Project CO_2 adsorbtion improvement on board Walrusclass

by
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History

- In the conops of the Walrus class the maximum accepted CO_2 level at this moment is 1.5% with a maximum of 2 % for maximum 24 hours
- During the last years several Scrubber were reviewed for fitting on board Walrus class
- Because of hi costs and storage problems non of the reviewed scubbers were usable on board
- In cooperation with vendors the RNLN submarine service investigated other solutions resulting in the powercube adapters with Micropore Power cubes blocks

Situation now

- The Conops of the Walrus class will be changed to an level of maximum of 1% of accepted CO_2 level with a maximum of 2 % for maximum 24 hours.
- Aim should be to have the level of CO2 at 0,7 %
- During 2014 and 2015 we performed several number of test to proof to ourselves and other interested parties , that it is possible to improve the CO_2 scrubbing

CO_2 trial on board Zr.Ms. Dolfijn

static trail at piereside Den Helder

Start Friday June 13th 07:30

End Sunday June 15th 18:30

Trial

This trial is set up to find a best solution on CO_2 scrubbing on board Walrusclass Submarines.

In this trial we are comparing three different products using in the two standard scrubbers at the start of each day and switching on the third scrubber during the day.

How to simulate a crew of 62? Put 6 guys in a closed down submarine, give them fire extinguishers and have them discharge aprox 2,8 kg CO_2 /hour into the submarine

Products

Product used on:

- Day one, Powercube adapter with Lithium Hydroxide blocks,
- VM-2560P(Micropore)
- Day two, Powercube adapter with Calcium Hydroxide blocks,
- VM-1050P(Micropore)
- Day three, standard Sodium Hydroxide canister,
- 300604-00

Weight of absorbing material

- Lithium Hydroxide blocks VM-2560P (Micropore) 2,93 kg

- Calcium Hydroxide blocks VM-1050P (Micropore) 4,93 kg

•Standard canister Sodium Hydroxide 300604-00 (Molucular) 4,3 kg

Events

- Day one,
  trial using Powercube adapter in combination with LiOH blocks

- Day two,
  trial using Powercube adapter in combination with Sodalime blocks

- Day three,
  trial using Sofnolime canisters

- Every day we performed a zero CO_2 measurement before closing all hatches to know what reading the separate SUBASPIDA's gave at the start of the trial (a Δ%).
- To simulate 62 persons we released an average of 1,4 kg CO_2 every half an hour. And took local measurements of O_2 and CO_2 in between of the discharge moments with the same interval of every half an hour.
- (In ANEP 85 it is stated that a person producer about 23 liters of CO_2/hour, that makes 0,046 kg/hour. Given that for one hour and 62 people we had to discharge 2,852 kg/hour)

Prior to the events for day one and two we prepared the two standard scubbers (on Sonar loft and wardroom) and a third extra scubber (engineroom) with the powercube adapters

Wardroom scrubber fitted with Powercube adapters

Torpedoroom scrubber fitted with Powercube adapters

Engineroom scrubber fitted with Powercube adapters

Day 1 June 13th 2014 (LiOH powercube trial)
Before closing down we took all measuring equipment on deck to get a zero reading. After shutting the hatches we applied 18 kg of CO_2 into the boat (released from fire-extinguishers in: torpedoroom, controlroom, engineroom and E-swithroom)
After discharging we loaded with powercube prepared standard scrubbers with LiOH absorbing blocks and started scrubbing at the measurement on the lower deck SUBASPIDA at 0,85% CO_2. Started scrubbing at 10:24 hours with the two standard scrubbers on board Walrus class submarines. Measured pressure difference and airflow of both scrubbers.

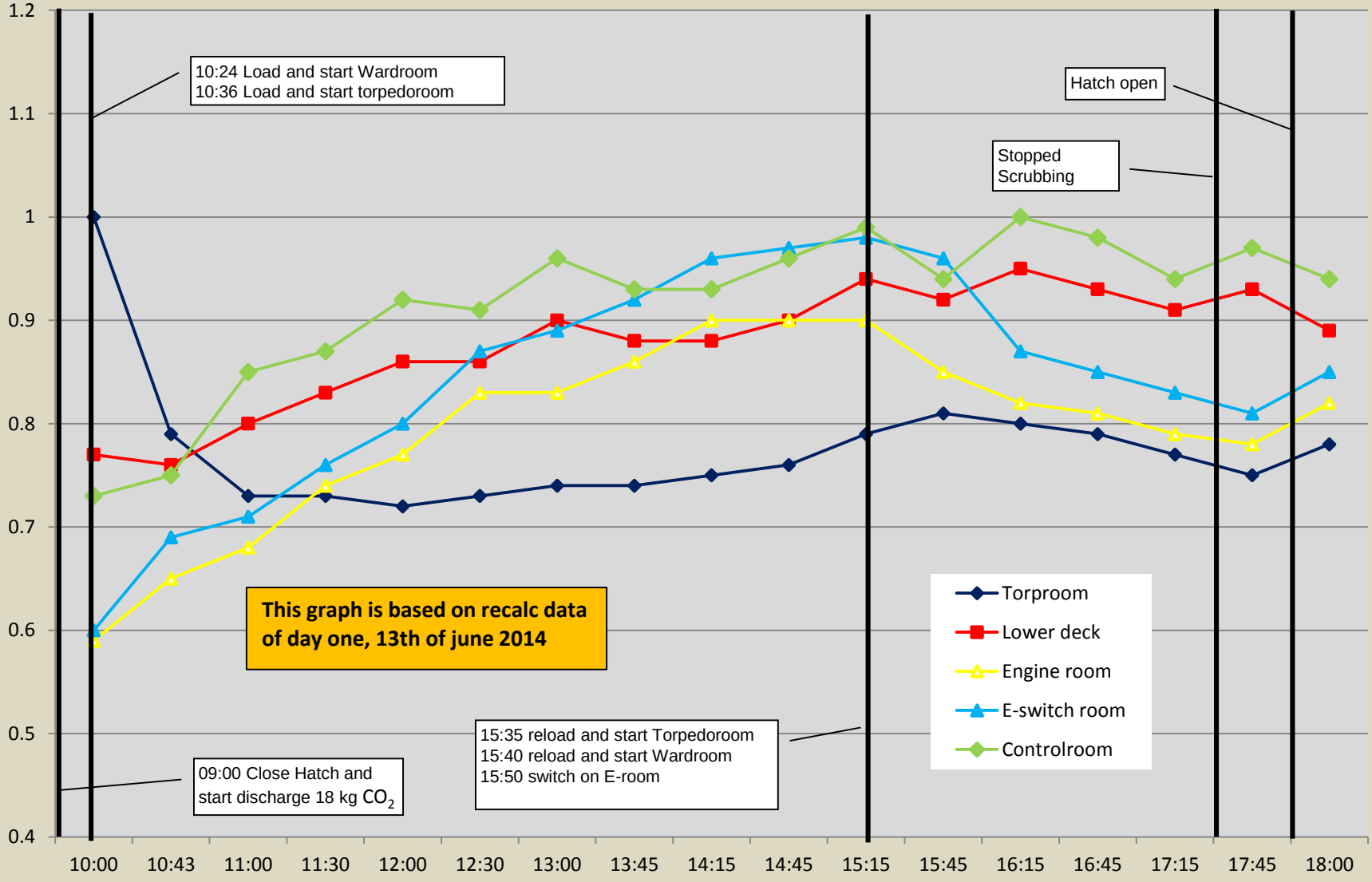
Scrubber position	ΔP	m^3/hr
Torpedoroom	0,51	67
Wardroom	0,5	65
Engineroom	NA**	160

Table 1

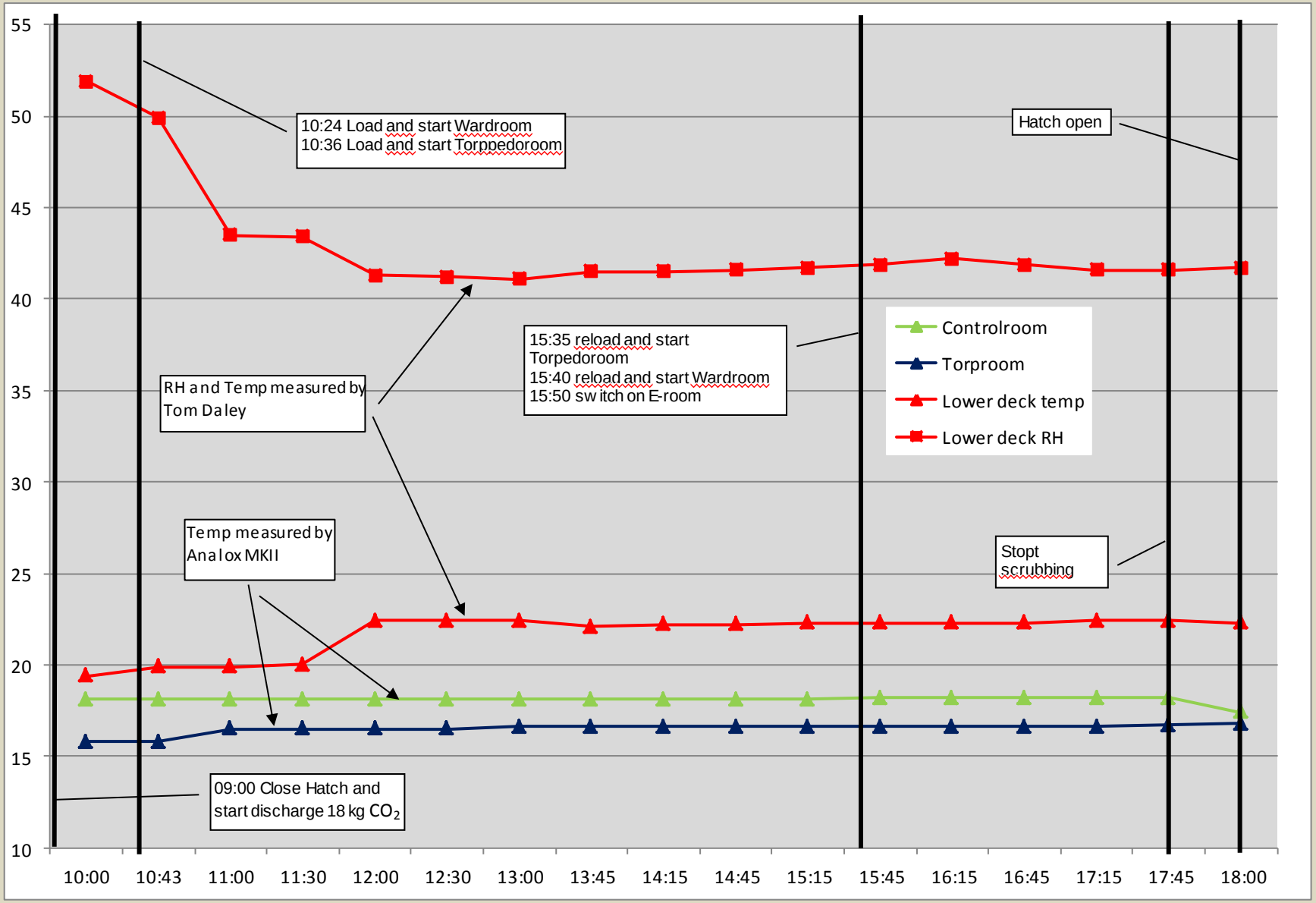
** Not Applicable

Because of some installing problems of the powercubes in the third scrubber on Thursday, we toke a second go on Friday. So the third scrubber was available for the trial. Reloaded the standard scrubbers at 15:35 hours and loaded/started the 3th scrubber at 15:50 hours.

Graph of day one (powercube with LiOH block)



Day one RH & Temperature



Day 2 June 14th 2014 (Calcium powercube trial)
Before closing down we took all measuring equipment on deck to get a zero reading. After shutting the hatches we applied 18,8 kg of CO_2 into the boat (released from fire-extinguishers in: torpedoroom, controlroom and engineroom) and starter scrubbing at the measurement on the lower deck SUBASPIDA at 0,93% CO_2. Started scrubbing at 09:21 hours with the two standard scrubbers on board Walrus class submarines. Measured pressure difference and airflow of both scrubbers.

Scrubber position	ΔP	m^3/hr
Torpedoroom	0,46avg	67
Wardroom	0,47avg	65
Engineroom	NA**	NM*

Table 2

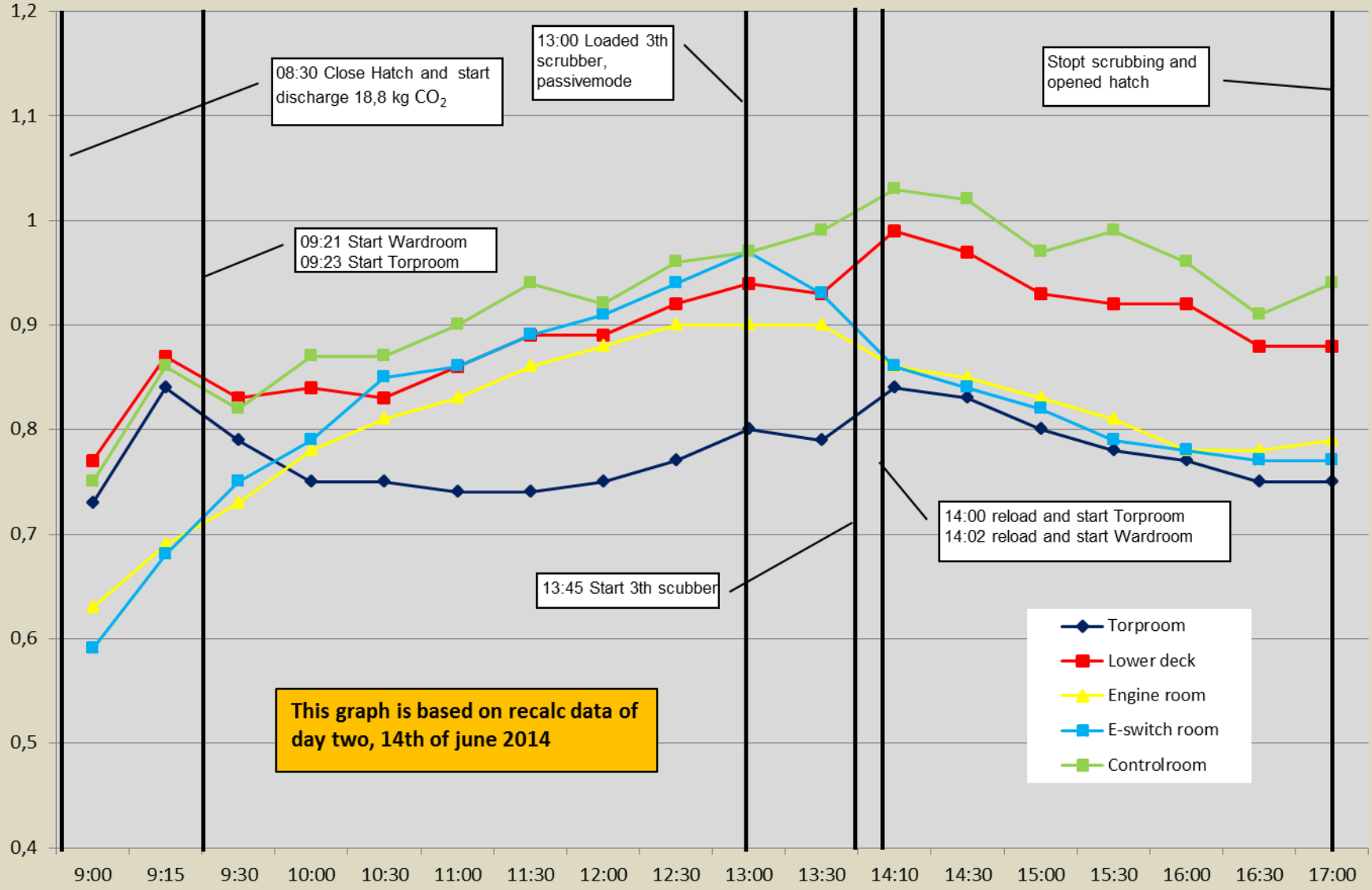
*Not Measured, ** Not Applicable

Just before 13:00 hours we loaded the third scrubber with the calcium powercube blocks but did not start the scrubber. At 13:15 hours we saw a significant drop in CO_2 level in the E-switch room (closest in the vicinity of the third scrubber). At that point we realized the third scrubber has a constant flow through the scrubber because of its position in the ships ventilation system. Because at first we did not notice and understand what was going on we decided at 13:45 hours to switch the third scrubber on so we were using the full capacity of the scrubber . As the CO2 level in torpedoroom, controlroom and lower deck were still going up we reloaded at 14:00 hours the two standard scrubbers . From that point on the CO2 levels in all area's started to go down.

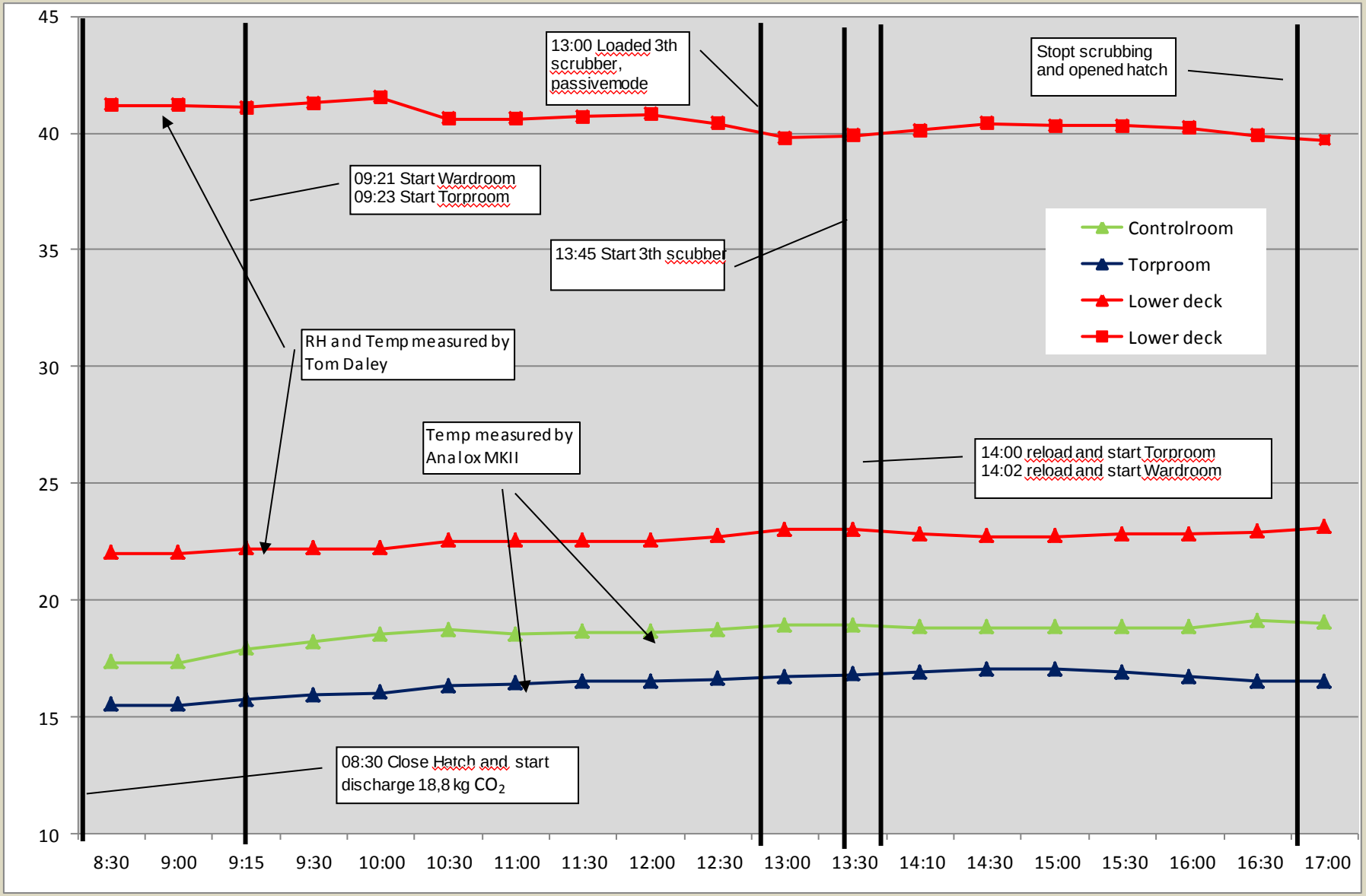
At 17:00 hours we stopped scrubbing and immediately after that we opened the hatch.

Because of the time consuming work of taking out the powercube adapters and making the three scrubbers standard again we stopped at 17:00 hours and started about one and a half hour and took care of a greater part of rebuilding the scrubbers.

Graph of day readings (powercube with CAOH block)



Day two RH & Temperature



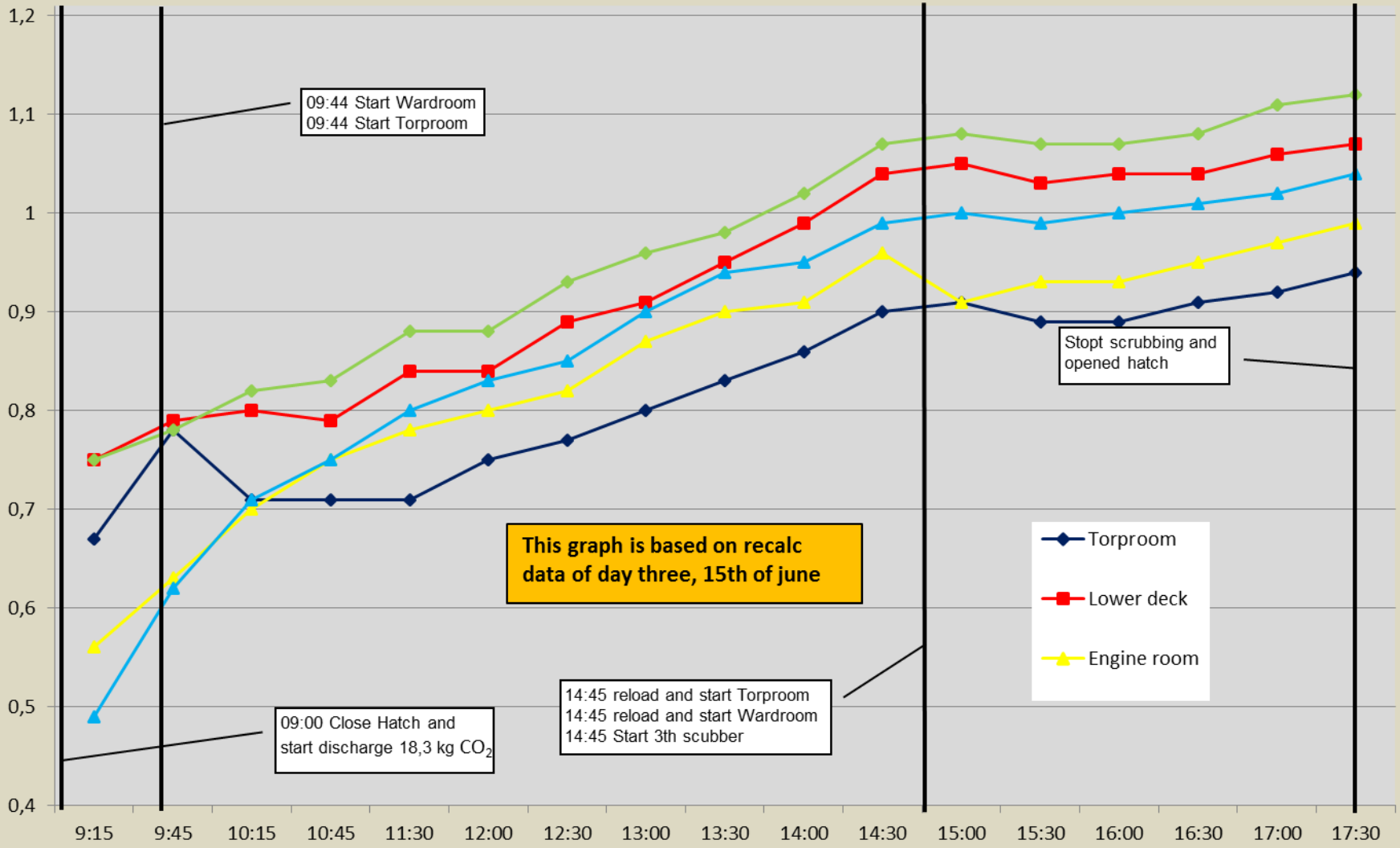
Day 3 June 15th 2014 (Calcium standard canister trial)
Before closing down we took all measuring equipment on deck to get a zero reading. During this time we restarted the work on the scrubbers and finished at approx. 09:15 hours.
After shutting the hatches we applied 18,3 kg of CO_2 into the boat (released from fire-extinguishers in: torpedoroom, controlroom and engineroom) and started scrubbing at the measurement on the lower deck SUBASPIDA at 0,85% CO_2. Started scrubbing at 09:21 hours with the two standard scrubbers on board Walrus class submarines. Measured pressure difference and airflow of both scrubbers.

Scrubber position	ΔP	m^3/hr
Torpedoroom	0,55avg	67
Wardroom	0,5avg	64
Engineroom	NA**	100/120

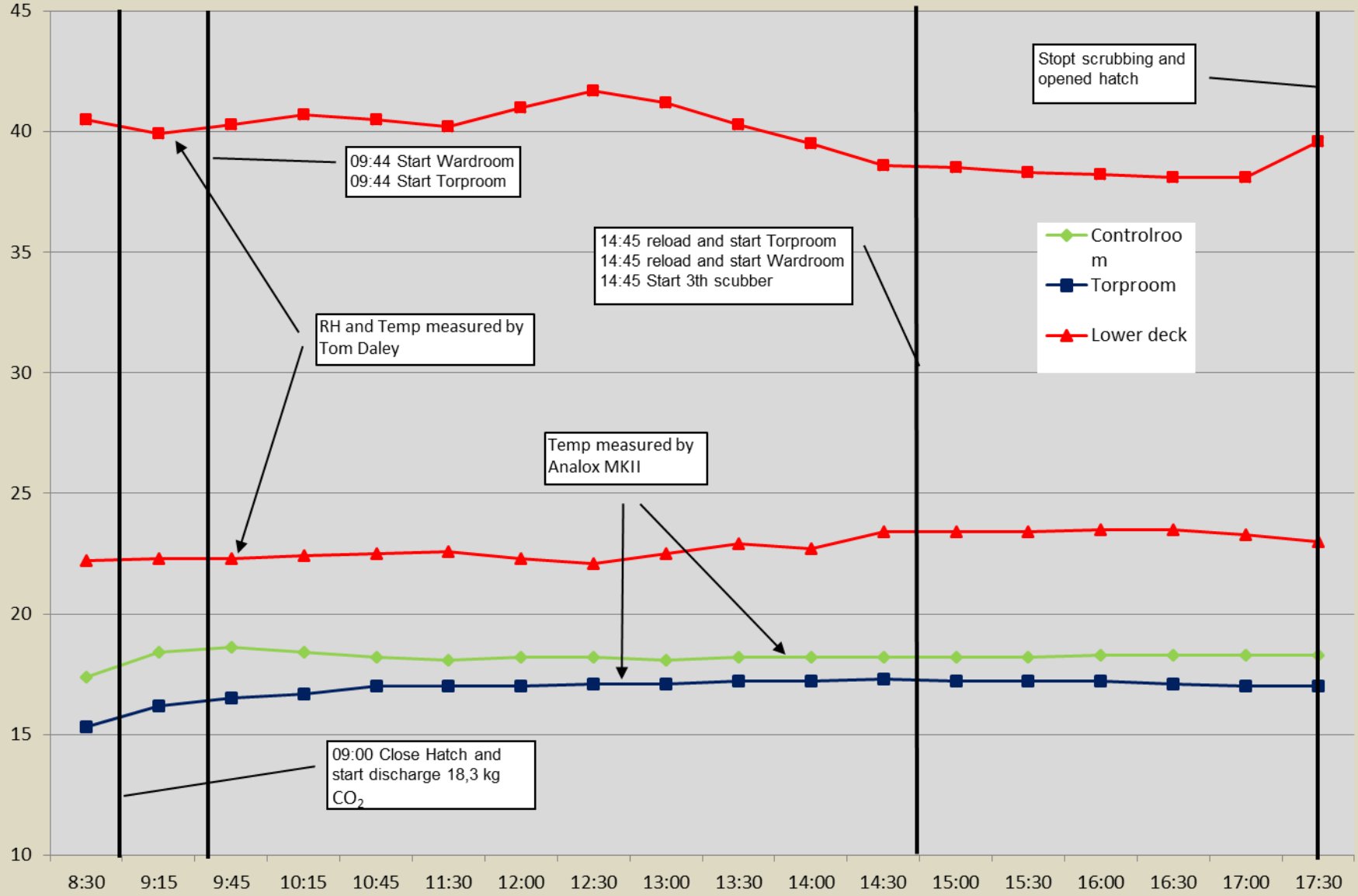
Table 6

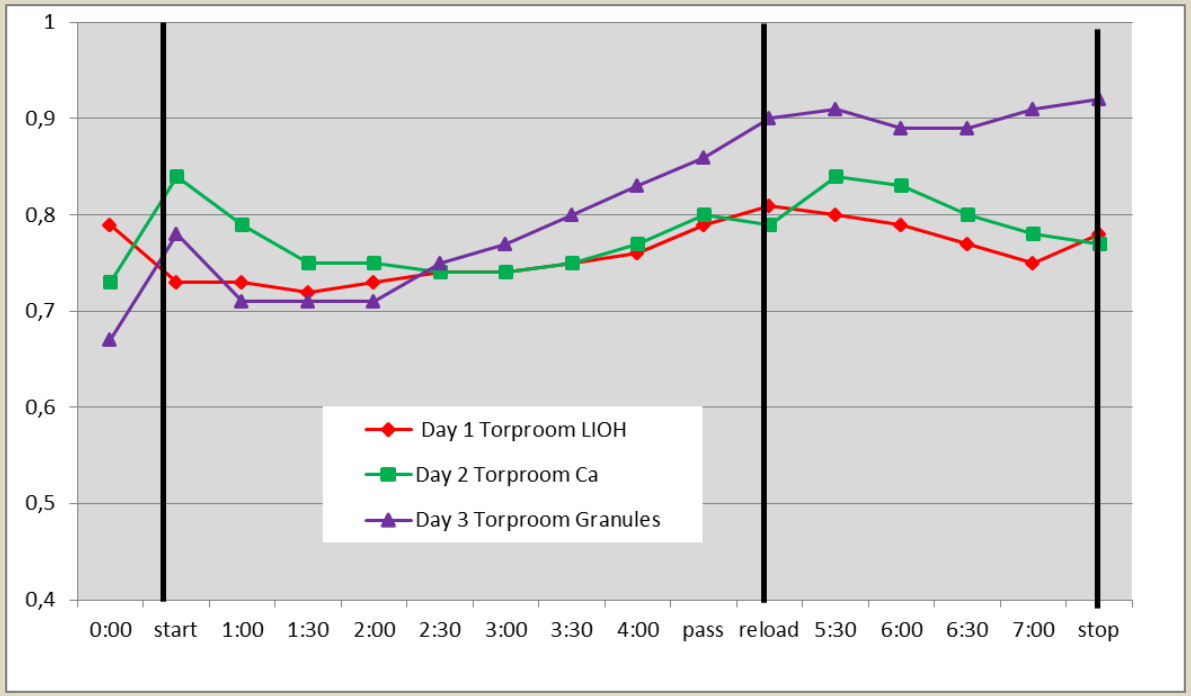
After the 15:30 hours measurement we discussed at what level of CO_2 we would start the third scrubber. At 14:45 hours we reloaded the standard scrubbers and loaded/started the third scrubber.
Looking at the graph during the trial and finding the CO_2 level keeps going up we decided to stop this trial at a CO_2 level of 1,2%, this was first reached in the controlroom at 17:30 hours. Opened the hatch just after that point.

Graph of day readings (Sofnolime canisters)



Day three RH & Temperature





Graphs per location

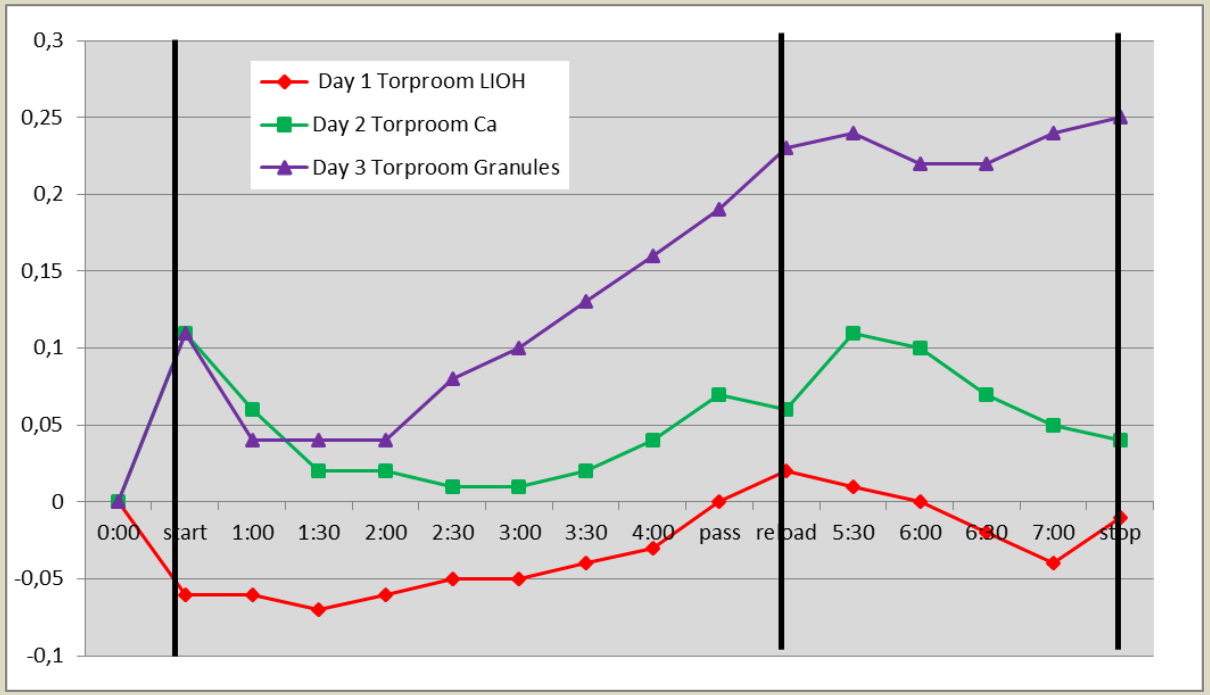
Torpedoroom

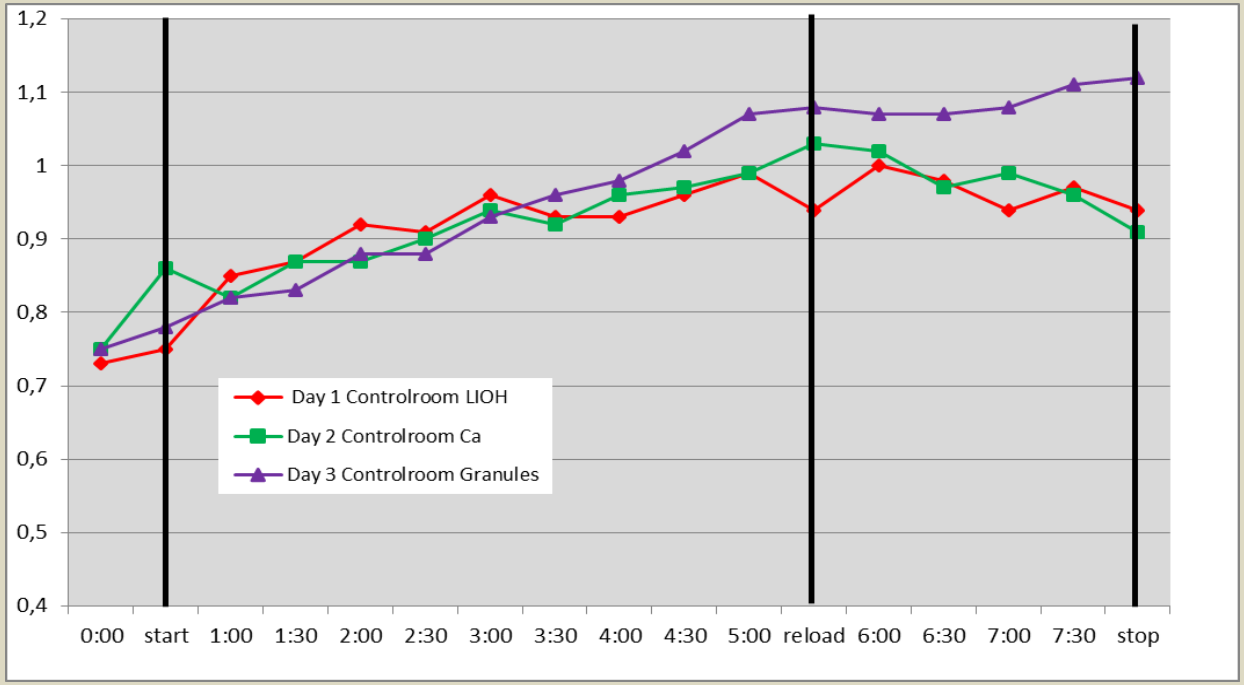
Graph 2

Graph 1

To compare the three days graphes 1 and 2 of each location were made

graph 1 is the data per location.
In graph 2 it is attempted to just see the slopes of each day





Graphs per location

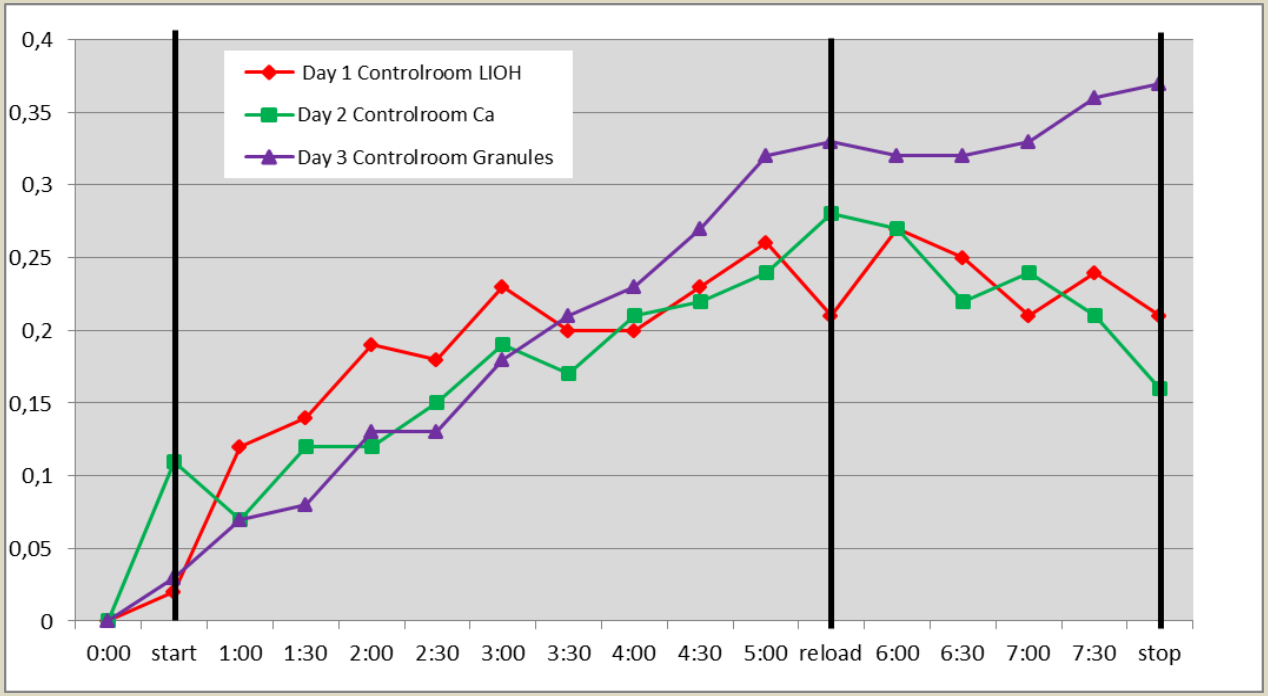
Controlroom

Graph 1

To compare the three days graphes 1 and 2 of each location were made

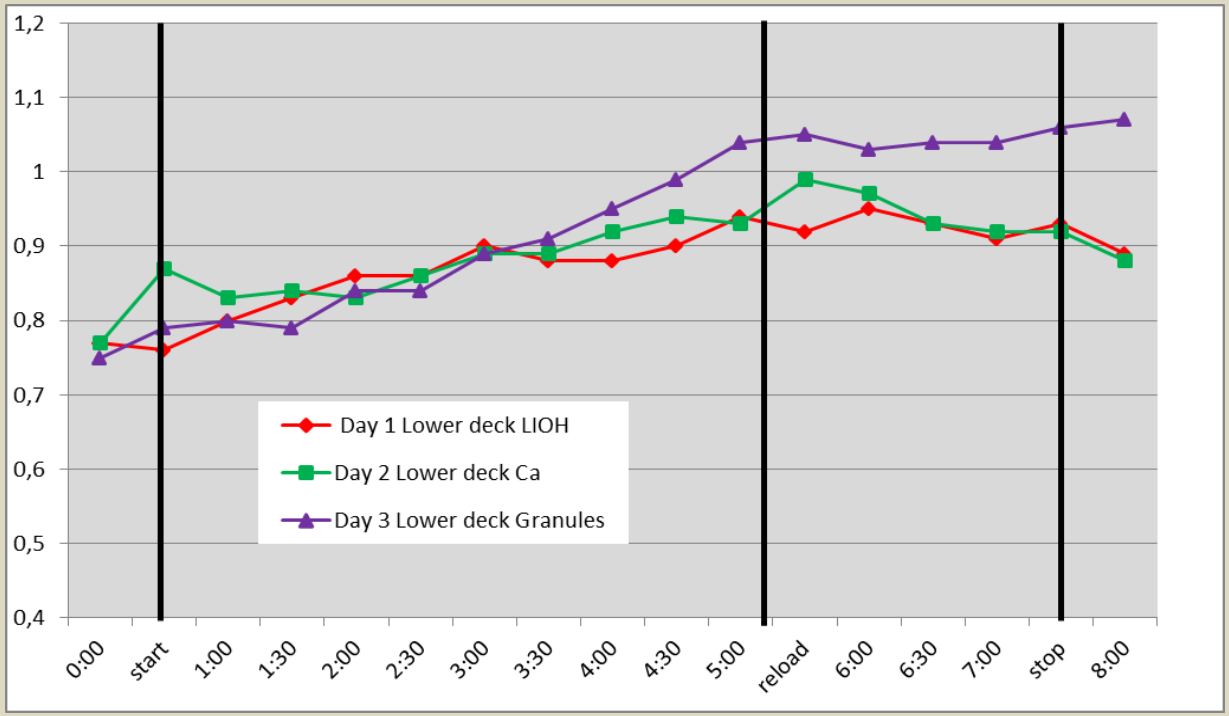
graph 1 is the data per location.
In graph 2 it is attempted to just see the slopes of each day

Graph 2



Graphs per location

Lower deck

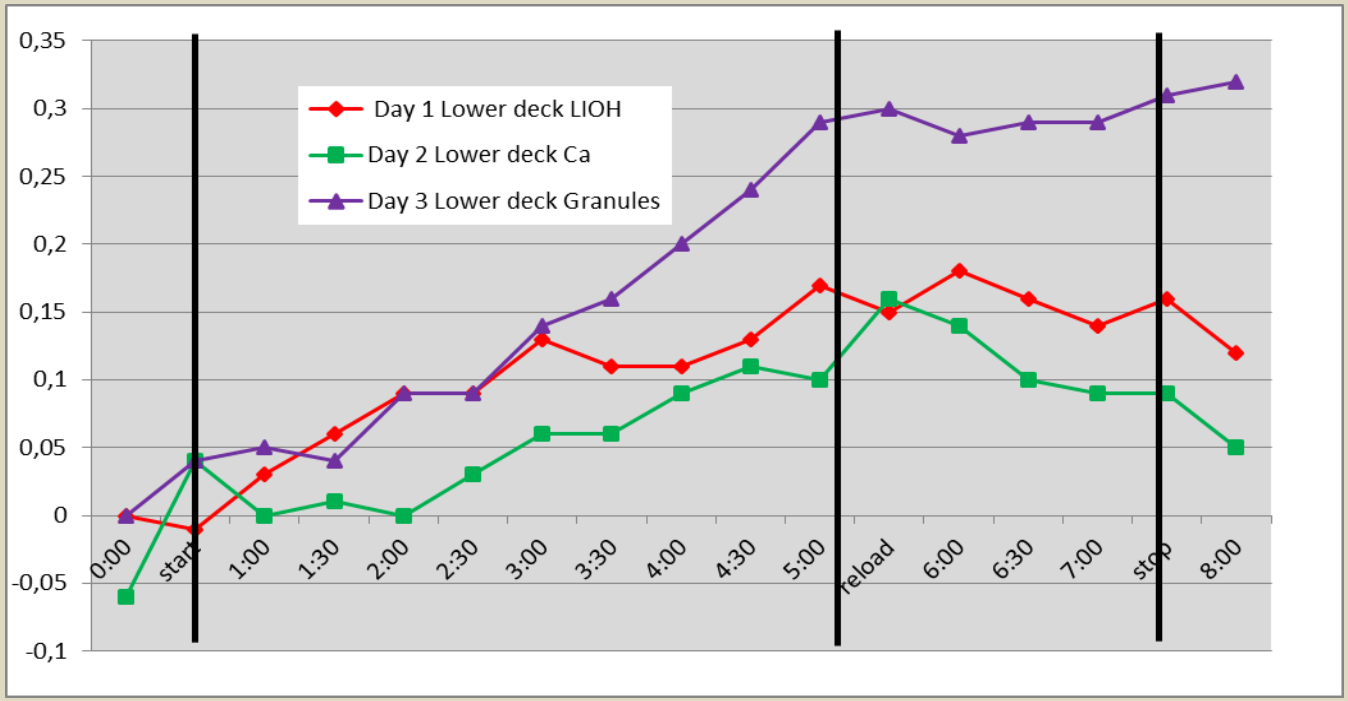


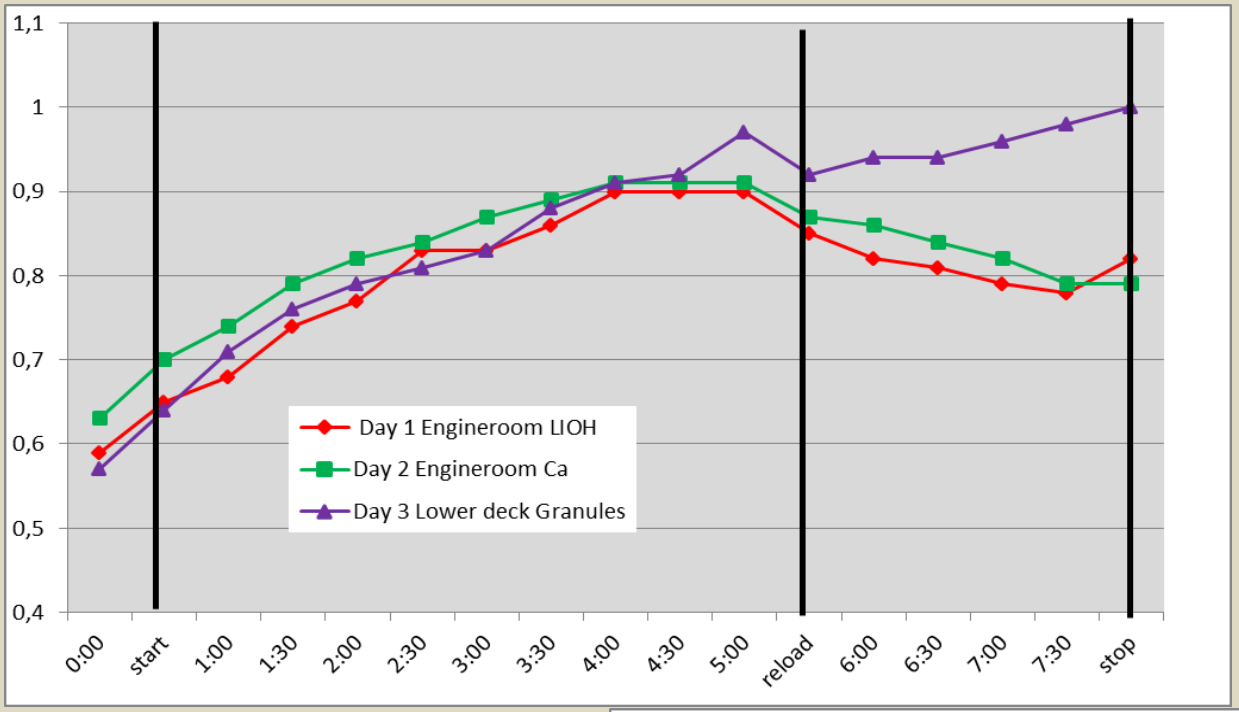
Graph 1

To compare the three days graphes 1 and 2 of each location were made

graph 1 is the data per location.
In graph 2 it is attempted to just see the slopes of each day

Graph 2





Graphs per location

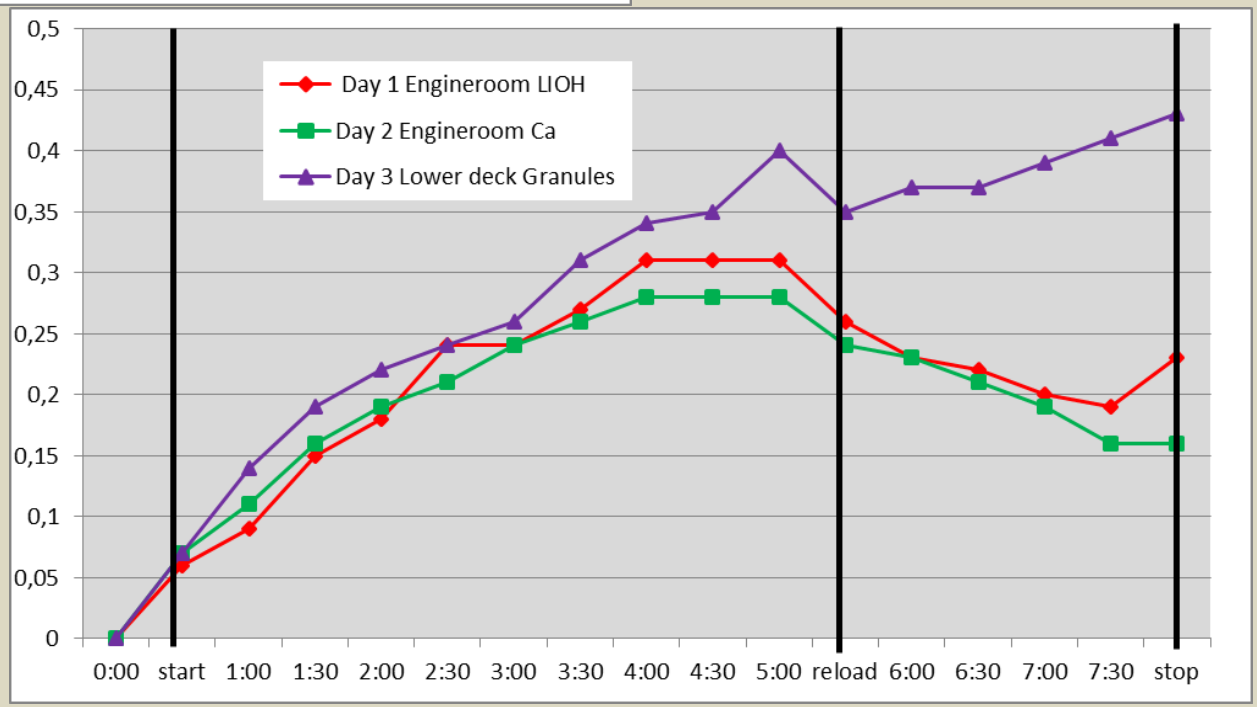
Engineroom

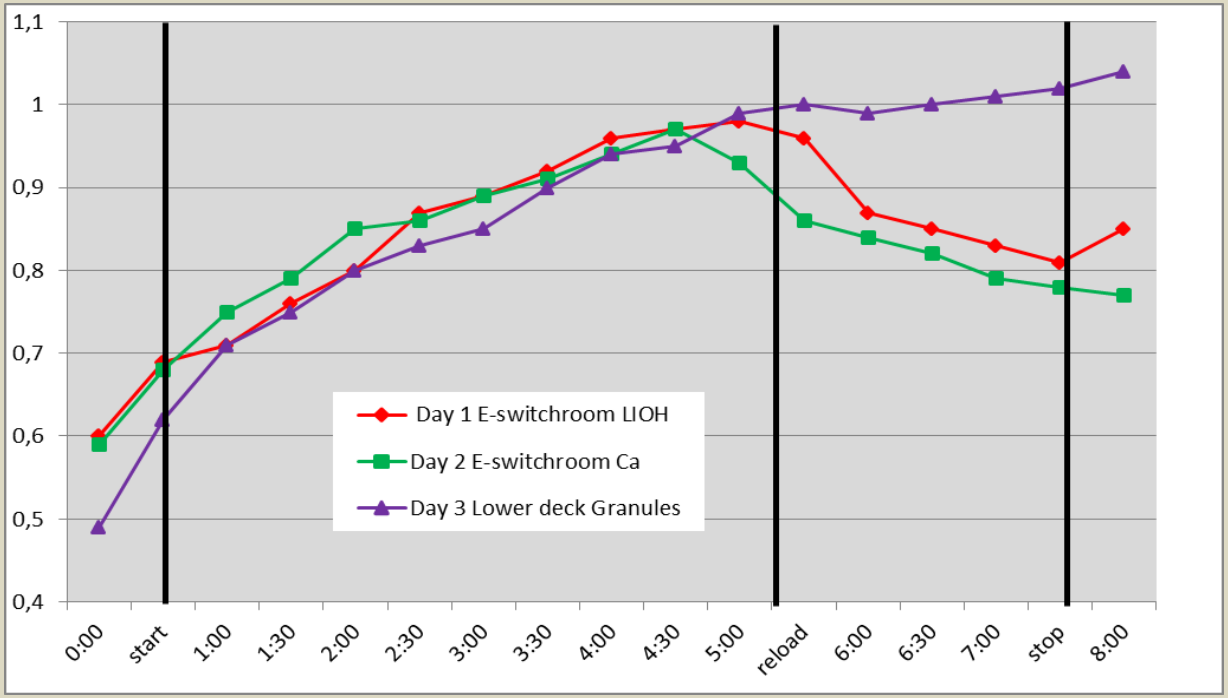
Graph 1

To compare the three days graphes 1 and 2 of each location were made

graph 1 is the data per location.
In graph 2 it is attempted to just see the slopes of each day

Graph 2





Graphs per location

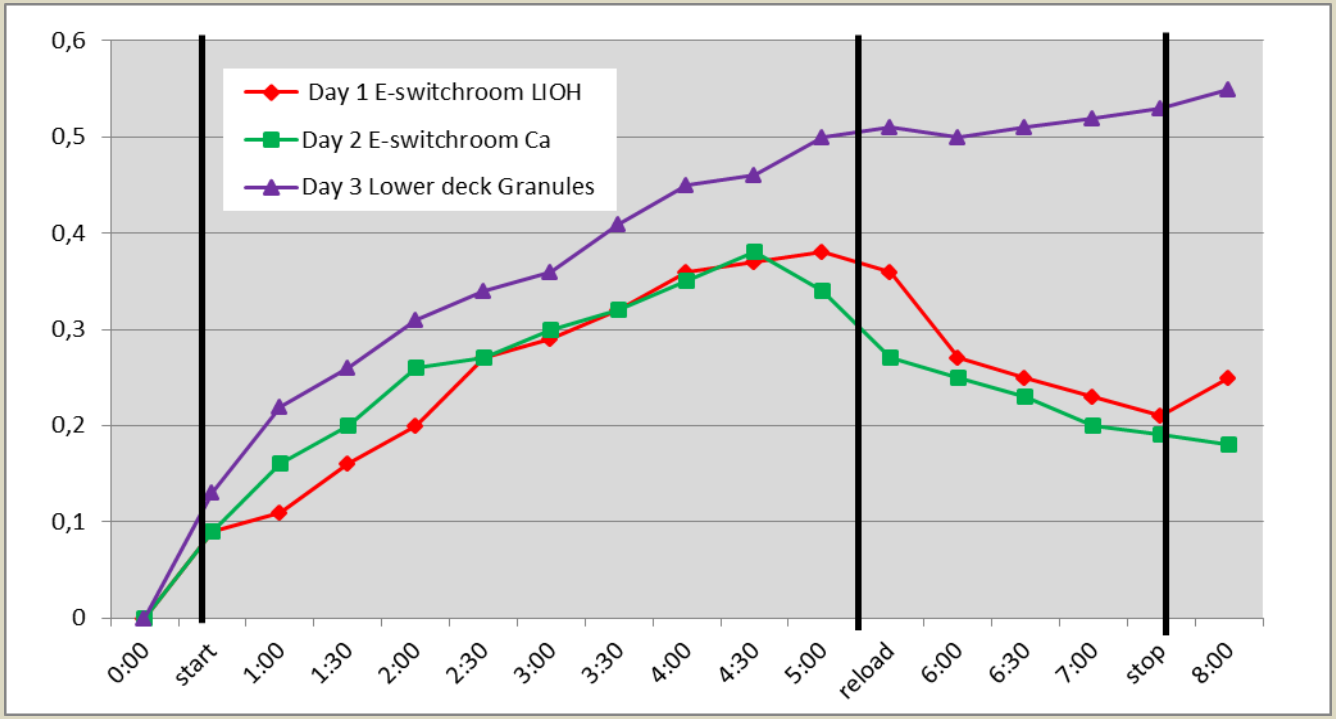
E- switchroom

Graph 1

To compare the three days graphes 1 and 2 of each location were made

graph 1 is the data per location.
In graph 2 it is attempted to just see the slopes of each day

Graph 2



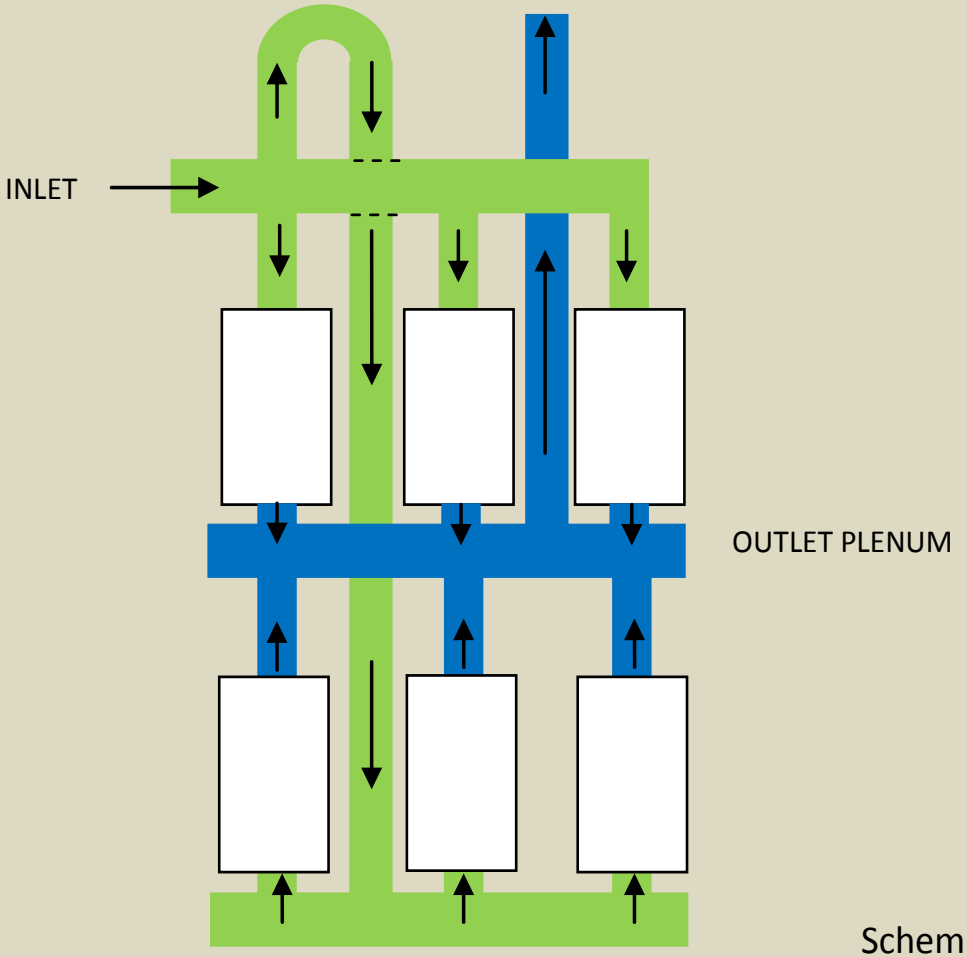


FIG 1

Schematic drawing of Wardroom scrubber

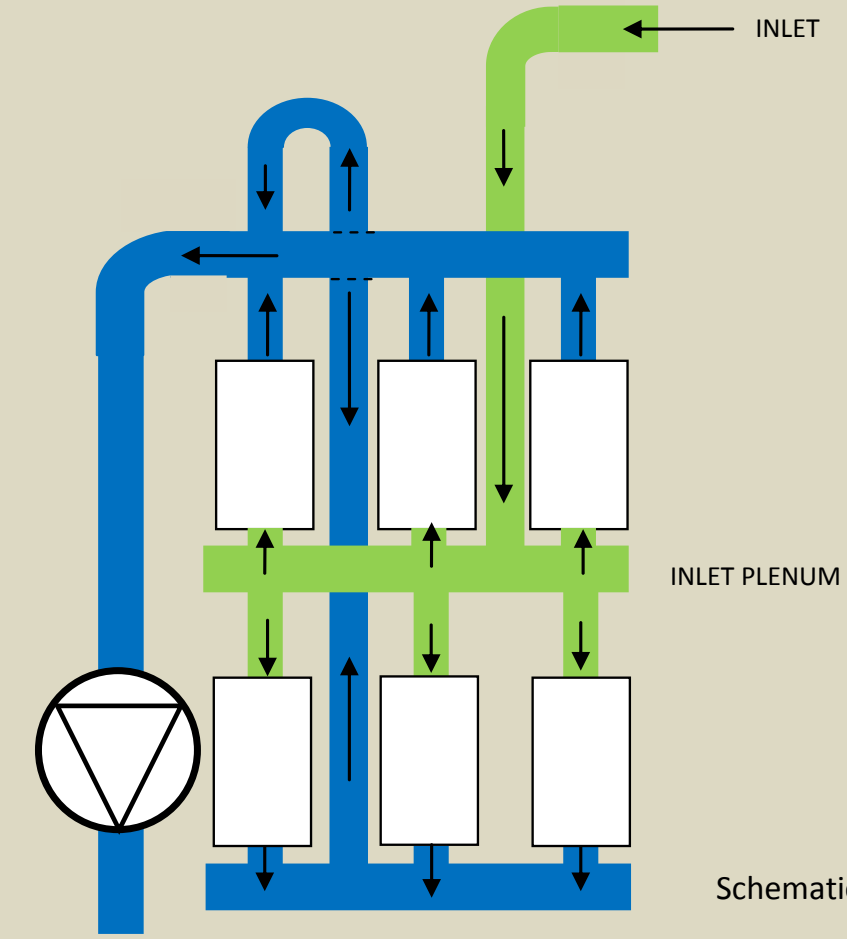


FIG 2
Schematic drawing of Torpedoroom scrubber

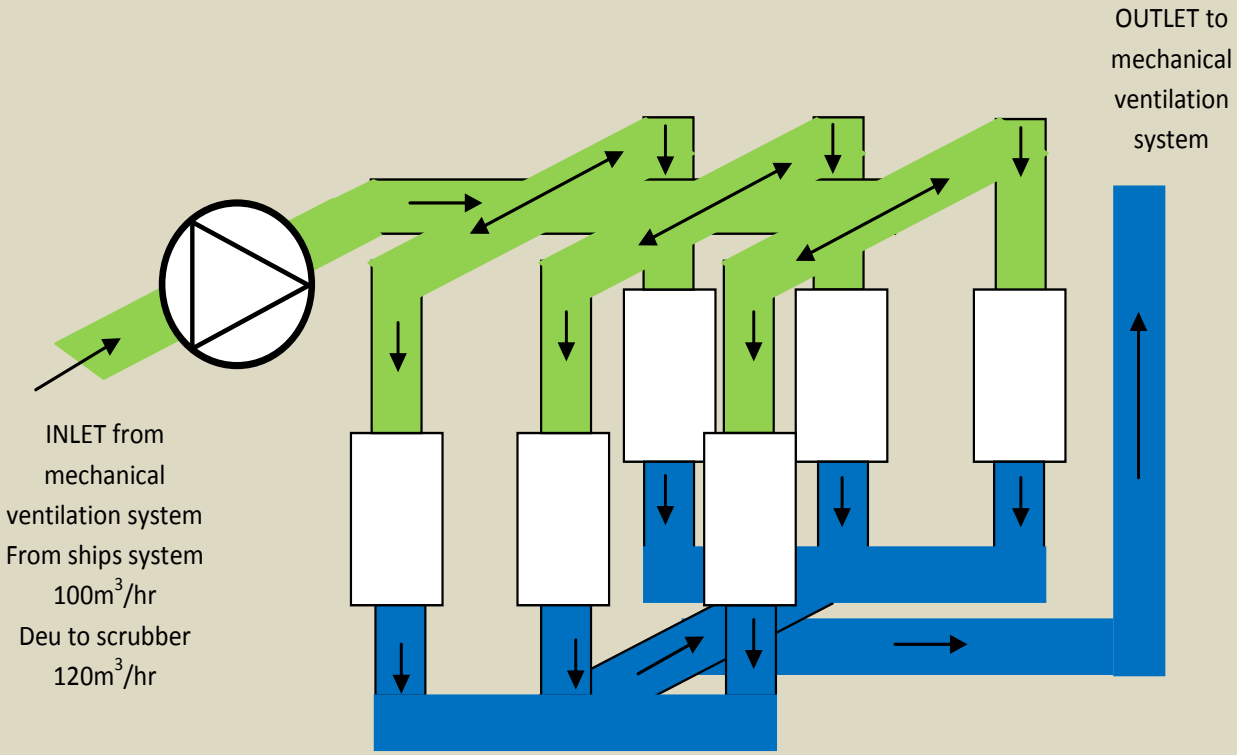


FIG 3

Schematic drawing of Engineroom scrubber

- Conclusions 1:

Reviewing the data and graphs the best solution for Walrusclass submarines seems to be the combination of:

1. Installing a third scrubber
2. Making use of the combination powercube with the Calcium Hydroxide absorbing material

The choise for Calcium Hydroxide over Lithium Hydroxide is based on the amount of absorbing material, Calcium being non corrosive and cost price

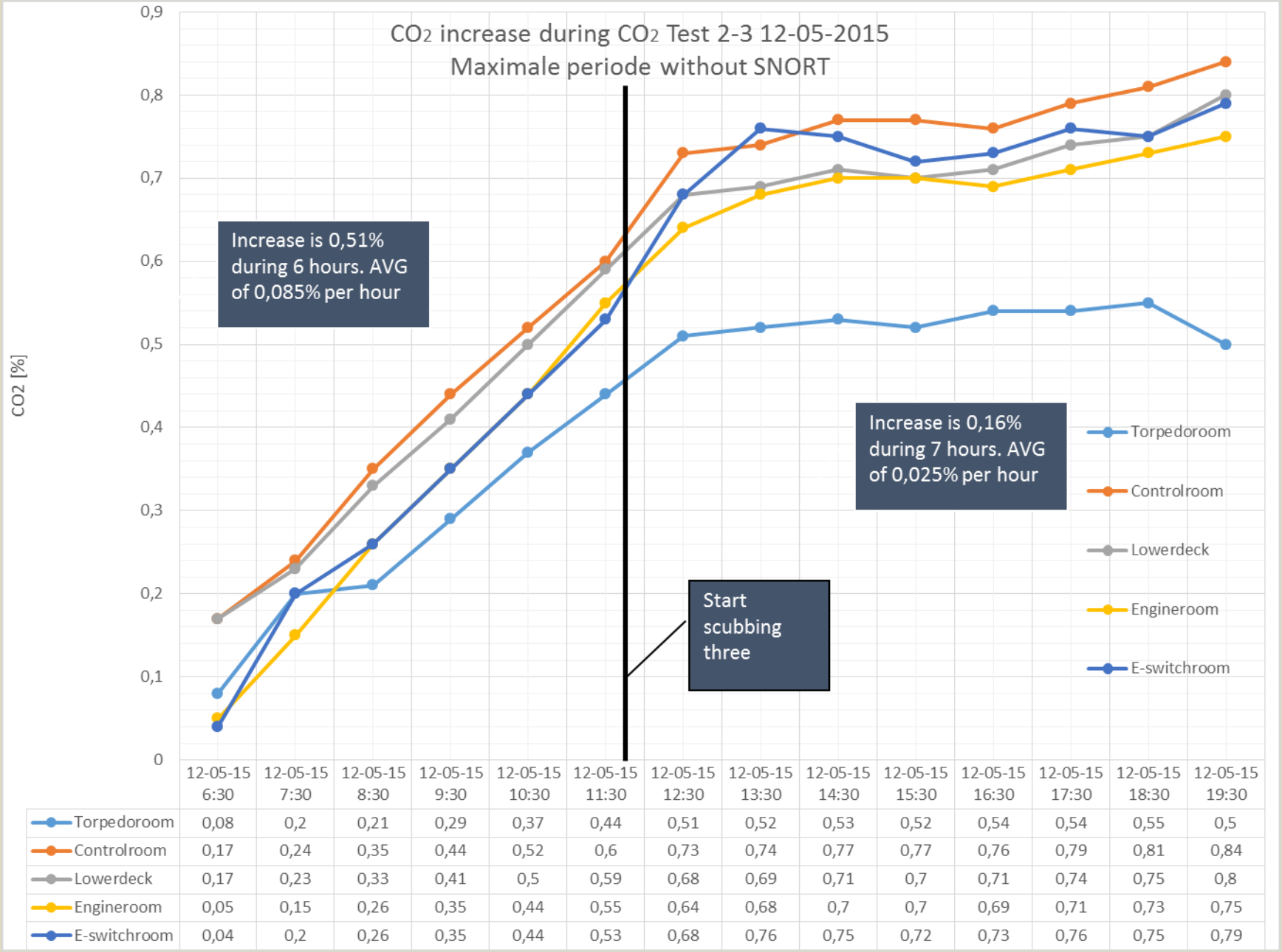
- Way ahead after this trail:

1. To perform a live operational test on board
2. Improve the existing two scrubbers

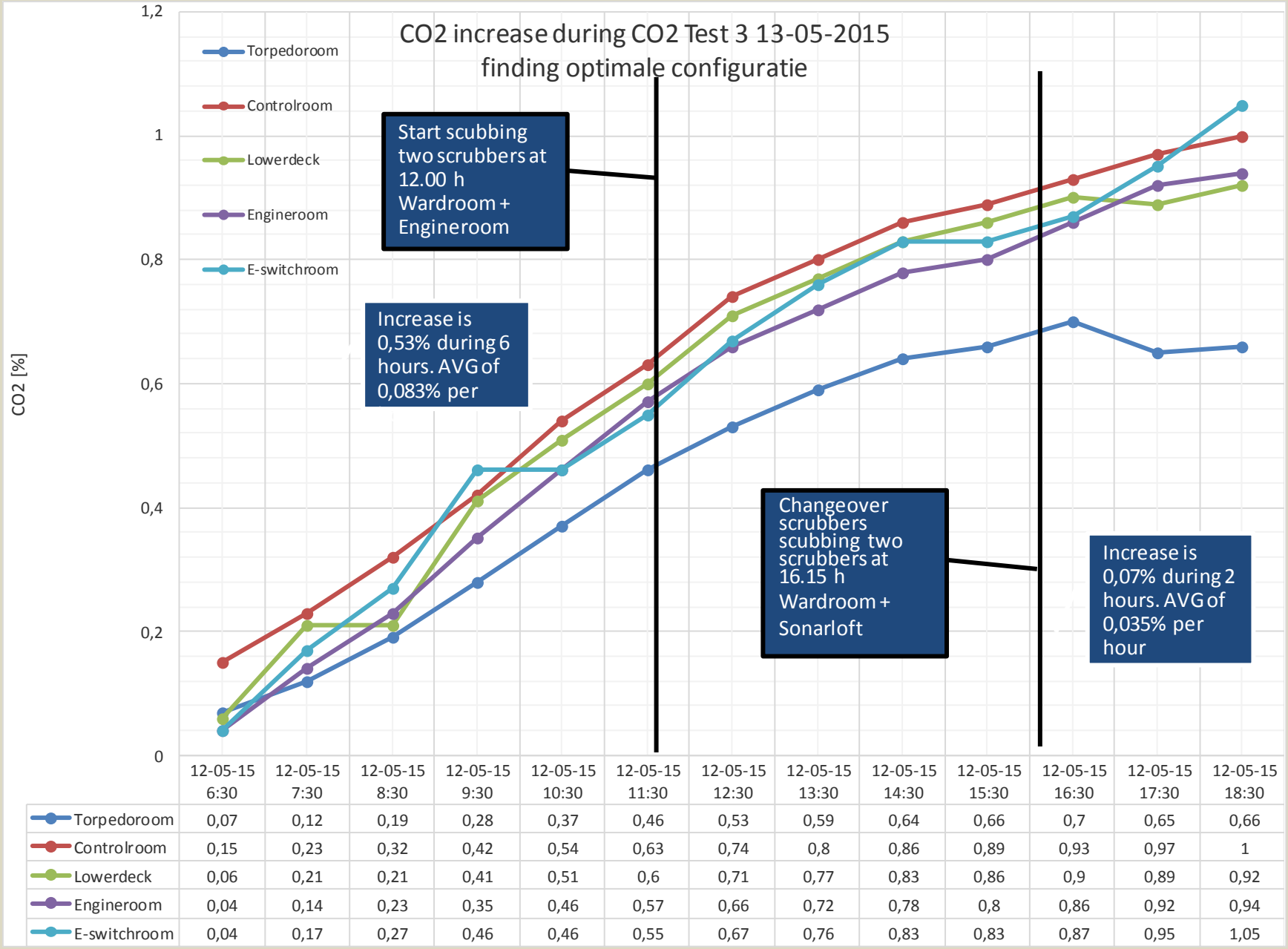
CO_2 trial on board Zr.Ms. Bruinvis

dynamic trail at sea

- In the beginning of 2015 Zr Ms Bruinvis was fitted with a third scrubber and all scrubbers were fitted with Micropore Power cube adapters.
- They went on a mission for 3 months to USA and the Carabian wit a test protocol
- During this voyage they only used sodalime powercubes for CO_2 Scrubbing
- Due to the program it was not possible to fully compllet the test protocol, the remaining part will be done in the fall of this year



	12-05-15 6:30	12-05-15 7:30	12-05-15 8:30	12-05-15 9:30	12-05-15 10:30	12-05-15 11:30	12-05-15 12:30	12-05-15 13:30	12-05-15 14:30	12-05-15 15:30	12-05-15 16:30	12-05-15 17:30	12-05-15 18:30	12-05-15 19:30
Torpedoroom	0,08	0,2	0,21	0,29	0,37	0,44	0,51	0,52	0,53	0,52	0,54	0,54	0,55	0,5
Controlroom	0,17	0,24	0,35	0,44	0,52	0,6	0,73	0,74	0,77	0,77	0,76	0,79	0,81	0,84
Lowerdeck	0,17	0,23	0,33	0,41	0,5	0,59	0,68	0,69	0,71	0,7	0,71	0,74	0,75	0,8
Engineroom	0,05	0,15	0,26	0,35	0,44	0,55	0,64	0,68	0,7	0,7	0,69	0,71	0,73	0,75
E-switchroom	0,04	0,2	0,26	0,35	0,44	0,53	0,68	0,76	0,75	0,72	0,73	0,76	0,75	0,79

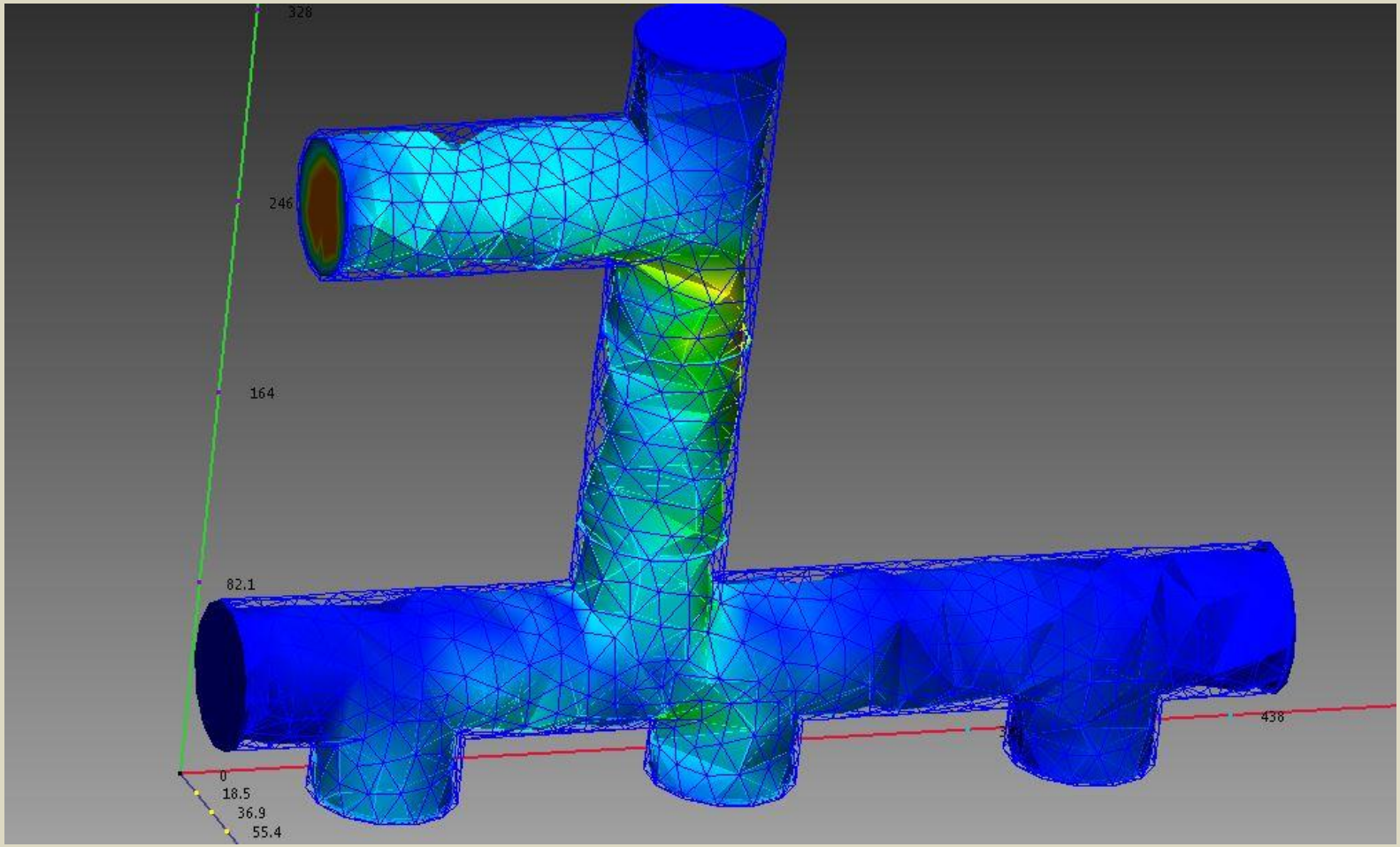


	12-05-15 6:30	12-05-15 7:30	12-05-15 8:30	12-05-15 9:30	12-05-15 10:30	12-05-15 11:30	12-05-15 12:30	12-05-15 13:30	12-05-15 14:30	12-05-15 15:30	12-05-15 16:30	12-05-15 17:30	12-05-15 18:30
Torpedoroom	0,07	0,12	0,19	0,28	0,37	0,46	0,53	0,59	0,64	0,66	0,7	0,65	0,66
Controlroom	0,15	0,23	0,32	0,42	0,54	0,63	0,74	0,8	0,86	0,89	0,93	0,97	1
Lowerdeck	0,06	0,21	0,21	0,41	0,51	0,6	0,71	0,77	0,83	0,86	0,9	0,89	0,92
Engineroom	0,04	0,14	0,23	0,35	0,46	0,57	0,66	0,72	0,78	0,8	0,86	0,92	0,94
E-switchroom	0,04	0,17	0,27	0,46	0,46	0,55	0,67	0,76	0,83	0,83	0,87	0,95	1,05

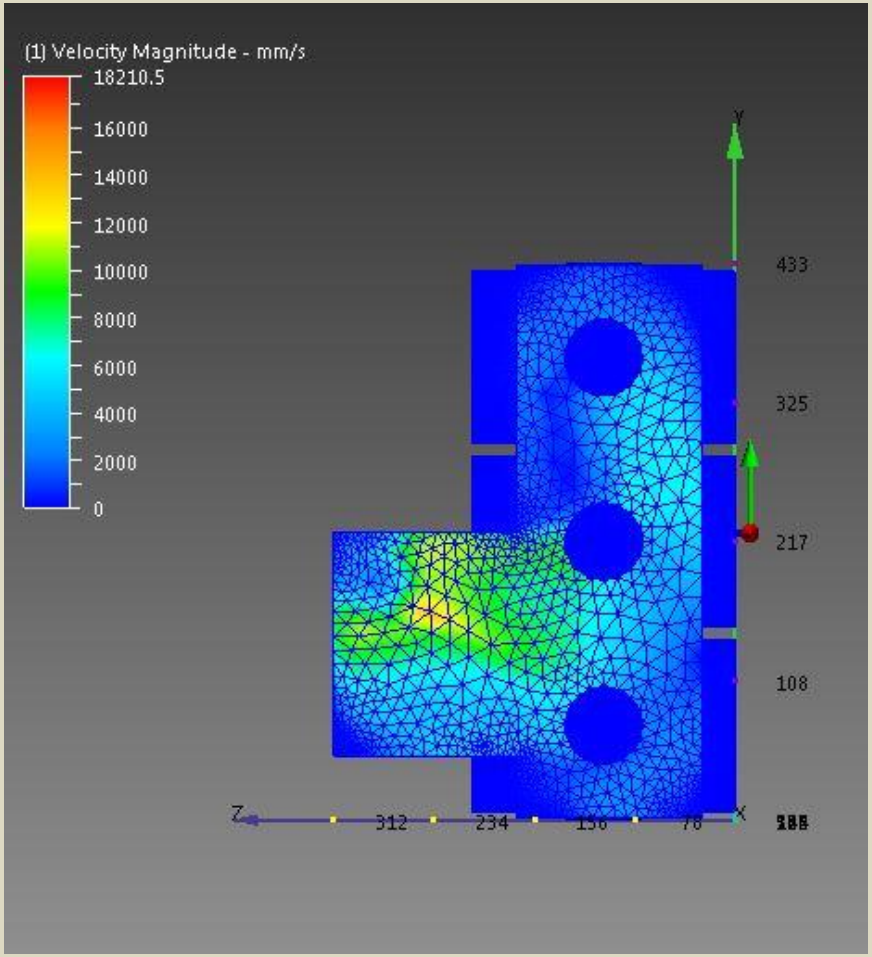
Results Live test

- Results of the live test were slightly worse then the static test that had been done pierside in Den Helder.
- Perform a second live (dynamic test on Bruinvis) during her current trip (rest of testprotocol)
- This made us look at the design of the scrubbers
- This was done first by CFD modelling and then a test in the workshop to compare modelling with live adsorbtion

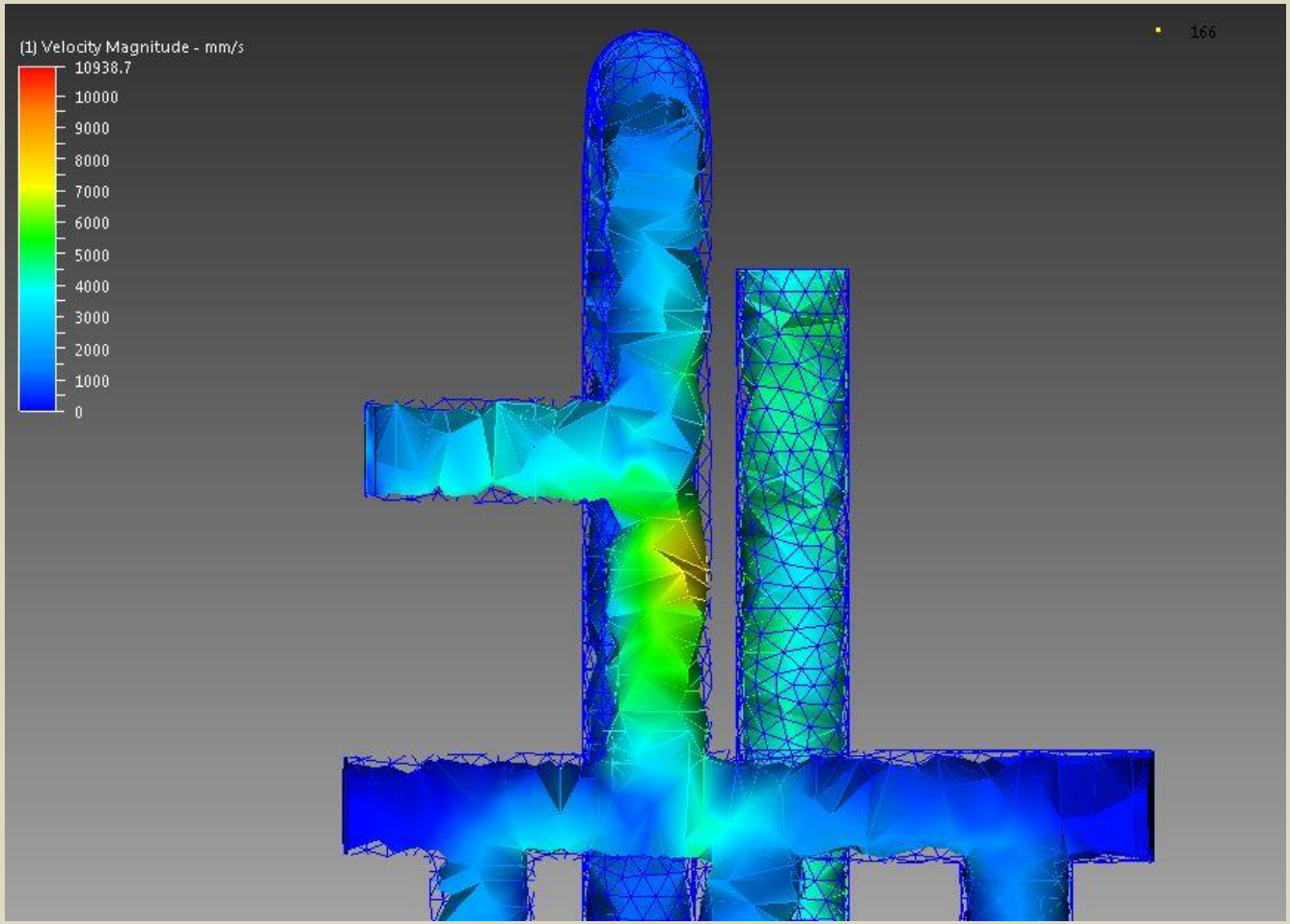
CFD Model



CFD Model 2


(1) Velocity Magnitude - mm/s
18210.5
16000
14000
12000
10000
8000
6000
4000
2000
0
Y
433
325
217
108
Z
312
234
156
78
X

CFD model 3


(1) Velocity Magnitude - mm/s
10938.7
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
166

Testing

- The present design of the CO_2 absorption unit is analysed in three ways: by testing the distribution of the flow through the unit, by CFD analysis and by simple pressure drop calculation using law of physics.
- Testing of the flow distribution on the unit is carried out by applying cacao powder at the inlet of the unit, this test is carried out for both units on board.

Calculations

- The CFD calculation is carried out by using Autodesk software. With this software it was possible to create the 3D model and perform flow calculations using the build-in solver and post processing.
- In order to validate the results of the powder tests and the results of the CFD calculation, the flow rates on the system are calculated by iterative pressure drop calculations on each branch of the unit.

Analysis

- All three methods of analysis showed that the flow distribution in the unit is not equal. Canisters on the top row will run-out more quickly than the ones in the bottom row, therefore the top canisters are to be changed frequently.

Way ahead

- To improve capacity of the CO2 scrubber all manifolds have to be redesigned.
- This will give us a better flow over all 6 powercubes resulting in a higher adsorbtion capacity
- This redesign will be done early 2016

Future Plans

- We hope to have redesign ready end of 2016
- Plan is to implement redesigned excisting scrubbers on board Zeeleeuw after SLEP and add a third scrubber in the auxiliary engine room

Questions ????