2024 SAMAP

THE DESIGN, CONSTRUCTION AND TESTING OF A NEW CARTRIDGE SCRUBBER FOR SMALL SUBMERSIBLES

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INTRODUCTION

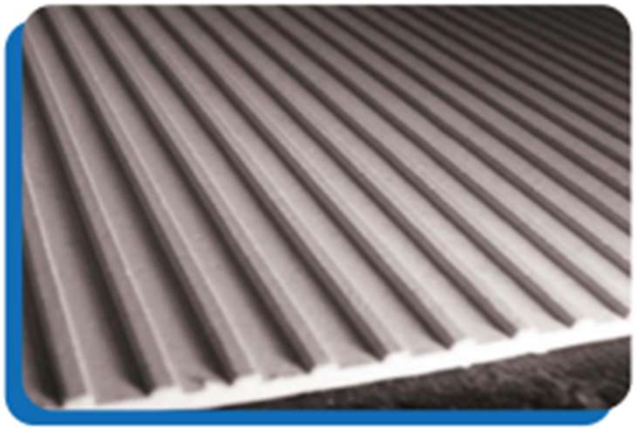
- Micropore (MD, USA); Submarine Atmosphere Control Equipment, SubACE (Winchester, UK) and SMP, Submarine Products Ltd., (Lancashire, UK) partner for new scrubbers
  - Use Micropore's unique carbon dioxide absorbents (structured absorbent).
  - Use SMP expertise in designed and built hyperbaric chambers, deep submergence submarine rescue vehicles and the supporting auxiliary equipment

- Designing scrubbers for Micropore's cube and cylindrical absorbents requires both normal and special design considerations. This paper will discuss two specific design requirements:
  - The requirement to carefully design the airflow into Micropore's absorbent for uniform velocity
  - The importance of prototype testing and design refinement

STRUCTURED ABSORBENTS

Micropores Absorbent

- Ribbed sheets (structured) rolled or stacked into absorbent bed



View of finished absorbent material
with preformed flow channels

- All structured absorbents have the advantage of constant flow down the absorbing bed.
- All structured absorbents have the disadvantage of constant (not uniform) flow down the absorbing bed.

AIR FLOW MODELLING FOR STRUCTURED ABS

- SMP / SubACE are designing two custom scrubbing systems that integrate Micropore's CO2 absorbent. One scrubber is a small unit appropriate to submersibles and submarine rescue vehicles. The submersibles scrubber uses 3 Micropore ExtendAir® cylindrical cartridges. This absorbent media was selected due to ease of use; no dusting and consistent performance regardless of orientation or vibration.

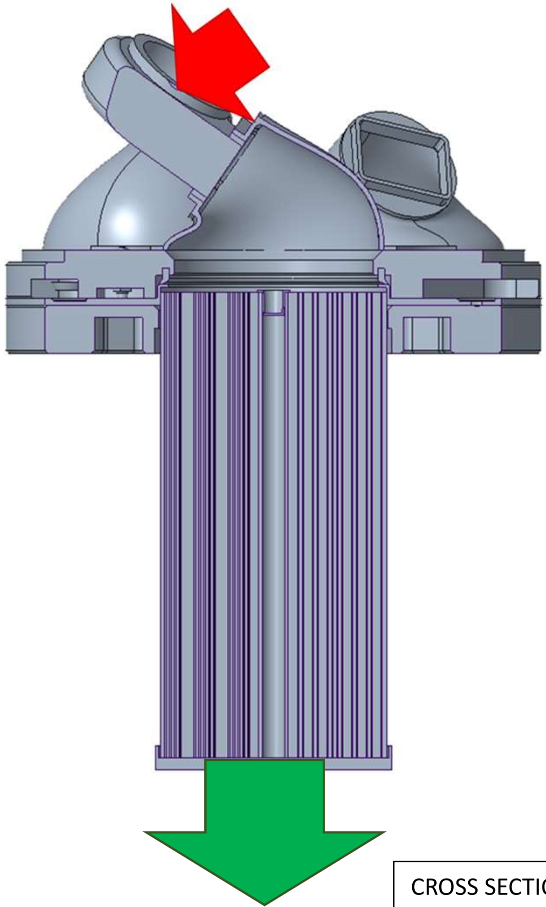
Small submersibles scrubber


Submersibles scrubber cut-away

- SMP is also designing and qualifying a scrubber for Habitat Conditioning Units (HCU). This scrubber will operate inside the pressure vessel used to pressurize/depressurize and serve as home base to deep sea divers. The absorbent selected for this scrubber is Micropore PowerCube®. The SubACE scrubber will be used as an example of flow modeling.

INITIAL MODELLING CFD RESULTS

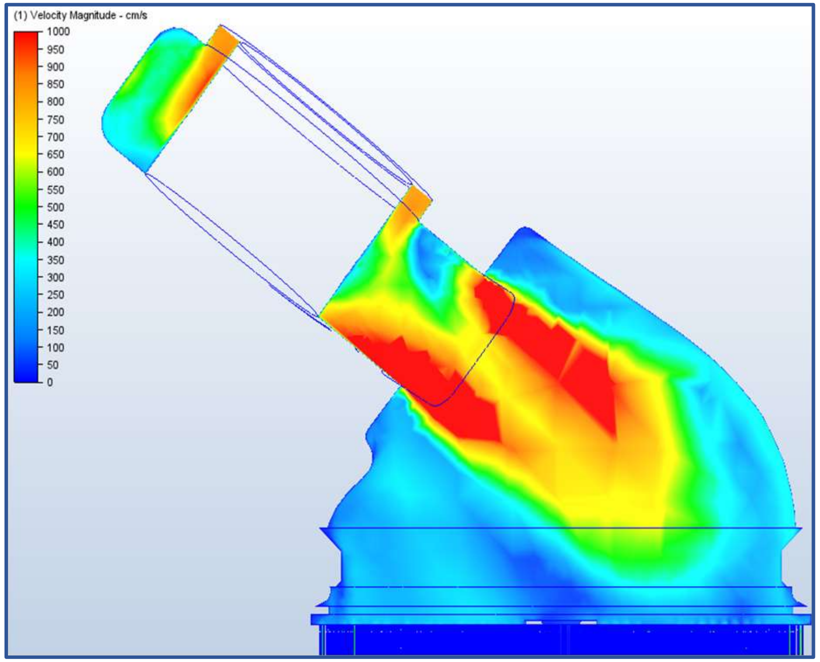
- The 3 cartridges and fans are identical so only need to model one

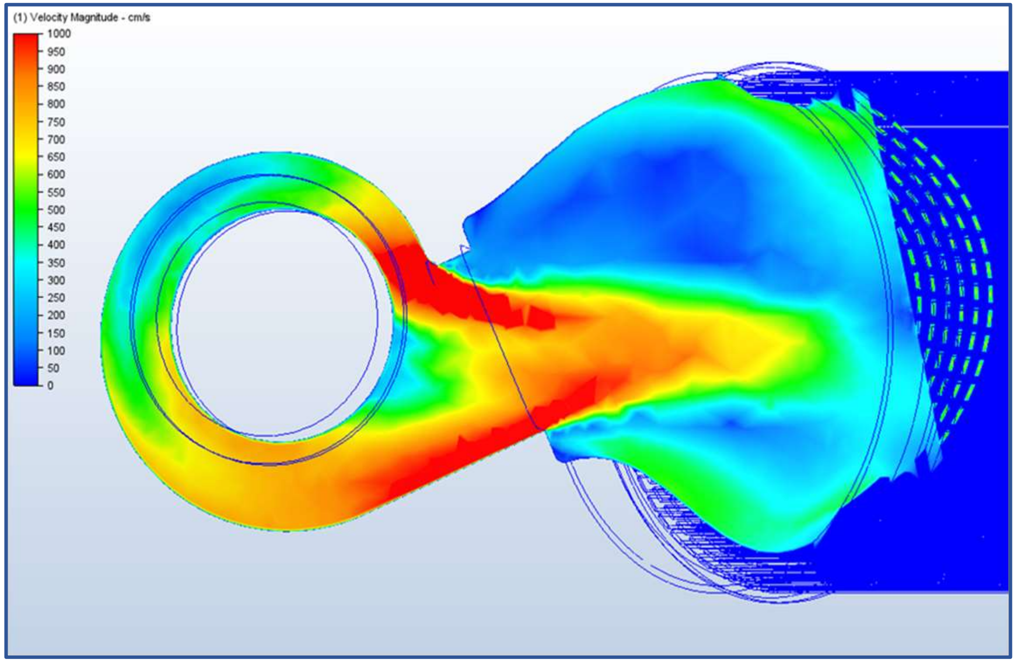


CROSS SECTION THROUGH CART

- For the analysis performed on the canister the boundary conditions were as follows:
  - 0.36 m^3 per minute volumetric flow rate into the inlet.
  - A gauge pressure of 0 at the outlet (creating a free-flow condition)

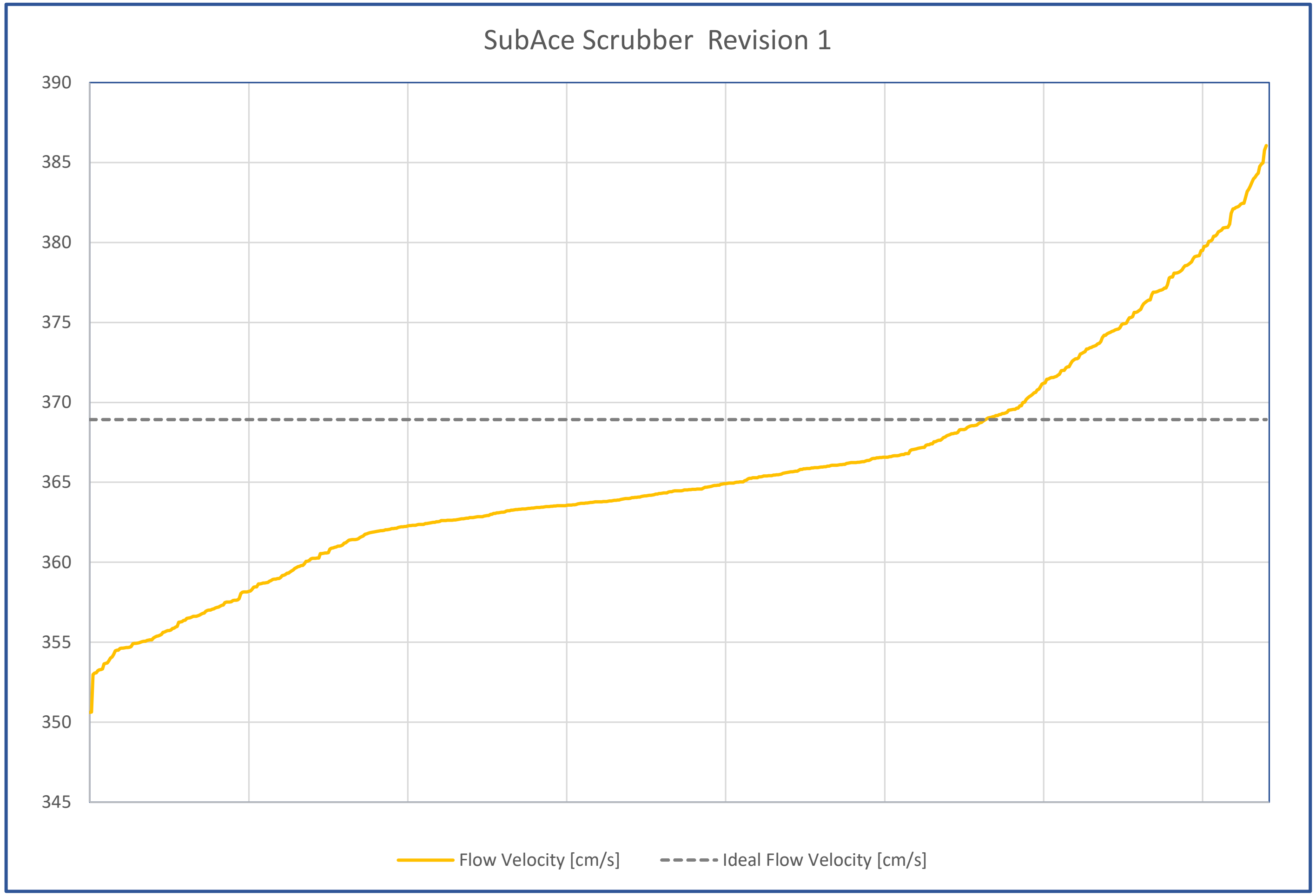
BASELINE DESIGN CFD ANALYSIS – CONT.





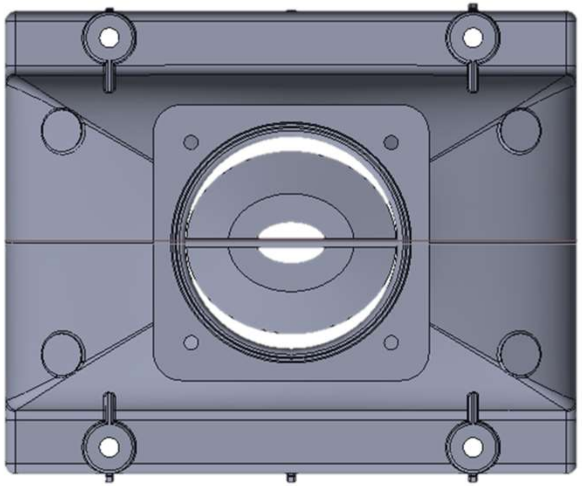
- These figures show the airflow velocity in a cm/s plane bisecting the canister at the inlet.

INTERPRETING THE RESULTS

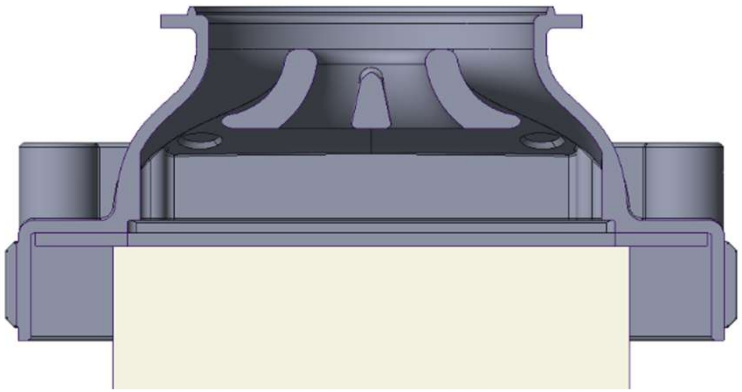


- 741 regions in the grid
- volumetric flow rate in cm^3/s.
- The dashed "ideal" flow rate line illustrates the flow if it was distributed perfectly between all 741 regions (Ideal here is 368.9 cm/s).
- Maximum Flowrate: 386.0 cm/s (4.6% above ideal)
- Minimum Flowrate: 350.6 cm/s 5.0% below Ideal)

CFD INCONSISTENT FLOW PROFILE; FLOW DISTRUBUTORS?

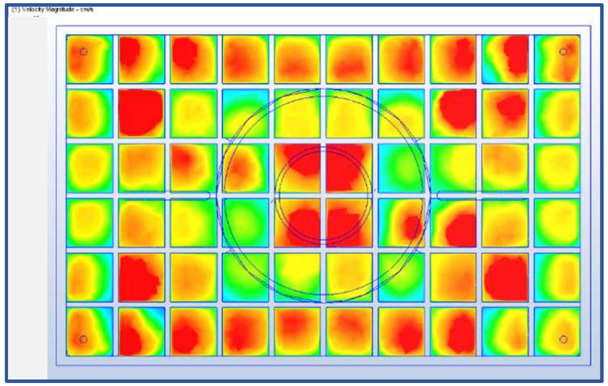


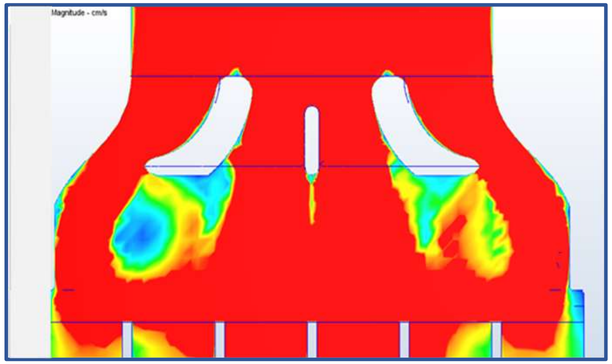
- The figure left represents design iterations modifying the inlet flow stream to establish uniform velocity.

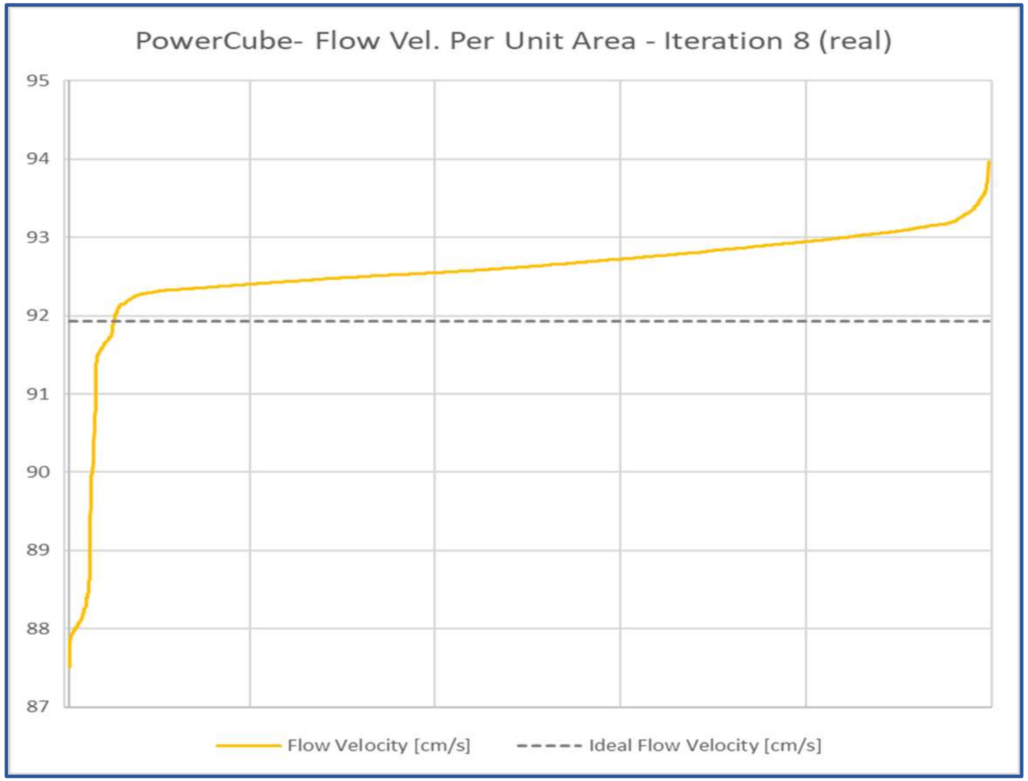


The final design accomplished after many iterations

FINAL ANALYSIS RESULTS







This is an order on magnitude improvement over the first This is an order of magnitude improvement over the first iteration as shown by the flow distribution plot. Maximum Flowrate is 2.2% above Ideal and the Minimum Flowrate is 4.8% below Ideal.

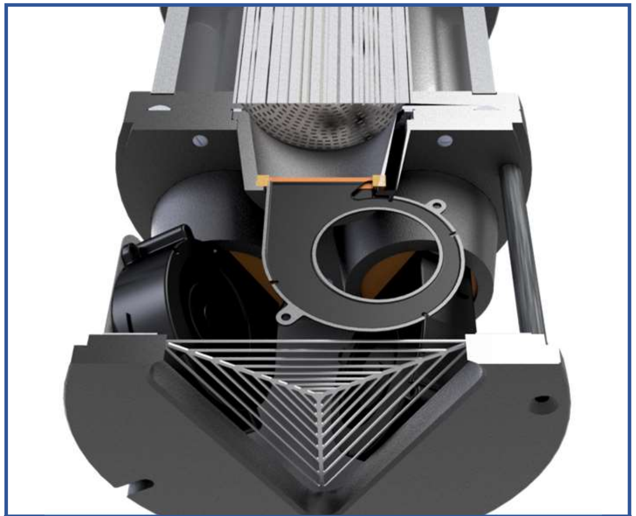
SubACE SCRUBBER – REVISION TIMELINE

REVISION 0

REVISION 1

SubACE SCRUBBER – REVISION TIMELINE CONT.

REVISION 2



REVISION 3

REVISION 4

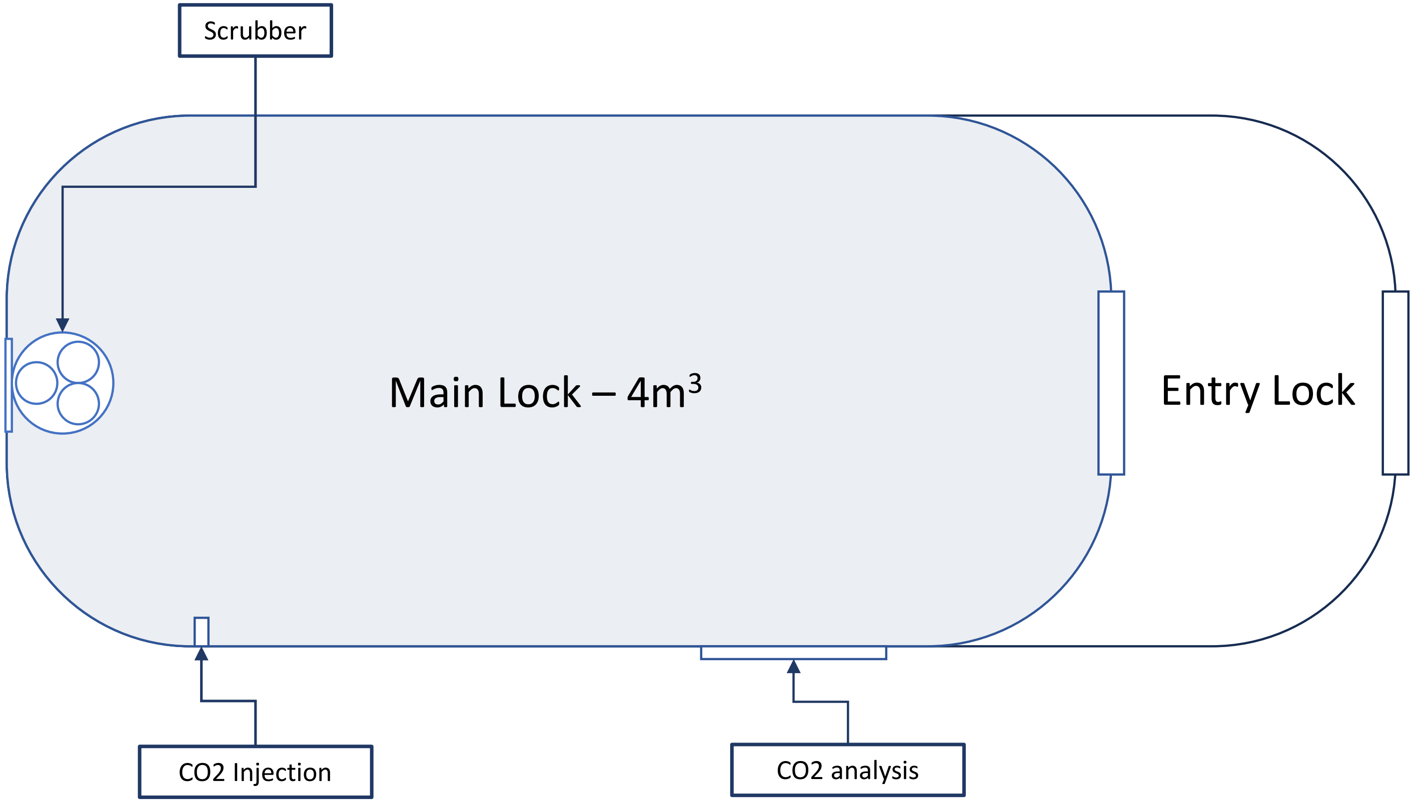
SubACE SCRUBBER – CURRENT REVISION

Current Design – Revision 4

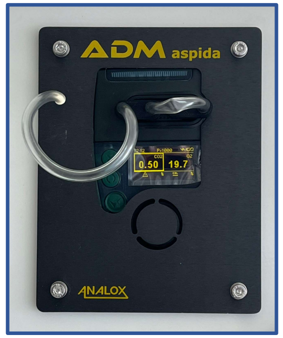
Sliced Section View

Exploded View

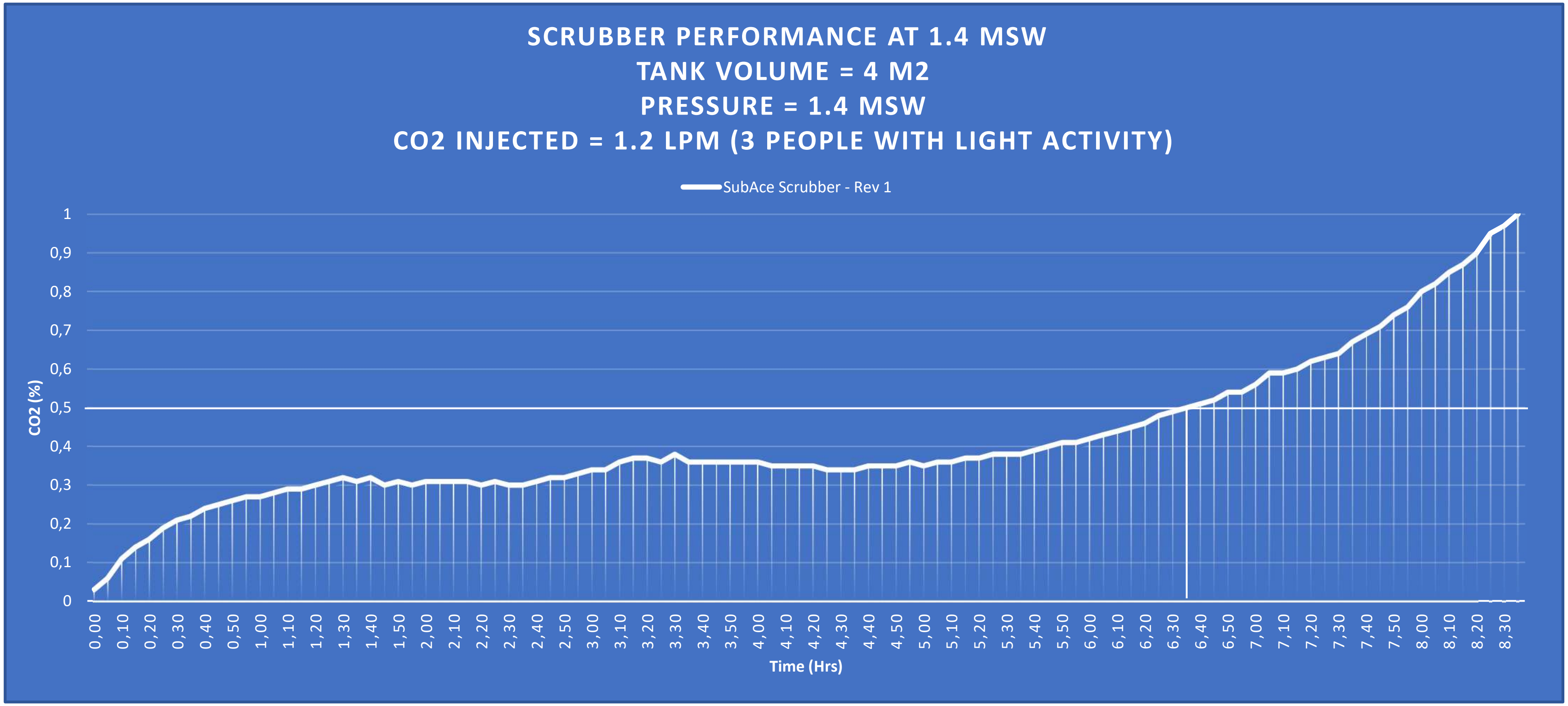
Test Setup



- 4 cubic meter hyperbaric chamber
- CO2 injected via a mass flow controller
- Chamber CO2 analysis via infrared analyzer

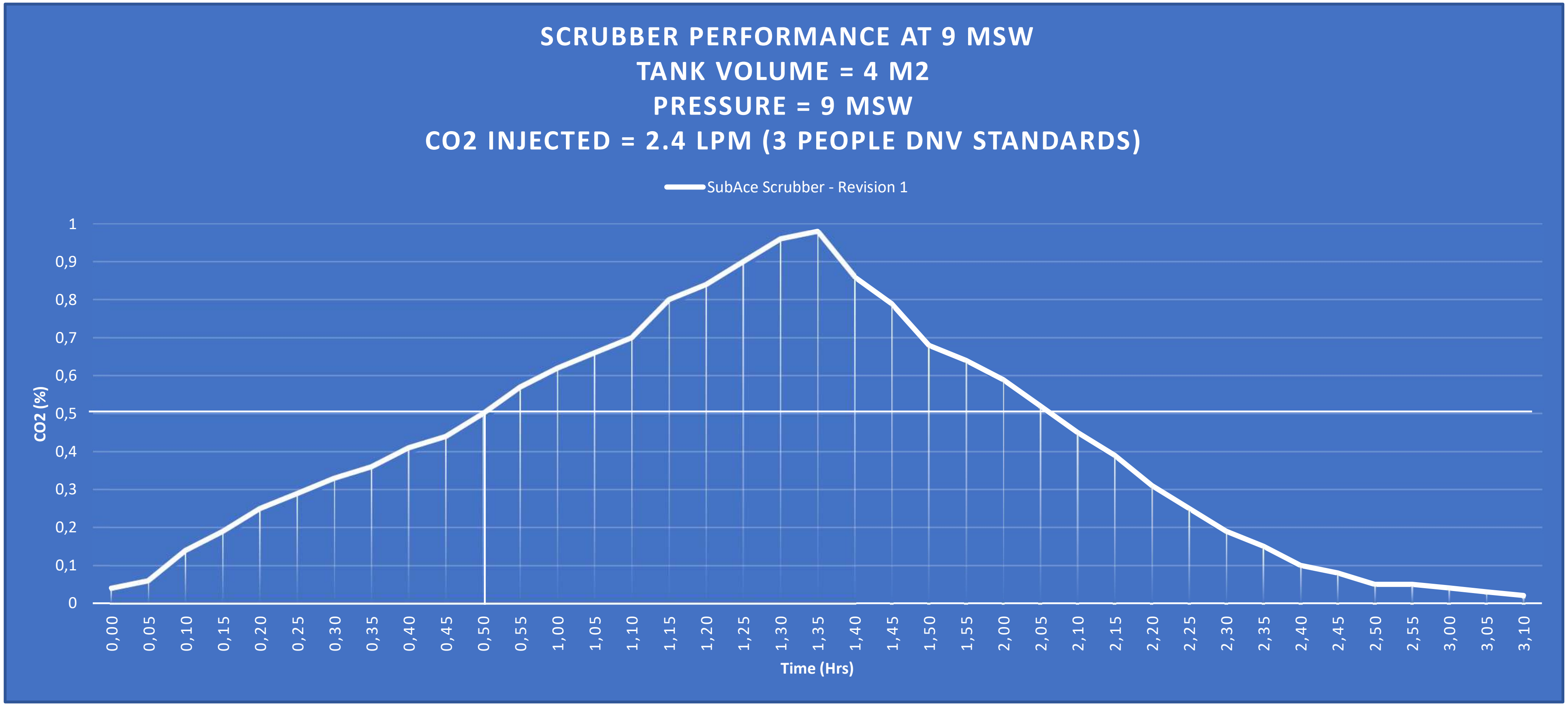


PROTOTYPE TESTING: BASELINE 1.2 LPM CO2



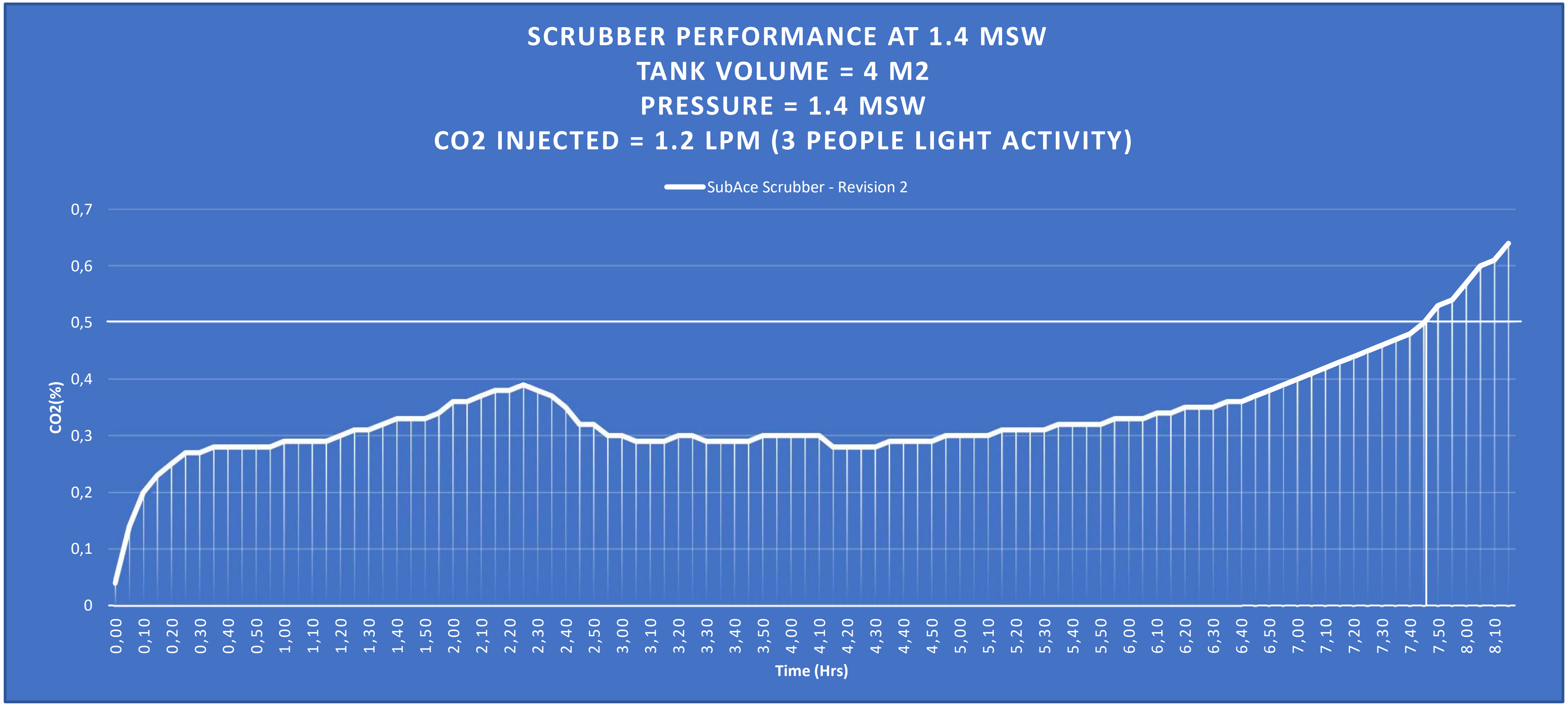
The CO_2 levels reached 0.5% <u>6 hours and 35 minutes</u> into the test.

PROTOTYPE TESTING: BASELINE 2.4 LPM CO2



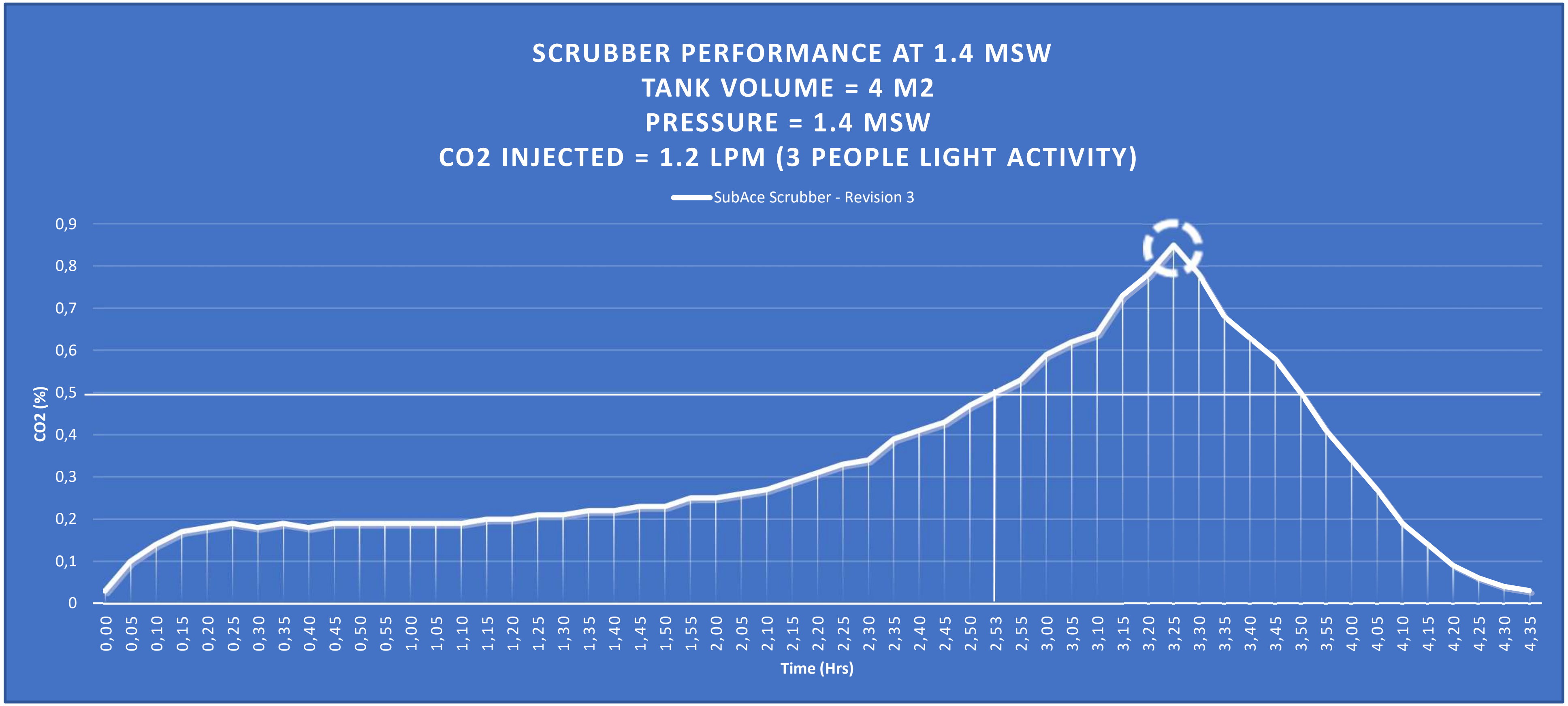
The CO2 levels reached 0.5% 50 minutes into the test.

PROTOTYPE TESTING: NEW FAN



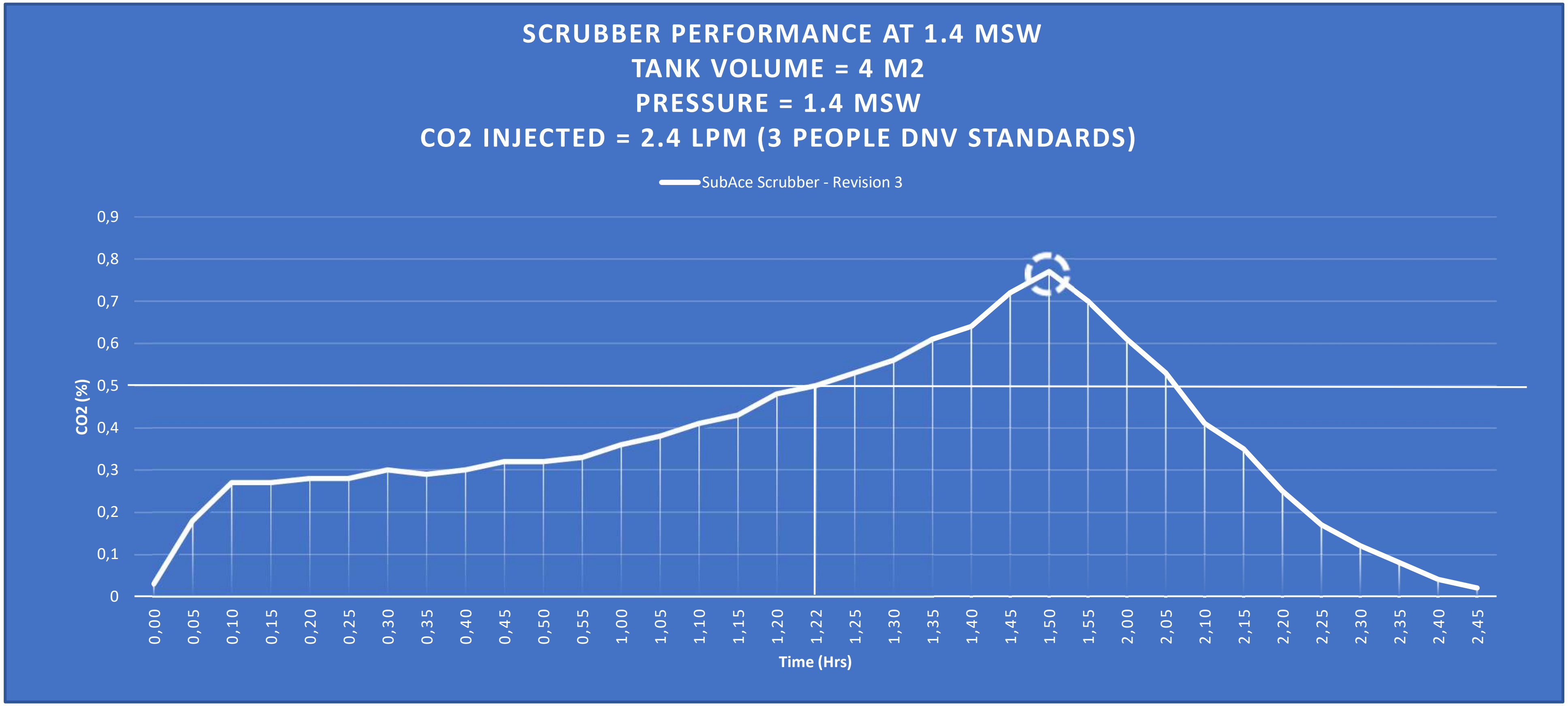
The CO_2 levels reached 0.5% 7 hours and 45 minutes into the test.

PROTOTYPE TESTING: NEW SEAL



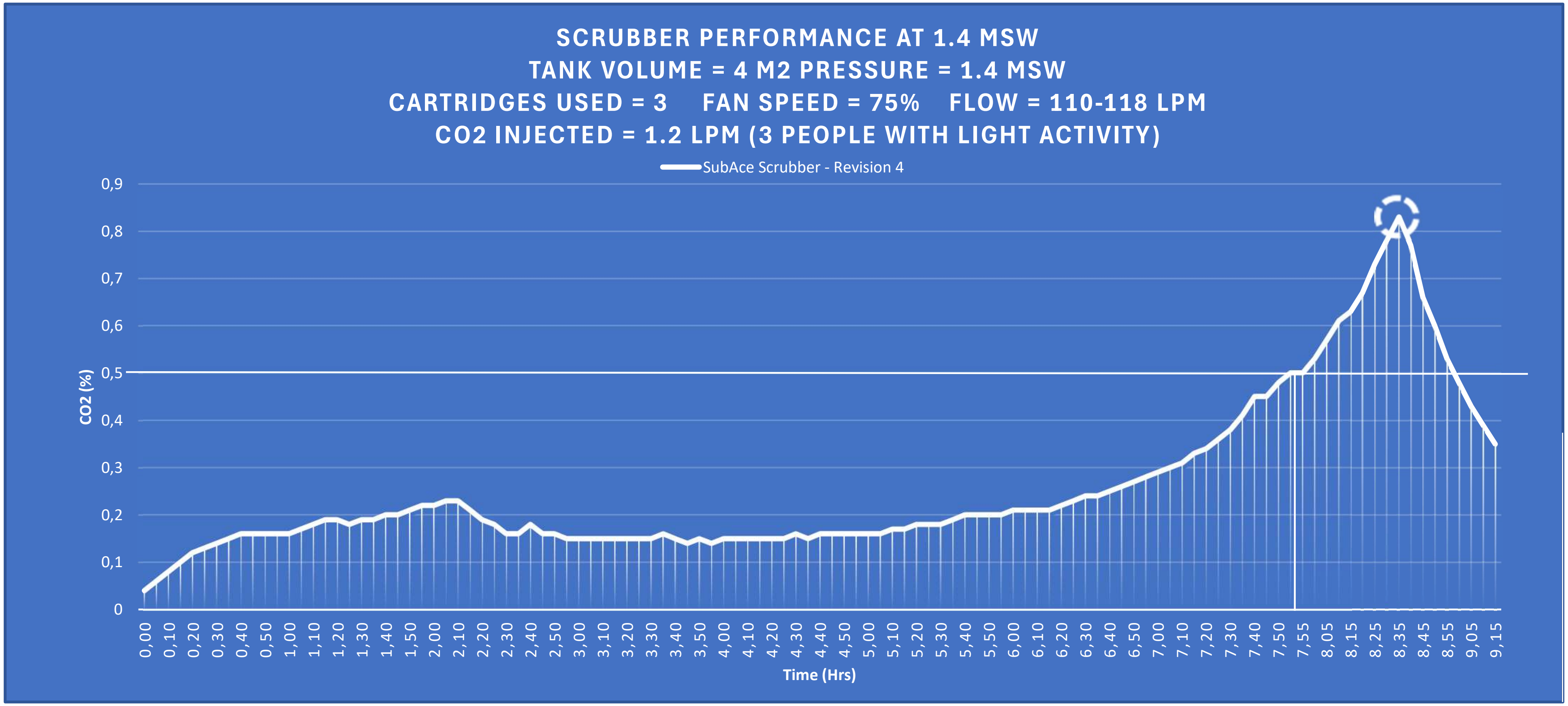
The CO2 levels reached 0.5% <u>2 hours and 53 minutes</u> into the test.

PROTOTYPE TESTING: NEW SEAL – HIGH FLOW



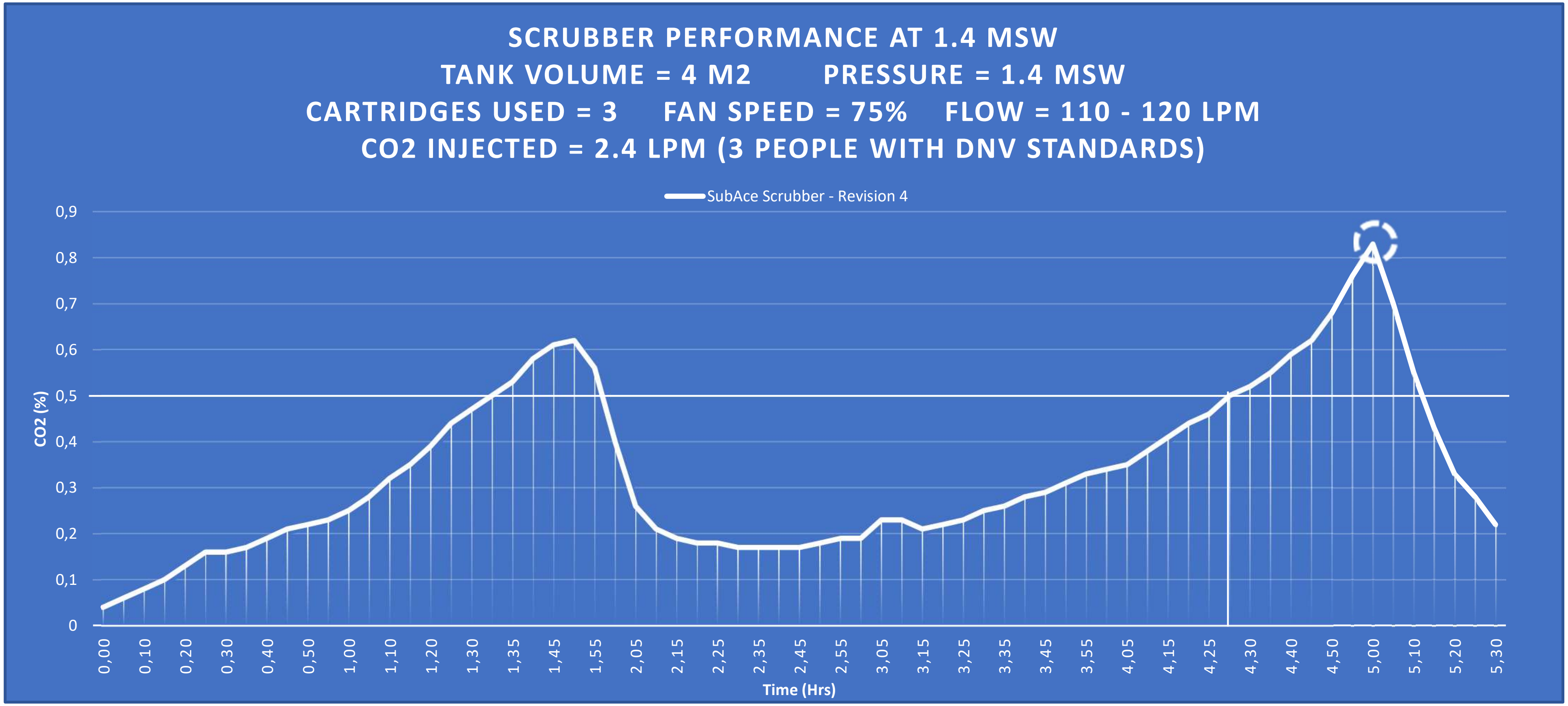
The CO2 levels reached 0.5% 1 hour and 22 minutes into the test.

PROTOTYPE TESTING: LEAKS CORRECTED



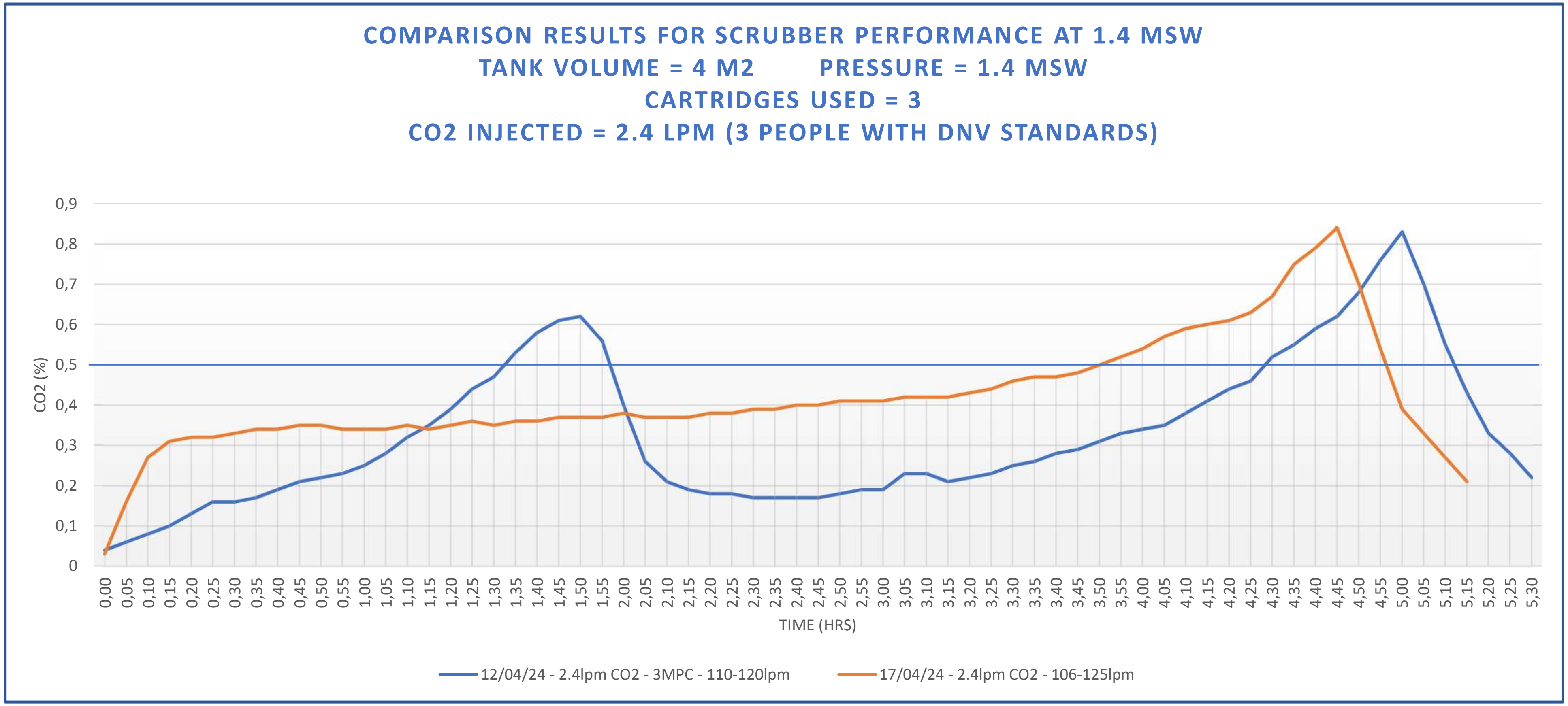
The CO2 levels reached 0.5% 7 hours and 54 minutes into the test.

PROTOTYPE TESTING: LEAKS CORRECTED - HIGH CO2 FLOW



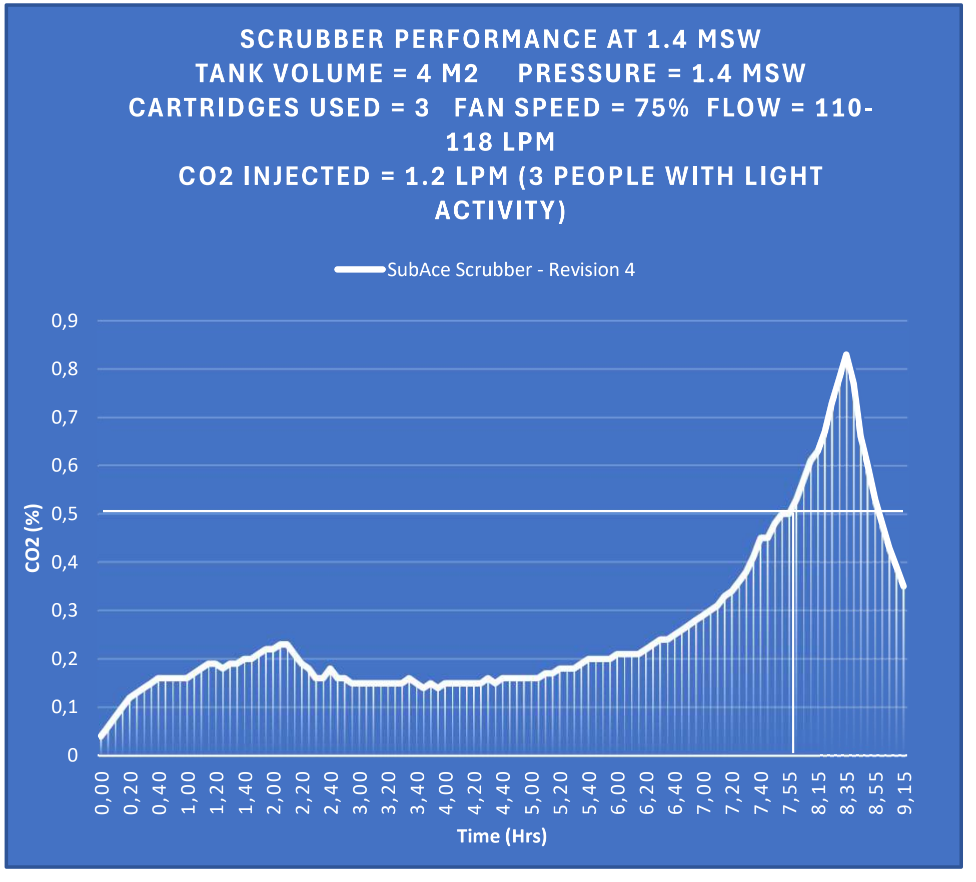
The CO2 levels reached 0.5% (Second) <u>4 hours and 29 minutes</u> into the test.

TEST COMPARISON; HIGH CO2 FLOW

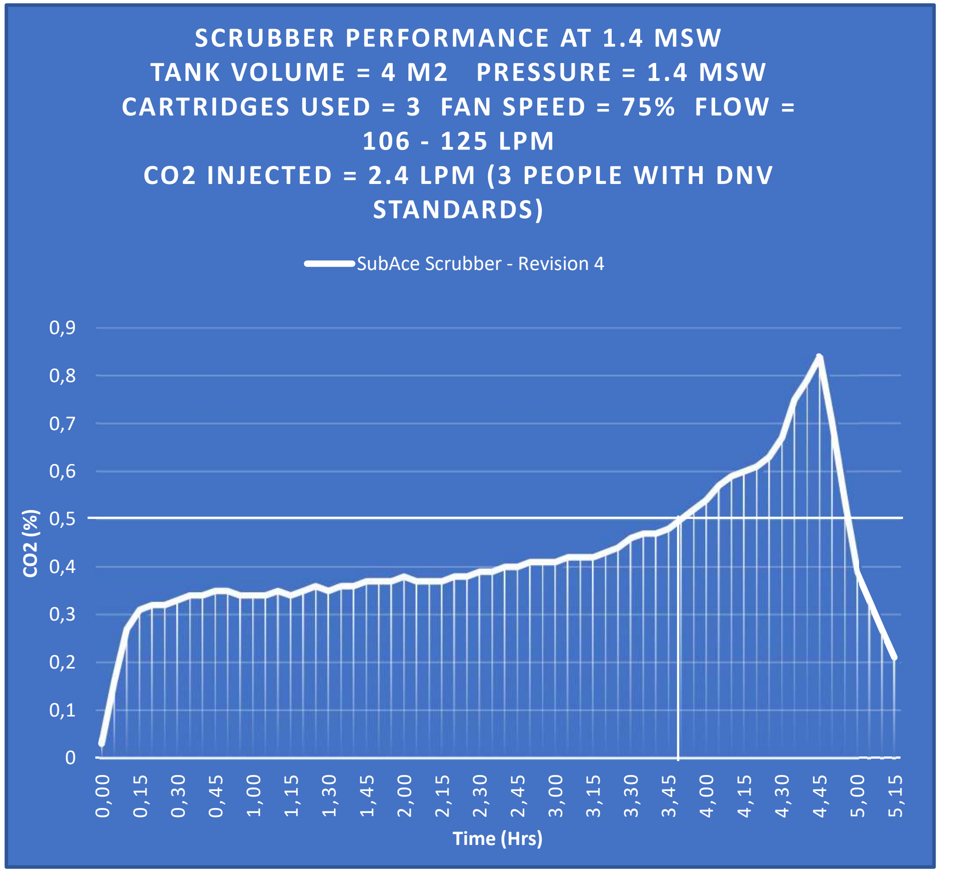


Test 12/04/24 took place at the beginning of the day when the temperature of the container was recorded at <u>8°C.</u>
Test 17/04/24 took place in the afternoon when the temperature of the chamber was recorded at <u>18°C.</u>

REVISION 4 – KEY RESULTS



Flow Rating: 0.4lpm CO^2 per person
Time CO reached 0.5%: 7 Hours 45 Minutes



Flow Rating: 0.8lpm CO^2 per person
Time CO reached 0.5%: 3 Hours 50 Minutes

CONCLUSIONS AND ROAD FORWARD

- Ambient conditions strongly affect the performance of calcium hydroxide absorbents.
  - Pressure and temperature adversely affect calcium hydroxide performance
    - Lithium hydroxide absorbents are much less affected by ambient conditions

- Modeling required to provide uniform flow (velocity) and optimize structured absorbent performance.
  - Flow adapters can have little or no effect on pressure drop
  - Flow will remain unchanged for the life of the scrubber
  - Testing is mandatory to validate the model

- The SubACE/SMP scrubber will complete the prototype phase of testing when
  - Seal design is finalized
  - Fan performance is set
  - Minor mechanical adjustments are being considered.

Micropore INCORPORATED

ACEL

Submarine Manufacturing & Products Limited
Manufacturer of Commercial Diving, Medical Hyperbaric Applications and Military Subsea & Emergency Rescue Solutions