

## MICROPORE REPORTS RESULTS OF POWERCUBE® PIER-SIDE SUBMARINE TEST

**Background:** Within closed environments such as submarines, carbon dioxide will reach toxic levels much sooner than oxygen depletion health concern. Chemical based scrubbing systems are used on submarines to control carbon dioxide (CO<sub>2</sub>). Non-regenerative scrubbers use an alkali adsorbent such as calcium hydroxide to neutralize/capture acidic CO<sub>2</sub>. Micropore has developed a carbon dioxide adsorbent to replace granular cans used in submarine scrubbers. The Micropore adsorbent PowerCubes® are sized to store in the same volume as the granule cans. PowerCube® adsorbent requires canister adapters to mate to shipboard scrubbers. The canister accommodates flow in both directions. This allows operation in the 6 can scrubber installed on many diesel electric submarines.



PowerCube® Adsorbent Block



Canister for one PowerCube®

**Testing:** In third quarter of 2014 the Royal Dutch Navy conducted onboard testing of Micropore's PowerCube® adsorbent that replaces granular cans. The test was designed to compare performance of solid adsorbent cubes with granule cans. The test was conducted on the Royal Dutch Submarine Hr. Ms. DOLFIJN. The submarine was pier side and hatches were sealed. All three compartments in the submarine were open; ventilation and air conditioning was aligned for submerged operation. Prior to operating the scrubbers, the CO<sub>2</sub> concentration in the submarine was increased to 0.75% by injecting 18 kg of CO<sub>2</sub>. Carbon dioxide concentration was monitored at 7 fixed locations throughout the submarine using NDIR analyzers manufactured by

Analog. This test replicated scrubber operation after diving the submarine. Two scrubbers (12 adsorbent containers total) were energized and testing begun. CO<sub>2</sub> was injected at a rate to replicate a crew of 62 people (1.3 kg CO<sub>2</sub> every 30 minutes to represent 56 sailors plus 6 people onboard (62 equivalent people total injected CO<sub>2</sub>)). For the first batch of adsorbent, two scrubbers were operated; each scrubber with six cubes or cans. As the carbon dioxide concentration increased to 1.0%, fresh adsorbent was installed and a third scrubber was operated. This paper reports test results for granules and calcium hydroxide PowerCubes<sup>®</sup>.



Six canisters installed in shipboard scrubber



PowerCube<sup>®</sup> being installed into canister

**Discussion of Results:** The results of the test are detailed in the attached Table and Figure.

<b>OPERATING HOURS</b>	<b>LITERS CO<sub>2</sub> PER SCRUBBER POWERCUBE<sup>®</sup></b>	<b>LITERS CO<sub>2</sub> PER SCRUBBER GRANULES</b>
<b>1</b>	460	645
<b>2</b>	1530	1075
<b>3</b>	2145	1485
<b>4</b>	2775	1875

Table 1 Scrubber Performance (Liters of CO<sub>2</sub> at NTP)

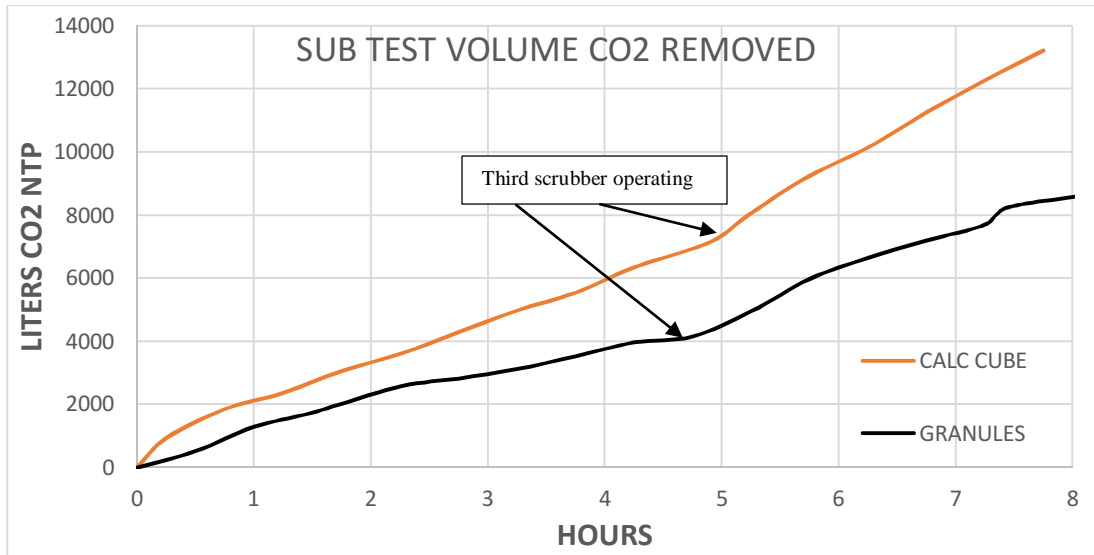


Figure 1 Liters of CO<sub>2</sub> removed on test submarine

Table 1 performance is measured for single scrubber operation (6 PowerCubes<sup>®</sup> or granular adsorbents per scrubber). CO<sub>2</sub> concentration started at 0.75% when the scrubbers were first energized and increased to 1.0% after 5 hours. As indicated in Figure 1, energizing the third scrubber increased the CO<sub>2</sub> removal rate (note the rate equals the slope of the curve). The initial removal rate for the PowerCube<sup>®</sup> is higher than for granules; this is shown at both the start of the test and when the third scrubber is energized. This increase is explained by the higher airflow through a scrubber operating with PowerCube<sup>®</sup> adsorbent (due to the lower pressure drop through the cube). The higher capacity for PowerCube<sup>®</sup> results from the increased mass of adsorbent compared to granules (approximately 4.90 kg versus 3.75 kg). The improved performance of PowerCubes<sup>®</sup> offers real shipboard advantages. Using the data reported from the Dutch submarine trial and extending the time to 48 hours continuous closed boat operation results in:

- ***120 PowerCubes<sup>®</sup> to maintain CO<sub>2</sub> concentration below 1.0%***
- ***246 cans of granules for the same results.(50% storage savings)***

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