CE Test Document

Title: PO2 Display

EN143143:2013 Test Number: 6.10.2

Breathing Apparatus: VMS Sentinel

Unit Serial Number: 5004

Test Facility: Vobster Quay

Test Procedure:

The standard states the following:

The partial pressure of oxygen in the inhalation hose shall be measured and compared with the indicated value.

Test the oxygen partial pressure monitor by exposure to partial pressures of oxygen in the range 0,1 bar to 2,0 bar in increments of 0,2 bar. Note if the reading stabilises within the response time requirements. Note the readings of the monitor and compare with the limits given in Table 6.

The oxygen partial pressure monitor shall be pressurised to 1,1 times the maximum stated depth with suitable gases to maintain constant partial pressure of oxygen at 0,2 bar and 2 bar. The rate of pressurisation shall be 30 m min-1. The partial pressure of oxygen monitor reading shall be recorded at 10 m intervals.

The partial pressure oxygen monitor shall be held at 1,1 times of the maximum stated depth for a period of 1,5 times the maximum bottom time specified by the manufacturer.

The oxygen partial pressure monitor shall be decompressed using the stop depth specified by the manufacturer. The rate of ascent shall be 20 m min-1 and the partial pressure oxygen monitor held at each stop for a period of 2 min. After a period of 1 min the indicated value shall be compared with the partial pressure of oxygen in the inhalation hose.

Note: There are a number of issues with the way that this standard is written, so we have implemented a range of tests to achieve as close as possible the desired aspects of this standard, but there are simply some requirements that we are unable to test

We approached the requirements of this by breaking it down into 4 sub tests, each of which in combination the PO2 tracking tests already performed demonstrates that the unit can achieve the desired performance requirements.

Test Apparatus

To achieve these tests, we first of all reduced the unit parts down to the electronics control/display system and the PO2 monitoring system. These were placed in a pressure chamber with a viewing window on the top, with the depth sensor of the electronics submerged in water and the O2 cells of the PO2 Monitor exposed to the internal gas environment of the chamber.

The chamber has 3 gas feeds controlled by needle valves, and the pressure in the chamber is displayed by a calibrated pressure gauge with a 1mb resolution, and a full scale deflection of less than 40mb. Each feed is connected via a one way check valve to remove possible leaks and cross contamination of gases.

There is a drain from the chamber, also controlled via a needle valve (able to control the pressure of the chamber to 1mb). The drain passes via a calibrated fast response oxygen analyser to enable us to measure the fraction of oxygen in the exhaust gas from the chamber.

The calibration certificates can be found in 6.10.2b_certs.pdf.

Pictures Fig1 and Fig2 below, show the setup of the chamber, and the unit in the chamber ready for testing.

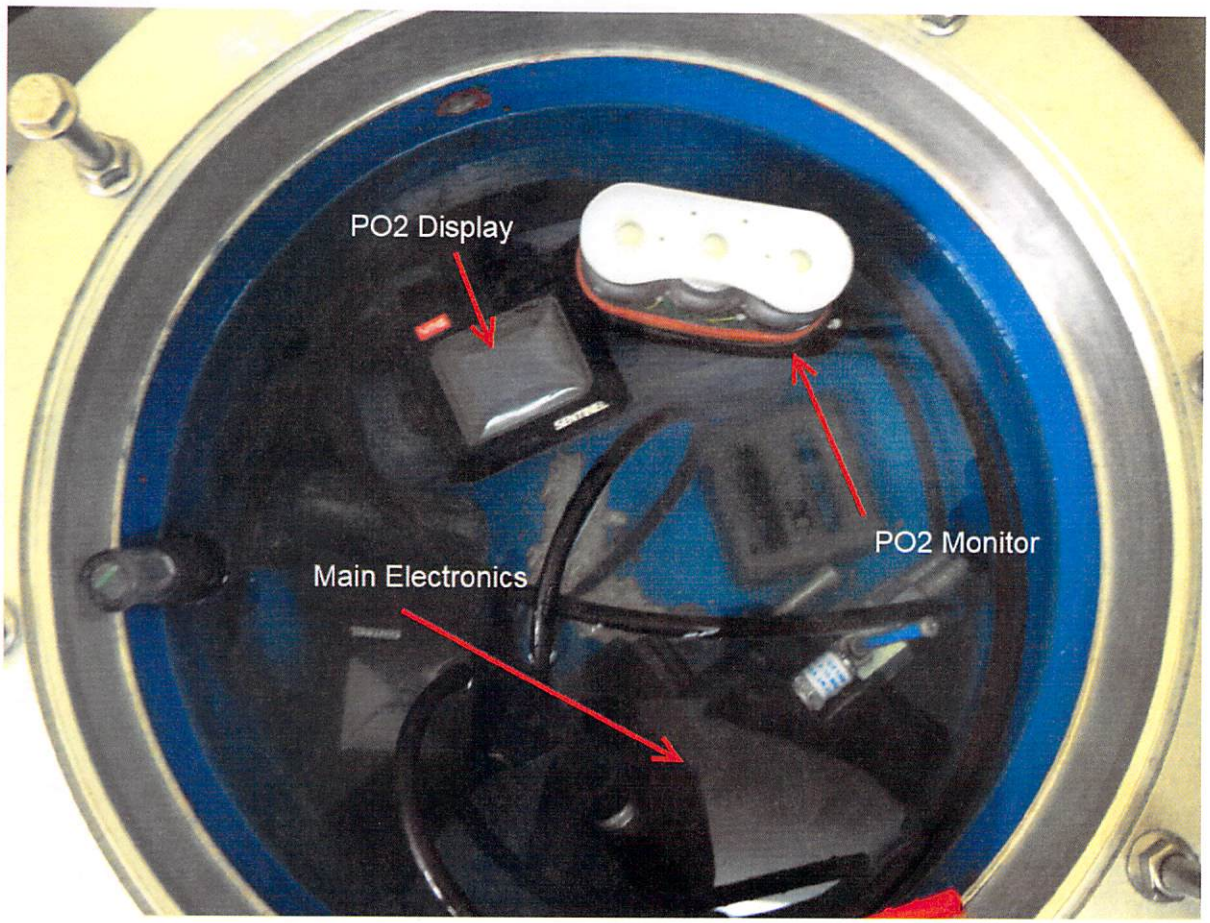


Fig 1

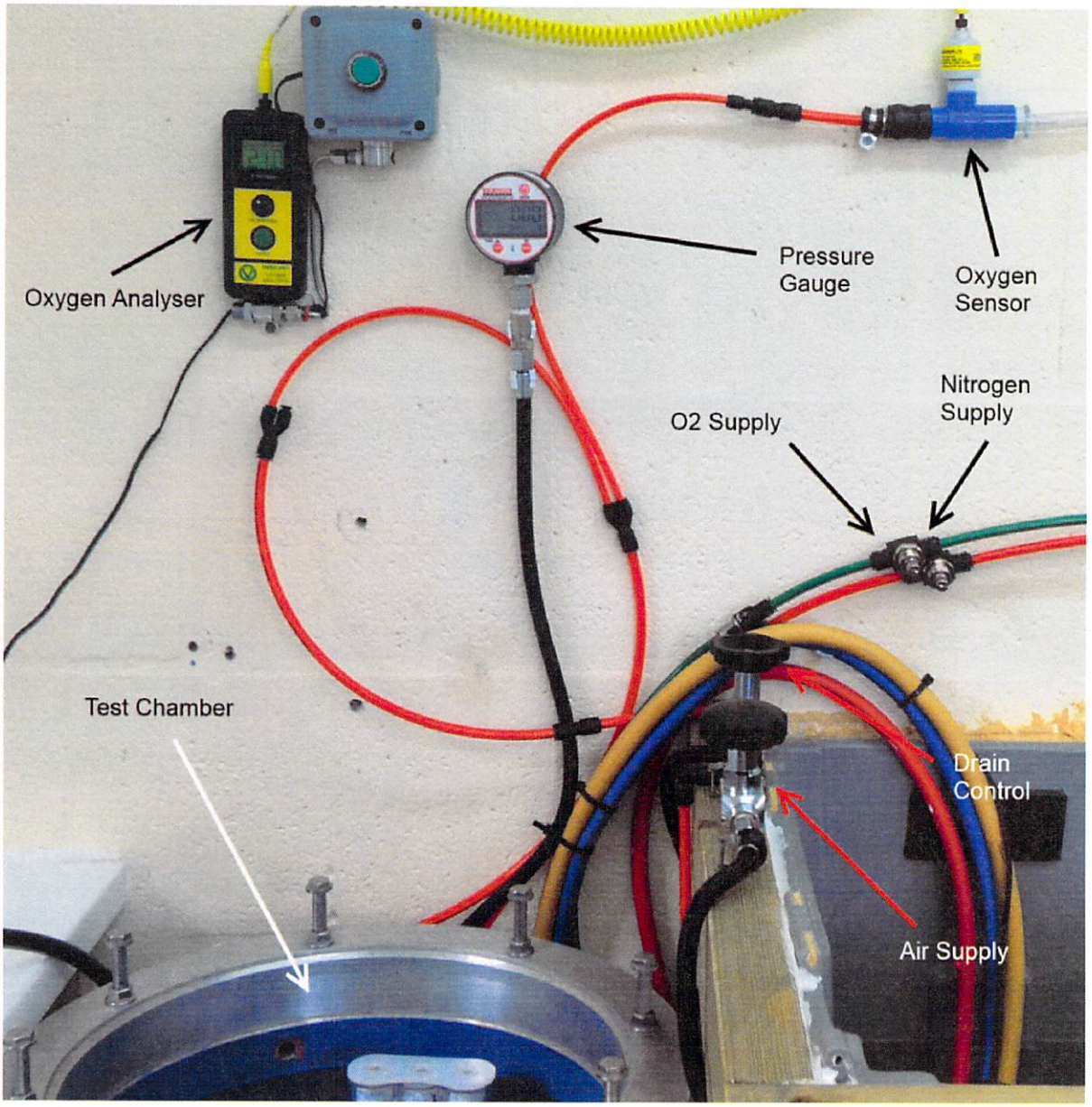


Fig2

Gas stabilisation Procedure.

For each test we used the following procedure to set up the chamber:

1. The chamber was sealed, then the calibration test for the test was flushed through the system for 2 minutes by opening both the supply and drain valves.
2. The chamber was pressurised to 10 bar, using the calibration gas. This was to dilute any remaining unwanted gases in the chamber to as small a fraction as possible.
3. The chamber was brought back up to 0.1 bar ready to start the test.

Test 1 – Air PO2 by depth

This test used air (20.95 Oxygen in dry air) as the calibration test. The unit was pressurised to 8.547 bar and modified until it was stable (to remove the effects of gas expansion), then depressurised according to a calculated schedule of pressures to achieve chamber PO2's of 2.0 to

0.3. At each pressure the displayed PO2 was recorded after 30 seconds of stabilisation. Table 1 below indicates the target pressures and PO2, against the recorded pressure and PO2.

Target PO2	Target Chamber Pressure (bar)	Recorded Chamber Pressure (bar)	Recorded PO2 (bar)	Variance (bar)
0.3	0.432	0.433	0.29	-0.01
0.4	0.909	0.908	0.39	-0.01
0.5	1.387	1.388	0.50	0.00
0.6	1.864	1.865	0.60	0.00
0.7	2.341	2.342	0.70	0.00
0.8	2.819	2.818	0.80	0.00
0.9	3.296	3.296	0.89	-0.01
1.0	3.773	3.772	0.99	-0.01
1.1	4.251	4.251	1.09	-0.01
1.2	4.728	4.729	1.20	0.00
1.3	5.205	5.205	1.30	0.00
1.4	5.683	5.685	1.40	0.00
1.5	6.160	6.158	1.50	0.00
1.6	6.637	6.637	1.59	-0.01
1.7	7.115	7.115	1.70	0.00
1.8	7.592	7.593	1.79	-0.01
1.9	8.069	8.069	1.89	-0.01
2.0	8.547	8.547	1.99	-0.01

Table 1

Photographs showing both the chamber pressure and PO2 displayed are contained in folder "Test Documents/Test Images/6-10-2b/test1/".

Test 1 – Heliox by depth

This test was conducted in the same manner as Test 1, however we had to use a gas with a lower fraction of oxygen to the requirements of PO2 0.1 and 0.2. We chose 7/93 as our target gas, which when analysed was shown to have a fraction of oxygen of 7.3%. Table 2 below gives the results for this test.

Target PO2	Target Chamber Pressure (bar)	Recorded Chamber Pressure (bar)	Recorded PO2 (bar)	Variance (bar)
0.1	0.370	0.370	0.09	-0.01
0.2	01.740	1.740	0.19	-0.01

Table 2

Pictures of the PO2 readout and pressure readings for this test can be found in folder "Test Documents/Test Images/6-10-2b/test2/".

Test 3 – 2 Bar PO2 Test

This test is designed to show how the cells cope with prolonged exposure to high PO2, and how this effects their accuracy. To achieve this we first of all pressurised the chamber to 1bar using pure oxygen. This gave us our starting point of PO2 2.0. In order to maintain this PO2 to target depth, pure Nitrogen was added (BOC zero impurity grade) to pressurised the chamber to 1.1 times the rated depth of the unit, so 11 bar (110m). The unit was then held there for 1.5 x the maximum duration at maximum depth, so 70 minutes and 30 seconds.

The PO2 display was recorded at intervals during the bottom time. The table below shows the recorded values.

Minutes	PO2	Chamber Pressure
1	2.05	11.032
2	2.03	11.024
3	2.00	11.008
4	1.99	10.997

5	1.99	11.000
10	1.98	11.001
20	1.98	10.995
30	1.99	10.998
40	2.01	11.002
50	2.01	11.007
60	2.02	11.010
70	2.03	11.013

Table 3

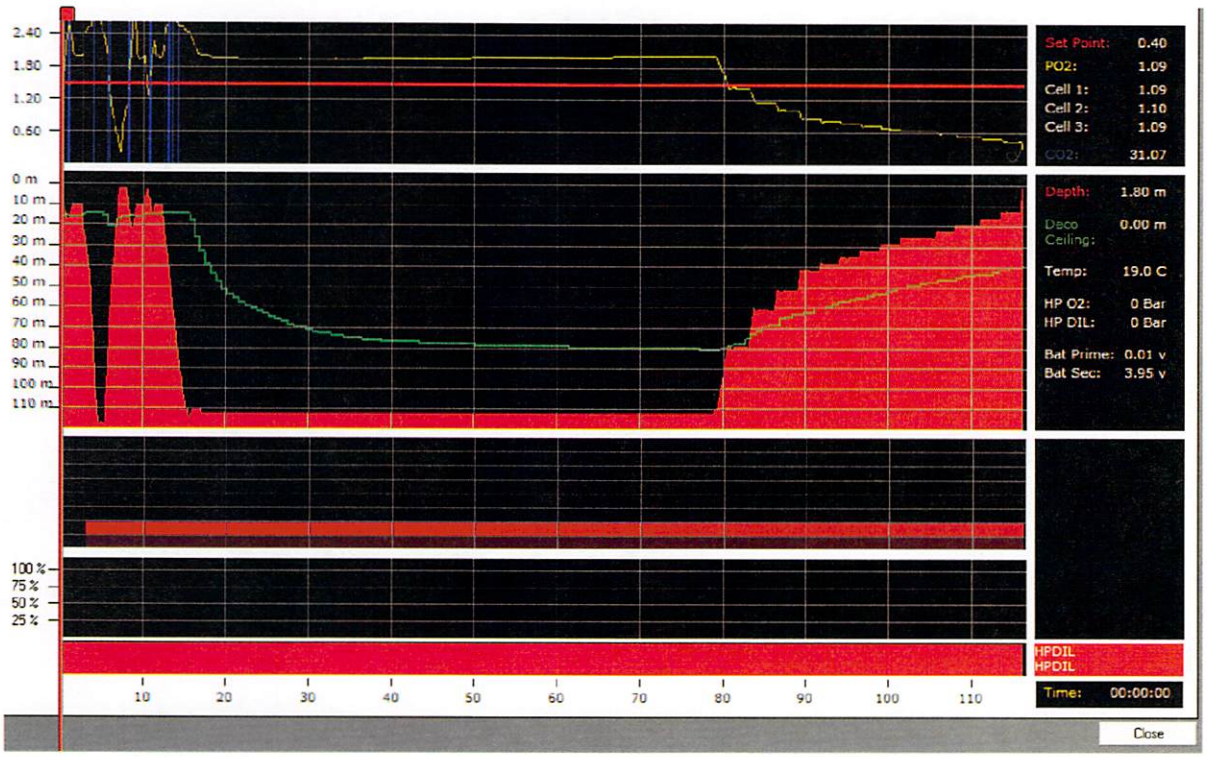
Once this conditioning had been completed, the chamber was depressurised at a rate of 20m/min between the stop depth schedule for a 100m dive. During the depressurisation the fraction of oxygen was recorded from the vented gas. Once the chamber had achieved the required stop pressure, it was held there for 2 minutes, with the PO2 on the display being recorded after 1 minute.

The below table shows the target pressures for the ascent schedule, the recorded fraction of oxygen, the recorded PO2 from the display, and the variance between the recorded PO2 and that calculated from the recorded pressure and fraction of oxygen.

Stop Depth m	Target Chamber pressure (bar)	Recorded FO2 %	Recorded Chamber Pressure (bar)	Calculated PO2	Recorded PO2	Variance (bar)
110	11.00	16.70	11.013	2.00	2.03	+0.03
74	7.40	16.80	7.419	1.41	1.45	+0.04
57	5.70	17.00	5.718	1.14	1.17	+0.03
48	4.80	17.20	4.814	1.00	1.03	+0.03
39	3.90	17.40	3.914	0.85	0.87	+0.02
36	3.60	17.60	3.608	0.81	0.83	+0.02
33	3.30	18.00	3.299	0.77	0.78	+0.01
30	3.0	18.20	3.001	0.73	0.74	+0.01
27	2.70	18.50	2.699	0.68	0.69	+0.01
24	2.40	18.80	2.401	0.64	0.64	0.00
21	2.10	19.00	2.100	0.59	0.60	+0.01
18	1.80	19.20	1.825	0.54	0.55	+0.01
15	1.50	19.50	1.517	0.49	0.50	+0.01
12	1.20	19.80	1.201	0.44	0.44	0.00

Table 4

Pictures of the PO2 display, FO2 % and chamber pressure can be found on "Test Documents/Test Images/6-10-2b/test3/". Below is a screen shot of the downloaded data from the unit.



Test 4 – 0.2 Bar PO2 Test

This is a duplicate of test 3, however, rather than starting at 10m with Oxygen to achieve a starting Po2 of 2.0, we started with air at 0m.

The PO2 display was recorded at intervals during the bottom time. The table below shows the recorded values.

Minutes	PO2	Chamber Pressure
1	0.22	10.900
2	0.21	10.945
3	0.21	10.981
4	0.21	10.976
5	0.21	10.970
10	0.21	10.953
20	0.21	10.937
30	0.21	10.926
40	0.21	10.917
50	0.21	10.910
60	0.21	10.903
70	0.21	10.896

Table 5

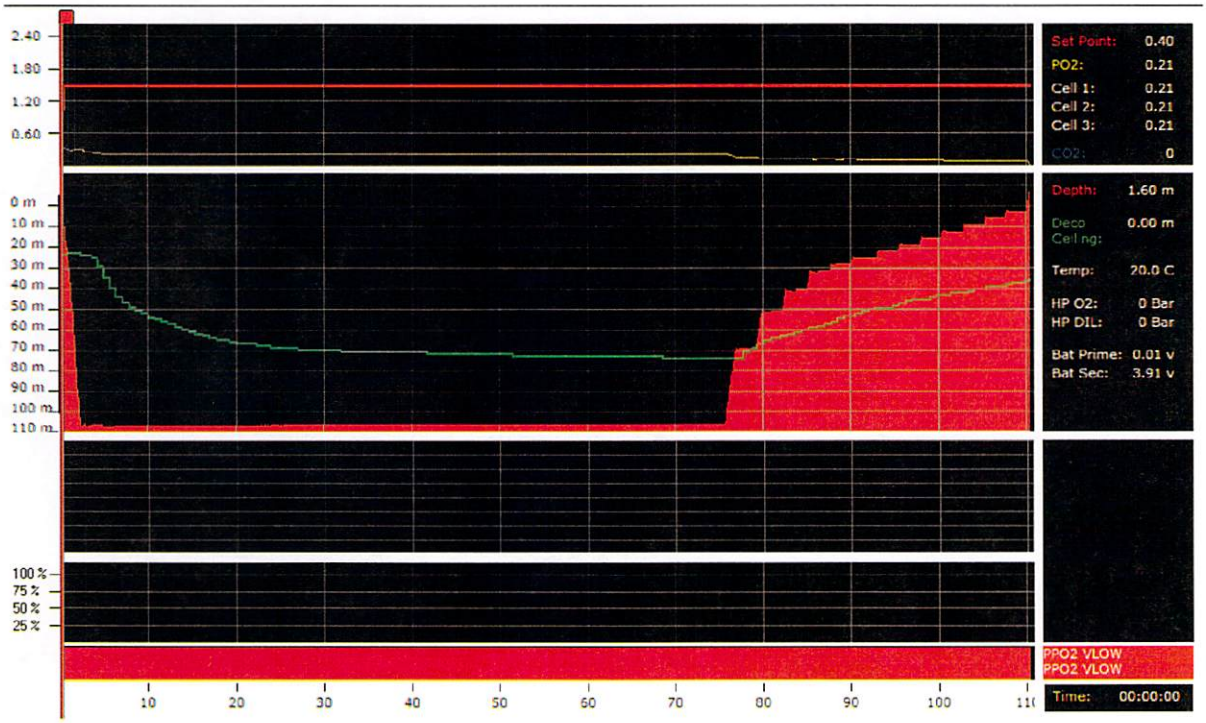
Once this conditioning had been completed, the chamber was depressurised at a rate of 20m/min between the stop depth schedule for a 100m dive. During the depressurisation the fraction of oxygen was recorded from the vented gas. Once the chamber had achieved the required stop pressure, it was held there for 2 minutes, with the PO2 on the display being recorded after 1 minute.

The below table shows the target pressures for the ascent schedule, the recorded fraction of oxygen, the recorded PO2 from the display, and the variance between the recorded PO2 and that calculated from the recorded pressure and fraction of oxygen.

Stop Depth m	Target Chamber pressure (bar)	Recorded FO2 %	Recorded Chamber Pressure (bar)	Calculated PO2	Recorded PO2	Variance (bar)
110	11.00			0.21	0.21	0.00
74	7.40	1.5	7.423	0.13	0.15	+0.02
57	5.70	1.6	5.719	0.11	0.12	+0.01
48	4.80	1.7	4.837	0.10	0.13	+0.03
39	3.90	1.9	3.904	0.09	0.12	+0.03
36	3.60	2.0	3.582	0.09	0.11	+0.02
33	3.30	2.2	3.322	0.09	0.11	+0.02
30	3.0	2.3	3.007	0.09	0.10	+0.01
27	2.70	2.4	2.707	0.09	0.10	+0.01
24	2.40	2.5	2.409	0.09	0.09	0.00
21	2.10	2.7	2.109	0.08	0.09	+0.01
18	1.80	2.8	1.827	0.08	0.08	0.00
15	1.50	2.9	1.520	0.07	0.08	+0.01
12	1.20	3.1	1.204	0.07	0.07	0.00

Table 6

Pictures of the PO2 display, FO2 % and chamber pressure can be found on "Test Documents/Test Images/6-10-2b/test4/". Below is a screen shot of the downloaded data from the unit.



Conclusions:

Tests 1 and 2 are pretty straight forward, and clearly show that with a known gas of a known PO2, the unit performs within +/- 0.01 accuracy.

Test 3 and 4 are very difficult test to run, and there was a surprising increase in FO2 for both the 2.0 and 0.2 bar tests. However given the recorded FO2, it is clear that the unit performs within the required parameters even when subjected to high descent and ascent rates, and there is little or no change to the readings as the result of prolonged exposure to high or low PO2's at depths exceeding those we recommend.

Stop Depth	Pressure	PO2	ata	Fo2	Target Fo2	New PO2	Add O2 Bar	Ascent Time
110	11.00	2	12.00	0.1667	0.2381	2.8571	0.786	
74	7.40	2	8.40	0.2381	0.2985	2.5075	0.447	108
57	5.70	2	6.70	0.2985	0.3448	2.3103	0.264	51
48	4.80	2	5.80	0.3448	0.4082	2.3673	0.304	27
39	3.90	2	4.90	0.4082	0.4348	2.1304	0.104	27
36	3.60	2	4.60	0.4348	0.4651	2.1395	0.109	9
33	3.30	2	4.30	0.4651	0.5000	2.1500	0.115	9
30	3.00	2	4.00	0.5000	0.5405	2.1622	0.122	9
27	2.70	2	3.70	0.5405	0.5882	2.1765	0.129	9
24	2.40	2	3.40	0.5882	0.6452	2.1935	0.137	9
21	2.10	2	3.10	0.6452	0.7143	2.2143	0.145	9
18	1.80	2	2.80	0.7143	0.8000	2.2400	0.154	9
15	1.50	2	2.50	0.8000	0.9091	2.2727	0.164	9
12	1.20	2	2.20	0.9091				9

Tested By: Martin Stanton

Title: Managing Director

Signed: 

Date: 2/10/15

Witnessed By: Tim Clements

Title: Operations Manager

Signed: 
T. R. CLEMENTS

Date: 2/10/15