molecular

CASE STUDY

The Design of Life Support Systems for Submarines

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DCNS is a major export manufacturer of diesel-electric/hybrid AIP submarines and together with HDW (owned by Thyssen Krupp) and Kockums (owned by Saab) are the major technology drivers for developing world navy submarine manufacture. There are other construction facilities – notably in Brazil, Chile and India – but these tend towards manufacture under license after 'pattern ships' have been purchased abroad.

DCNS is therefore a major opinion former in the world market and their latest class of boat – the Scorpene class – is enjoying considerable success with ten boats ordered by Chile, India and the Royal Malaysian Navy.

The first of the Malay boats was formally handed over on 30 January 2009 after initial manufacturer's trials in the Bay of Biscay and subsequent post trial inspection/work up.

This boat has a displacement (dived) of around 1800 tons (according to model), a stated complement of 31, diving depth of >200m and a speed in excess of 20 knots submerged. These figures are all published by the manufacturer DCNS.

Molecular Products Ltd supplies the soda lime (Sofnolime® S-grade) used in the life support system for carbon dioxide removal or 'scrubbing', with two units for CO_2 absorption designed by DCNS.

S-grade is specially formulated for this application to cope with the particular conditions encountered on a submarine compared to those found in a low volume closed anaesthesia circuit. It is of a different profile (triangular cross section) and moisture content is elevated to cope with the comparatively dry atmosphere. DCNS also take special steps to ensure the Sofnolime® remains hydrated as a result of experience gained with the Scorpene class submarines built for Chile. These steps ensure it has a higher absorption capacity under standard conditions than our USP medical grades whilst still offering superior dust performance.

We are able to offer technical advice to our customers based upon our many years of practical experience. This became especially relevant recently in connection with the trials done at the end of December 2008 on board of the Scorpene class submarine Tunku Abdul Rahman officially handed over to the Royal Malaysian Navy 30 January 2009.

DCNS had undertaken some trials on the CO_2 removal units of the Malaysian submarine which showed their performance were lower than forecast on board this submarine. The data recorded during the trials indicated that the maximum concentration of CO_2 allowed on board was reached before a steady state could be achieved. Since two boats have already been sold with success to the Chilean Navy with results that were satisfactory regarding the CO_2 level on board, and the architecture of the scrubbers on board of the Scorpene boat for Malaysia is identical to those on board the Scorpenes for Chile, a question arose from DCNS about the efficiency of Sofnolime® S-grade supplied.

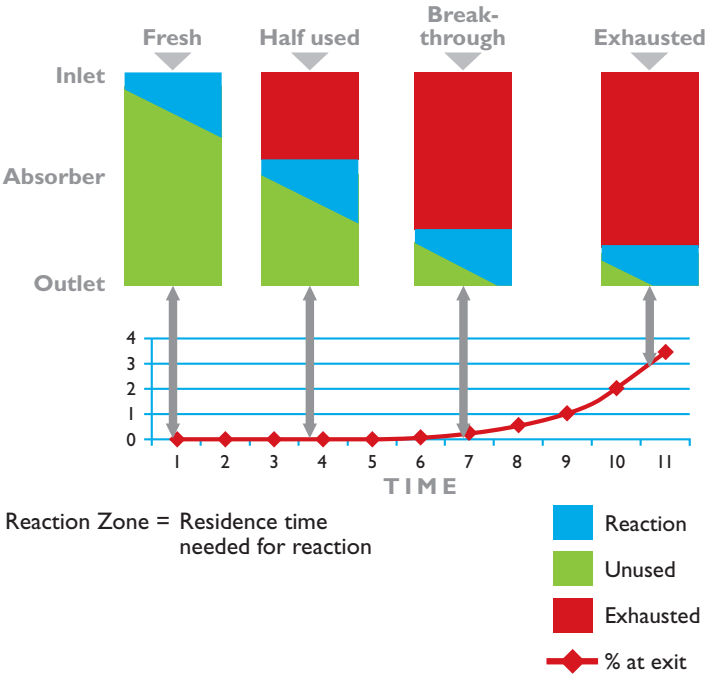
The information supplied by DCNS to Molecular Products Ltd included the results of the trials as well as the conditions for use: the total quantity of material used in each of the scrubbers, the internal volume of the submarine, the flow rate of the scrubber fans, standard respiration rate and crew numbers.

In order to optimise the system and find a good compromise between the flow rate treated by the scrubbers, which must be high enough to provide a good flow rate through the scrubbers and the minimum residence time of the CO_2 through the S Grade, DCNS reduced the flow rate through the absorbers. They expected to see little detrimental effect on CO_2 concentration due to an incomplete consideration of the factors which interact to produce a viable life support system.

It was their expectation that at lower flow rates the soda lime within the scrubbers would be more efficient because there would be a longer residence time. The fact is that above a certain minimum time (>0.3-0.5 seconds) the scrubbers will not remove more CO_2 per pass, although the overall capacity of the scrubber may be extended since the reaction zone will form a smaller proportion of the total volume within the scrubber unit. Thus a common misunderstanding arose between scrubber capacity and rate of removal per hour.

See below for how a scrubber would be expected to perform.

How an absorber works



The important point to note here is that the flow rate through any scrubber will affect the size of the reaction zone – sky blue colour – but that the rate of removal is NOT connected to the residence time but to the number of times the enclosed (submarine) atmosphere is exposed to the scrubbers per unit time. Thus, an absorber removing 100% of the CO_2 passing through it will be working at maximum efficiency, however, if the environment to be scrubbed is only being passed through at very long intervals then the rate of removal will be very low and if exceeded by the rate of production the overall concentration of CO_2 will inexorably rise.

The answer offered by Molecular Products Ltd was to increase the flow through the scrubbers whilst still maintaining the residence times above the threshold level. This was modelled internally by the technical team and once various factors had been applied to account for the relative mixing occurring within the environment, we were able to achieve good agreement with the results obtained empirically during the acceptance trials of various members of the class.

We were thus able to re-assure the manufacturer, offering advice on operations outside the standard operating conditions with different crew configurations and because of the good agreement between our models, give confidence on the viability of the CO_2 absorbers installed by DCNS using S Grade Sofnolime® and confirming the forecast that the results on Scorpene for Malaysia will be the same as those on board of the Chilean Scorpenes.

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