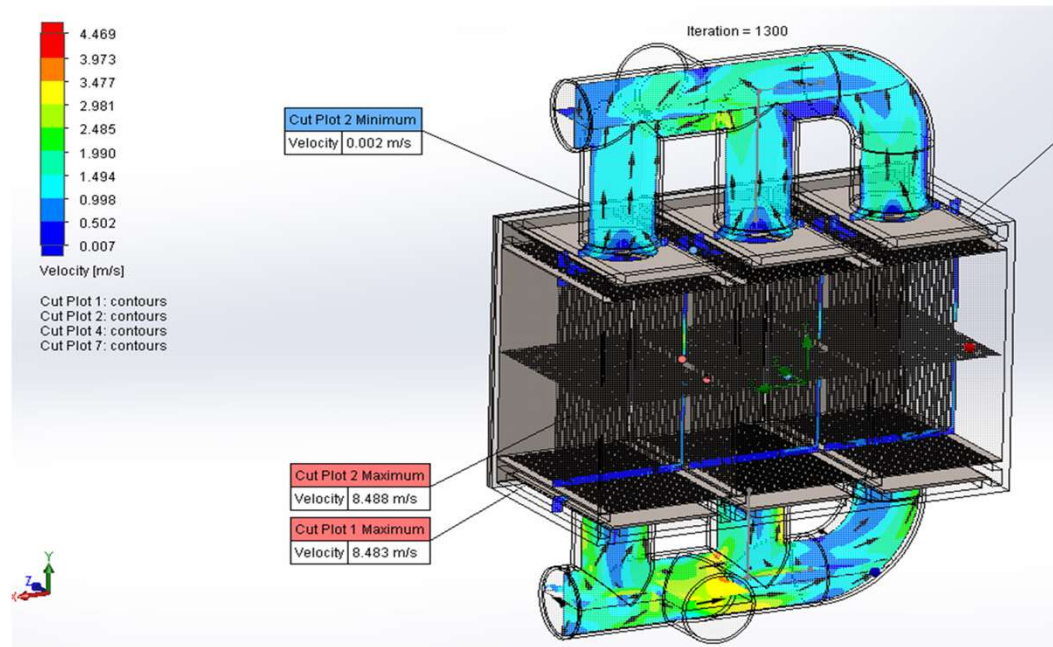
/ Straight 6 Computational Fluid Dynamics

- Optimisation of baffles to assure even flow distribution and performance
- As it can be seen whilst the flow in the feet pipes reduces from red to blue as it distributes to the 6 cubes, the flow colour through all the cube areas is an even shade of dark blue indicating even flow distribution



- A section view through the manifold on the end of the cubes showing the different flow balancing plates in each segment. Again the colours are even indicating even flow

/ 3 Block Scrubber

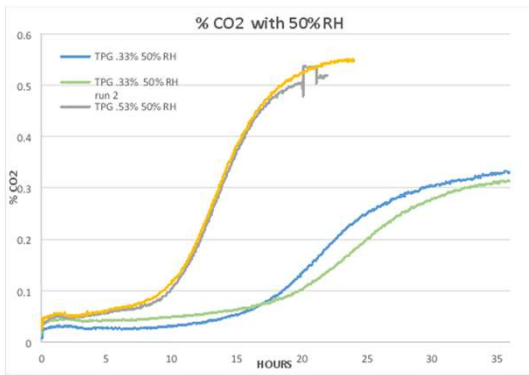


- An early flow analysis on the 3 block scrubber unit
- This shows slight variation in the flow which will be optimized

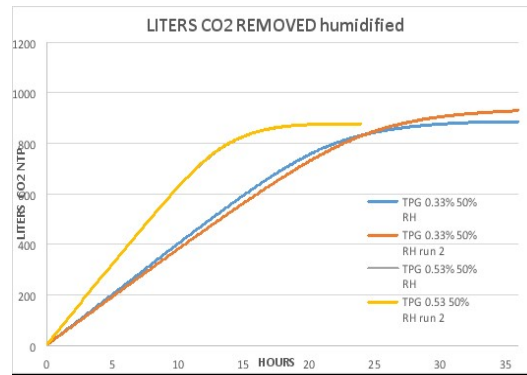
/ Performance Data Single Cube Core Scrubber

- The single cube CO₂RE scrubber was test in the laboratory at varying CO₂ inlet concentrations
- The humidity was controlled to 50% RH
- The testing was conducted with calcium hydroxide cubes
- Note that calcium hydroxide adsorbents are sensitive to relative humidity of the feed gas
- For controlled/air conditioned environments such as submarines the adsorbent becomes exhausted due to removal of water from the granule or Micropore block 5
- Note that lithium hydroxide adsorbent is not sensitive to feed stream humidity
- The inlet gas temperature was controlled to 70OF and the pressure was ambient. The test rig was detailed previously 6
- The test apparatus is calibrated in accordance with Micropore's quality procedures
- The **following illustrations** show performance of the CO₂RE Scrubber when operated at low inlet CO₂ concentrations

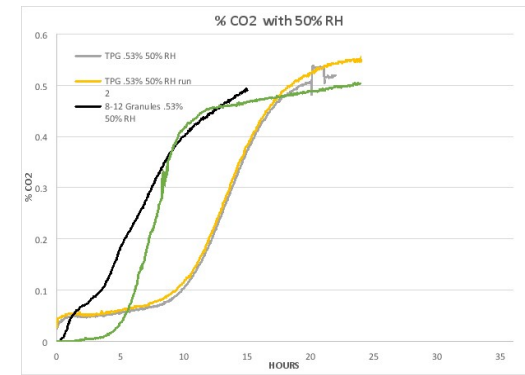
CO₂RE Scrubber performance operated at low inlet CO₂ concentrations



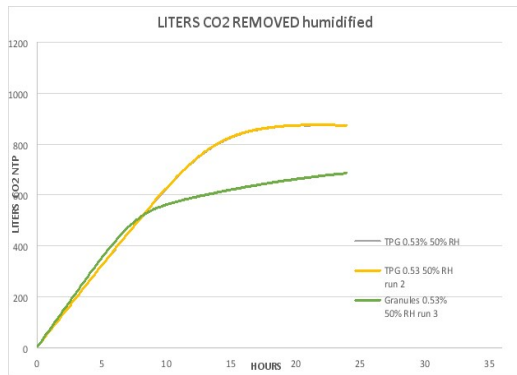
CO₂RE Scrubber CO₂ vs time



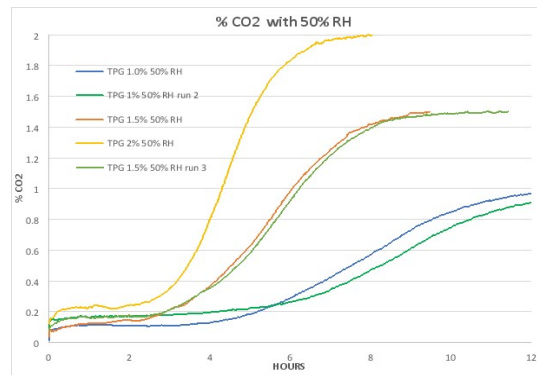
CO₂RE Scrubber litres CO₂ Removed vs time



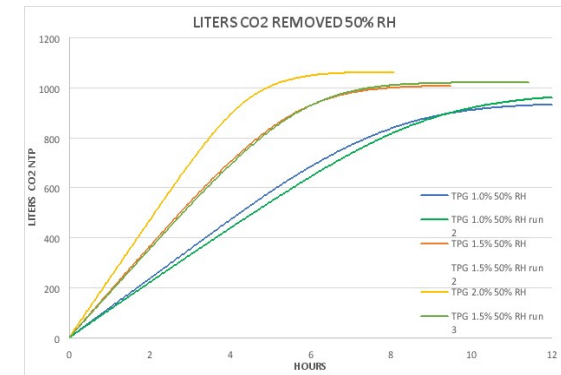
CO₂RE Scrubber and Granules - % CO₂ vs time



CO₂RE Scrubber and Granules – Litres CO₂ Removed vs time



CO₂RE Scrubber with High CO₂ Inlet % CO₂ vs time



CO₂RE Scrubber with High CO₂ Inlet Litres vs time

/ Future Testing and Performance outcomes

- In the next few months TP Group have test bay work planned to confirm the CFD performance predictions
 - The following will be measured:-
 - Inlet CO₂ concentration
 - Flow rate bulk
 - Pressure drop across each cube
 - Temperature of the room
 - Humidity
 - In order to do this in broad outline the following will be completed:-
 - Test plan generated
 - Fixtures and EUT setup
 - Testing in both LiOH and Calcium Hydroxide
 - Test report generated
- CO₂RE scrubbers both single cube and STRAIGHT-6 have the PowerCube® adsorbent advantages:
 - No dusting
 - No settling
 - Increased CO₂ removal at same storage volume
 - Designed to operate at submarine humidity levels
 - Working with TP GROUP for submarine CO₂ control has numerous advantages:
 - 50 years experience with SM atmosphere control systems
 - System/component design for crew sizes of 30 to 150
 - Manufacturing expertise for submarine hardware
 - Compact designs that can be back fit into existing spaces
 - Through life support capability

/ Conclusions and References

- The next step in the CO₂RE new product launch is shipboard testing
- The CO₂RE single cube scrubber can easily installed for localized CO₂ control to supplement existing scrubbers
- The CO₂RE can also be used for CO₂ control in submarine rescue vehicles although hyperbaric testing is required
- The STRAIGHT-6 or multiple 3 UP scrubbers require some engineering for installation and operator access

1. In USA NIOSH has set CO₂ concentration at 0.5% TWA
2. Add citation
3. For example super-oxides react violently with water
4. Non-toxic materials are easy to transport and dispose of
5. SAMAP 2011, Taranto, Water is the Key;
6. Dr. Michael Clarke and Dr. Mandy Crudace
7. SAMAP 2011, Taranto, Further Developments and Full Scale Testing Of Micropore's Calcium Hydroxide and Lithium Hydroxide Powercubes®

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Thank you.

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/ Single cube option

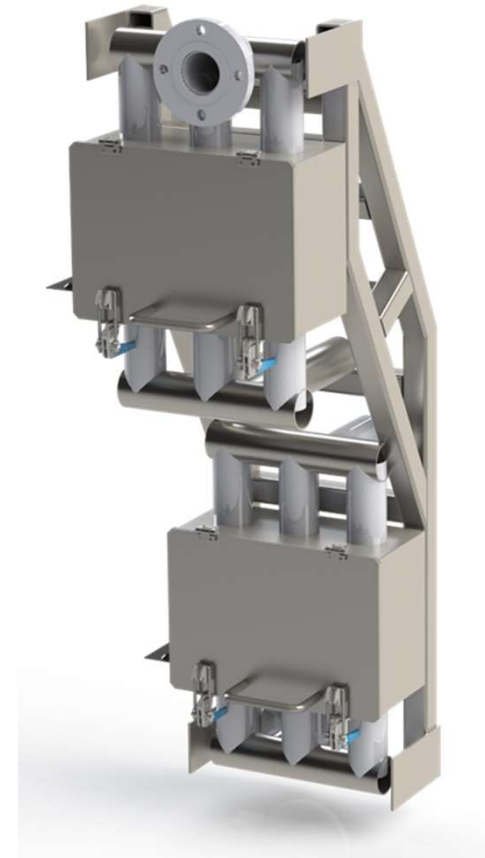
- The first available scrubber was the single cube CO₂RE (Carbon Dioxide Removal Equipment) scrubber.
- This has an installed fan (AC or DC powered)
- option of inlet and outlet infrared CO₂ analyzers for automated operation and indication on when to change the adsorbent cube.
- The power requirement is low (7 watts) due to low airflow resistance through the scrubber and adsorbent



CO₂RE Single Cube Scrubber

/ 3 Block scrubber option

- A third TP Group scrubber option for Micropore PowerCube® adsorbent is the 3 block scrubber
- This unit is powered by an external fan and can be ganged together as 3, 6, 9 or 12 cubes
- Flow is either parallel or parallel/series. This style scrubber is intended to fit into the frame bay of a submarine
- A small fan can be supplied with the scrubber if needed



CO2RE 3+3 Scrubber