HYDROSTATIC IMBALANCE OF DL OPEN REVOLUTION REBREATHERS: COMPLIANCE ASSESSMENT TO EN 14143, NORSOK U101, NATO STANAG 1410 AND NEDU TA05-12 REQUIREMENTS

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Revision History

Revision	Date	Description
A0	1st Oct 2009	Full retest using production samples to design documentation revision in Bill Of Materials D3. Format and procedure follows that of hydrostatic tests on previous versions of these products, but with complete retest.
A1	8th Oct 2009	Additional comparison with the proposed prEN14143:2010 limits
A2 – A5	29th Oct 2010 to 4th Nov 2010	Repeated all tests using optimised fixed volume, using 0 pitch,±90 roll to set volume to provide analysis points for 3rd party lab figures. Provided separate sections for optimisation for boundary case loop volume, optimal loop volume, and variable loop volume. Updated Ideal Values and Method Sections. Consideration of the effect of Lissajou optimised loop volumes that appears to be used by an external lab. Reexamination of optimal loop volume results using the method recommended by the manufacturer to obtain the optimal loop volume resulting in removal of restriction that error in EN 14143:2003 Table 1 should be corrected for compliance as apparatus now complies with both corrected and uncorrected tables using the optimised fixed volume method presented herein. Clarifications to references from proof reading
A6	16th Nov 2010	Separation of plots and tables of results, for easier reading, following reviewer JNO's comments. Added plots for EN14143:2003 as printed including error, and corresponding analysis.

Baltic Assessment Institute is an ISO 9001:2008 test laboratory registered with BVQI.

Tests were witnessed by Deep Life Ltd and other parties.

Table of Contents

1 PURPOSE AND SCOPE

Baltic Assessment Institute (BAI) was instructed by Deep Life Ltd to carry out Hydrostatic Imbalance and respiratory pressure tests on samples of the September 2009 production of Open Revolution family of rebreathers, models:

- OR_Umbilical
- OR_Incursion
- OR_Apocalypse Type IV

The scope of the tests is to quantify Hydrostatic Imbalance and respiratory pressures for the above rebreather models and determine their compliance with the requirements on Hydrostatic Imbalance imposed by all relevant standards and recommendations. This has been interpreted to mean EN14143:2003, the CEN May 2009 draft proposal for prEN14143:2010, NORSOK U-101 1999, NATO STANAG 1410:2006 and the NEDU recommendation for Hydrostatic Imbalance in TA05-12, January 2007. For each standard, the scope of this assessment is:

1. Clear statement of the interpretation of the standard, test method and compensation for differences in mannequin dimensions with respect to the Hydrostatic imbalance and elastance tests.
2. Determine the empirical values of Hydrostatic Imbalance and related respiratory parameters.
3. Provide evidence of the tests and the extent of compliance with the requirement, to conclude on a pass or fail basis whether the equipment complies with that standard.

The document is a Design Verification and Validation Report in terms of BAI Quality Procedure QP-20 (Safety Critical Systems).

2 SOURCE DOCUMENTATION

The following documentation was provided by Deep Life Ltd:

- Norwegian Technology Standards Institution Standard NORSOK U-101:1999 Rev.1 Aug.1999.
- European Normative Standard EN 14143:2003. September 2003
- Sight of N285_EN_14143_May09_Seville_E.pdf, which is understood to be the basis for the proposed prEN14143:2010 to be published in 2009
- NATO Standardisation Agency Standard STANAG 1410:2006. 20 October 2006; 2nd edition
- NEDU Technical Report by D. E. Warkander, "COMPREHENSIVE PERFORMANCE LIMITS FOR DIVERS' UNDERWATER BREATHING GEAR: OF ADOPTING CONSEQUENCES DIVER-FOCUSED LIMITS, Navy experimental Diving Unit TA05-12,15 January 2007
- Full Bill of Materials and Exploded drawings of the rebreathers under test, referenced by BOMs 16 to BOM 20, to confirm that the products tested are representative of the design.
- Mantis Safety Requirements of Deep Life Ltd. The Mantis safety requirements identified that pertain to Hydrostatic Imbalance are Number 474.

3 RELEVANT REQUIREMENTS

3.1 Mantis Safety Requirement pertaining to Hydrostatic Imbalance

The Deep Life Safety Requirement pertaining to Hydrostatic Imbalance is to Support Diver's Access to Breathable Gas in all positions, with not more than a +/-25mbar pressure differential between the mouthpiece and the Lung Centroid, measured with a 4.5 litre tidal volume.

This breathable volume requirement is a hydrostatic imbalance requirement recorded in the Deep Life Requirements tracking system as Mantis 474. The Mantis 474 safety requirement is satisfied if the rebreather complies with EN 14143:2003 Section 5.6.3 **in all positions** used for Hydrostatic Imbalance testing. The compliance with Section 5.6.3 is tested and reported separately, as it is considerably more onerous than the test in EN 14143:2003 Section 5.6.1.4. because it uses a 4.5 litre tidal volume. That is, the Section 5.6.3 test is a super-set of the Section 5.6.1.4 test: meeting the former means the latter is met automatically. There is therefore no additional safety requirement in Mantis that relates to the EN 14143:2003 requirement in Section 5.6.3: the latter is simply not a safety requirement but a compliance requirement, meaning the test has to be carried out but the results have no safety value whatsover if the requirement in EN 14143:2003 Section 5.6.3. has been met.

3.2 EN14143 Hydrostatic Imbalance Requirements

EN14143:2003 stipulates the following requirements for Breathing Simulator, Hydrostatic imbalance and respiratory pressures tests (quotes from the standard are in serif font):

3 Terms and definitions

3.5 respiratory pressure

the differential pressure in the facepiece relative to the no flow pressures in the facepiece at the end of inhalation and exhalation (see Figure 1)

3.7 Hydrostatic Imbalance

the difference at end exhalation "no flow" between the pressure within the facepiece (see Figure 1) and that at the reference point which could either be the suprasternal notch or the lung centroid of the diver (see Figure 2)

5 Requirements

5.6.1.1 General

The breathing performance shall be measured using a sinusoidal waveform from a breathing machine with simulated RMVs up to 75 l min-1 (BTPS; Body Temperature and Pressure Saturated (see Table 4)). The performance of the apparatus shall be determined using an oxygen in nitrogen gas mixture at an ambient pressure of 5 bar and where appropriate using an oxygen in helium based mixture at an ambient pressure of 11 bar or a reduced pressure specified by the manufacturer.

The apparatus shall provide sufficient volume of respirable gas for the diver at all phases of a dive. In the event of a failure of an automatic volume addition system an alternative means shall be provided to add respirable gas to the breathing circuit or the diver.

The manufacturer shall supply to the test house ideal values in x and y from a reference point on the apparatus to the supra-sternal notch. For details see Figure 2.

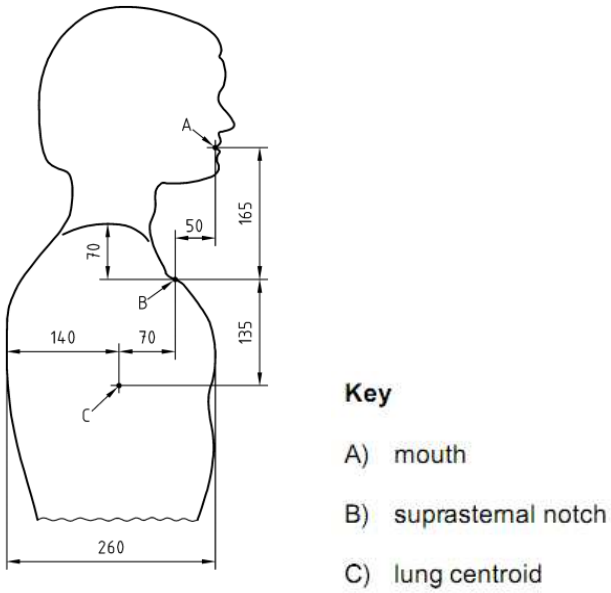


Figure 1. Reproduction of Figure 2 in EN14143:2003

5.6.1.3 Respiratory pressures

Peak to peak and inspired and expired respiratory pressures shall be determined as shown in Figure 1. The peak to peak respiratory pressure shall not exceed 50 mbar. The inspired and expired respiratory pressures shall not exceed 25 mbar each.

Testing shall be done in accordance with 6.3.2.

5.6.1.4 Hydrostatic imbalance

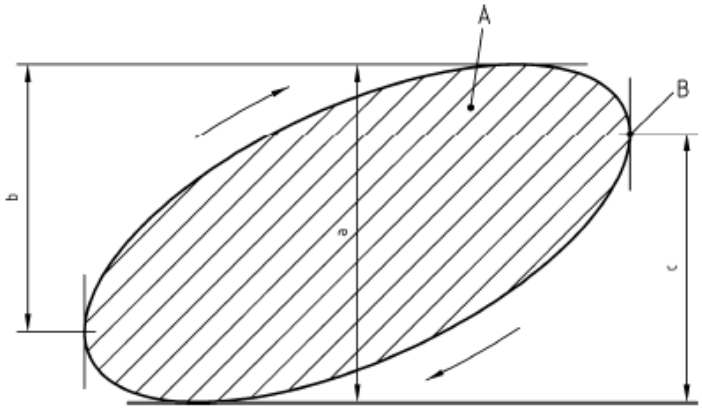
The Hydrostatic Imbalance shall not exceed the values specified in Table 1 under the following conditions:

- with 0º diver roll and diver pitch from + 180º to - 90º;
- with 0º diver pitch and diver roll from + 90º to - 90º.

Diver roll and pitch angles are defined in Figures 3 and 4 respectively.

Testing shall be done in accordance with Section 6.4

It has already been noted that the EN 14143:2003 requirements for Hydrostatic Imbalance in Section 5.6.1.4 are guaranteed if the apparatus meets the breathable volume test in Section 5.6.3: the breathable volume test is essentially a hydrostatic imbalance test, but using a 4.5 litre tidal volume compared to just 2.5 litres in the Section 5.6.1.4 test. The Section 5.6.3 test is a key safety test: the Section 5.6.1.4 is superfluous from a safety standpoint. However, the standard requires that both tests be carried out.



Key

a) peak to peak respiratory pressure

b) peak expired respiratory pressure (end inhalation to peak exhalation)

c) peak inspired respiratory pressure (end exhalation to peak inhalation)

A WOB

B Reference point of hydrostatic imbalance; end of exhalation ("no flow")

Figure 2. Reproduction of Figure 1 Lissajou in EN14143:2003

Table 1 — Hydrostatic imbalance

Pitch degrees (Roll at 0 degrees)	**Suprasternal notch**	
	+ mbar	- mbar
+180	+20,0	-20,0
+90	+20,0	-20,0
+45	+20,0	-20,0
0	+20,0	-25,0
-45	+20,0	-20,0
-90	+20,0	-20,0
Roll degrees (Pitch at 0 degrees)		
+90	+20,0	-20,0
+45	+23,0	-23,0
0	+20,0	-25,0
-45	+23,0	-23,0
-90	+20,0	-20,0

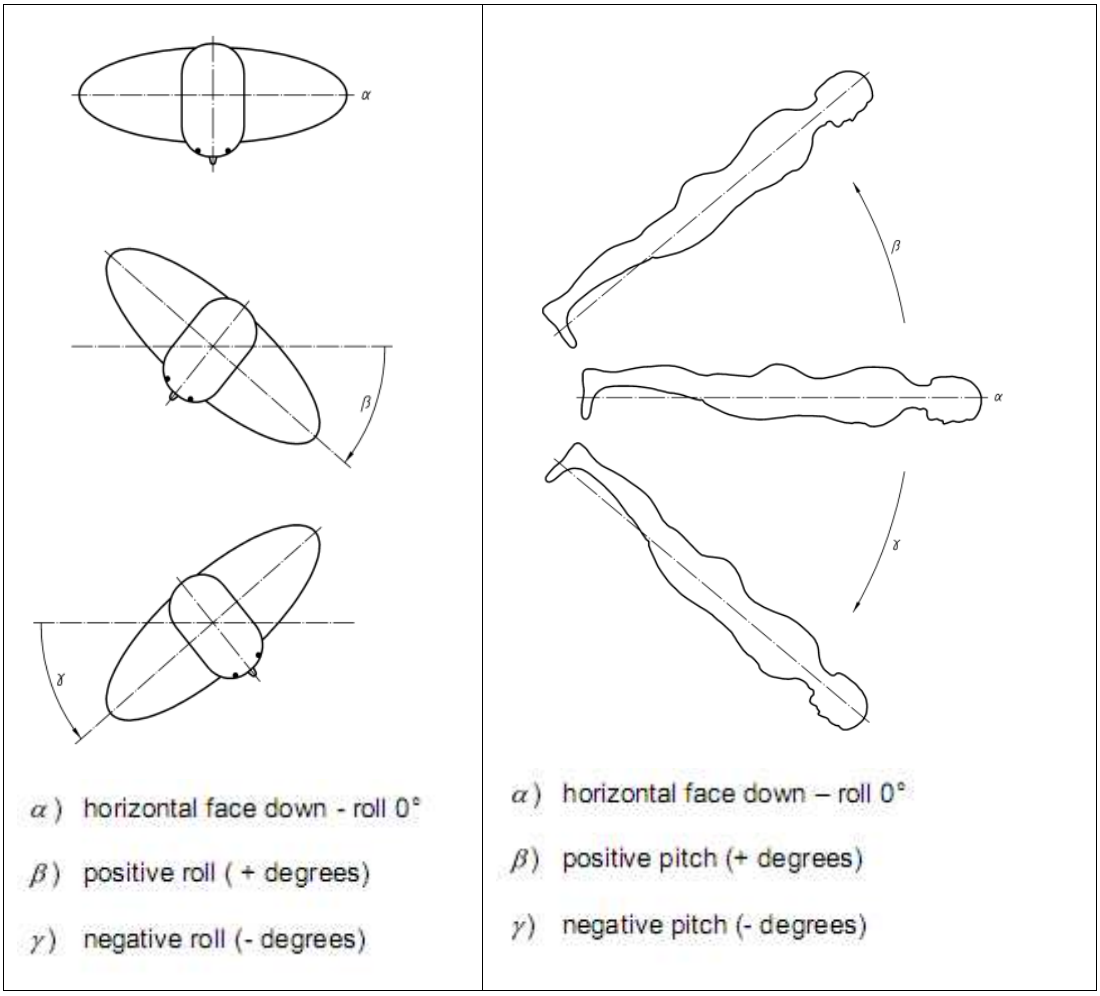


Figure 3. Reproduction of Figure 3 (left) and Figure 4 (right) in EN14143:2003

IMPORTANT NOTE: ERROR IN TABLE 1 OF EN14143:2003

The EN14143:2003 tabulation of Hydrostatic Imbalance limits in Table 1 contains Lung Centroid figures but is labelled Suprasternal notch. The CEN TC79 / SC7 Committee responsible for EN 14143 has accepted this was an error, and resolved in their June 2009 meeting in Seville to correct it for publication as prEN14143:2010. The corrected table is shown below for the Suprasternal Notch as the reference point. Correction values are provided to convert from Suprasternal Notch measurements to a Lung Centroid reference point, to enable suprasternal notch measurements to be mapped onto the actual Lung Centroid requirements.

For the purposes of the tests that the apparatus meets the PPE safety requirement, Table 1 in EN 14143:2003 will be adopted with the label corrected so the reference point is the Lung Centroid, matching the contents of the table.

Deep Life Ltd have advised BAI that the Notified Body requires that this correction be disclosed on all labelling claiming that the apparatus complies with the EN 14143:2003 standard. This qualification to the certification claim is highly undesirable for the client, Deep Life Ltd, who are seeking total compliance with all safety relevant and competent safety standards. BAI will therefore perform the test and determine compliance to the limits in for both the erroneous EN14143:2003 Table 1 and the correction to EN14143:2003 Table 1 (i.e. with reference to L.C.) which is in prEN14143:2010 Table 1, on the basis that the declaration is not necessary if the apparatus meets both sets of limits.

Table 1 Hydrostatic imbalance limits corrected for Suprasternal notch

Test Num.	Position		Hydrostatic imbalance prEN14143:2010 limits for Suprasternal Notch reference point, mbar (rounded limits)	Correction values for Lung Centroid reference point relative to Suprasternal Notch reference point for EN14143:2003 mannequin, mbar
	Pitch	Roll		
1	180	0	-13.0 +27.0 (-13 +27)	-7.0
2	90	0	-6.5 +33.5 (-7 +34)	-13.5
3	45	0	-15.4 +24.6 (-15 +25)	-4.6
4	0	0	-32.0 +13.0 (-32 +13)	+7.0
5	-45	0	-34.5 +5.5 (-35 +6)	+14.5
6	-90	0	-33.5 +6.5 (-34 +7)	+13.5
7	0	90	-20.0 +20.0 (-20 +20)	0.0
8	0	45	-27.9 +18.1 (-28 +18)	+4.9
9	0	-45	-27.9 +18.1 (-28 +18)	+4.9
10	0	-90	-20.0 +20.0 (-20 +20)	0.0

The revision proposed to EN 14143:2003 as the basis for prEN14143:2010 corrects this error by providing the table below, and reduces the limits to +/-20mbar relative to the Lung centroid in any

position. Table 1 from that standard proposal is reproduced below. The revised standard reduces the limits allowed for hydrostatic imbalance in uncommon diver attitudes.

Pitch (degrees)(roll at 0 degrees)	Lung centroid		Suprasternal notch	
	+mbar	-mbar	+mbar	-mbar
180	20	-20	27	-13
90	20	-20	33.5	-6.5
45	20	-20	24.6	-15.4
0	20	-20	13	-27
-45	20	-20	5.5	-34.5
-90	20	-20	6.5	-33.5
Roll (degrees) (Pitch at 0 degrees)	**Lung centroid**		**Suprasternal notch**	
	+mbar	**-mbar**	**+mbar**	**-mbar**
90	20	-20	20	-20
45	20	-20	15.1	-24.9
0	20	-20	13	-27
-45	20	-20	15.1	-24.9
-90	20	-20	20	-20

The reduced limit proposed for prEN14143:2010 will be used as a further basis for comparison.

6 Testing

6.3.1 General test conditions

The apparatus shall be fully rigged on a mannequin according to the information supplied by the manufacturer.

The breathing performance of the apparatus shall be determined using a sinusoidal gas flow from a breathing simulator with an allowable variation of +/- 3 % in both the frequency and the amplitude.

Completely immerse the apparatus in water at a depth sufficiently deep to preclude surface effects.

The gas supply shall be switched on and any adjustable relief valve set to a mechanical midpoint or the manufacturers recommended setting.

For apparatus that do not add gas during tests the breathable volume shall be optimised before starting each measurement.

Record the performance of the apparatus at test pressures of 5 bar with oxygen in nitrogen gas mixtures and at 11 bar with oxygen in helium based mixtures or a reduced pressure specified by the manufacturer

Stabilise the temperature of the water in the test chamber at (4 +/- 1) °C, or lower if specified by the manufacturer.

6.3.2 Breathing performance

Set the breathing simulator at the ventilation rates in Table 4.

Measure the respiratory pressure at the mouth and determine performance from the pressure-volume diagram generated by plotting the low (respiratory) pressure against the displaced volume. Analyse the pressure-volume diagram in accordance with figure 1.

Simulate the diver in both the vertical and horizontal orientation (+ 90° and 0° pitch - see figure 4).

6.4 Hydrostatic imbalance

Fully rig the apparatus on a rotating mannequin as specified in Section 6.3.1 and completely immerse in water at a depth sufficiently deep to preclude surface effects, but not deeper than 2 m. This test shall be undertaken at a RMV of 62,5 l min-1 and the mouth pressure recorded at the end of exhalation (see figure 1).

After breathable volume optimisation as defined in Section 6.3.1 no further adjustment is allowed for roll and pitch variation measurements.

During this test the mannequin shall be rotated about the Lung Centroid.

The EN 14134:2003 Hydrostatic Imbalance test uses a fixed volume, and rotates the rebreather with that constant volume. There is no addition or loss of gas with each rotation of the rebreather. The entire cycle of positions is tested, and then the first position tested is retested to ensure that gas was lost or added: if the first position retest is materially the same then it is assumed the volume has been held constant during the test.

As the Hydrostatic Imbalance measurement is relative to the lung centroid in the mannequin, there is no meaning to the requirement in Section 6.4 that it must be rotated about the Lung Centroid: the requirement appears to be another error in this portion of the standard. This requirement, whilst meaningless in terms of affecting any results, precludes test houses that do not use Hydrostatic Imbalance test fixture that is specific to this requirement. BAI now uses such a fixture and used the fixture for all tests reported here.

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3.3 NORSOK U101 Requirements

NORSOK U-101:1999 stipulates the following requirements for Hydrostatic imbalance, respiratory pressures tests and the Breathing Simulator (only parts belonging to Hydrostatic imbalance and respiratory pressures tests):

3.1 Definitions

Hydrostatic imbalance (Hl):

Pressure difference between the reference pressure (Pr) and the lung-centroid pressure (Plc), Hl = Pr - Plc (Measured in kPa).

The Hydrostatic Imbalance may be positive, negative or zero, depending on the position of the demand valve (or equivalent device) and the orientation of the diver. The Hydrostatic Imbalance can only be measured when there is no respiratory gas flow.

Lung Centroid pressure (Plc):

Pressure maintaining the normal resting volume of the lungs (Measured in kPa). The Lung Centroid pressure may be measured at a point 1.24 kPa inferior to and 0.7 kPa posterior to the Suprasternal Notch or 2.84kPa inferior to and 1.4 kPa posterior to the mouth.

Respiratory pressure:

Differential pressure measure in the diver's mouth during inhalation and exhalation, in relation to the reference pressure (Measured in kPa).

Reference pressure (Pr):

Pressure in the diver's mouth with relaxed muscles of respiration and no breathing gas flow (Measured in kPa).

5 PERFORMANCE REQUIREMENTS

5.5 Respiratory pressure

The respiratory pressure (P) should ideally be limited to ± 1.5 kPa and shall not exceed ± 2.5 kPa relative to the reference pressure (Pr) during a breathing cycle.

5.6 Hydrostatic imbalance

The Hydrostatic Imbalance (Hl) varies with the orientation of the diver and the position of the demand valve and may affect the total load on the diver. The difference between the reference pressure (Pr) and the lung centroid pressure (Plc) should be as small as possible.

The reference pressure shall be between minus 2.0 and plus 1.0 kPa relative to the lung centroid pressure, or if applicable to the suprasternal notch. This limit applies whether the diver is standing in upright position or is lying face down.

6 TESTING

6.2 Requirements for the breathing simulator

6.2.2 Test environment

The equipment shall be tested with the gas and in the environment in which it is intended to be used (e.g. heliox, water, air etc.) as documented by manufacturer. When tested in water, the equipment shall be immersed to a depth sufficient to preclude surface effects. It shall be ensured that the conditions during testing reflect the most unfavourable operational conditions of the equipment.

6.2.3 Wave form

The breathing simulator shall be able to exhibit a sinusoidal wave form with a maximum variation of ± 5 %. If this wave form greatly effects the results for certain types of

equipment, a more realistic wave form may be used in any additional tests that may be carried out.

6.2.4 Pressure measurement

Respiratory pressure shall be measured with pressure variations up to 5 Hz with less than 3 dB dampening. This in order to establish whether the breathing apparatus complies with the requirements specified in clause 5.5. Measurements shall be carried out with an accuracy better than 0.1 kPa.

In order to measure high frequency pressure variations in the breathing apparatus, the measuring equipment shall be capable of registering this at frequencies up to 50 Hz with less than 3 dB dampening.

The test depth shall be maintained within ± 1% throughout the breathing cycle.

6.2.5 Temperature measurement

The temperature of the inspired gas shall be measured with an accuracy of ± 0.25°C and a time constant (63%) of 150 ms or better.

6.2.6 Heat recovery

When the breathing apparatus makes use of heat from the diver's exhaled gas, the breathing simulator shall have the capacity to provide this heat. This heat is part of the total heat input required to attain the temperature stipulated in clause 6.4.10.

6.2.7Ambient test temperature

The temperature of the water surrounding the equipment in the test chamber shall be kept at 5°C, ± 2°C.

The temperature and the relative humidity of the breathing gas affect the freezing properties of the breathing apparatus when in use.

6.2 Test procedures

6.3.5 Hydrostatic imbalance

Breathing apparatus should be assessed and if applicable tested to establish the circumstances under which the Hydrostatic Imbalance may increase.

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3.4 NATO STANAG 1410:2006 Requirements

NATO STANAG 1410:2006 does not contain information on Hydrostatic Imbalance limits, or elastance limits for the apparatus under test: it merely defines elastance as part of a calibration procedure for the breathing machine. The definition of elastance in STANAG 1410 is not clear, but its application means it is a difference in pressure due to changes in the height of water pressure expressed in mbar under the influence of the tidal volume.

The acceptance criteria lists a Work of Breathing Limit, Respiratory Pressures, but not a Hydrostatic Imbalance or elastance limit. The standard includes the general description of test procedures, the diagrams showing the methods of measurement work of breathing and respiratory pressures, see below:

ANNEX A

TEST PROCEDURES

BREATHING PERFORMANCE

1. The dynamic performance of the breathing apparatus shall be tested at appropriate ventilation rates, shown in Table A-1, with the apparatus immersed.

2. The ventilation rates shall be measured under Actual Temperature, Pressure and humidity (ATP) conditions. All relevant data should be included to allow ventilation rates to be corrected for Body Temperature Pressure Saturated (BTPS) conditions, by calculation, after testing.

TABLE A-1

Standard Temperature and Pressure Dry (STPD) 0 °C, 1.013 bar
Actual Temperature and Pressure (ATP)

TIDAL VOLUME (litres) ATP	BREATHS PER MINUTE (BPM)	VENTILATION (litres per minute) ATP	CARBON DIOXIDE FLOW (litres per minute) STPD	OXYGEN REMOVAL (litres per minute) STPD
1.0	10	10.0	0.4	0.44
1.5	15	22.5	0.9	1.00
2.0	20	40.0	1.6	1.78
2.0	25	50.0	2.0	2.22
2.5	25	62.5	2.5	2.78
3.0	25	75.0	3.0	3.33
3.0	30	90.0	3.6	4.00
4.0	10	40.0	1.6	1.78

ANNEX E

DATA CAPTURE, ANALYSIS AND DISPLAY

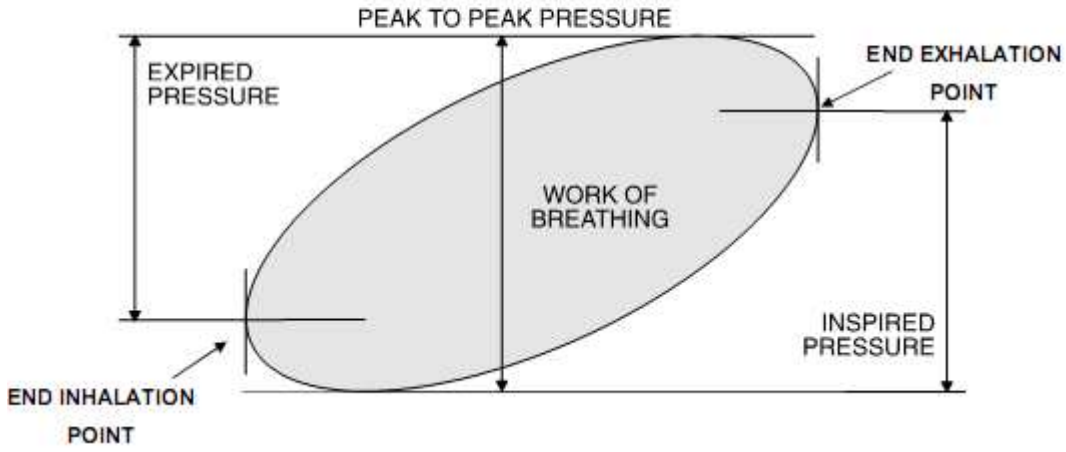
DATA DISPLAY AND ANALYSIS

4. Counter-lung equipment: The maximum values for a combination of inspired/expired pressures along with the calculated value for work of breathing shall be recorded and measured, for a range of ventilation rates, in accordance with the diagram shown in Figure E-2.

Note: the described above test was carried out and is reported separately with other WOB results for the apparatus.

FIGURE E-2

COUNTERLUNG EQUIPMENTS
MEASUREMENT OF WORK OF BREATHING AND RESPIRATORY PRESSURES



ANNEX F

DIVING BREATHING APPARATUS – ACCEPTANCE CRITERIA

RESPIRATORY PRESSURES

Within ± 2.0 kPa at ventilation rates from 10 to 90 l·min-1 ATP.

Note: NATO STANAG 1410:2006 does not define reference point for the differential pressure measurement. Annex C contains information about method of pressure measurement.

ANNEX C

MEASURING INSTRUMENTS

MOUTH PRESSURE

1. The mouth pressure sensor shall measure, differentially, the pressure variations occurring at the inlet to the mouth or mouthpiece. It may be referenced to the air space above the immersed equipment provided the dynamic range of the mouth pressure sensor is not exceeded either by the sum of the depth plus 2.5 kPa or the sum of the depth plus the maximum positive pressure variation recorded during dry testing. The sensor must have a minimum frequency and amplitude response of 50 Hz and ± 6.0 kPa respectively.

The pressure measurement description in Annex C above does not clearly specify the reference point.

3.5 NEDU TA05-12 recommendations

The NEDU report by D. E. Warkander, "COMPREHENSIVE PERFORMANCE LIMITS FOR DIVERS' UNDERWATER BREATHING GEAR: OF ADOPTING CONSEQUENCES DIVER-FOCUSED LIMITS, Navy experimental Diving Unit TA05-12,15 January 2007" recommends a lower WOB limit and also gives elastance and Hydrostatic Imbalance limits for rebreathers.

The principle of the NEDU report TA05-12 is to determine what Work of Breathing causes the diver's RMV to increase by 50%. This is a function of depth, gas and apparatus configuration. Whilst the report considers primarily Work of Breathing, there are references to hydrostatic limits, and the recommendation of the introduction of a new limit for elastance.

The TA05-12 NEDU report, in the section entitled "ELASTANCE AND HYDROSTATIC IMBALANCE" on page 12, reads as follows:

> **Open circuit demand valves**
>
> A demand valve has no elastance of practical importance. The hydrostatic load is determined by the vertical distance between the lung centroid and the demand valve (usually the button on the side of the valve). Since the demand valve is typically level with the diver's mouth, all open circuit demand valves have about the same Hydrostatic Imbalance. The vertical distance between the lung centroid and the mouth for an upright diver is typically given as 17 cm, equivalent to about 1.7 kPa. For a prone diver, the distance is about 10 cm, equivalent to about 1 kPa. For a vertical, head-up diver the mouth is shallower (i.e., at a lower pressure) than the lung centroid, a position which induces a negative hydrostatic load.
>
> **Rebreathers**
>
> The elastance and the hydrostatic load in a rebreather are not fixed values; they vary with diver orientation and the volume of gas in the breathing bag. NEDU has recently revised its procedures for elastance and hydrostatic load testing in rebreathers to reflect this fact.

Table 2 Example of Hydrostatic Imbalance (kPa) relative to the suprasternal notch with different diver positions and different amounts of gas in the rebreathing bag for one of the UBAs presented in the NEDU report.

Position	Bag volume		
	Empty at end of inspiration	Middle	Full at start of inspiration
Vertical	1.5	1.8	2.2
Face down	0.5	1.6	2.6
Left shoulder down	0.8	1.6	2.2
Right shoulder down	3.3	3.9	4.3

Table 3 Example of Elastance (kPa/L) with different diver positions and different amounts of gas in the rebreathing bag for an example UBA.

Position	Bag volume		
	Empty at end of inspiration	Middle	Full at start of inspiration
Vertical	0.22	0.35	0.37
Face down	0.27	0.36	0.69
Left shoulder down	0.72	0.74	0.48
Right shoulder down	0.75	0.90	0.97

TA05-12 NEDU report, CONCLUSIONS Page 23:

The elastance should not exceed 0.7 kPa/L (approx. 7mbar/L) independent of depth and ventilation. The maximum tolerable Hydrostatic Imbalances, relative to the suprasternal notch, should be in the range +0.4 to +2.9 kPa for a vertical diver and in the range -0.3 to +1.7 kPa for a horizontal diver.

The total acceptable respiratory load can be calculated by adding the relative value for each load.

Table 4 Reproduction of Table 2 (p.6 TA05-12 NEDU report). Maximum tolerable Hydrostatic Imbalances (kPa) for different reference points.

Diver orientation	Reference point	
	Lung centroid	Suprasternal notch
Upright (vertical)	-1 to +1.5	+0.4 to +2.9
Prone (swimming face down)	-1 to +1	-0.3 to +1.7

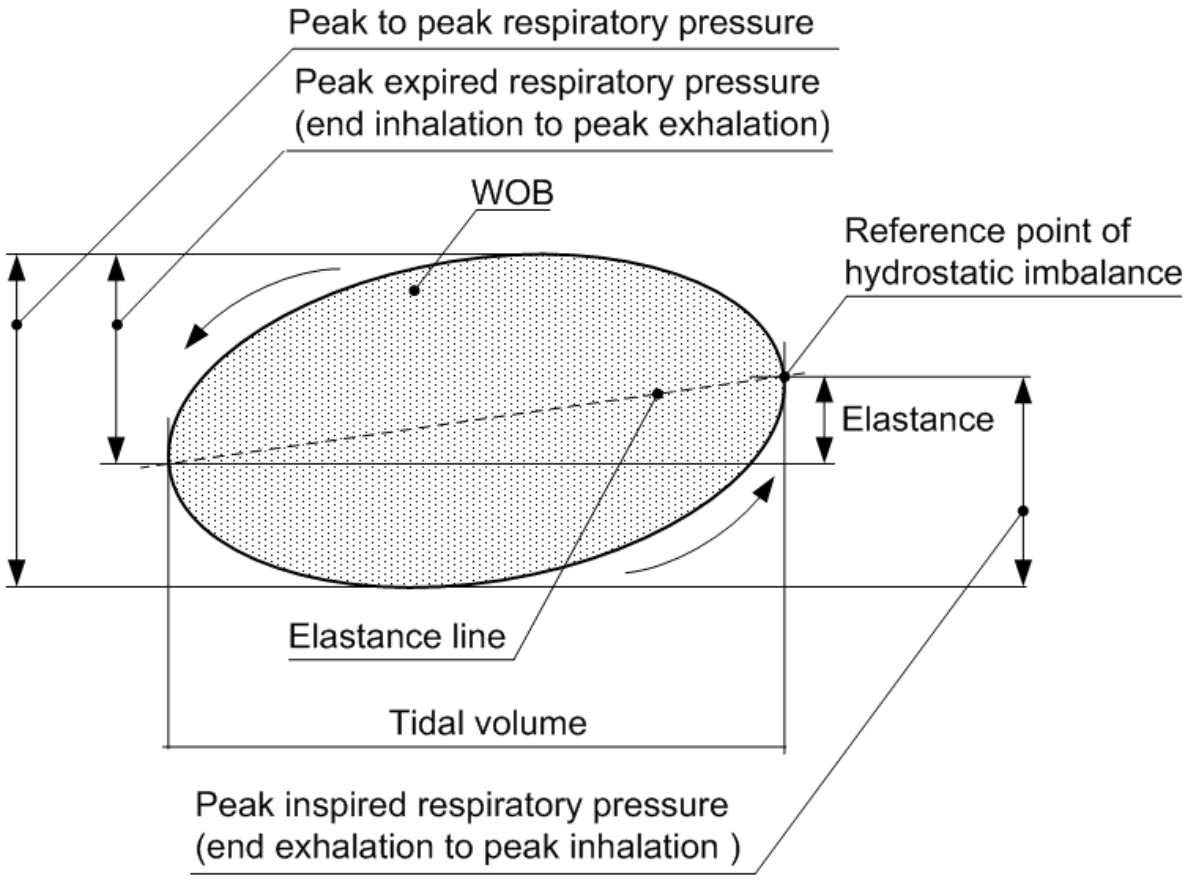


Figure 4. Lissajou showing terms used in STANAG 1410 and NEDU report. Note the direction of the Lissajou is the opposite to that in EN14143:2003.

Note: the NEDU Hydrostatic Imbalance requirements are defined for minute ventilation rate up to 62.5L/min and the tidal volume of 2.5L. The elastance should not exceed 0.7kPa/L independent of depth and ventilation. As the tidal volume of the breathing machine is constant for the hydrostatic tests and equal to 2.5L, so the difference between the Lissajou points on the elastance line should not exceed 1.75 kPa or 17.5mbar.

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3.6 Compilation of Requirements

Table 5 Compilation of Hydrostatic Imbalance limits

Test Num	Pitch	Roll	Hydrostatic Imbalance Limits				
			EN14143: 2003 relative to LC[1]	prEN14143 :2010 relative to LC	NORSOK U101: 1999 relative to LC	STANAG 1410: 2006[2]	NEDU TA05-12 relative to LC
1	180	0	±20	±20	-	-	-
2	90	0	±20	±20	-20…+10	-	-10 to +15
3	45	0	±20	±20	-	-	-
4	0	0	-25..+20	±20	-20…+10	-	-10 to +10
5	-45	0	±20	±20	-	-	-
6	-90	0	±20	±20	-	-	-
7	0	90	±20	±20	-	-	-
8	0	45	±23	±20	-	-	-
9	0	-45	±23	±20	-	-	-
10	0	-90	±20	±20	-	-	-

Table 6 Compilation of Respiratory Pressures limits

Parameter	Respiratory pressures limits, mbar			
	EN14143:2003	NORSOK U101:1999	STANAG 1410:2006	NEDU TA05-12
Inhale/exhale respiratory pressure	25	-15…+15 ideal (-25…+25 crit.)	-20…+ 20	-
Peak to peak pressure	50	-	-	-

[1] Reference point adopted is the Lung centroid.

[2] STANAG 1410:2006 does not clearly specify the reference point.

Table 7 Compilation of Elastance limits

N.	Elastance limits, kPa/L			
	EN14143:2003	NORSOK U101:1999	STANAG 1410:2006	NEDU TA05-12
1	-	-	-	0.7

It is noted that EN14143 states the Suprasternal Notch is used as the reference for the ideal conditions without there being any requirement to meet any particular limits: empirical testing has limits specified, and in both EN14143 and NORSOK U101 that involves a rotation about the Lung Centroid. However the position of the breathing machine in the water is stated in Table 1 of EN14143 to be the Suprasternal Notch, which means the practical measurement, is with respect to that notch. The table showing the correction to results for NORSOK U101 Lung Centroid results is shown in the table below.

Table 8 Hydrostatic imbalance correction for NORSOK U-101 due to changing reference point from Lung Centroid to Suprasternal Notch

Test Num.	Position		Correction values for Suprasternal Notch reference point relative to Lung Centroid reference point for NORSOK U101:1999 mannequin, mbar	NORSOK U101 limits for Suprasternal Notch, mbar
	Pitch	Roll		
1	90	0	+12.4	-7.6…+22.4
2	0	0	-7.0	-27…+3

The mannequin dimensions determine the Hydrostatic Imbalance limits. Refer to Section 4.2 for details on final compilation table of Hydrostatic Imbalance limits for different standards.

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4 EQUIPMENT AND CALIBRATION

4.1 Samples Tested

All relevant parts of the apparatus under test matched that described in drawing in BOM 16, except as stated relating to the helmet, DSV and side cylinders.

One sample of the OR_Umbilical and OR_Apocalypse Type IV O2-CCR was tested, marked Sample 1 and Sample 2 respectively. The logs were checked for these samples to confirm they had previously undergone environmental conditioning as required by EN 14143:2003.

The OR_Incursion and the OR_Apocalypse have identical geometry and breathing loops, other than the Incursion has a different plastic moulding at the inlet to the scrubber: this is a the same as the OR_Apocalypse scrubber inlet moulding except for providing an enclosed space outside the breathing loop to house electronics. The moulding is rigid, so cannot effect Hydrostatic Imbalance, and the geometry in the breathing loop is the same as for the OR_Apocalypse. The two models, OR_Incursion and OR_Apocalypse will be treated as one product for the purposes of these tests: the test will be performed with the OR_Apocalypse scrubber head fitted. Similarly, it is noted that the OR_Apocalypse Type IV has two submodels, one is the O2-CCR and the other is the iCCR: the breathing loops are identical for Hydrostatic Imbalance purposes.

4.2 Hydrostatic Imbalance Test Fixture

All Hydrostatic Imbalance tests were carried out in a 1.6m deep tank using a test frame designed specifically for EN 14143:2003 Hydrostatic Imbalance testing, shown below. The breathing simulator was installed into to the chest of the mannequin to avoid the water pressure biasing the piston movement.

Figure 5. **Hydrostatic test frame with the mannequin fitted**

4.3 Other Test Equipment Used

The test equipment is listed below.

Equipment	Serial Number	Calibration Log Number	Calibration Next Due
DL, Human Respiratory Emulator (Breathing simulator) DL Rev C2	DL 001	See below	July 2011 and Check cal prior to test
Differential pressure sensor. Druck LPM9381	2393261	D22	Prior to each test series using water column in elastance calibration fixture
National Instruments Data Capture System PCI-6014	HA4375847	L15	Against TTi 1906, Serial Number 111474 Prior to test
Power supply GPR – 1850	033624	N/A	N/A
Hydrostatic Imbalance test pool	BAI 016	N/A	N/A
Hydrostatic Imbalance test frame	BAI 017	N/A	N/A
Pool Cooling System	-	-	Temperature checked before use
Temperature Probe and Multimeter	2S19C89361	T2	Checked before use on ice, body temperature and in boiling water to confirm integrity of probe

Note: the Breathing Simulator is a complex measurement system and contains additional sensors not listed in the table above. This information is provided at Breathing Simulator Calibration report *Cal_Breathing_Simulator_Assessment_090707.pdf*.

4.4 Calibration references and means

- NEDU Small Calibration Orifice (S/N DL 008), sample of calibration data reproduced herein
- EN14143 Calibration Orifice (S/N DL 009), sample of calibration data reproduced herein

Calibration orifices, calibration weight set, calibrated graduated volume are not subject to annual calibration, but are inspected for wear on each use.

4.5 Pre-Test Calibration

For standards compliance work, it is necessary to perform a traceable calibration of the Breathing Simulator. For Breathing Simulator calibration, the standards specify the performance using test orifices and an elastance test fixture. There are two orifices used: one is the NEDU orifice, the second is the EN14143 orifice. The elastance test fixture is described in the NATO STANAG 1410 edition 2 Figure D-3.

4.5.1 NEDU Orifice

The Breathing simulator was calibrated using the NEDU TM01-94 calibration orifice (Figure 4.1 of NEDU TM01-94), under all conditions described by NEDU in TM01-94 (Figure 9). Samples of those calibrations, which were repeated with each series of tests, are reproduced along with the test results.

Figure 6. NEDU TM01-94 Test Orifice

Table 9. Reproduction of Table 4-1 of NEDU TM01-94 (p.4-2) "CLM Orifice Calibration Values (Daily Calibration)"

RMV (L/min)	minimum $\overline{P}_v$ (kPa or J/L)	maximum $\overline{P}_v$	mean $\overline{P}_v$
22.5	0.17	0.31	0.24
40.0	0.70	0.82	0.76
62.5	1.58	1.84	1.71
75.0	2.17	2.45	2.31
90.0	3.10	3.43	3.26

RESPIRATORY WORK AND RESISTANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	Br.sim. S/N DL 001 (NEDU N01-94 orifice, S/N DL008)	
TEST METHOD		NEDU TM N01-94	SINE FLOW
DATE AND TIME		01/10/2009 09:58	
TEST CARRIED OUT BY	MS	WITNESS: -	

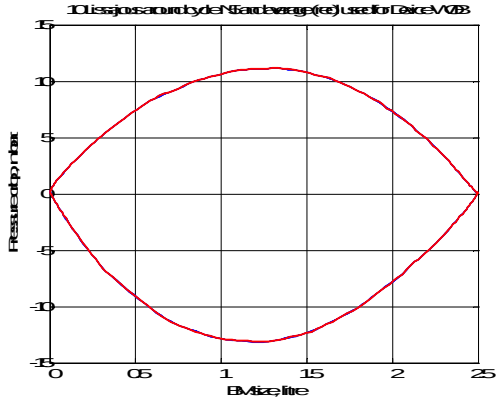
CONDITIONS OF TEST

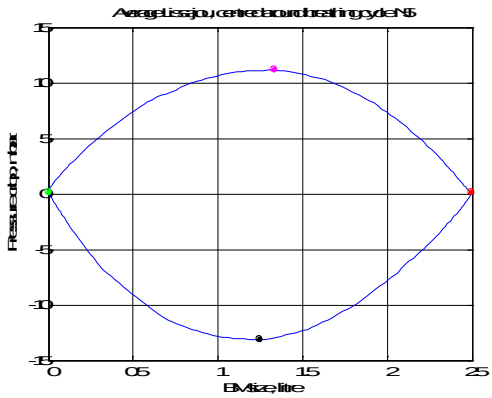
ATTITIDE: PITCH & ROLL	:	-/-	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0	msw
ROOM / WATER TEMPERATURE	:	20.0 / -	℃
EHXALE GAS TEMPERATURE	:	-	℃
GAS SUPPLY PRESSURE	:	-	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/25.0bpm/62.5lpm	metric

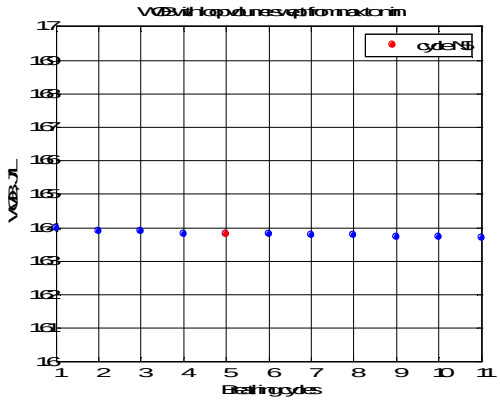
RESULTS

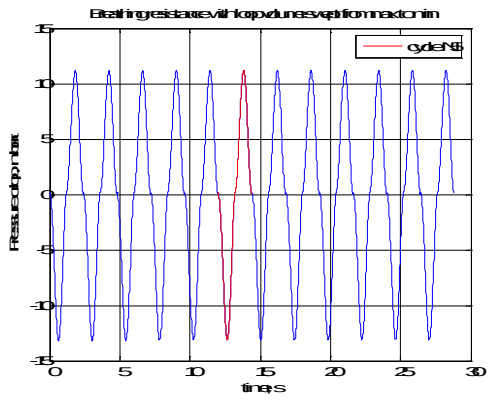
PRESSURE@START INHALE / EXHALE	=	0.1 / 0.1	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	-12.7 / 11.5	mbar
PEAK TO PEAK PRESSURE	=	24.2	mbar
EN14143 RELATIVE PEAK PRESSURES	=	12.8 / 11.6	mbar
TOTAL WORK OF BREATHING (WOB)	=	N.A.	J/l
WOB OF BREATHING SIMULATOR	=	N.A.	J/l
WOB OF DEVICE UNDER TEST	=	1.65	J/l
TOTAL POS / NEG WORK	=	N.A.	J/l
POS / NEG WOB OF DEVICE UNDER TEST	=	0.76 / 0.89	J/l

ALL DATA STORED AS # (DATA FILE): CAL_BM001RC2_NEDUcal_1ATA_62_5lpm_091001









4.5.2 EN14143 Orifice

The Breathing simulator was calibrated using the EN14143:2003 orifice. It produces a breathing resistance of 5mbar at 1 ATM and 50mbar at 5 ATM at an RMV of 62.5l/min. Sample of those calibrations, which were repeated with each series of tests, is reproduced along with the test results. As the Hydrostatic Imbalance test is performed at a depth of 2msw, then the EN 14143:2003 orifice was calibrated at a depth of 0msw immediately before the test sequence.

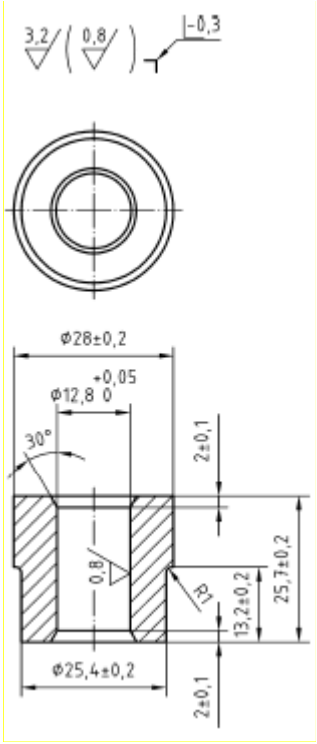


Figure 7: The test orifice specified in Fig 5 of the EN14143 Standard to test the Breathing Simulator. All dimensions in mm.

Figure 8: EN14143:2003 Test Orifice

RESPIRATORY WORK AND RESISTANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	Br.sim. S/N DL 001 (EN14143:2003 calibration orifice, S/N DL 009)	
TEST METHOD		EN14143:2003 Breathing Simulator calibration method	SINE FLOW
DATE AND TIME		01/10/2009 16:05	
TEST CARRIED OUT BY	MS	WITNESS: VS	

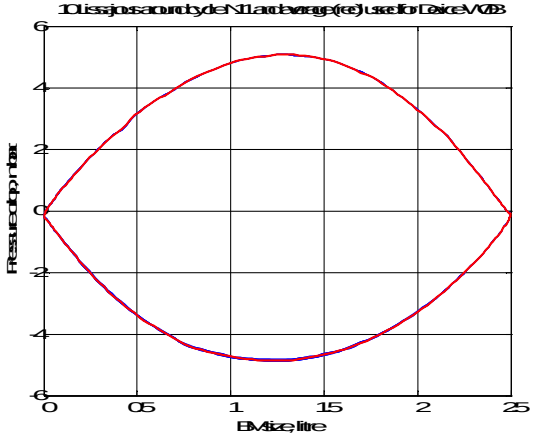
CONDITIONS OF TEST

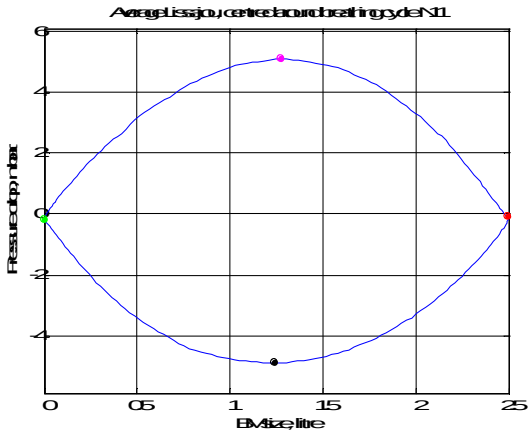
ATTITIDE: PITCH & ROLL	:	-/-	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	18.0 / -	℃
EHXALE GAS TEMPERATURE	:	-	℃
GAS SUPPLY PRESSURE	:	-	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/25.0bpm/62.5lpm	metric

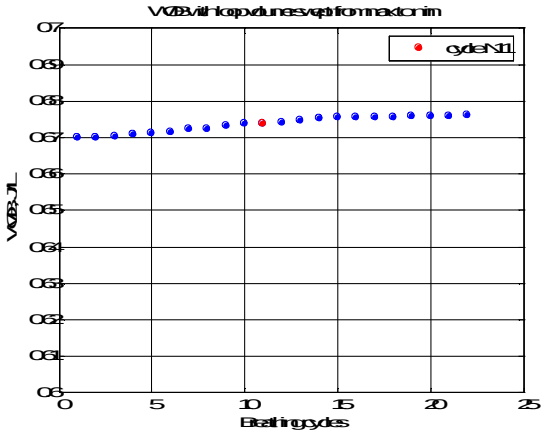
RESULTS

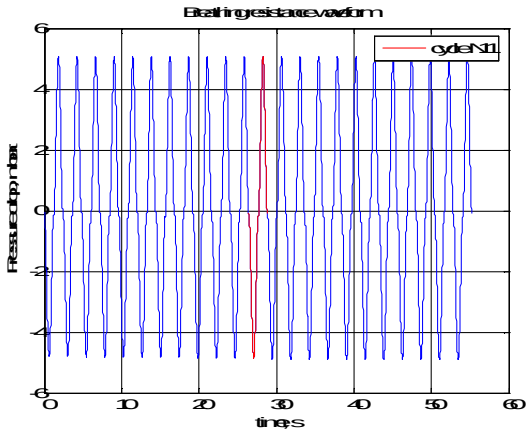
PRESSURE@START INHALE / EXHALE	=	-0.1 / -0.1	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	-4.9 / 5.1	mbar
PEAK TO PEAK PRESSURE	=	9.9	mbar
EN14143 RELATIVE PEAK PRESSURES	=	4.8 / 5.2	mbar
TOTAL WORK OF BREATHING (WOB)	=	N.A.	J/l
WOB OF BREATHING SIMULATOR	=	N.A.	J/l
WOB OF DEVICE UNDER TEST	=	0.67	J/l
TOTAL POS / NEG WORK	=	N.A.	J/l
POS / NEG WOB OF DEVICE UNDER TEST	=	0.34 / 0.33	J/l

ALL DATA STORED AS # (DATA FILE): CAL_BM001RC2_EN14143cal_1ATA_62_5lpm_091001









4.6 Mannequin Measurements in NORSOK U-101 and TA05-12 NEDU report compared to EN14143 and BAI's test lab mannequin

A mannequin forms part of the test frame, with dimensions shown on the right below.

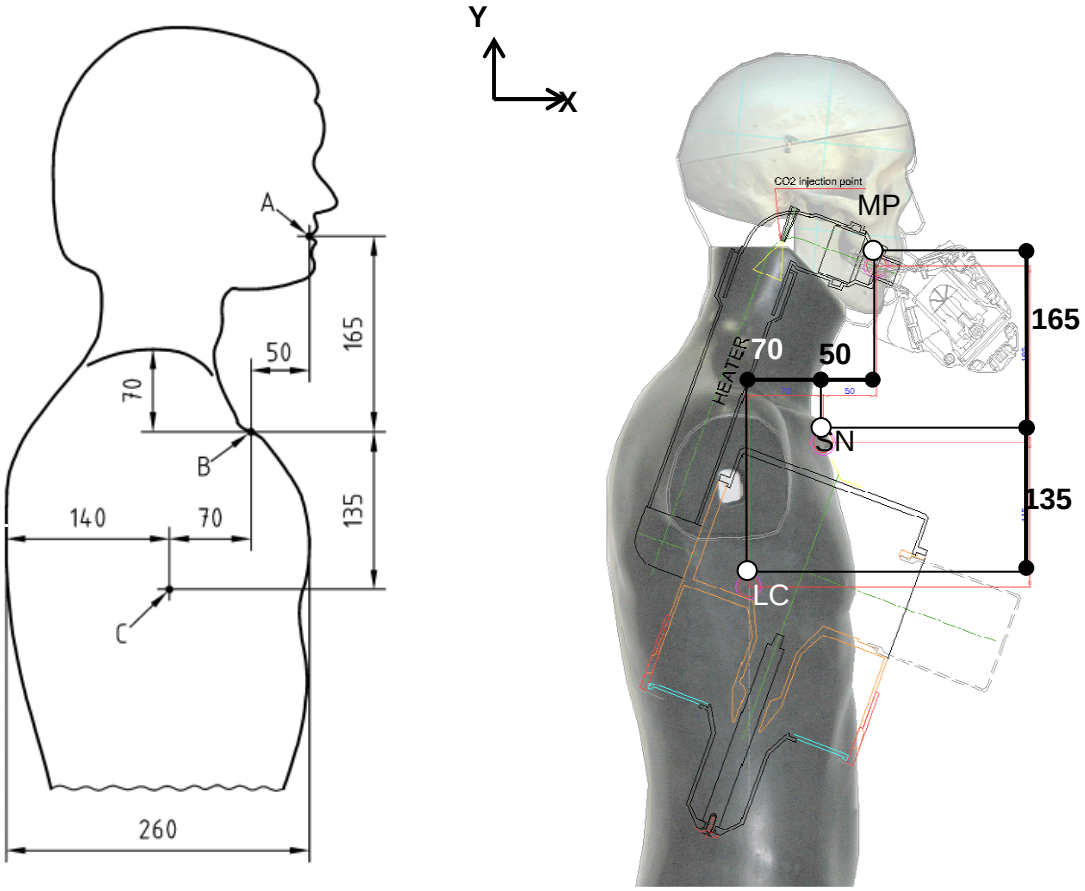


Figure 9. Left: EN 14143:2003 Figure 2 giving mannequin measurements, Right: BAI's test mannequin with installed Breathing Simulator.

The mannequin measurements determine the Hydrostatic Imbalance as much as the rebreather geometry. The mannequin measurements differ between each standard.

For the 90°(pitch),0°(roll) attitude, i.e. the dive r standing upright, EN14143 Suprasternal Notch vertical position is 11mm higher than for the U101 mannequin, thus there is positive pressure offset of about 1.1mbar. If the reference measurement hose is placed on the Suprasternal Notch of a EN14143 mannequin to the true Lung Centroid, the +22.4/-7.6mbar NORSOK U101 limits equate to +23.5/-6.5mbar on the EN14143:2003 mannequin.

The TA05-12 NEDU test mannequin has differs from the EN14143 mannequin: an upright position gives a negative offset of 0.5mbar if the reference measurement hose is placed on the Suprasternal Notch of the EN14143 mannequin.

BAI's mannequin reference points are compensated to correspond to EN14143:2003 mannequin dimensions, therefore there is no need for any offset for the test results. The compensation values are shown in the table below.

	Vertical dimensions, mm			Horizontal dimensions, mm			
Mannequin Dimensions	**From mouth to SN**	**From SN to LC**	**From Top of shoulder to SN**	**From Back to LC**	**From LC to SN**	**From SN to mouth**	**From chest to back**
In EN14143:2003	165	135	70	140	70	50	260
In NORSOK U-101	160	124	-	-	70	70	-
In NEDU TA05-12	-	140	-	-	70	-	-
Test Mannequin	165	135	-	-	70	50	-

NORSOK U-101 to EN14143:2003 and TA05-12 NEDU to EN14143:2003 conversion tables for standards' mannequin positions are shown below (Table 9 and Table 10):

Table 10 Hydrostatic imbalance correction for NORSOK U-101 due to the dimension differences of test mannequin

Test Num	**Position**		**Hydrostatic imbalance correction for NORSOK U101:1999 true Lung Centroid reference point, from an EN14143:2003 Lung Centroid measurement due to the differences of test mannequin and the Figure 2 of EN14143, mbar**	**Corrected Hydrostatic imbalance limits for NORSOK U101:1999 true Lung Centroid reference point on EN14143: 2003 mannequin, mbar**	**Hydrostatic imbalance correction for NORSOK U101:1999 Suprasternal Notch reference point (see) due to the differences of test mannequin and the one in Figure 2 of EN14143, mbar**	**Corrected Hydrostatic imbalance limits for NORSOK U101:1999 Suprasternal Notch reference point on EN14143:2003 mannequin, mbar**
	Pitch	**Roll**				
1	90	0	+1.1	-18.9…+11.1	+1.1	-6.5…+23.5
2	0	0	0.0	-20.0…+10.0	0.0	-27.0…+3.0

Table 11 Hydrostatic imbalance correction for TA05-12 NEDU limits due to the dimension differences of test mannequin

Test Num.	Position		Hydrostatic imbalance correction for TA05-12 NEDU true Lung Centroid reference point, from an EN14143:2003 Lung Centroid measurement due to the differences of test mannequin and the Figure 2 of EN14143, mbar	Corrected Hydrostatic imbalance limits for TA05-12 NEDU true Lung Centroid reference point on EN14143:2003 mannequin, mbar	Hydrostatic imbalance correction for TA05-12 NEDU Suprasternal Notch reference point due to the differences of test mannequin and the one in Figure 2 of EN14143, mbar	Corrected Hydrostatic imbalance limits for TA05-12 NEDU Suprasternal Notch reference point on EN14143:2003 mannequin, mbar
	Pitch	Roll				
1	90	0	-0.5	-10.5…+14.5	-0.5	+3.5…+28.5
2	0	0	0.0	-10.0…+10.0	-7.0 relative to LC	-17.0…+3.0

Table 12 Compilation of Hydrostatic Imbalance limits for EN14143:2003 with prEN14143:2010 correction, NORSOK U101:1999 and NEDU TA05-12 with correction factors due to the dimension differences of test mannequins

	Position		Hydrostatic imbalance limits relative to LC on EN14143 mannequin, mbar			
Test Num	Pitch	Poll	EN14143: 2003 (LC reference)	EN14143: 2009 (LC reference)	NORSOK U101:1999	NEDU TA05-12
1	180	0	±20	±20	-	-
2	90	0	±20	±20	-19…+11	-10…+15
3	45	0	±20	±20	-	-
4	0	0	-25..+20	±20	-20…+10	-10…+10
5	-45	0	±20	±20	-	-
6	-90	0	±20	±20	-	-
7	0	90	±20	±20	-	-
8	0	45	±23	±20	-	-
9	0	-45	±23	±20	-	-
10	0	-90	±20	±20	-	-

4.7 Test data processing

Test data is processed using the same algorithm for all types of Hydrostatic Imbalance and respiratory pressure tests. The step-by-step description is as follows:

1. Breathing Simulator motor position tracking is on and automatic exclusion of failed breathing cycles from test data is enabled.

2. Data filtering from the differential pressure sensor is set to use a 2nd order zero-phase digital filter (forward-backward moving average, window size of 40 samples with 2kHz sampling, i.e. a 50Hz cut off frequency), storing 100 samples per second.
3. Removal of synchronous noise by using an over-cycle moving average filter to reproduce an average cycle with window size of 10 cycles (see *Cal_Breathing_Simulator_Assessment_090707.pdf*).
4. Calculating the respiratory parameters using the average cycle data as follows:
    a. PRESSURE@END EXHALE/INHALE: end exhale pressure = pressure_drop(find(Tidal_Volume==2.5L)); end inhale pressure = pressure_drop(find(Tidal_Volume==0L)).
    b. HYDROSTATIC IMBALANCE (RELATIVE TO LC) = end exhale pressure (*according to EN14143:2003 definition*) + appropriate correction from **Error! Reference source not found.**.
    c. HYDROSTATIC IMBALANCE (RELATIVE TO SN) = end exhale pressure (*according to EN14143:2003 definition*).
    d. PHYSIOLOGICAL PEAK PRESSURES: peak exhalation = max(pressure_drop at the average cycle); peak inhalation = min(pressure_drop at the average cycle).
    e. INHALE/EXHALE RESP PRESSURE: inhale resp pressure = end exhale pressure - peak inhalation pressure; exhale resp pressure = end inhale pressure - peak exhalation pressure.
    f. PEAK TO PEAK PRESSURE = peak exhalation pressure - peak inhalation pressure.
    g. ELASTANCE = (end exhale pressure - end inhale pressure)/2.5L
    h. WORK OF BREATHING = area(Tidal_Volume at the average cycle, pressure_drop at the average cycle) / 2.5L
5. Average cycle Lissajou is reproduced with marking the end exhale, end inhale and physiological peak pressures. Work of breathing, all test cycles and cycle averaged pressure drop waveform are also plotted.

5 METHOD

5.1 General Test Conditions

The pitch and roll rotation axes of the test mannequin is around the Lung Centroid point.

The water is at a temperature of +4ºC.

All samples of the apparatus were pre-dive checked. All samples had undergone preconditioning, including cold storage and hot storage tests, cleaning and stress testing.

The Exhaust valve is set to the maximum pressure setting. All ALVBOVs and ALVs are plugged to prevent gas being added during the test.

In both EN 14143:2003 and prEN14143:2010 the Hydrostatic Imbalance is measured with a fixed loop volume in all positions.

BAI received sight of a non-conformance report from Deep Life's Notified Body, in that previous tests to EN 14143:2003 were performed with an optimised loop volume, and required that a fixed volume is used. Careful reading of EN 14143:2003 confirmed that the requirement is that the loop volume is optimised once, then the Hydrostatic Imbalance is measured in all positions without any further change in loop volume being allowed.

The use of a fixed loop volume in both EN14143:2003 and the proposed prEN14143:2010 and means there are two types of Hydrostatic Imbalance test that have to be applied to each sample of the apparatus: one set with optimised volume of the breathing loop for NORSOK U101:1999 and one set with fixed breathing loop volume to satisfy EN14143:2003.

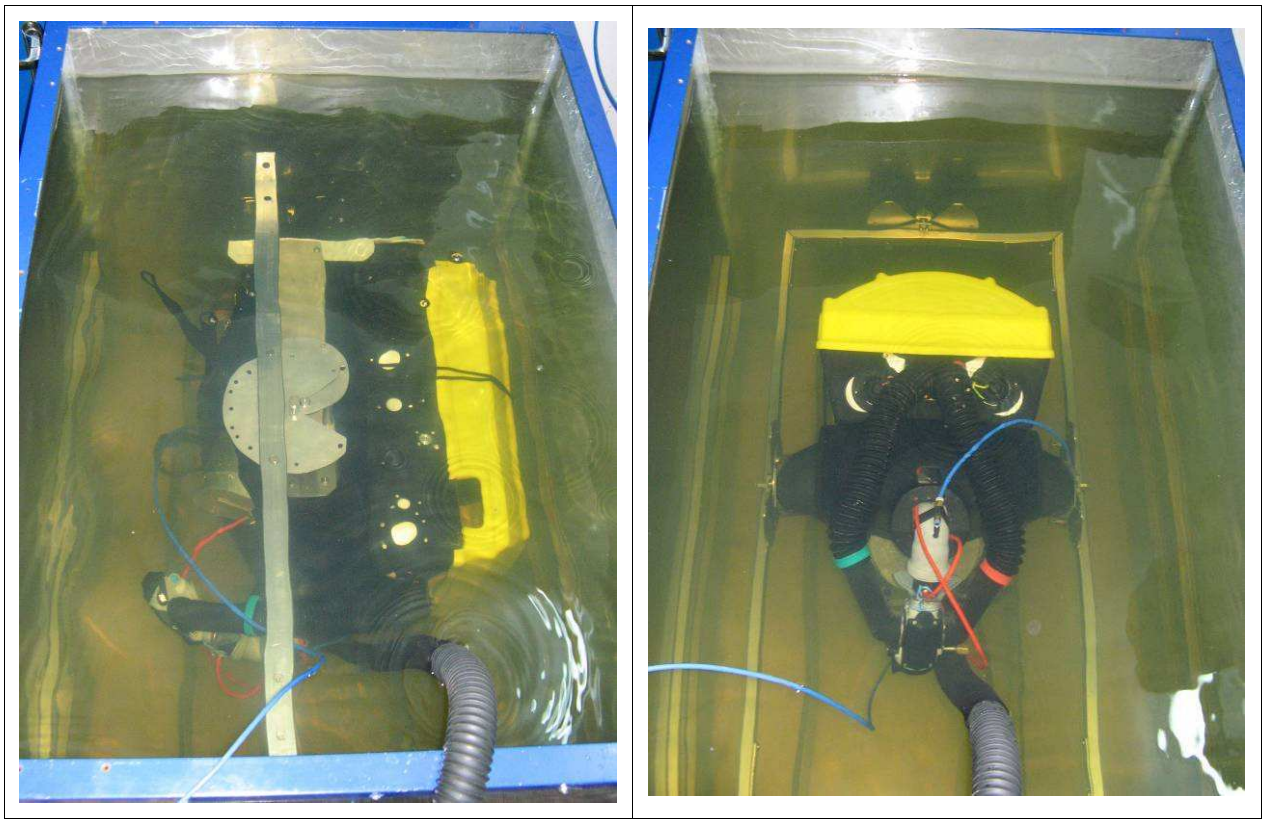


Figure 10. Hydrostatic Imbalance test pool with installed Hydrostatic Imbalance test frame and sample of the apparatus (OR_Umbilical).

5.2 NORSOK U101 Breathing Loop Volume Optimisation Procedure

The general method of Hydrostatic Imbalance and respiratory pressures testing is as follows:

1. The Breathing Simulator is calibrated and set for an RMV of 62.5lpm.
2. The apparatus is fully checked, equipped and fixed on the mannequin. The manufacturer's instructions for position on the mannequin are the same as for the EN 14143 test.
3. Loop volume is optimised in each position by adding gas or venting gas, such that the breathing resistance is a sinusoidal waveform with a mean as close to zero as possible.
4. The Breathing Simulator is run for 25 cycles (i.e. for 1 minute) in each position to avoid any transients and the test data is recorded.
5. After the Breathing Simulator is stopped the test data is processed by the same script as used for calibration (Section 6.2), with output onto the Hydrostatic Imbalance document template.
6. Items 4-6 are repeated until all diver's positions are measured.

5.3 EN 14143 Fixed Breathing Loop Volume Procedure

EN 14143 requires the breathing loop volume to be optimised and then fixed for the entire Hydrostatic Imbalance test.

What is meant by optimal is not defined in the standard, but the standard implies that the manufacture advises what is optimal: if the optimal point appears to be an unreasonable diving condition to the test house, then should be reported in the results taken using the manufacturer's optimisation method.

The optimal loop volume advised by Deep Life is to achieve zero mean loop pressure in the 0 pitch +/- 90 roll position. This is a normal diving condition: a diver optimises the loop such that there is no perceived hydrostatic imbalance when horizontal rolling to either side.

The optimal condition advised by Deep Life is in fact the best case optimal volume setting for all rebreathers with symmetrical counterlungs. Only the 0 pitch +/- 90 position pair should be used for optimising the loop volume.

Using the 0 pitch +/- 90 roll position to optimise volume, rebreather Hydrostatic Imbalance tests take just 11 mins for all ten measurements, with very consistent and repeatable results.

The method is as follows:

1. Carry out positive and negative pressure on the rebreather and confirm that the loop pressure is stable with +/-30mbar loop pressures, with no leaks. Confirm that the ALV and ALVBOV gas supply is off, and the Exhaust valve (OPV) is closed: this will result in a closing pressure of the OPV of around 35mbar.
2. Attach the rebreather to the mannequin used in the hydrostatic test cradle. The harness shall be attached to the mannequin firmly such that each counterlung is symmetrical in the horizontal position about the vertical mannequin centre line, and the longitudinal centre of the counterlungs is within 39mm of the mannequin's lung centroid when the mannequin is in the vertical position (diver head up). This position corresponds to the X-Y positions shown in the table of Ideal Hydrostatic Imbalance values.
3. Confirm calibration of the breathing machine using NEDU orifice. Block or close all ALVs, OPVs. Ensure rebreather cannot inject gas automatically from oxygen injectors.

4. Immerse the rebreather & cradle into 4°C water in position 0 pitch +90 roll at a depth such that the entire rebreather is underwater by at least 10cm regardless of which position it is in.
5. Run the breathing machine with the 62.5 lpm RMV settings.
6. Inject gas into the breathing simulator until the mean pressure in the mouthpiece is zero with respect to the lung centroid.
7. Flip the position to 0 pitch, -90 roll, and check that the mean pressure is close to zero. Any asymmetry between the two positions should be removed by fixing the rebreather firmly to the mannequin, or by adding or removing small amounts of gas, such that the 0 pitch +/-90 roll positions have waveform that have a mean as close to zero as possible.
8. Then run the test sequence without changing the volume, capturing the data. Wait until the Lissajou is stable after switching positions, and capture the data for at least 30s to ensure the no changes in volume shift is occurring.

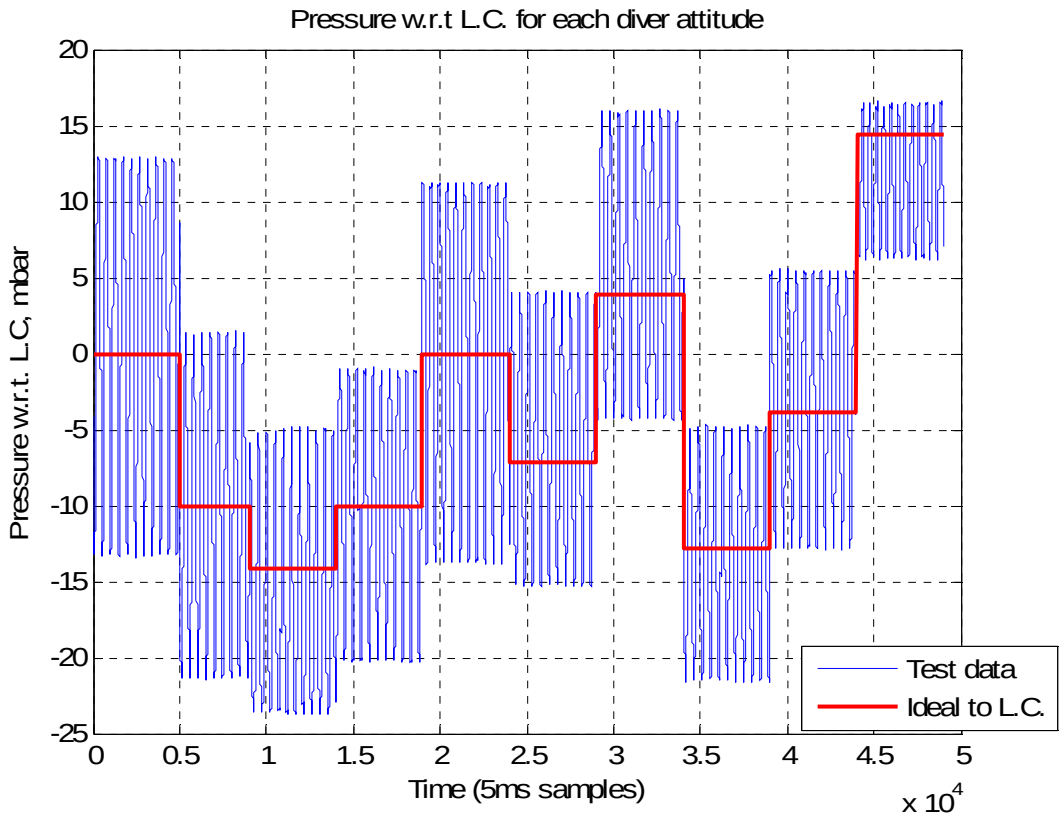


Figure 11. Hydrostatic Imbalance waveforms measured for each position of OR_Umbilical rebreather, for the positions: Pitch 0 ; roll +90, Pitch 0 , roll +45; Pitch 0 , roll 0; Pitch 0 , roll -45; Pitch 0 , roll -90; Pitch -45 , roll 0; Pitch -90 , roll 0; Pitch 45 , roll 0; Pitch 90 , roll 0; Pitch 180 , roll 0 / Pitch 0 , roll 180. The key positions for setting up loop volume are the first and fifth result in this sequence.

EN 14143:2003 expresses the Hydrostatic Imbalance requirements as a maximum end of exhale pressure in a table marked as “Suprasternal Notch” but it is in fact Lung Centroid values. The end of exhale is between the high peak and the mean: the exact point depends on the phase of the breathing machine relative to the mouthpiece gas. It can be seen from the above plot that regardless of the phase, the OR rebreathers pass comfortably a 20mbar limit.

5.4 Fixed Volume Boundary Case Procedure

The boundary case procedure is the same as the EN 14143:2003 procedure above, except that instead of using the optimal loop volume, the loop volume takes the worst case that is within the standard. This is done by selecting the diver pitch and roll position with the worst case ideal values, and then adjusting the loop volume until all this case falls just within the limits of the EN14143:2003 standard, or are as low as possible if they cannot achieve the standard.

This boundary case procedure is time consuming, as it is iterative. To find the boundary case loop volume: each time one worst case point is adjusted, it changes the breathing resistance and offset for all the other points, such that one or more of the hydrostatic imbalance results can end up arbitrarily outside the limits – on any rebreather it is always possible to find a non-optimal loop volume which is outside all the standards considered here, just by adding enough gas, or removing enough gas from the breathing loop (i.e. creating conditions that would not occur in normal diving).

The worst case loop volume test results are provided here for both single and dual scrubber models, to enable any third party's results obtained with non-optimal loop volume to be checked. These results are labelled as the "Fixed Volume Boundary Case".

5.5 Comment on ALV Loop Volume Optimisation Methods

An optimised loop in the meaning of the standard cannot mean that the ALV optimises the loop, because the ALV pressure must be outside the pressures experienced by the breathing cycle, otherwise freeflow will occur. This means the ALV pressure must exceed 25mbar, which would cause any ALV optimised loop to fail any of these standards.

5.6 Comment on Lissajou Based Volume Optimisation Methods

It has been suggested that there may be a different view of what optimal loop volume means in EN 14143:2003 whereby rather than any of the definitions given on Page 34 herein, the proponent picks a position and then varies the loop volume to produce what the technician considers is the "right" Lissajou. That is, the technician optimises the Lissajou shape. This will invariably produce a loop volume that is far from optimal: whether the equipment meets the standard under those conditions would be a lottery.

There are several technical problems with tests that use a Lissajou shape optimisation procedure, in addition to the arbitrary nature of the results:

1. The breathing simulator is imbalanced during Hydrostatic Imbalance tests. Special care has to be taken to ensure the imbalance does not distort the Lissajou: it is not good enough to check just the calibration orifice.
2. The phase offset from the breathing simulator piston to the mouthpiece must be calibrated. Tiny errors in that phase, can cause enormous changes to the Lissajou. As the flexible hose to the equipment under test is stretched and compressed as the test is carried out in each position, the phase will vary in each position. That phase offset has to be known, otherwise the Lissajou the technician is looking at may have almost no relation to the Lissajou experienced by a diver.
   This problem of phase offset is demonstrated in the table overleaf.
3. The Lissajou shape differs in each dive position: this is illustrated in **Figure 12** following the table overleaf. Which shape is "optimal"? It can be seen from this that optimising for Lissajou shape is an erroneous practice.

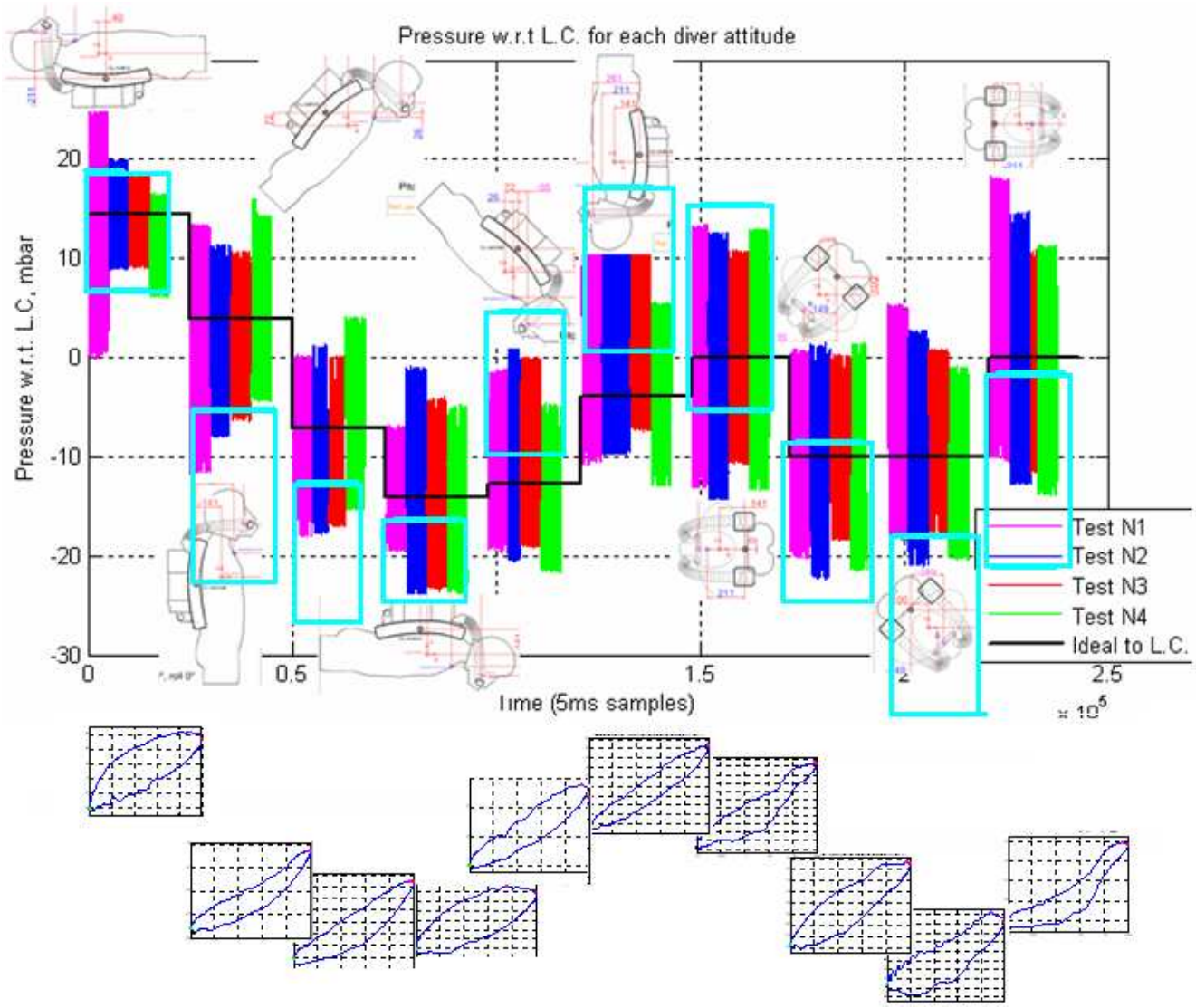
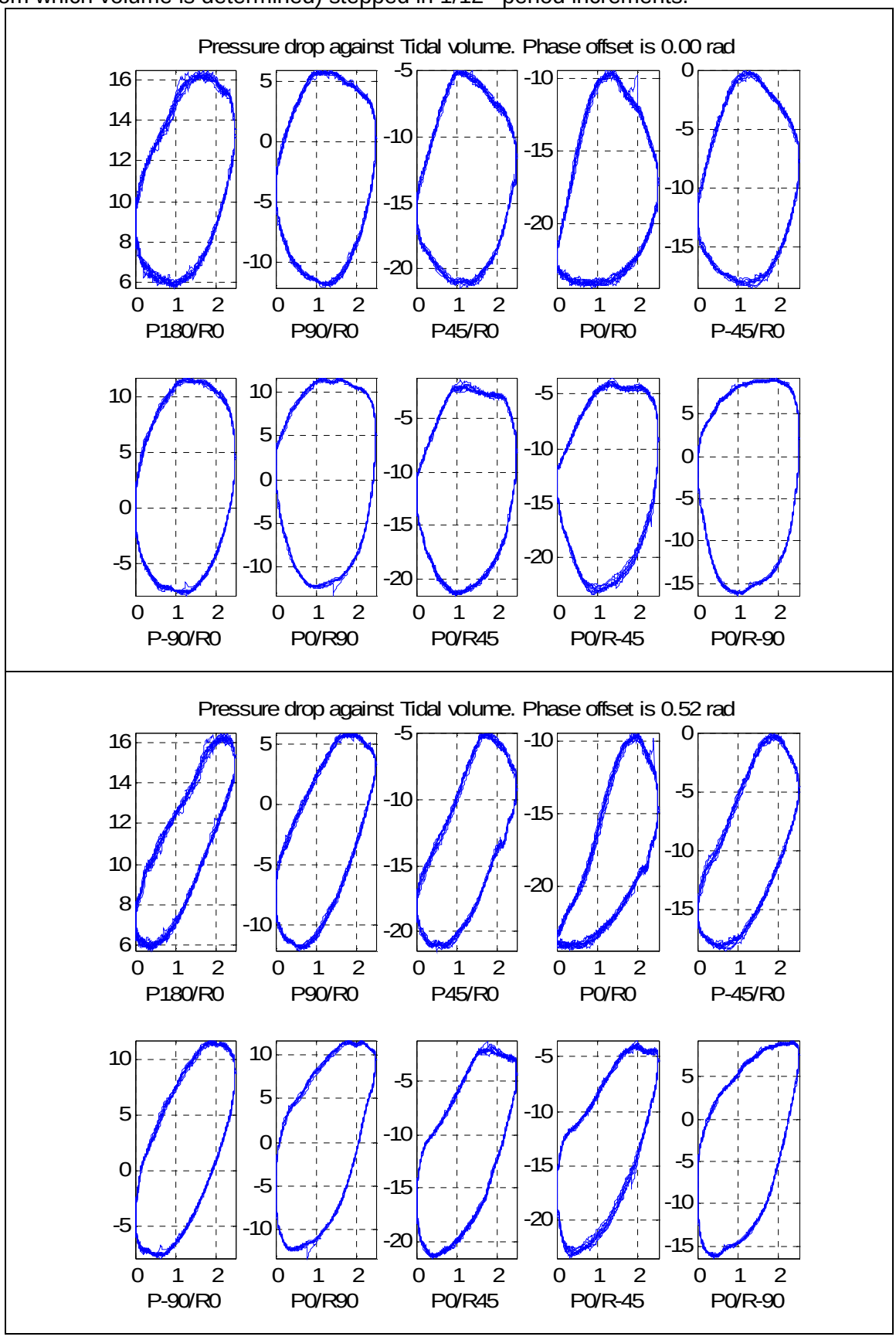


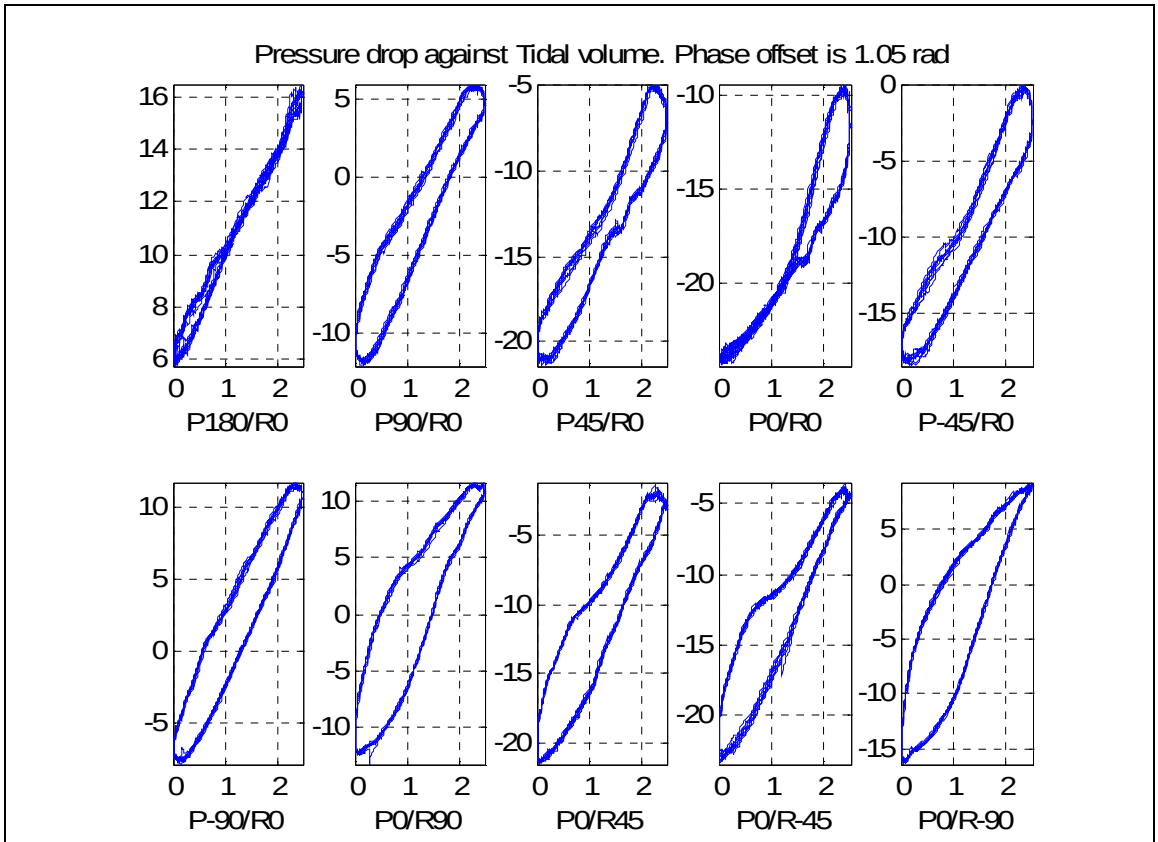
Figure 12. Lissajous for the OR_Umbilical taken with 5ms sampling, underneath the breathing pressure plots for each diver position. The purple, blue, red and green curves are the breathing resistance measurements over 30 seconds using different Counterlung types for a back mounted rebreather: the OR_Umbilical is Test N3 – other counterlungs were tested in Test N1, N2 and N4 for comparative purposes. The light Blue squares is the range of breathing resistance for the boundary case for the OR_Umbilical, and the black curve is the ideal pressure offset to the lung centroid. The same phase offset is used in each position: it can be seen that the lissajou has a different shape in each diver position.

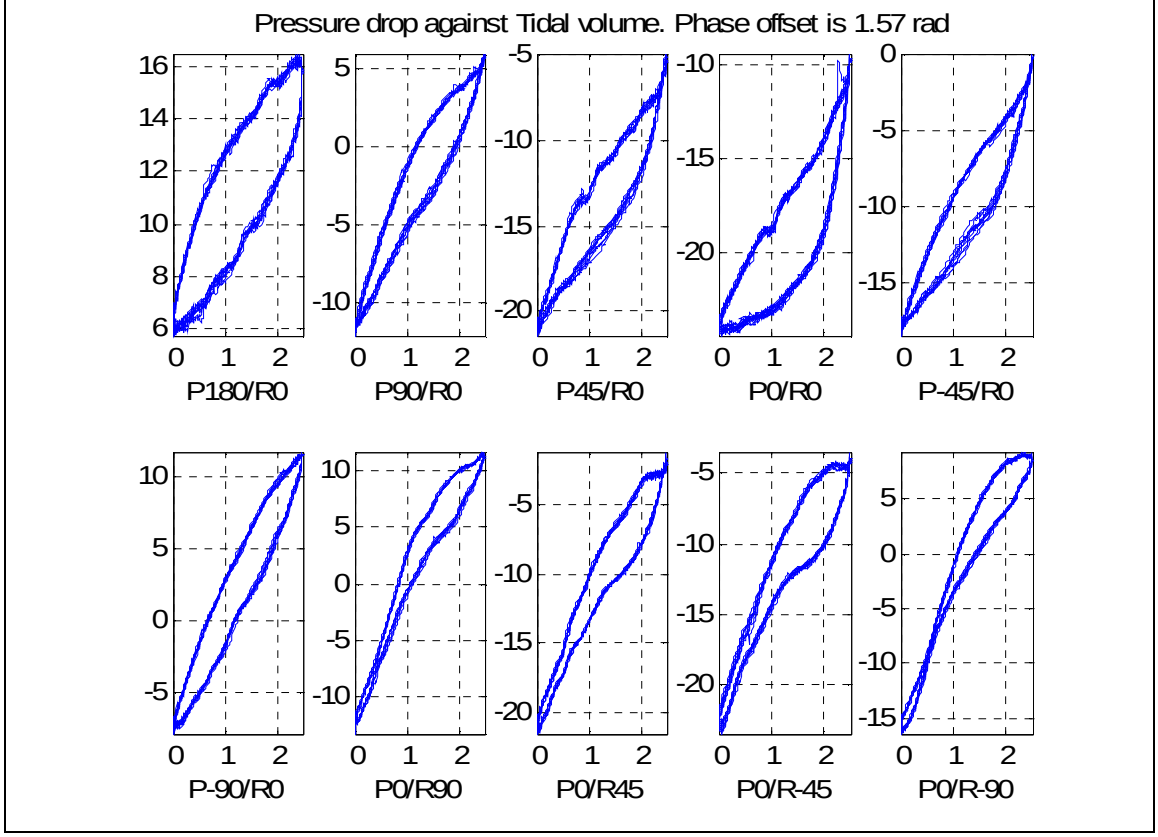
In order to correlate results from laboratories that might use the Lissajou optimisation, with the results reported here, the Lissajou curves are given in the following tables for the OR_Umbilical rebreather. The other rebreather models will have very similar curves.

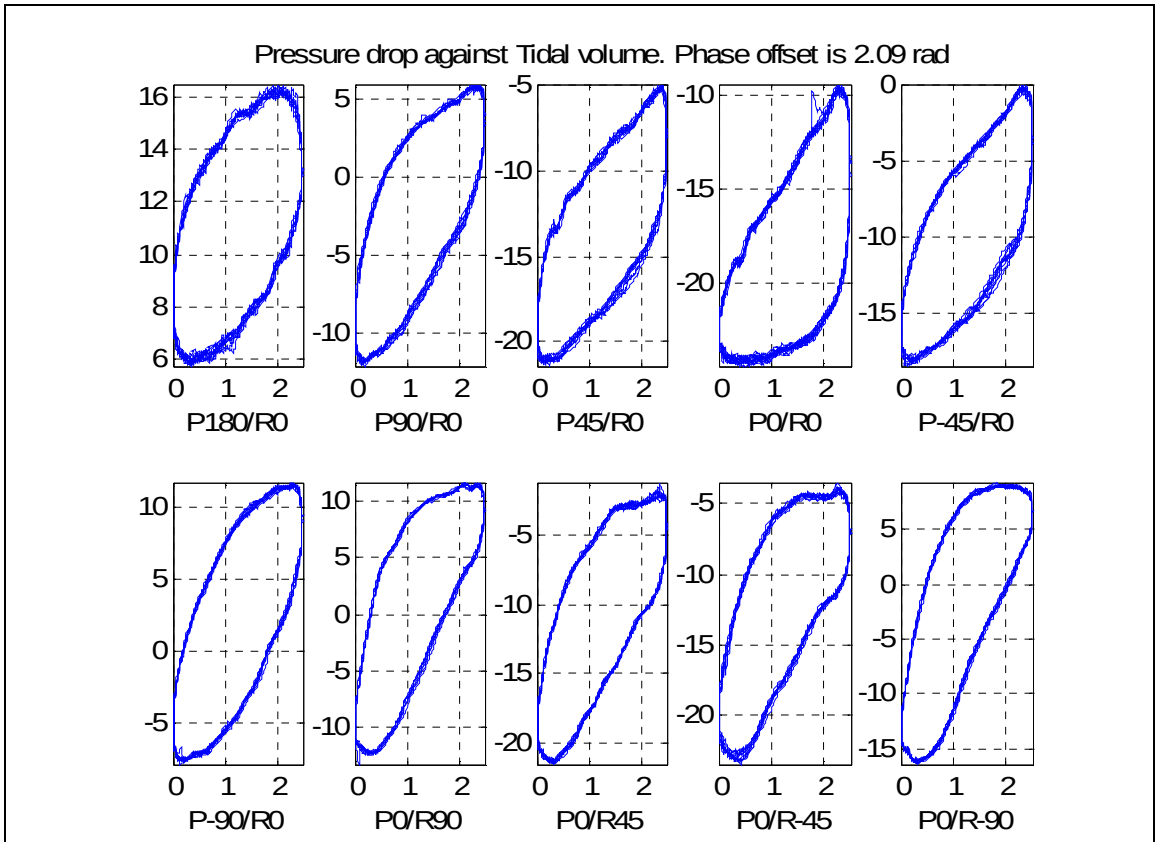
It can be seen that the Lissajou phase has no material effect on the end of tidal pressures, hence on EN 14143:2003 thresholds. However, the volume in the counterlungs does have a significant effect on the measured elastance, and the over pressure offsets. This means that where the loop volume is optimised for hydrostatic imbalance the elastance may not be optimal. It is necessary generally to sweep the loop volume to determine the elastance.

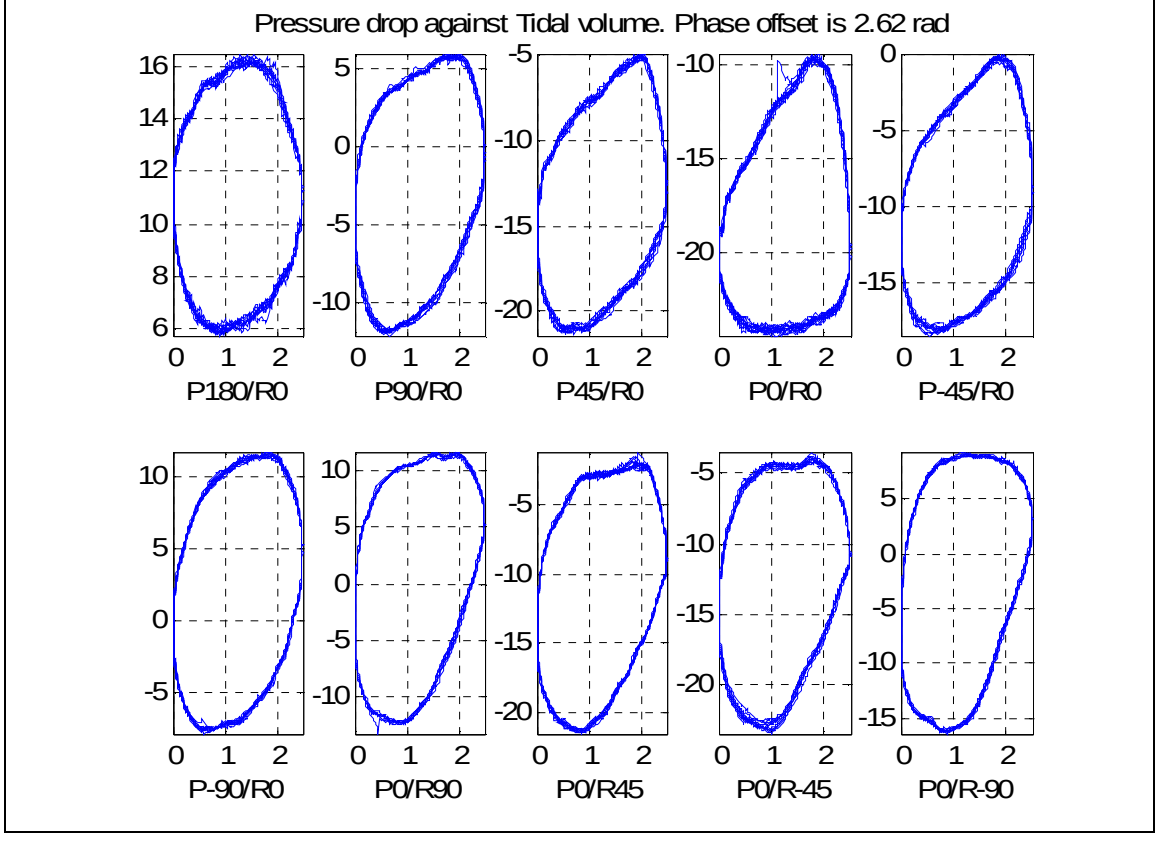
Table 13 Lissajou for OR_Umbilical in all positions showing volume (X axis) to differential pressure sensor (Y axis) at the Lung Centroid, with the phase of the breathing simulator piston (from which volume is determined) stepped in 1/12th period increments.

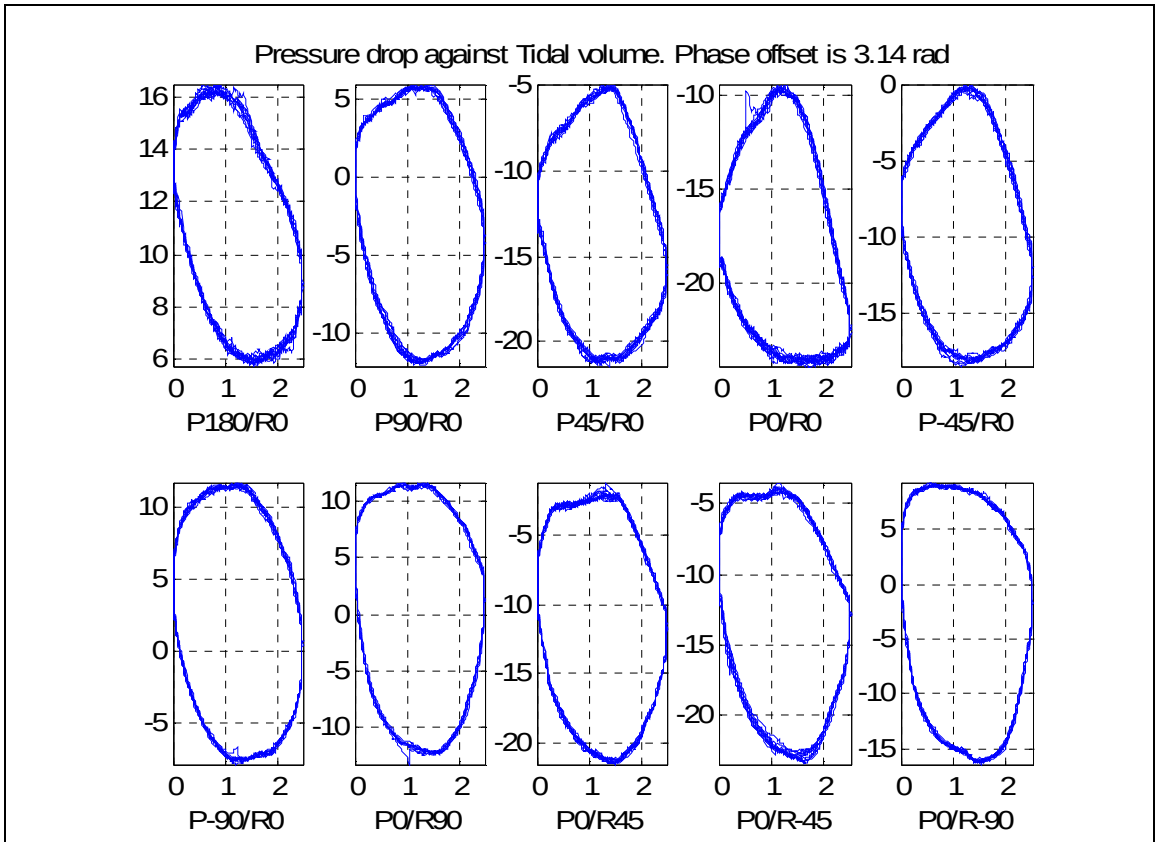


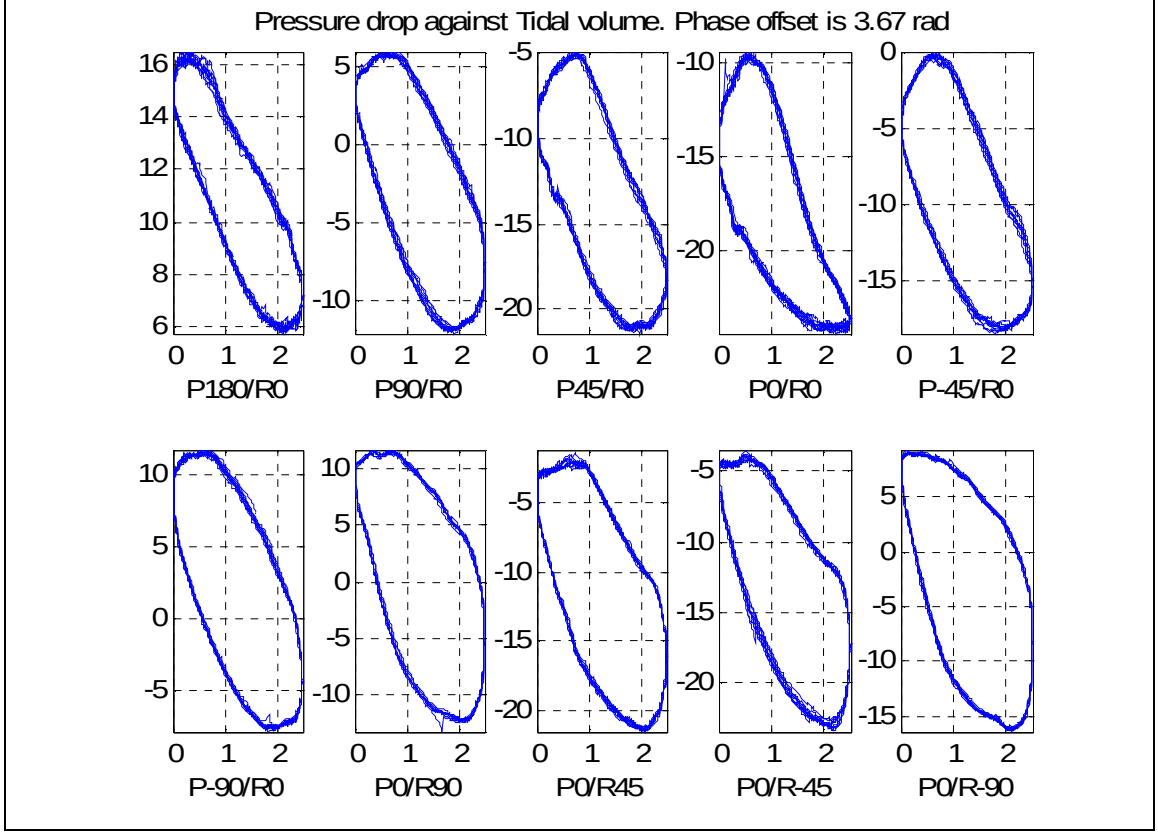


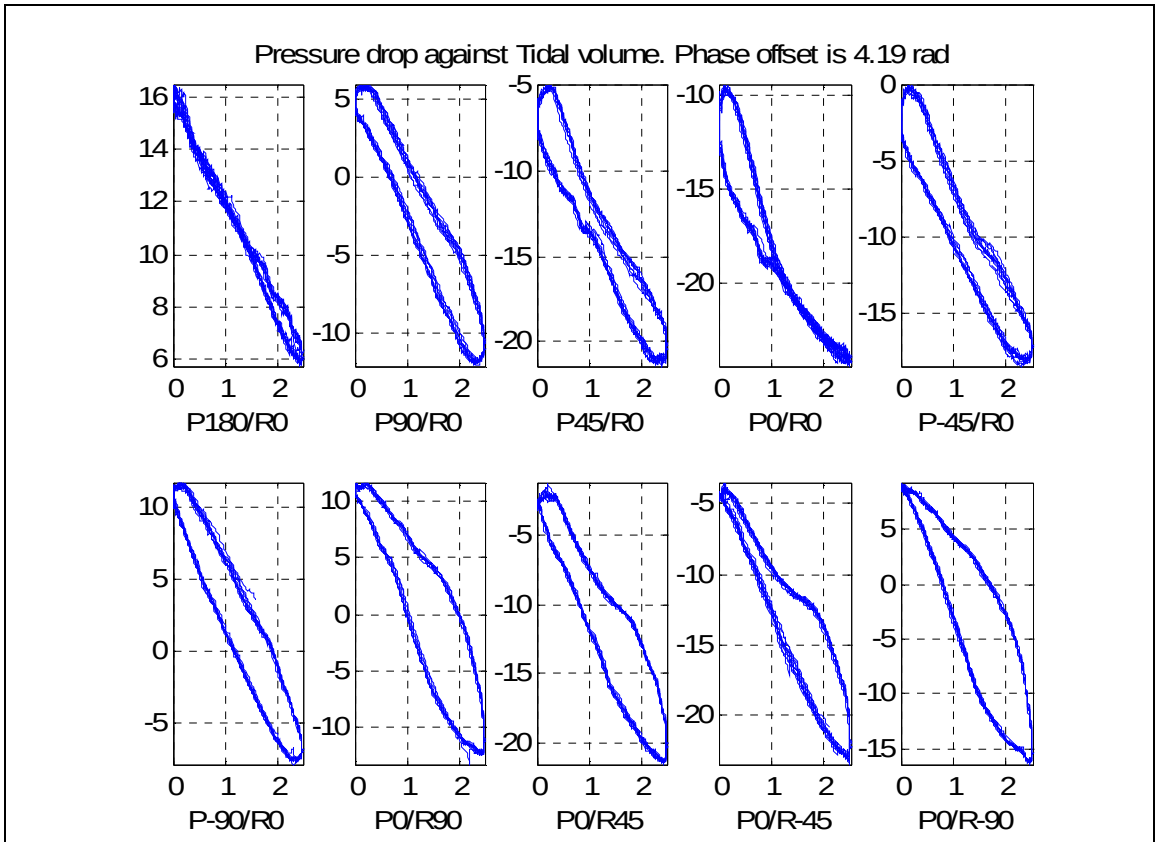


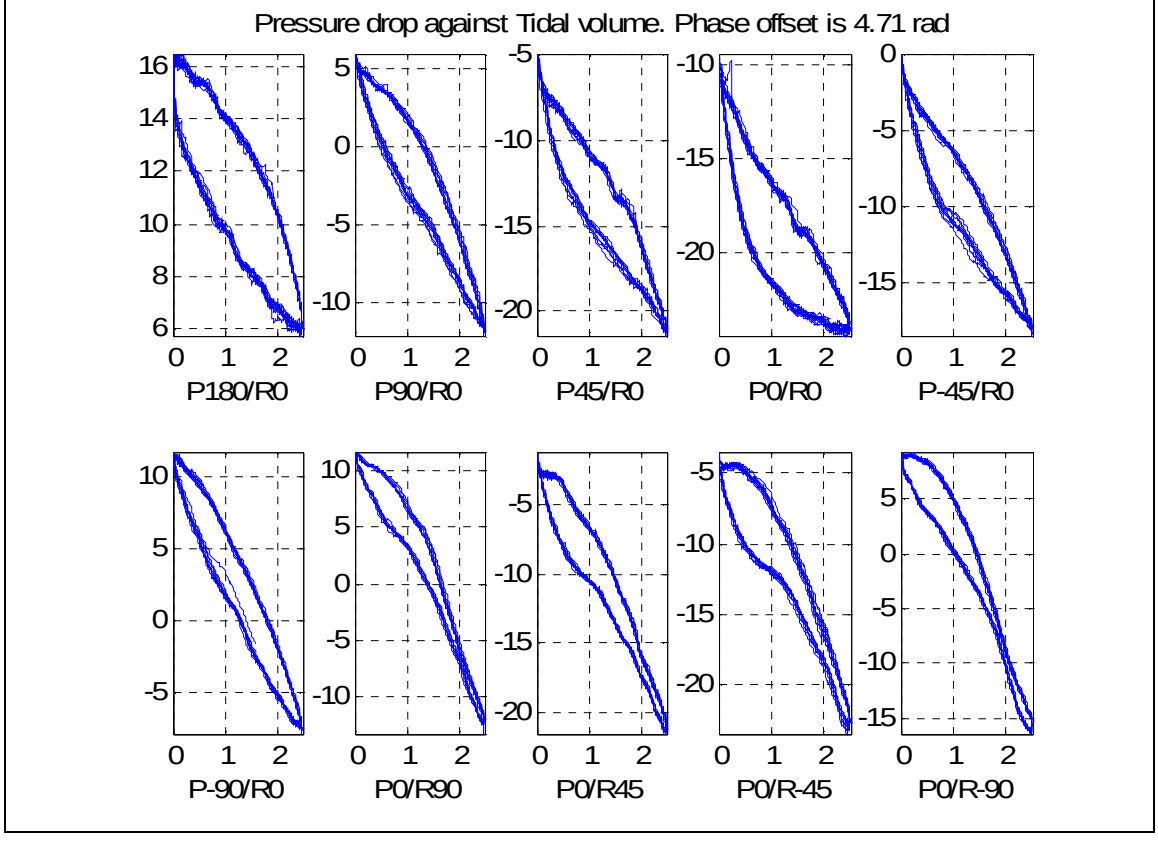


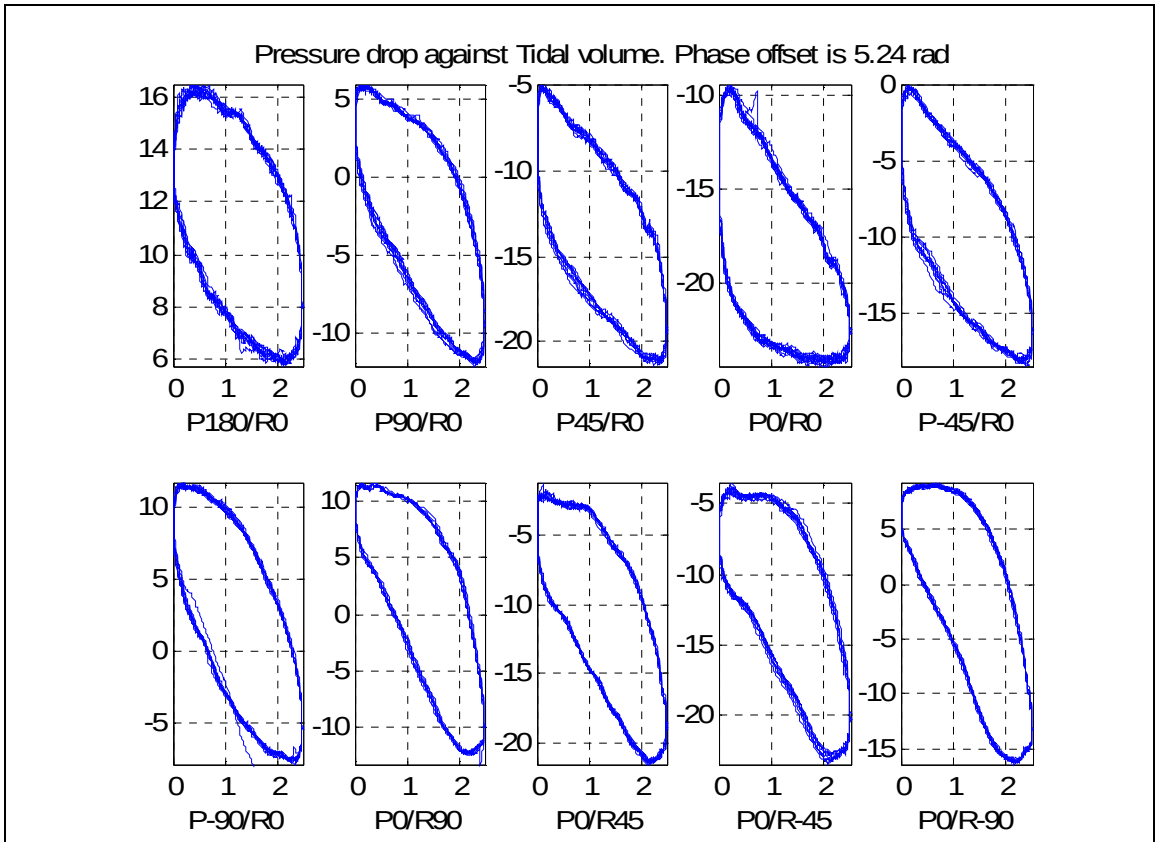


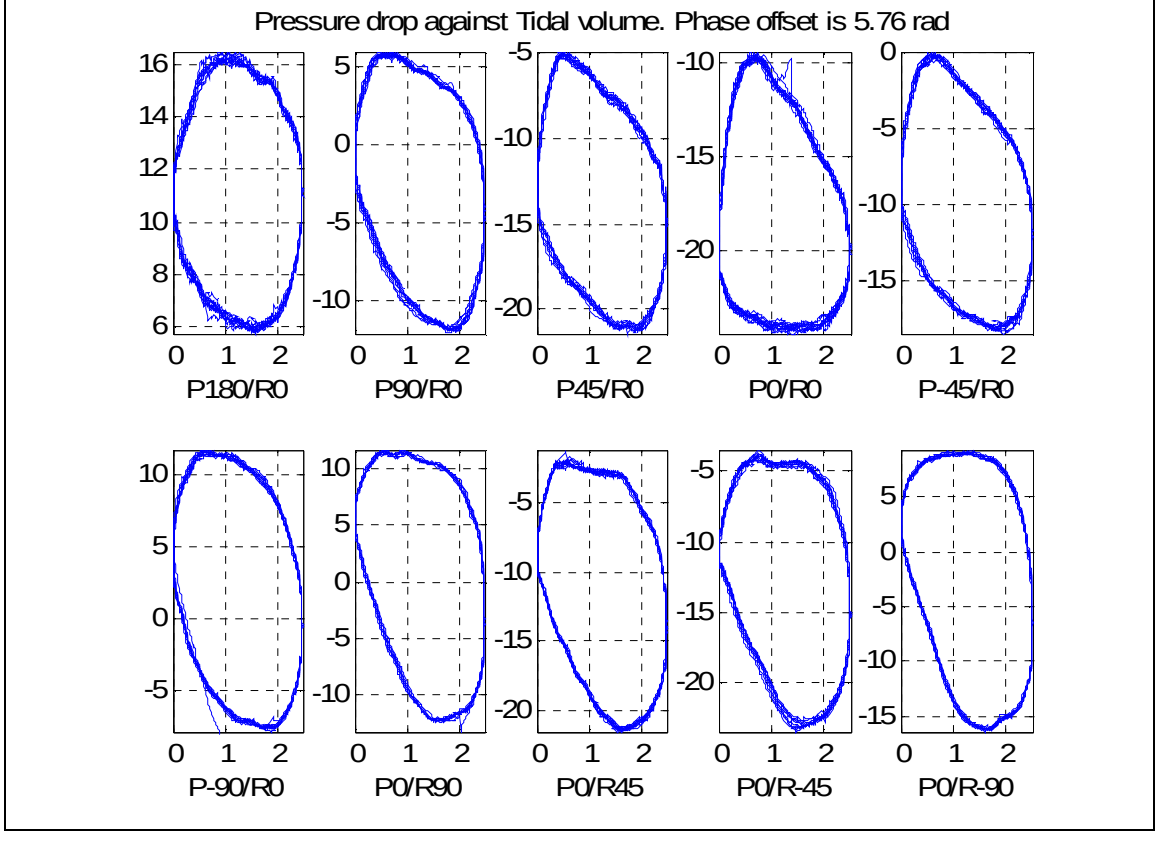












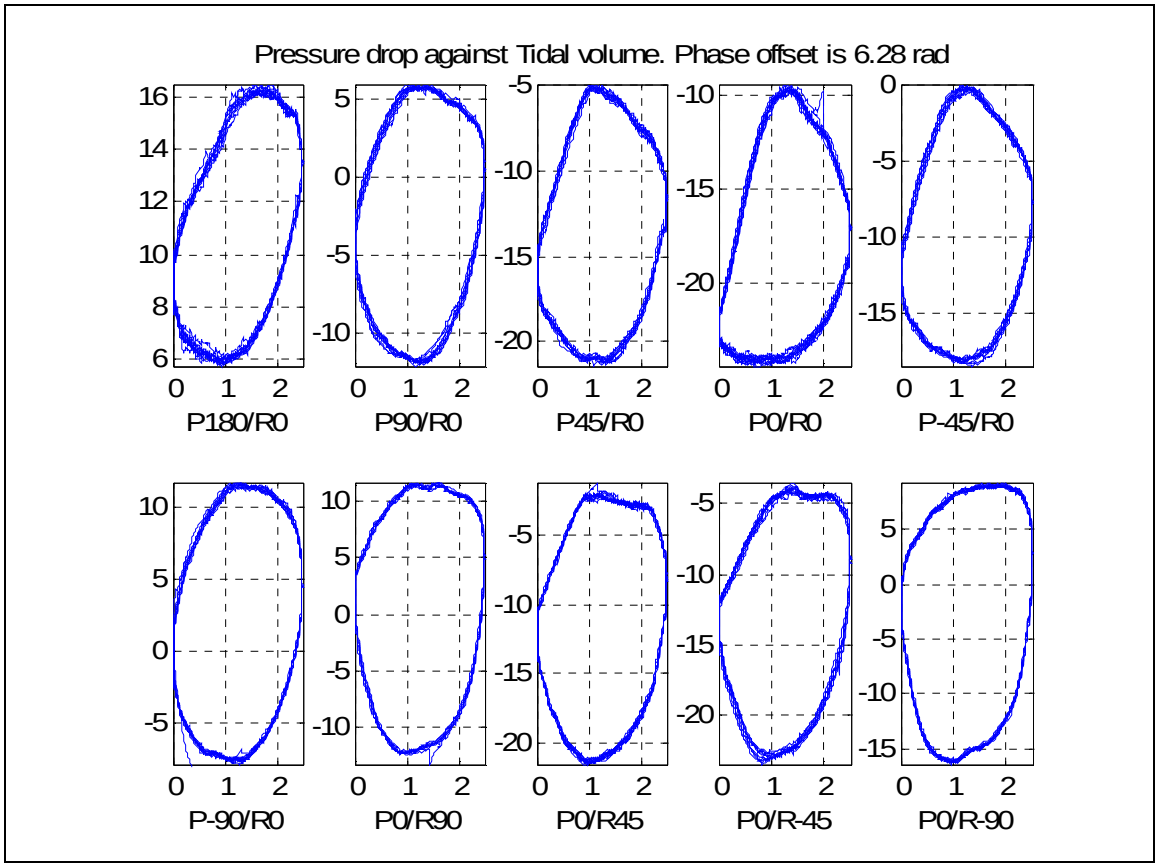
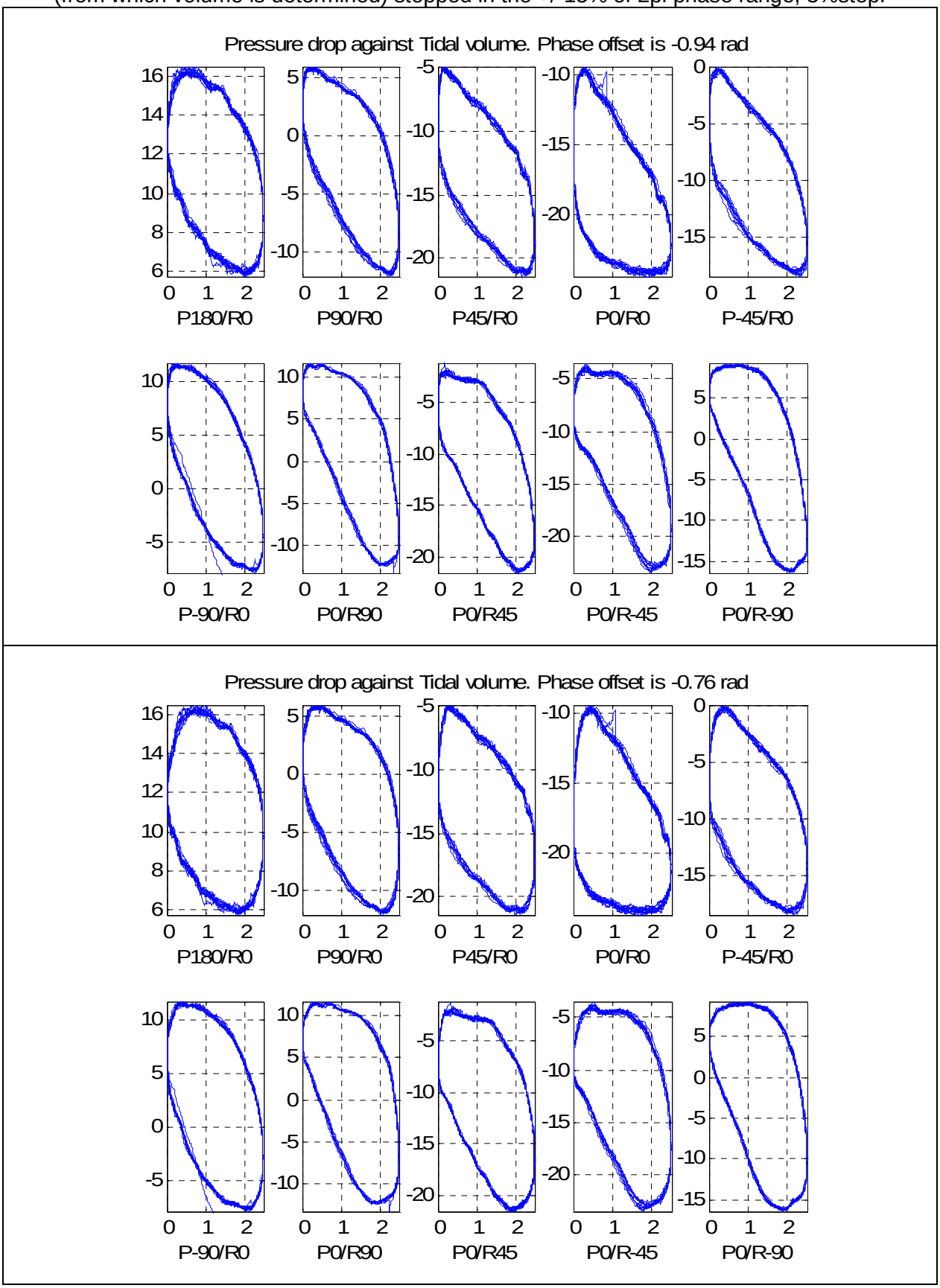
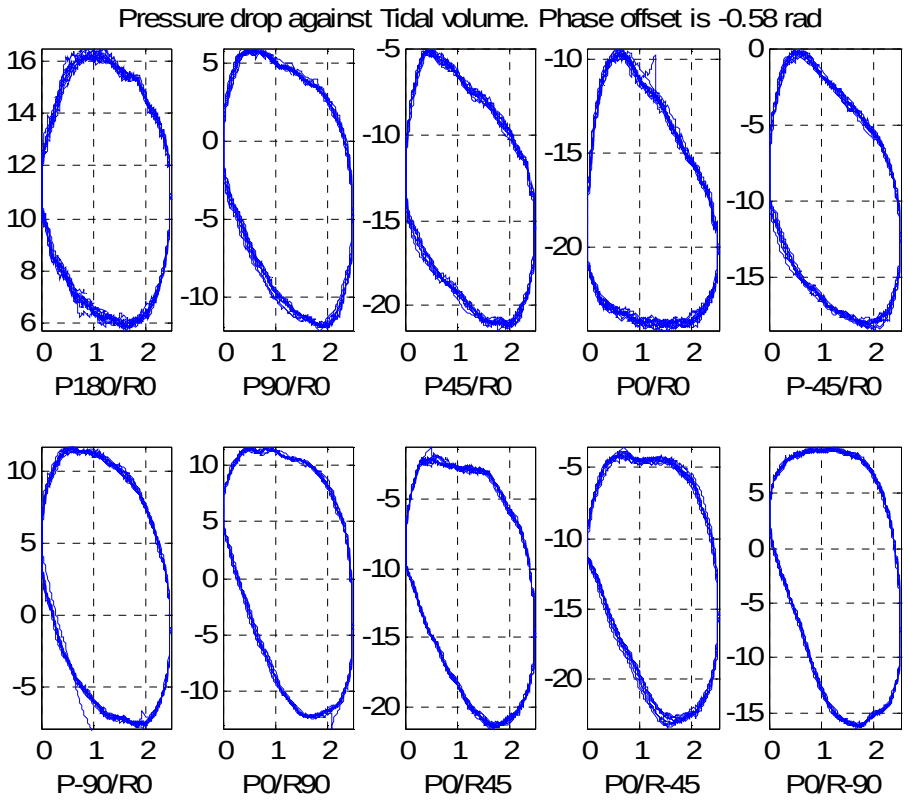
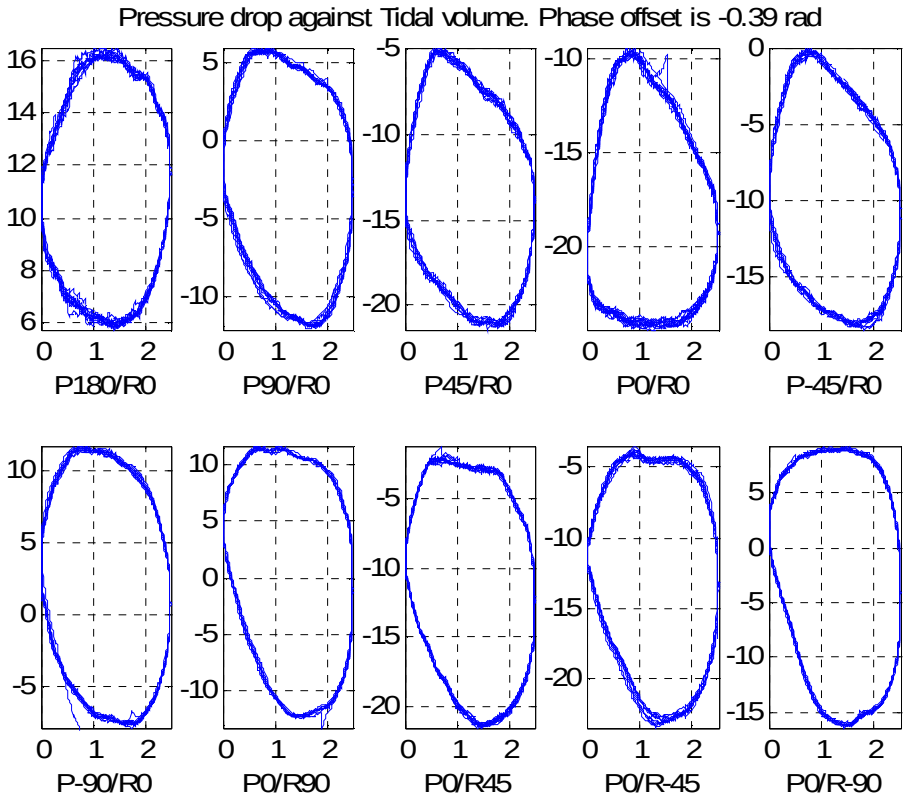
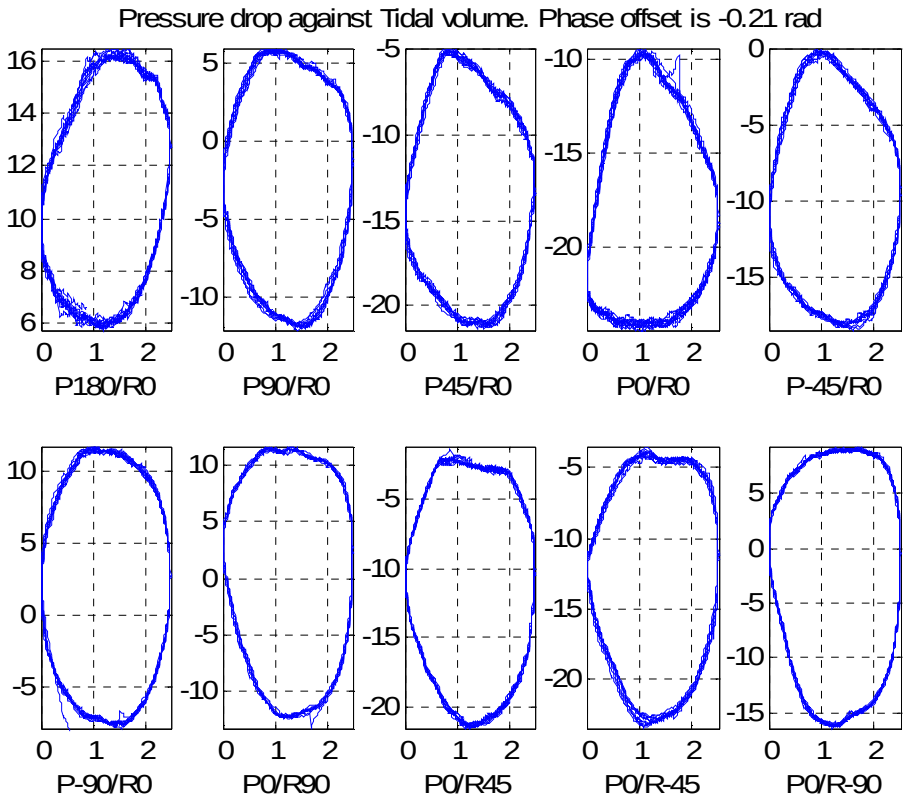


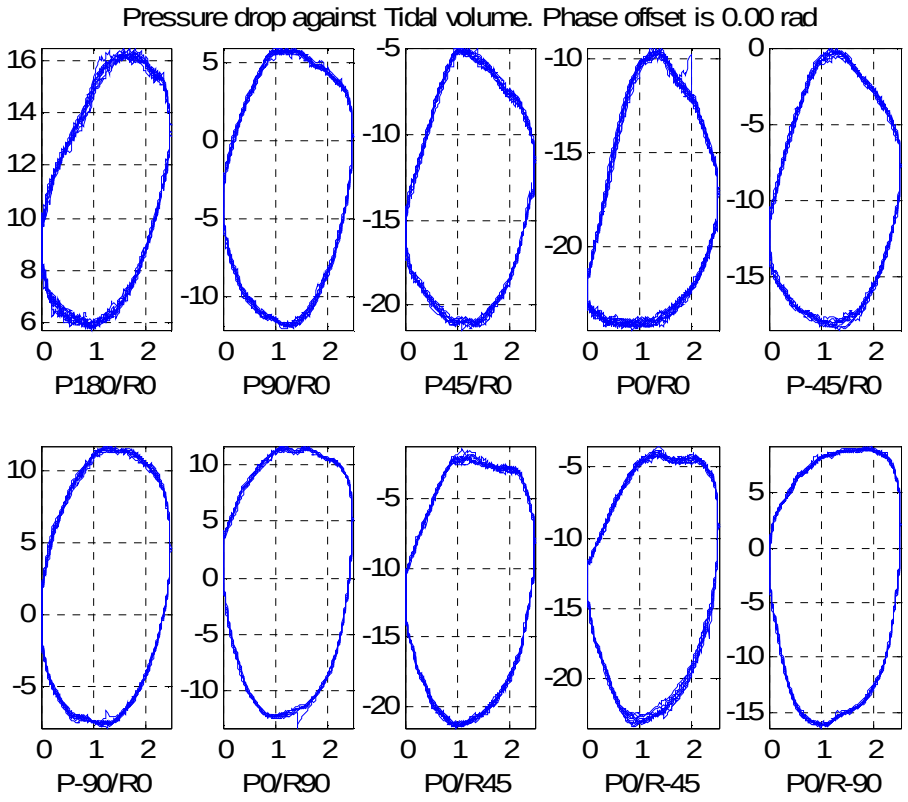
Table 14 Lissajou for OR_Umbilical in all positions showing volume (X axis) to differential pressure sensor (Y axis) at the Lung Centroid, with the phase of the breathing simulator piston (from which volume is determined) stepped in the +/-15% of 2pi phase range, 3%step.

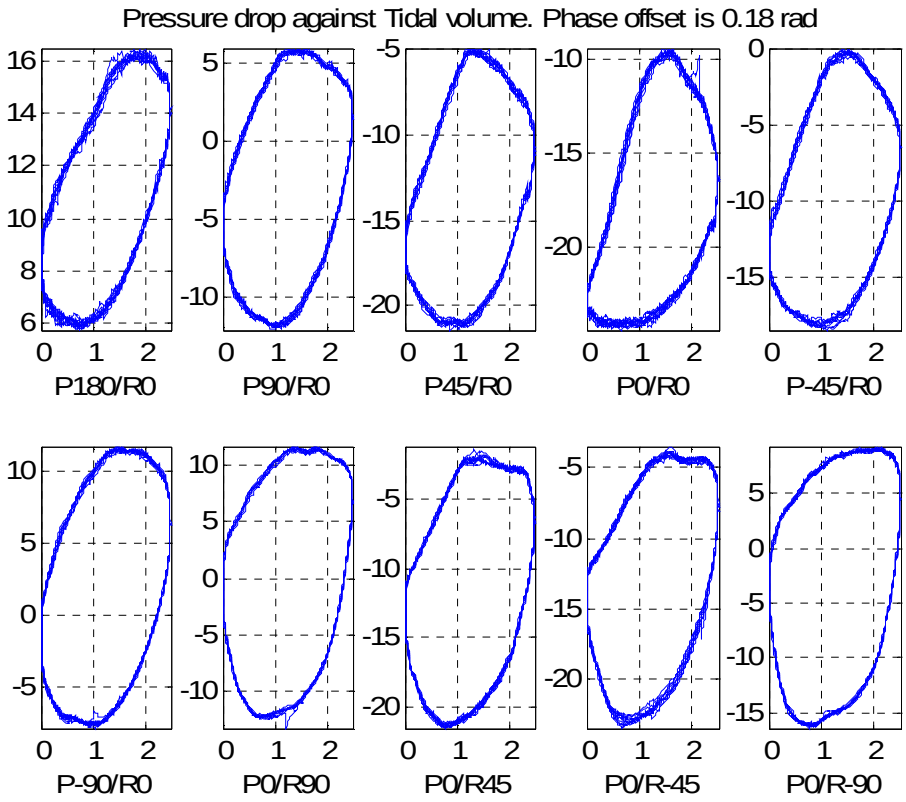




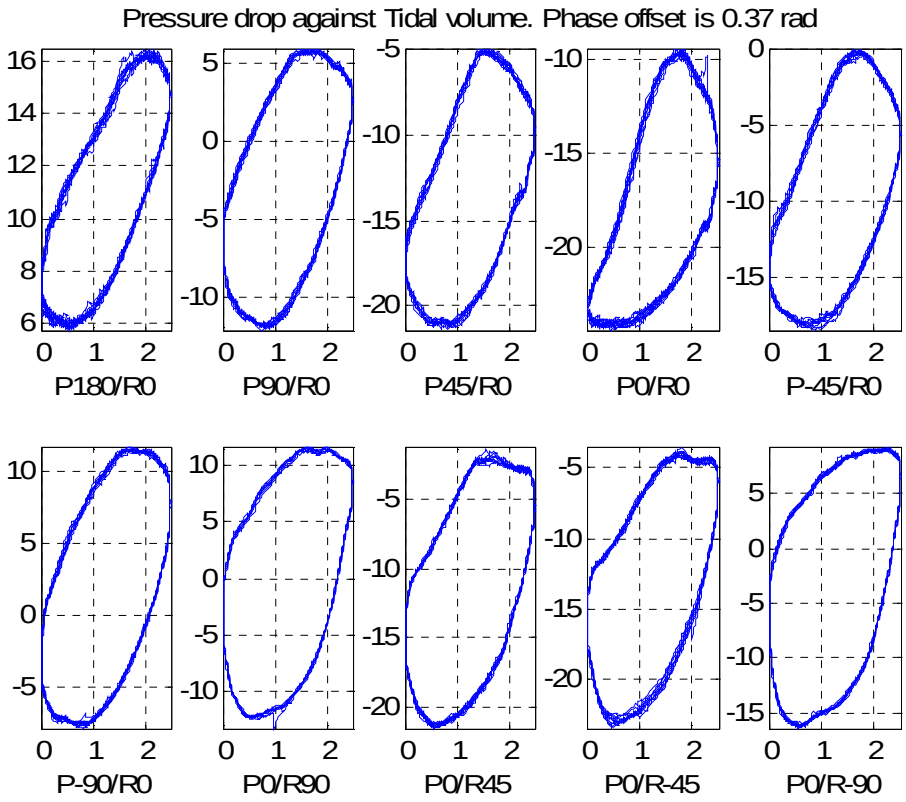


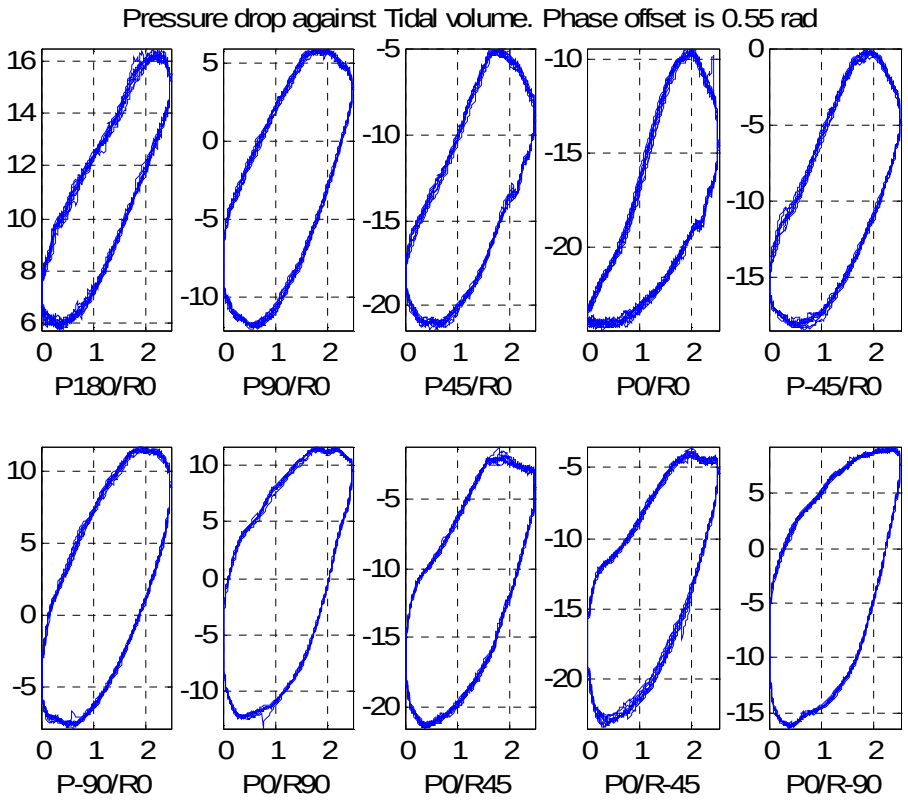


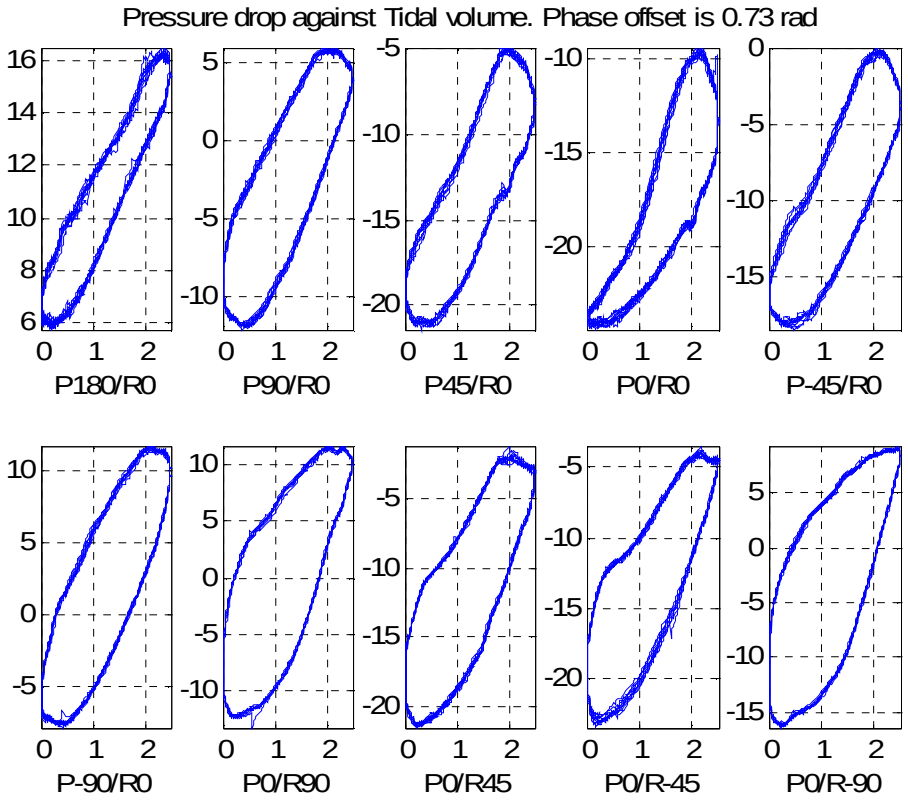


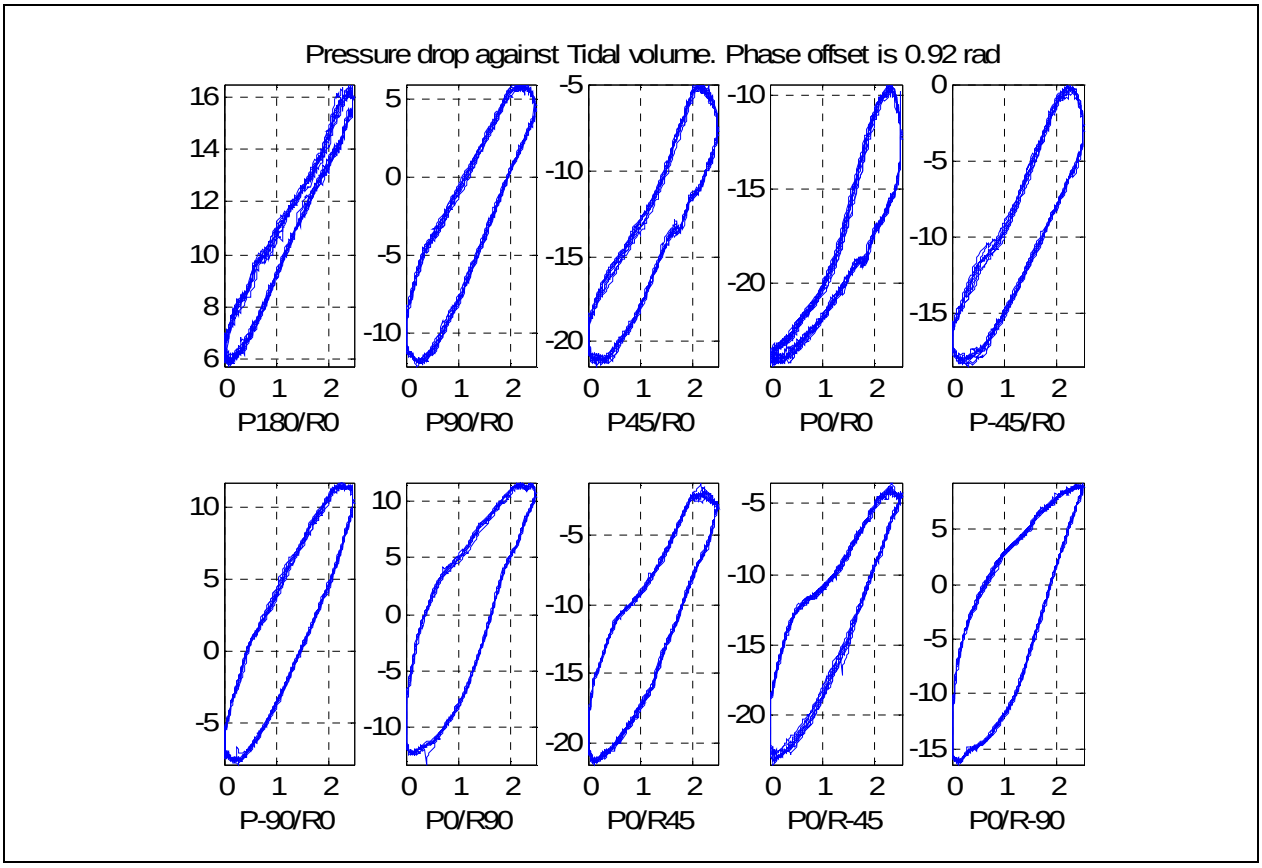


The pressure drop phase offset relative to the BM cycling is 0.21rad or 10deg or 2.9% or 0.07s (as 2.4s period x 0.029).









5.7 Test Schedule

Table 15 Hydrostatic Imbalance and Respiratory pressure tests according to NEDU TA05-12 and NORSOK U101:1999 (the optimised volume series tests)

Test Num.	Position	
	Pitch	Roll
1	90	0
2	0	0

Table 16 Hydrostatic Imbalance and Respiratory pressure tests according to EN14143:2003 (the fixed volume series tests).

Test Num.	Position	
	Pitch	Roll
1	180	0
2	90	0
3	45	0
4	0	0
5	-45	0
6	-90	0
7	0	90
8	0	45
9	0	-45
10	0	-90

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6 "IDEAL" VALUES FOR HYDROSTATIC IMBALANCE

The ideal values are useful for setting up the practical test of hydrostatic imbalance, in that they are equivalent to the hydrostatic imbalance when there is no flow and the RMV is zero. For most diver attitudes, the respiratory pressures during the Hydrostatic Imbalance practical test, are a sinusoid with a mean that is the ideal Hydrostatic Imbalance value.

There is nothing in EN14143 stating that the manufacturer's ideal values have to be within any particular range, only that the measured values are within the range. This is not unreasonable because the standards have a value for the maximum and minimum Hydrostatic Imbalance determined through a defined empirical test.

All OR Rebreather models have the same backmounted counterlung configuration, so all have the same ideal values.

6.1 Definitions of Pitch and Roll

In EN14143:2003 and NORSOK U-101, roll and pitch are defined as follows:

- Rotation around the side-to-side axis, where the depth of the diver's head changes, is call "pitch".
- Rotation around the head-to-toe axis, where the diver keeps the depth of his head the same, but rotates his head, is called "roll".

6.2 X-Y Positions of Mannequin Mounting Points

The manufacturer's reference measurement point on the rebreather is a an X,Y,Z point, where:

- X=0 is the point laterally midway between the two counterlungs,
- Y=0 is the point midway along the length of the shortest counterlung,
- Z=0 is the closest point to the above X,Y position on the side of the rebreather towards the diver's back.

The point X=Y=Z=0 corresponds closely to the mean counterlung centroid, due to the curvature of the rebreather housing around the diver's torso.

Measurements are given overleaf from that X=Y=Z=0 reference point and its axes, to the Suprasternal Notch, Lung Centroid and mouth, with the X and Y co-ordinates mapped onto the X and Y axis of the relevant projection.

All Open Revolution family rebreathers are configured with Back-Mounted Counterlungs. Figure 13 shows the projection X-Y-Z attachment positions in mm for the rebreather in each test position with respect to the counterlung centroid. In practice, only the diver head up (Pitch 90, Roll 0) position should be used for adjusting the rebreather mounting point.

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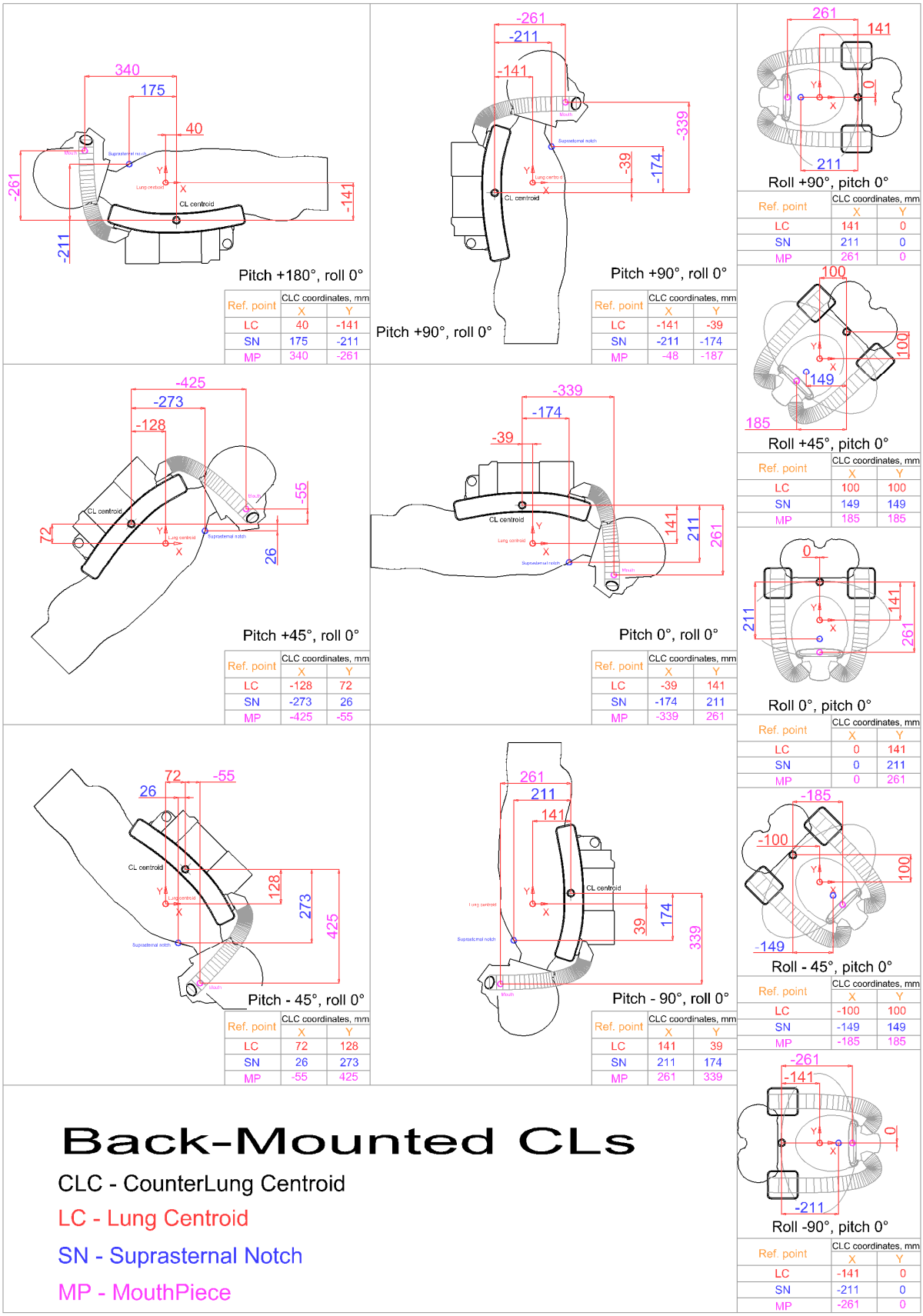


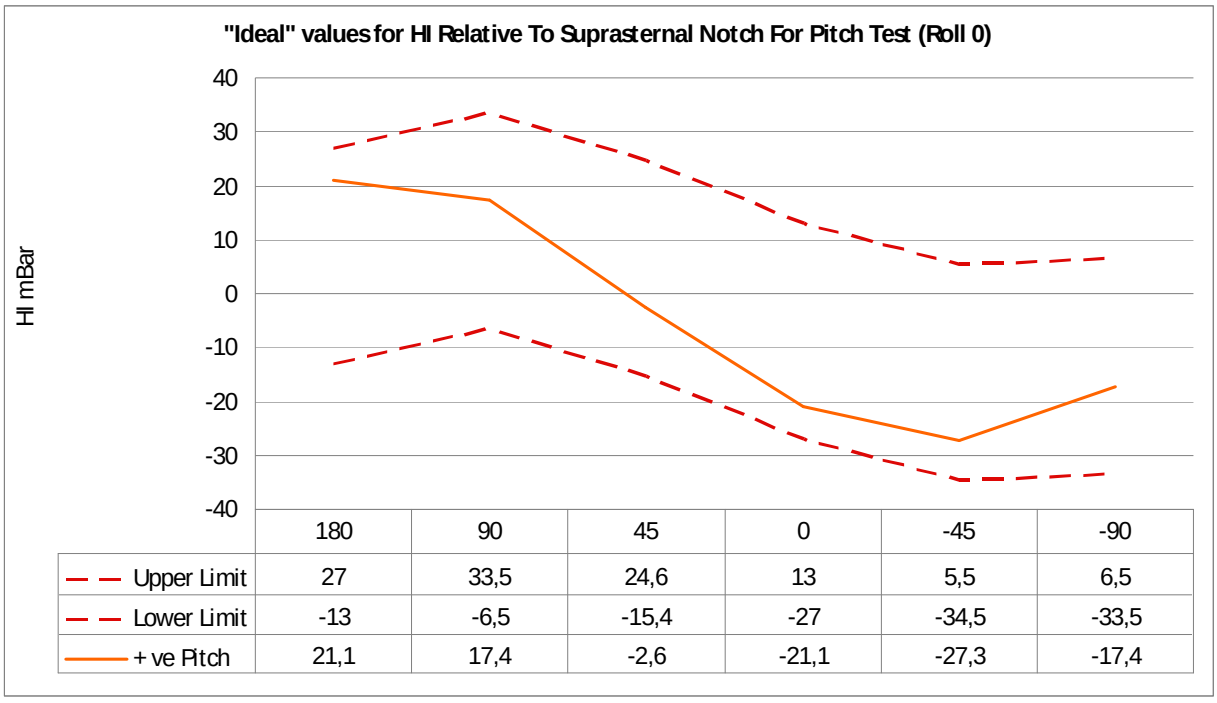
Figure 13. Position of the manufacturer's X=Y=Z=0 point w.r.t. to the Lung Centroid, to the Suprasternal Notch, Counterlung Centroid and mouthpiece.

6.3 Table of Ideal values for Hydrostatic Imbalance to Suprasternal Notch

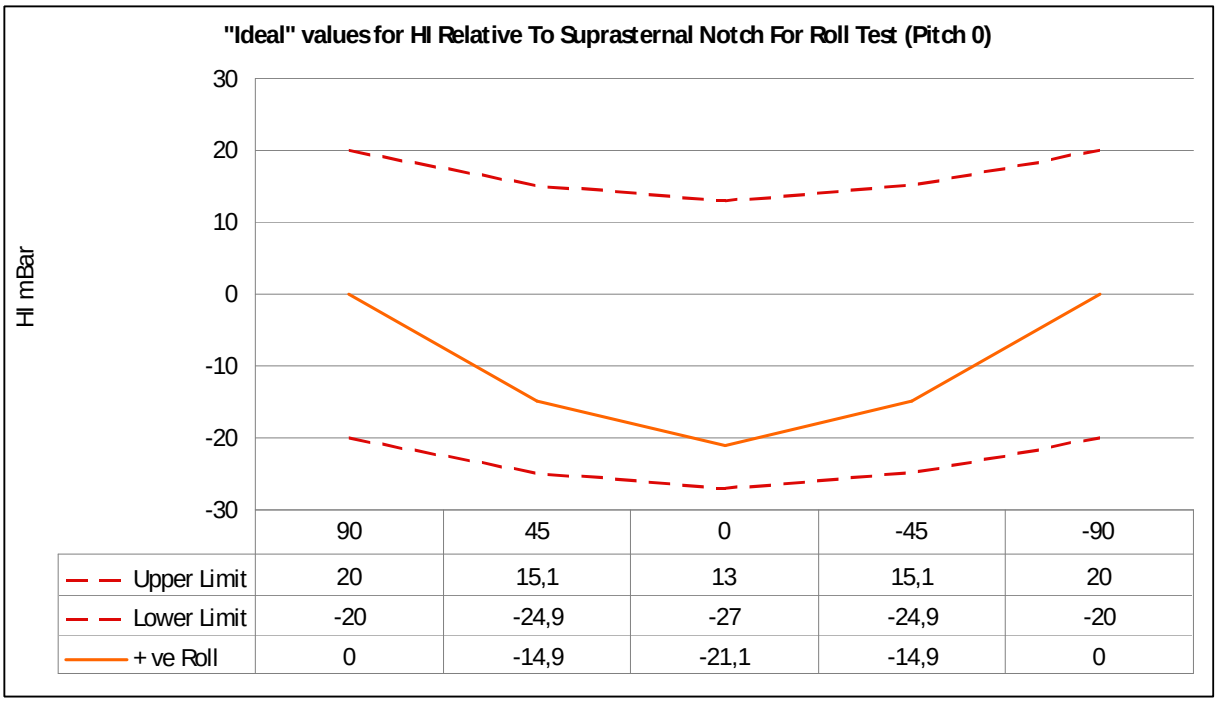
The table below show the Hydrostatic Imbalance with respect to the Suprasternal Notch.

Test Num.	Pitch	Roll	Back-Mounted CLs
1	+180	0	21.1
2	+90	0	17.4
3	+45	0	-2.6
4	0	0	-21.1
5	-45	0	-27.3
6	-90	0	-17.4
7	0	+90	0
8	0	+45	-14.9
9	0	-45	-14.9
10	0	-90	0

6.4 Plots of Ideal values for Hydrostatic Imbalance to Suprasternal Notch



	180	90	45	0	-45	-90
Upper Limit	27	33,5	24,6	13	5,5	6,5
Lower Limit	-13	-6,5	-15,4	-27	-34,5	-33,5
+ ve Pitch	21,1	17,4	-2,6	-21,1	-27,3	-17,4



	90	45	0	-45	-90
Upper Limit	20	15,1	13	15,1	20
Lower Limit	-20	-24,9	-27	-24,9	-20
+ ve Roll	0	-14,9	-21,1	-14,9	0

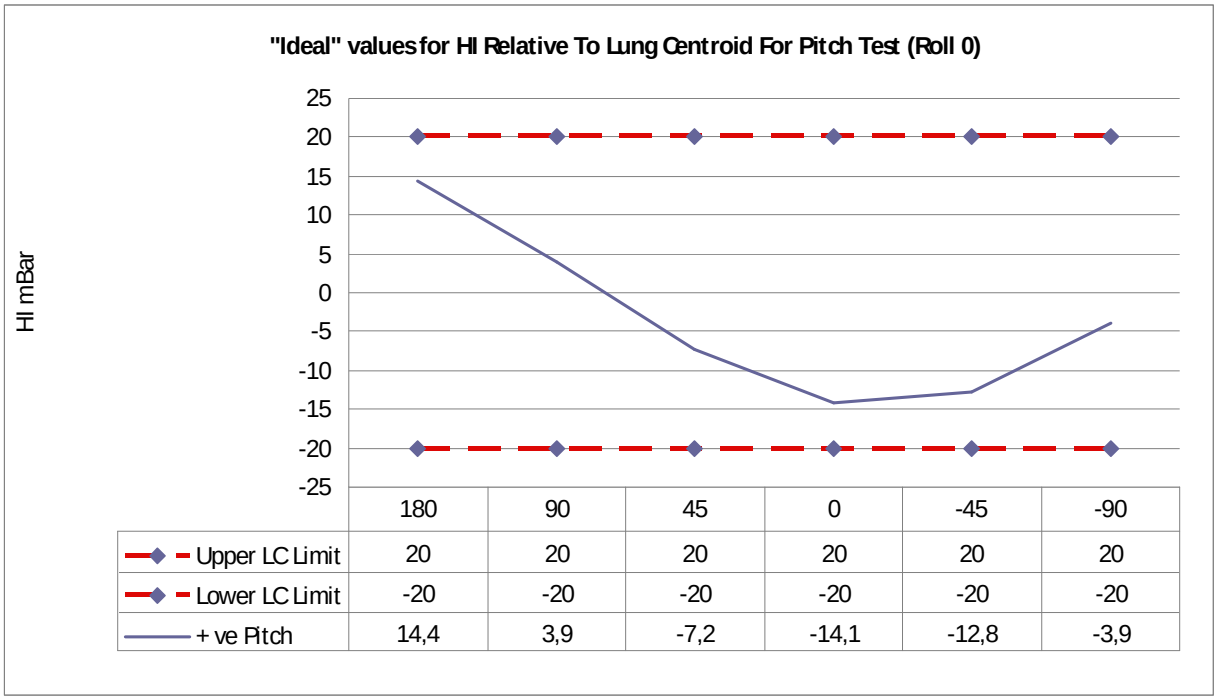
6.5 Table of Ideal values for Hydrostatic Imbalance to Lung Centroid

The table below shows the Hydrostatic Imbalance with respect to the true Lung Centroid.

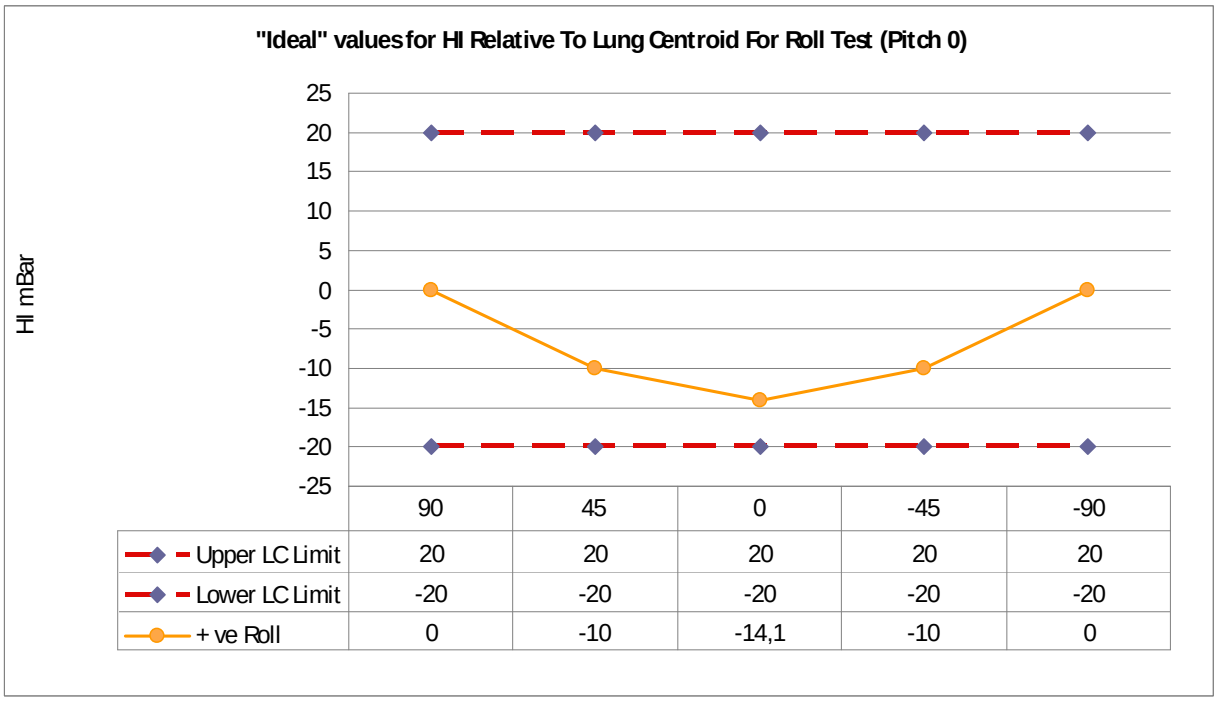
Test Num.	Pitch	Roll	Back-Mounted CLs
1	+180	0	14.4
2	**+90**	**0**	**3.9**
3	+45	0	-7.2
4	**0**	**0**	**-14.1**
5	-45	0	-12.8
6	-90	0	-3.9
7	0	+90	0
8	0	+45	-10.0
9	0	-45	-10.0
10	0	-90	0

In NORSOK U-101:1999 only Tests 2 and 4 are applied.

6.6 Plots of Ideal values for Hydrostatic Imbalance Lung Centroid



	180	90	45	0	-45	-90
Upper LC Limit	20	20	20	20	20	20
Lower LC Limit	-20	-20	-20	-20	-20	-20
+ ve Pitch	14,4	3,9	-7,2	-14,1	-12,8	-3,9



	90	45	0	-45	-90
Upper LC Limit	20	20	20	20	20
Lower LC Limit	-20	-20	-20	-20	-20
+ ve Roll	0	-10	-14,1	-10	0

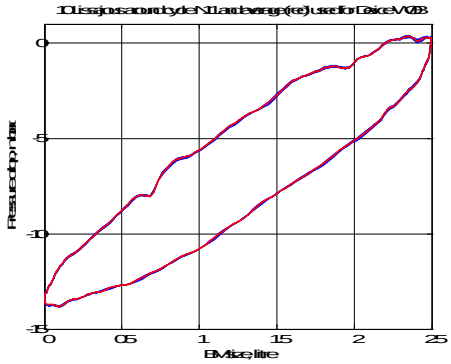
7 NORSOK U101 RESULTS WITH LOOP VOLUME OPTIMISED PER POSITION

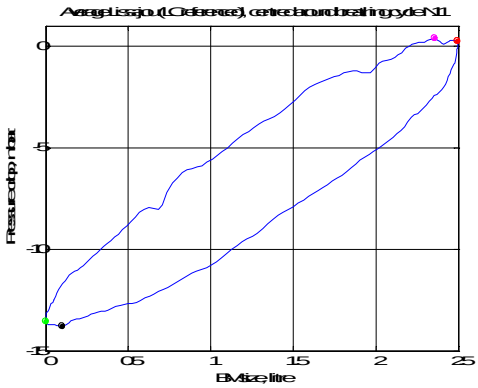
7.1 Empirical Results for OR_Incursion / OR_Apocalypse Type IV Models

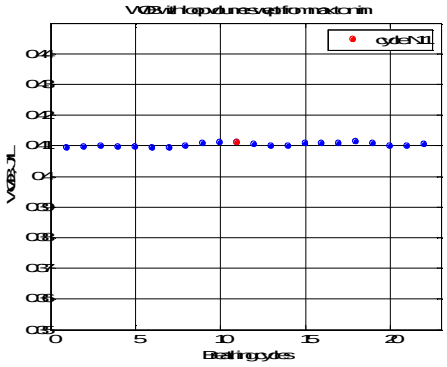
RESPIRATORY PERFORMANCE MEASUREMENT

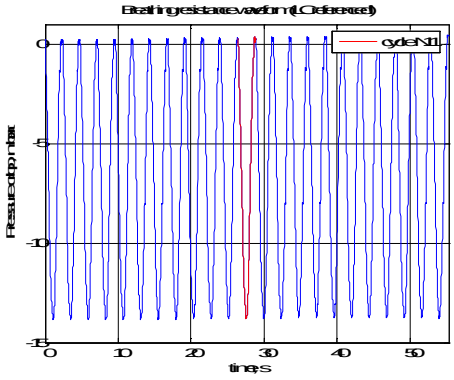
EQUIPMENT TYPE & SERIAL NUMBER	:	DL SRB SN1 (ALVBOV equipped)	
TEST METHOD		NORSOK U101:1999	SINE FLOW
DATE AND TIME		01/10/2009 17:11	
TEST CARRIED OUT BY		MS WITNESS: VS	
CONDITIONS OF TEST			
ATTITIDE: PITCH & ROLL	:	90/0	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	18.0 / 4.5	℃
EHXALE GAS TEMPERATURE	:	15.5	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/25.0bpm/62.5lpm	standard
RESULTS			
PRESSURE@END EXHALE/INHALE	=	0.2 / -13.6	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	0.2	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)	=	13.7	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	0.3 / -13.8	mbar
INHALE/EXHALE RESP PRESSURE	=	14.0 / 13.9	mbar
PEAK TO PEAK PRESSURE	=	14.1	mbar
ELASTANCE	=	5.5	mbar/litre
WORK OF BREATHING	=	0.41	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_SRB01_62_5lpm_90_0_091001_NEDU









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL SRB SN1 (ALVBOV equipped)	
TEST METHOD	:	NORSOK U101:1999	SINE FLOW
DATE AND TIME	:	01/10/2009 17:08	
TEST CARRIED OUT BY		MS WITNESS: VS	

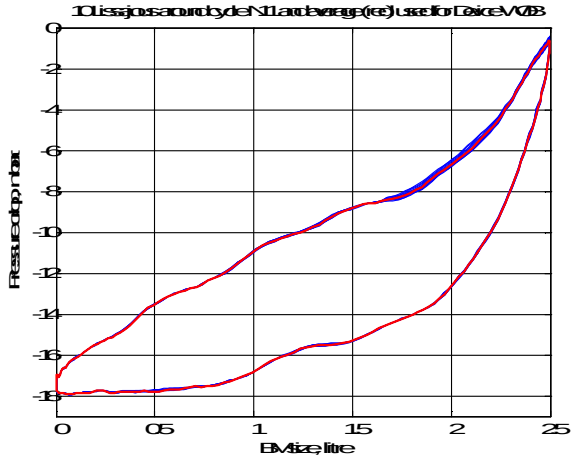
CONDITIONS OF TEST

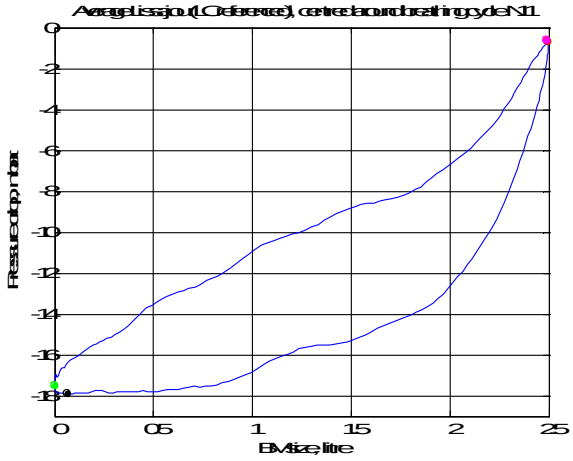
ATTITIDE: PITCH & ROLL	:	0/0	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	18.0 / 4.5	℃
EHXALE GAS TEMPERATURE	:	15.5	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/25.0bpm/62.5lpm	standard

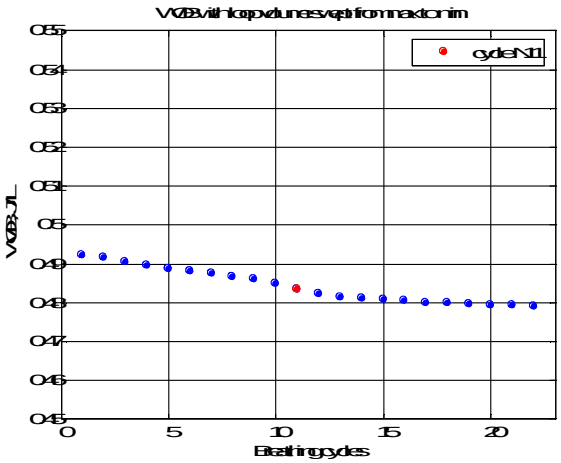
RESULTS

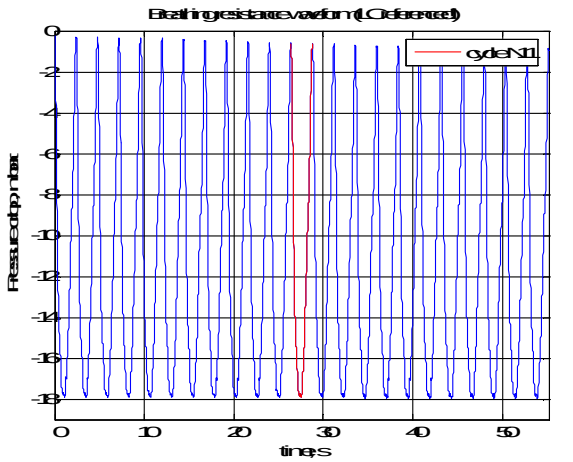
PRESSURE@END EXHALE/INHALE	=	-0.7 / -17.5	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	-0.7	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)	=	-7.7	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	-0.6 / -17.9	mbar
INHALE/EXHALE RESP PRESSURE	=	17.2 / 16.9	mbar
PEAK TO PEAK PRESSURE	=	17.3	mbar
ELASTANCE	=	6.7	mbar/litre
WORK OF BREATHING	=	0.48	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_SRB01_62_5lpm_0_0_091001_NEDU









7.2 Empirical Results for OR_Umbilical Model

RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL DRB SN1112 (ALVBOV equipped)	
TEST METHOD	:	NORSOK U101:1999	SINE FLOW
DATE AND TIME	:	01/10/2009 12:02	
TEST CARRIED OUT BY		MS WITNESS: VS	

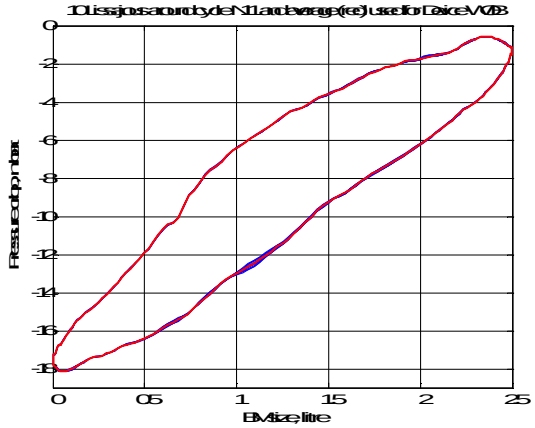
CONDITIONS OF TEST

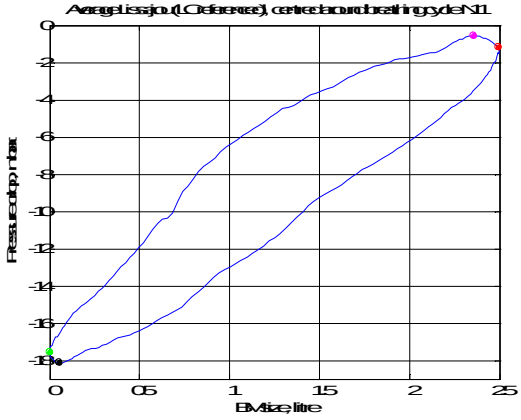
ATTITIDE: PITCH & ROLL	:	90/0	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	19.0 / 4.2	℃
EHXALE GAS TEMPERATURE	:	15.1	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/25.0bpm/62.5lpm	standard

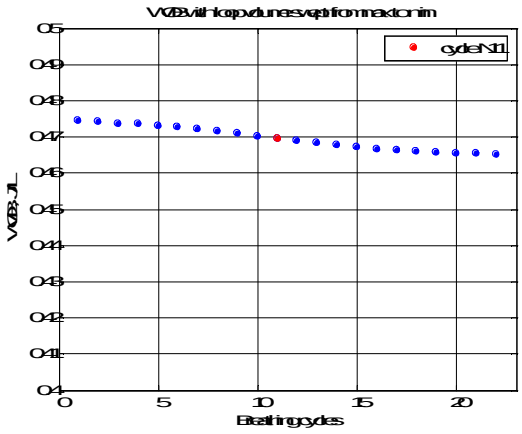
RESULTS

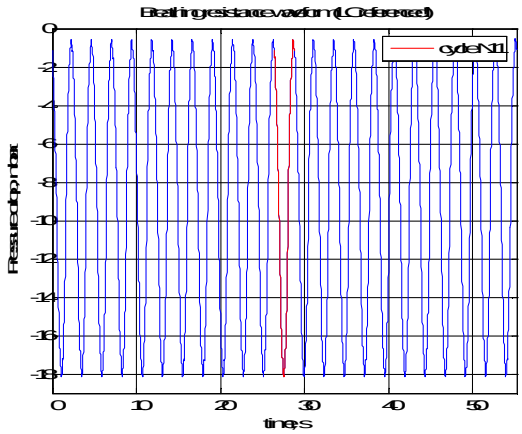
PRESSURE@END EXHALE/INHALE	=	-1.2 / -17.6	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	-1.2	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)	=	12.3	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	-0.6 / -18.1	mbar
INHALE/EXHALE RESP PRESSURE	=	17.0 / 17.0	mbar
PEAK TO PEAK PRESSURE	=	17.6	mbar
ELASTANCE	=	6.6	mbar/litre
WORK OF BREATHING	=	0.47	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_DRB01_62_5lpm_90_0_091001_NEDU









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL DRB SN1112 (ALVBOV equipped)	
TEST METHOD	:	NORSOK U101:1999	SINE FLOW
DATE AND TIME	:	01/10/2009 12:10	
TEST CARRIED OUT BY		MS WITNESS: VS	

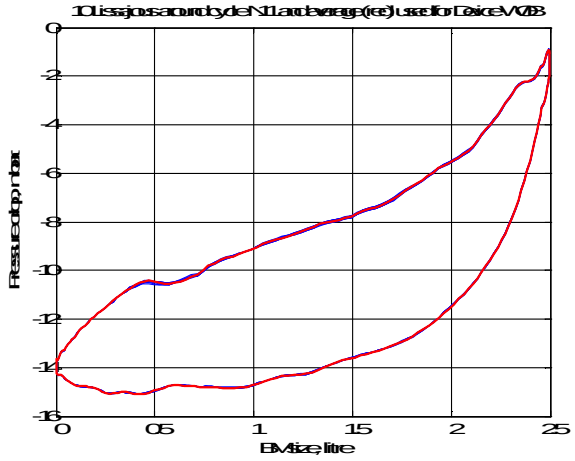
CONDITIONS OF TEST

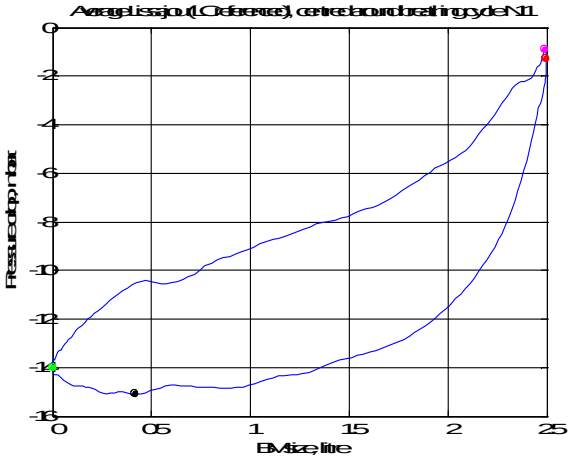
ATTITIDE: PITCH & ROLL	:	0/0	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	19.0 / 4.2	℃
EHXALE GAS TEMPERATURE	:	15.1	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/25.0bpm/62.4lpm	standard

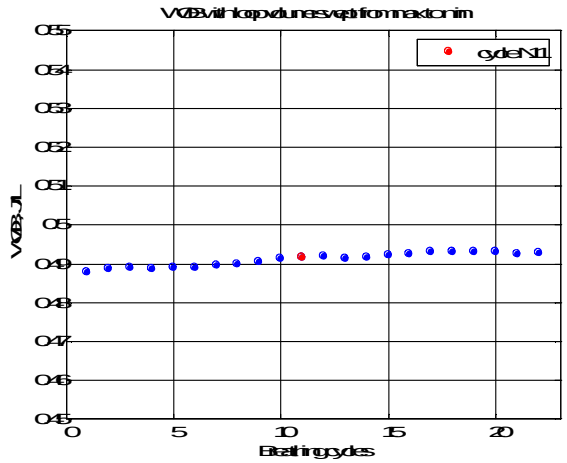
RESULTS

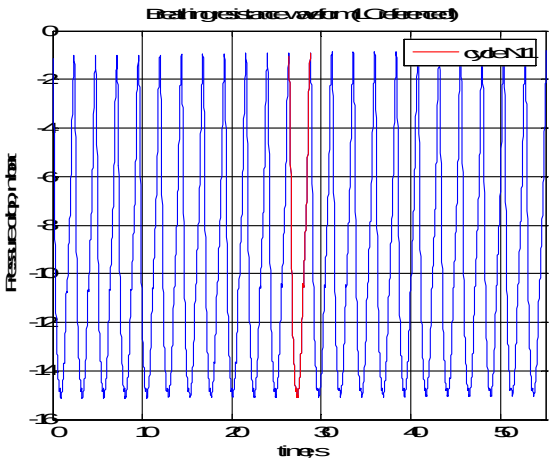
PRESSURE@END EXHALE/INHALE	=	-1.3 / -14.0	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	-1.3	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)	=	-8.3	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	-0.9 / -15.1	mbar
INHALE/EXHALE RESP PRESSURE	=	13.8 / 13.1	mbar
PEAK TO PEAK PRESSURE	=	14.2	mbar
ELASTANCE	=	5.1	mbar/litre
WORK OF BREATHING	=	0.49	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_DRB01_62_5lpm_0_0_091001_NEDU









7.3 Tabulated Results

Test Num.	Position		Hydrostatic Imbalance limits, mbar		OR Incursion / Apocalypse Type IV iCCR	OR Umbilical	Status
	Pitch	Roll	TA05-12 NEDU (LC reference)	NORSOK U101: 1999			
1	+90	0	-10…+15	-19…+11	+0.2	-1.2	Both OR pass
2	0	0	-10…+10	-20…+10	-0.7	-1.3	Both OR pass

Test Num.	Position		Respiratory pressures limits, mbar		Inhale/Exhale respiratory pressures, mbar		Status
	Pitch	Roll	STANAG 1410:2006	NORSOK U101: 1999	OR Incursion / Apocalypse Type IV iCCR	OR Umbilical	
1	+90	0	-20…+ 20	-15…+15 ideal	14.0 / 13.9	17.0 / 17.0	Both OR pass
2	0	0		(-25…+25 crit.)	17.2 / 16.9	13.8 / 13.1	Both OR pass

Test Num.	Position		NEDU TA05-12 elastance limits, mbar/L	OR Incursion / Apocalypse Type IV iCCR	OR Umbilical	Status
	Pitch	Roll				
1	+90	0	7.0	5.5	6.6	Both OR pass
2	0	0		6.7	5.1	Both OR pass

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8 EN 14143 RESULTS FOR OPTIMISED FIXED VOLUME

8.1 Empirical Results for OR_Incursion / OR_Apocalypse Type IV Models

RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL SRB SN1 (ALVBOV equipped)	
TEST METHOD	:	EN14143:2003	SINE FLOW
DATE AND TIME	:	29/10/2010 16:24	
TEST CARRIED OUT BY		VS WITNESS: MS	

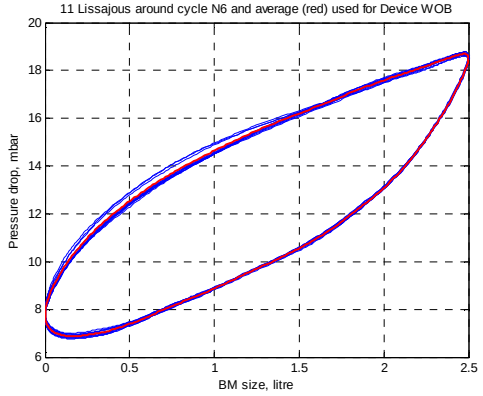
CONDITIONS OF TEST

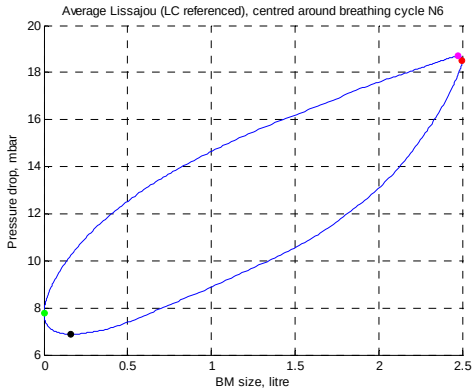
ATTITIDE: PITCH & ROLL	:	180/0	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	22.0 / 4.2	℃
EHXALE GAS TEMPERATURE	:	15.5	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/24.9bpm/62.4lpm	standard

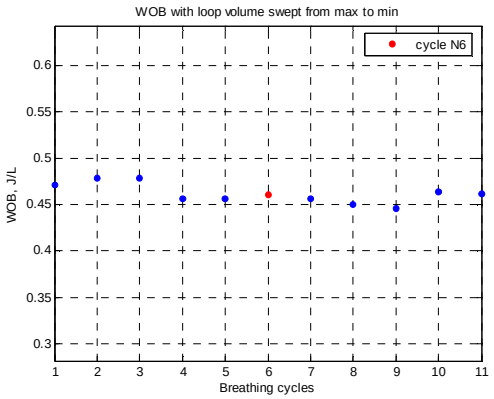
RESULTS

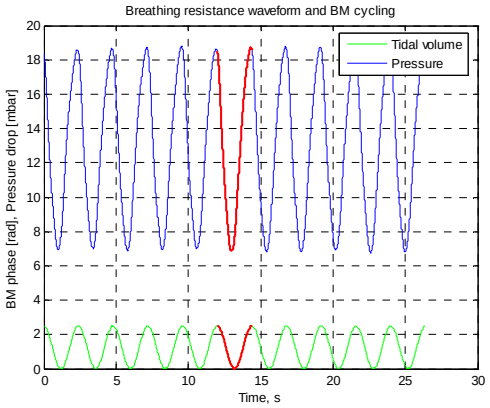
PRESSURE@END EXHALE/INHALE	=	18.5 / 7.8	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	18.5	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)	=	25.5	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	18.7 / 6.9	mbar
INHALE/EXHALE RESP PRESSURE	=	11.6 / 10.9	mbar
PEAK TO PEAK PRESSURE	=	11.8	mbar
ELASTANCE	=	4.3	mbar/litre
WORK OF BREATHING	=	0.46	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_SRB01_62_5lpm_101029_opt









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL SRB SN1 (ALVBOV equipped)	
TEST METHOD	:	EN14143:2003	SINE FLOW
DATE AND TIME	:	29/10/2010 16:29	
TEST CARRIED OUT BY		VS WITNESS: MS	

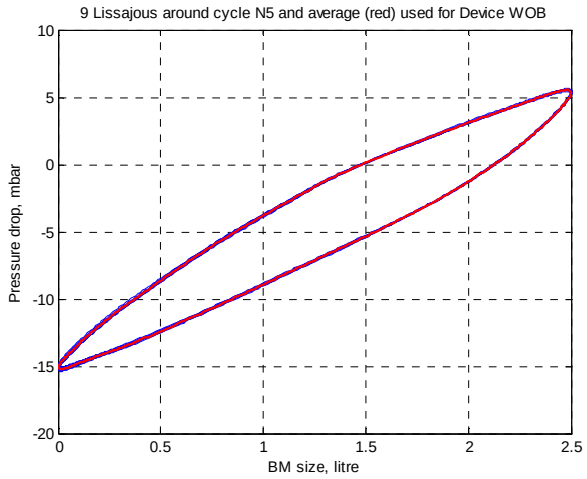
CONDITIONS OF TEST

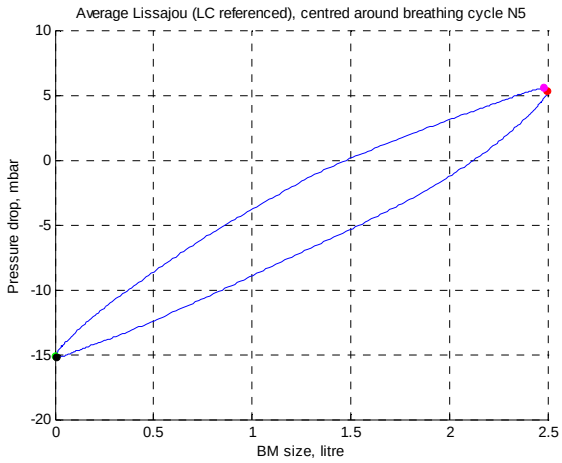
ATTITIDE: PITCH & ROLL	:	90/0	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	22.0 / 4.2	℃
EHXALE GAS TEMPERATURE	:	15.5	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/24.9bpm/62.4lpm	standard

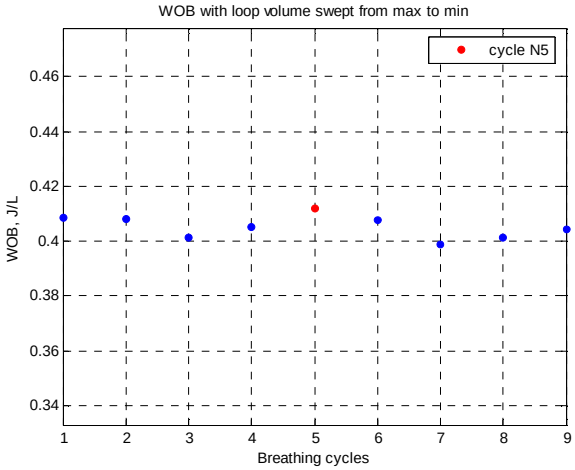
RESULTS

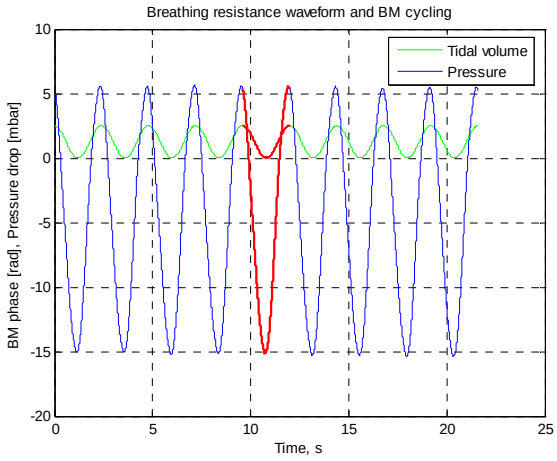
PRESSURE@END EXHALE/INHALE	=	5.3 / -15.1	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	5.3	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)	=	18.8	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	5.5 / -15.2	mbar
INHALE/EXHALE RESP PRESSURE	=	20.5 / 20.7	mbar
PEAK TO PEAK PRESSURE	=	20.8	mbar
ELASTANCE	=	8.2	mbar/litre
WORK OF BREATHING	=	0.41	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_SRB01_62_5lpm_101029_opt









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL SRB SN1 (ALVBOV equipped)	
TEST METHOD	:	EN14143:2003	SINE FLOW
DATE AND TIME	:	29/10/2010 16:33	
TEST CARRIED OUT BY		VS WITNESS: MS	

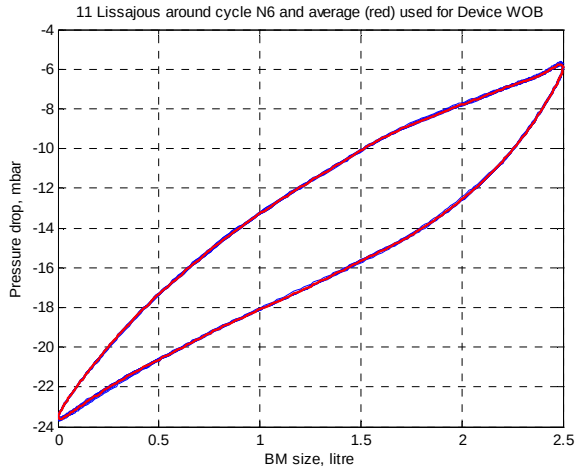
CONDITIONS OF TEST

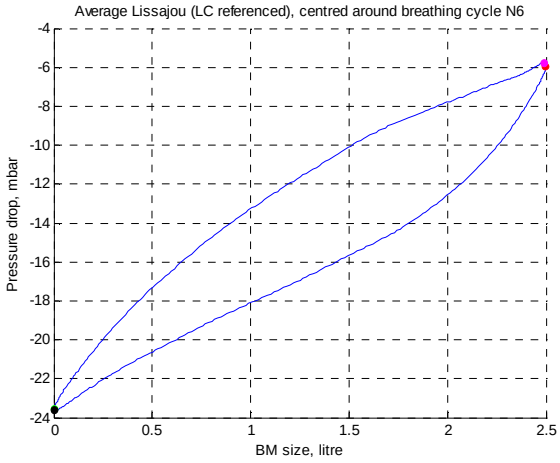
ATTITIDE: PITCH & ROLL	:	45/0	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	22.0 / 4.2	℃
EHXALE GAS TEMPERATURE	:	15.5	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/24.9bpm/62.4lpm	standard

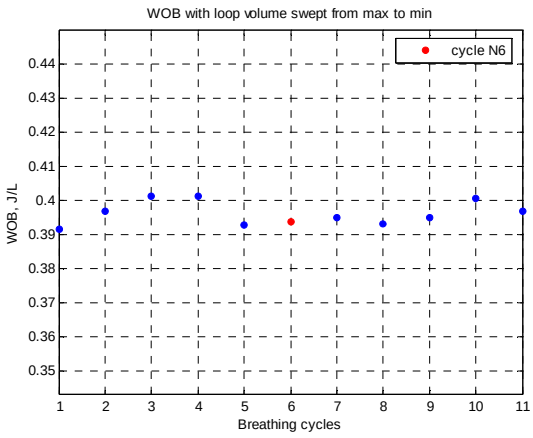
RESULTS

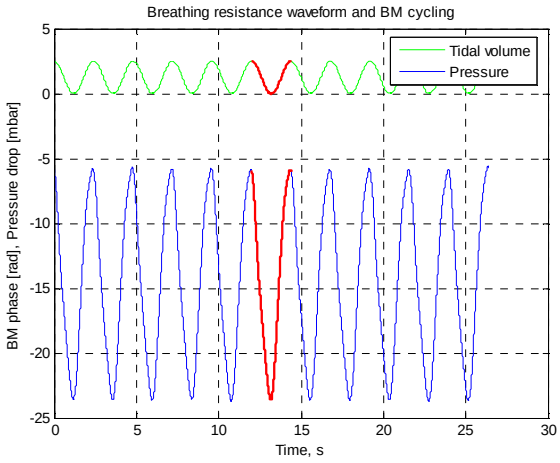
PRESSURE@END EXHALE/INHALE	=	-5.9 / -23.6	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	-5.9	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)	=	-1.3	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	-5.8 / -23.6	mbar
INHALE/EXHALE RESP PRESSURE	=	17.7 / 17.8	mbar
PEAK TO PEAK PRESSURE	=	17.9	mbar
ELASTANCE	=	7.1	mbar/litre
WORK OF BREATHING	=	0.4	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_SRB01_62_5lpm_101029_opt









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL SRB SN1 (ALVBOV equipped)	
TEST METHOD	:	EN14143:2003	SINE FLOW
DATE AND TIME	:	29/10/2010 16:38	
TEST CARRIED OUT BY		VS WITNESS: MS	

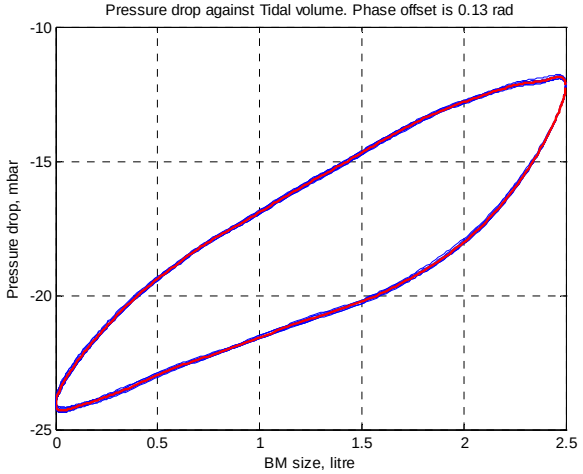
CONDITIONS OF TEST

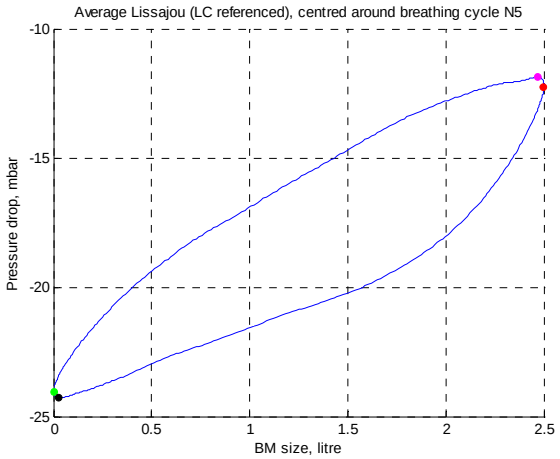
ATTITIDE: PITCH & ROLL	:	0/0	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	22.0 / 4.2	℃
EHXALE GAS TEMPERATURE	:	15.5	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/24.9bpm/62.4lpm	standard

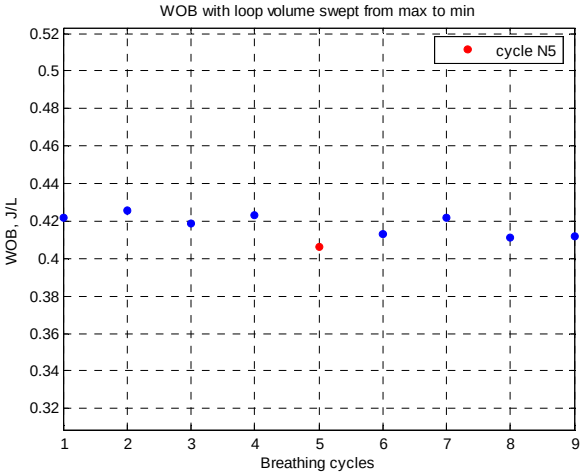
RESULTS

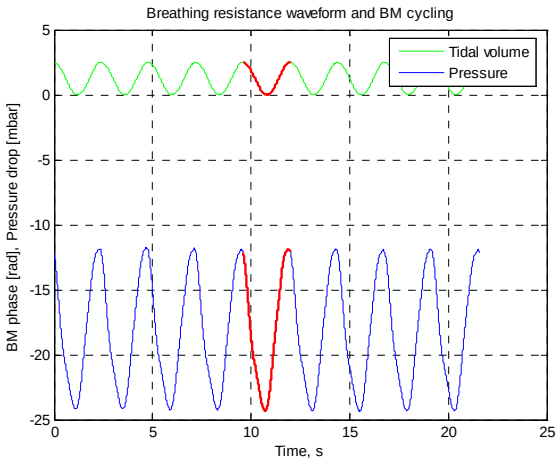
PRESSURE@END EXHALE/INHALE	=	-12.3 / -24.0	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	-12.3	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)	=	-19.3	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	-11.9 / -24.3	mbar
INHALE/EXHALE RESP PRESSURE	=	12.0 / 12.1	mbar
PEAK TO PEAK PRESSURE	=	12.4	mbar
ELASTANCE	=	4.7	mbar/litre
WORK OF BREATHING	=	0.43	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_SRB01_62_5lpm_101029_opt









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL SRB SN1 (ALVBOV equipped)	
TEST METHOD	:	EN14143:2003	SINE FLOW
DATE AND TIME	:	29/10/2010 16:43	
TEST CARRIED OUT BY		VS WITNESS: MS	

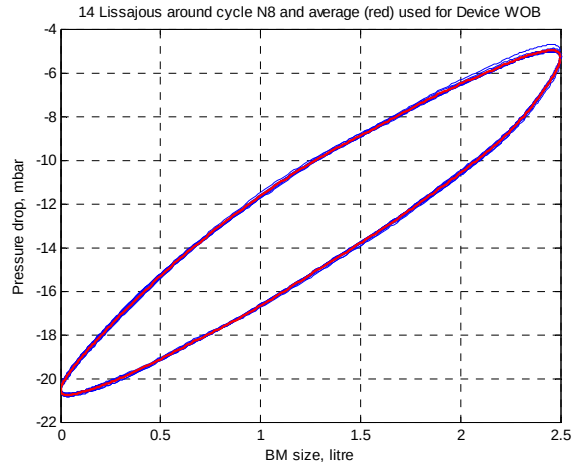
CONDITIONS OF TEST

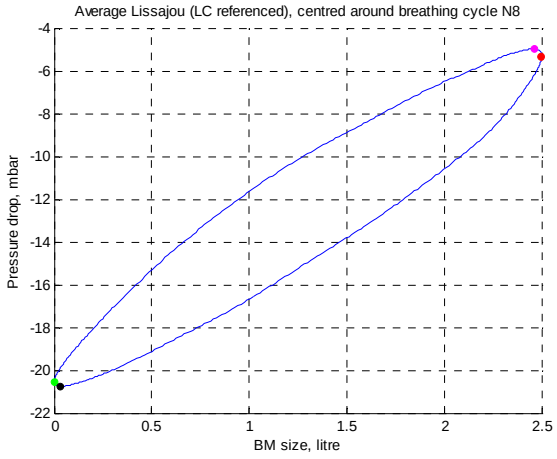
ATTITIDE: PITCH & ROLL	:	-45/0	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	22.0 / 4.2	℃
EHXALE GAS TEMPERATURE	:	15.5	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/24.9bpm/62.4lpm	standard

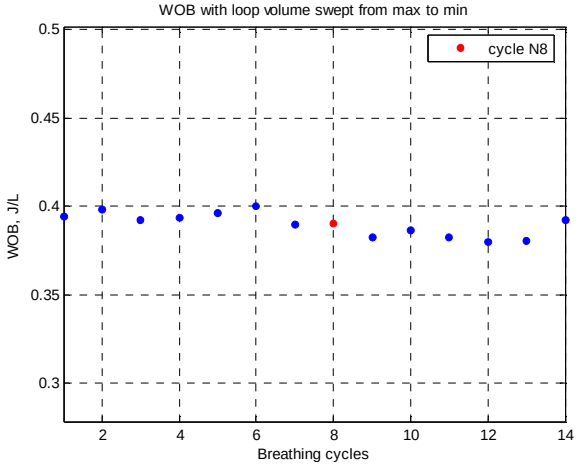
RESULTS

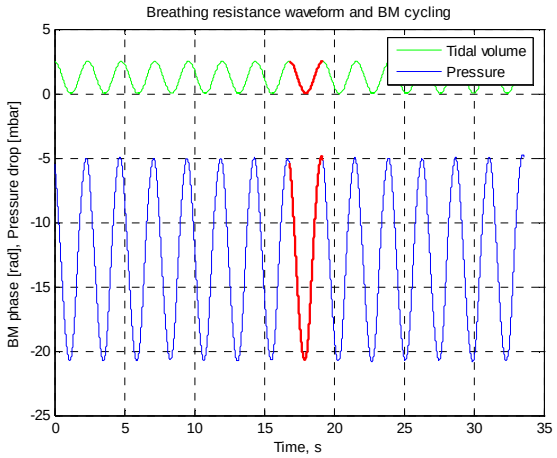
PRESSURE@END EXHALE/INHALE	=	-5.3 / -20.5	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	-5.3	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)	=	-19.8	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	-5.0 / -20.8	mbar
INHALE/EXHALE RESP PRESSURE	=	15.4 / 15.6	mbar
PEAK TO PEAK PRESSURE	=	15.8	mbar
ELASTANCE	=	6.1	mbar/litre
WORK OF BREATHING	=	0.39	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_SRB01_62_5lpm_101029_opt









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL SRB SN1 (ALVBOV equipped)	
TEST METHOD	:	EN14143:2003	SINE FLOW
DATE AND TIME	:	29/10/2010 16:48	
TEST CARRIED OUT BY		VS WITNESS: MS	

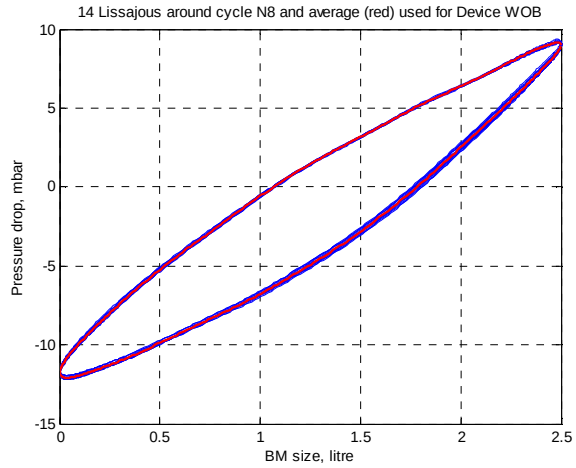
CONDITIONS OF TEST

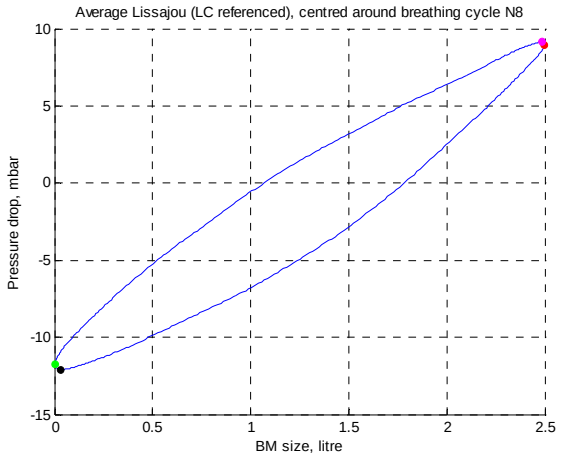
ATTITIDE: PITCH & ROLL	:	-90/0	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	22.0 / 4.2	℃
EHXALE GAS TEMPERATURE	:	15.5	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/24.9bpm/62.4lpm	standard

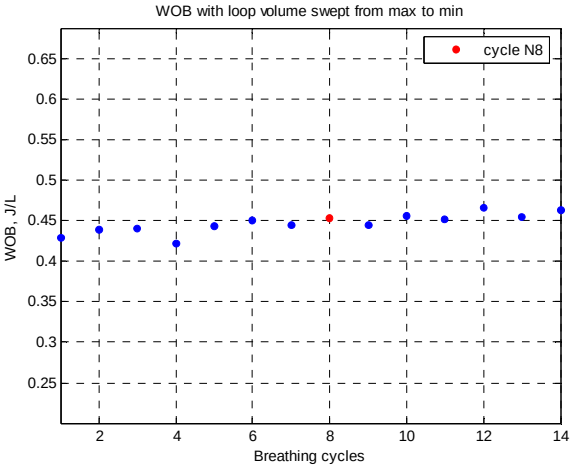
RESULTS

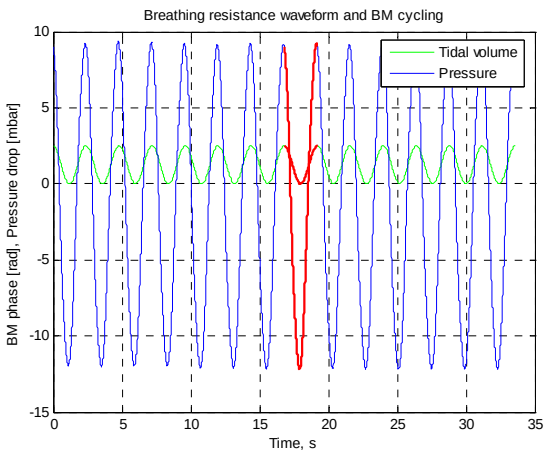
PRESSURE@END EXHALE/INHALE	=	9.0 / -11.8	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	9.0	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)	=	-4.5	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	9.2 / -12.1	mbar
INHALE/EXHALE RESP PRESSURE	=	21.1 / 20.9	mbar
PEAK TO PEAK PRESSURE	=	21.3	mbar
ELASTANCE	=	8.3	mbar/litre
WORK OF BREATHING	=	0.47	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_SRB01_62_5lpm_101029_opt









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL SRB SN1 (ALVBOV equipped)	
TEST METHOD	:	EN14143:2003	SINE FLOW
DATE AND TIME	:	29/10/2010 16:52	
TEST CARRIED OUT BY		VS WITNESS: MS	

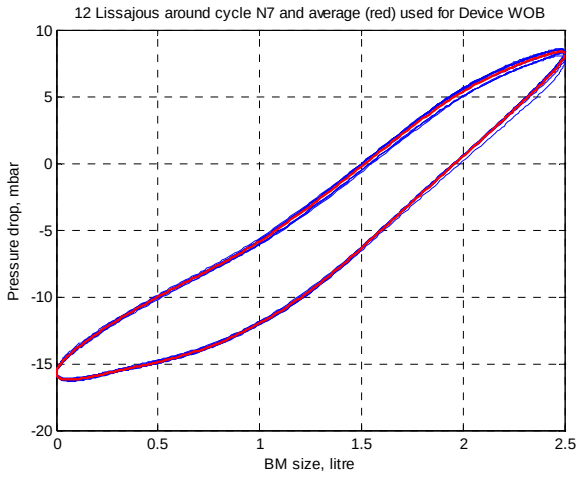
CONDITIONS OF TEST

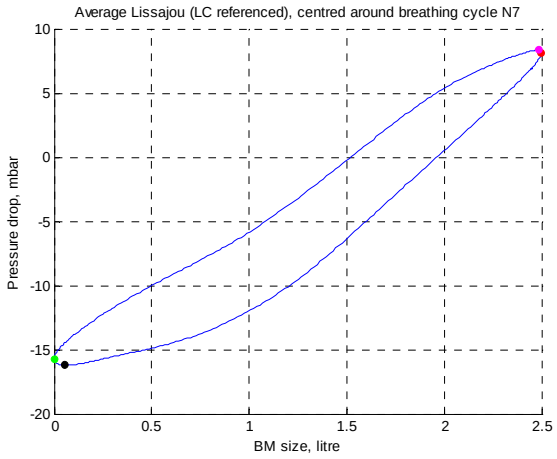
ATTITIDE: PITCH & ROLL	:	0/90	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	22.0 / 4.2	℃
EHXALE GAS TEMPERATURE	:	15.5	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/24.9bpm/62.4lpm	standard

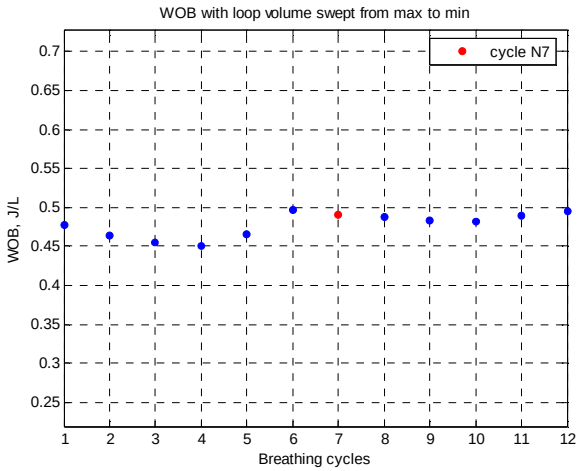
RESULTS

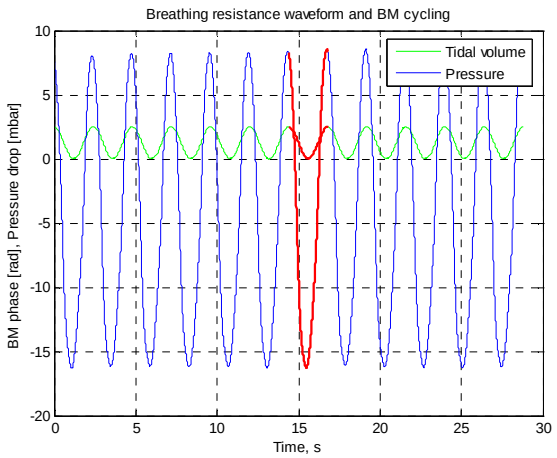
PRESSURE@END EXHALE/INHALE	=	8.1 / -15.7	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	8.1	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)	=	8.1	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	8.4 / -16.2	mbar
INHALE/EXHALE RESP PRESSURE	=	24.3 / 24.1	mbar
PEAK TO PEAK PRESSURE	=	24.6	mbar
ELASTANCE	=	9.5	mbar/litre
WORK OF BREATHING	=	0.5	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_SRB01_62_5lpm_101029_opt









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL SRB SN1 (ALVBOV equipped)	
TEST METHOD	:	EN14143:2003	SINE FLOW
DATE AND TIME	:	29/10/2010 16:57	
TEST CARRIED OUT BY		VS WITNESS: MS	

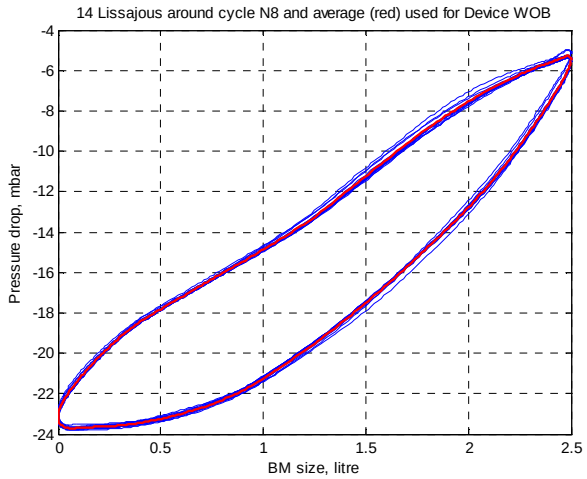
CONDITIONS OF TEST

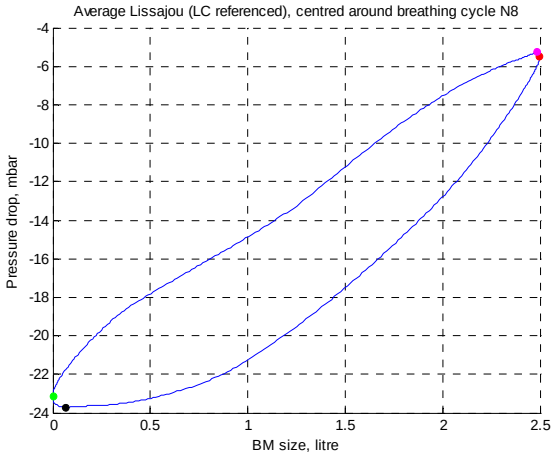
ATTITIDE: PITCH & ROLL	:	0/45	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	22.0 / 4.2	℃
EHXALE GAS TEMPERATURE	:	15.5	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/24.9bpm/62.4lpm	standard

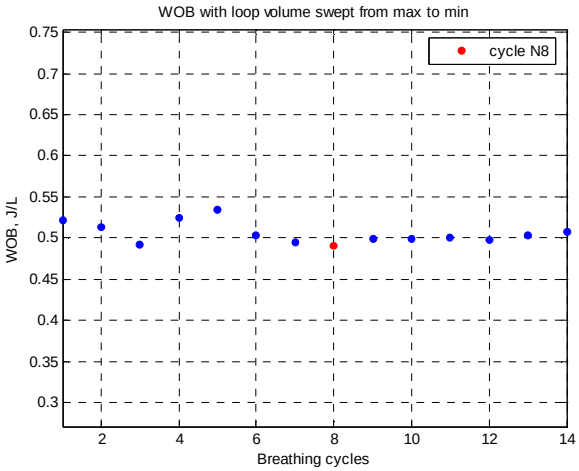
RESULTS

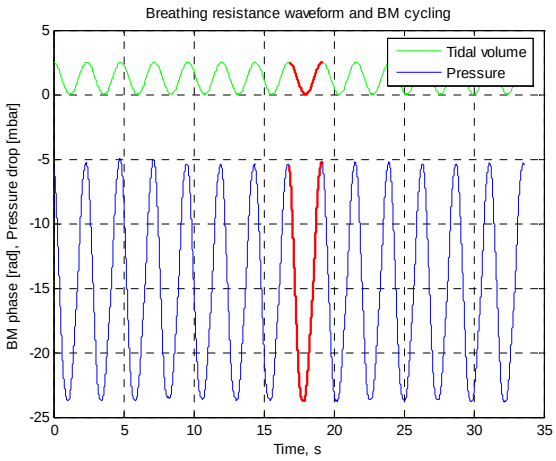
PRESSURE@END EXHALE/INHALE	=	-5.5 / -23.1	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	-5.5	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)	=	-0.6	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	-5.3 / -23.7	mbar
INHALE/EXHALE RESP PRESSURE	=	18.2 / 17.9	mbar
PEAK TO PEAK PRESSURE	=	18.4	mbar
ELASTANCE	=	7.1	mbar/litre
WORK OF BREATHING	=	0.51	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_SRB01_62_5lpm_101029_opt









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL SRB SN1 (ALVBOV equipped)	
TEST METHOD	:	EN14143:2003	SINE FLOW
DATE AND TIME	:	29/10/2010 17:01	
TEST CARRIED OUT BY		VS WITNESS: MS	

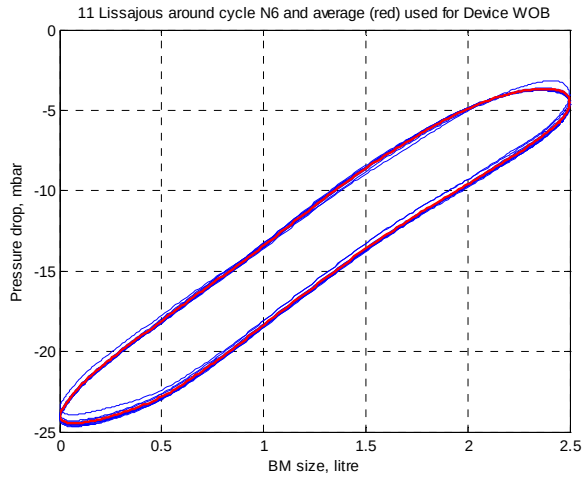
CONDITIONS OF TEST

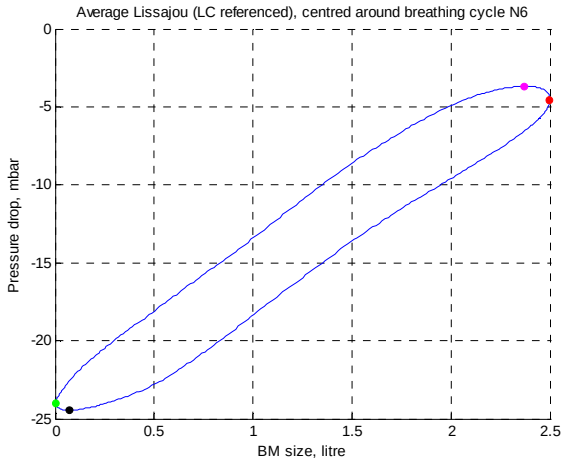
ATTITIDE: PITCH & ROLL	:	0/-45	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	22.0 / 4.2	℃
EHXALE GAS TEMPERATURE	:	15.5	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/24.9bpm/62.4lpm	standard

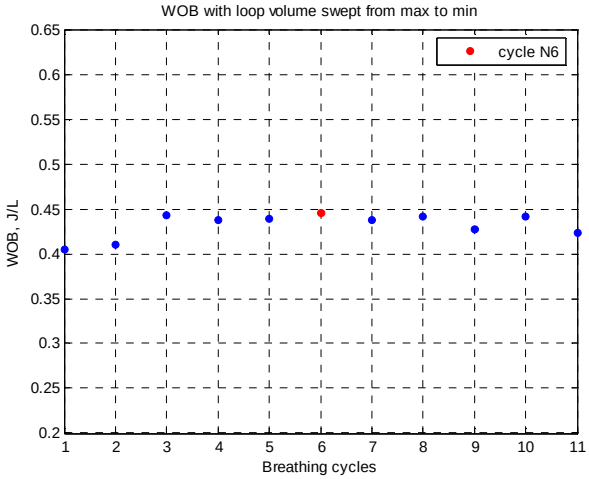
RESULTS

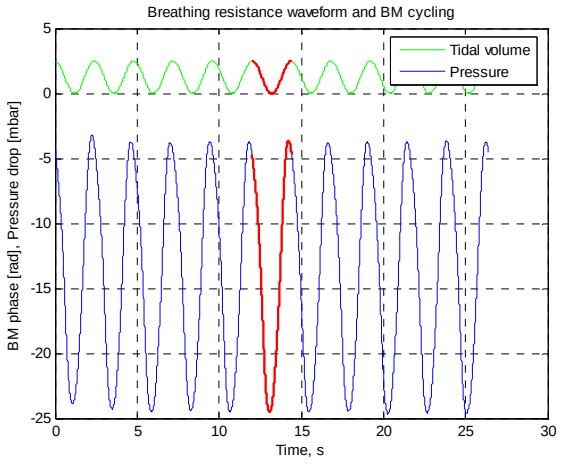
PRESSURE@END EXHALE/INHALE	=	-4.6 / -24.0	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	-4.6	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)	=	0.3	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	-3.7 / -24.5	mbar
INHALE/EXHALE RESP PRESSURE	=	19.9 / 20.4	mbar
PEAK TO PEAK PRESSURE	=	20.8	mbar
ELASTANCE	=	7.8	mbar/litre
WORK OF BREATHING	=	0.44	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_SRB01_62_5lpm_101029_opt









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL SRB SN1 (ALVBOV equipped)	
TEST METHOD	:	EN14143:2003	SINE FLOW
DATE AND TIME	:	29/10/2010 17:08	
TEST CARRIED OUT BY		VS WITNESS: MS	

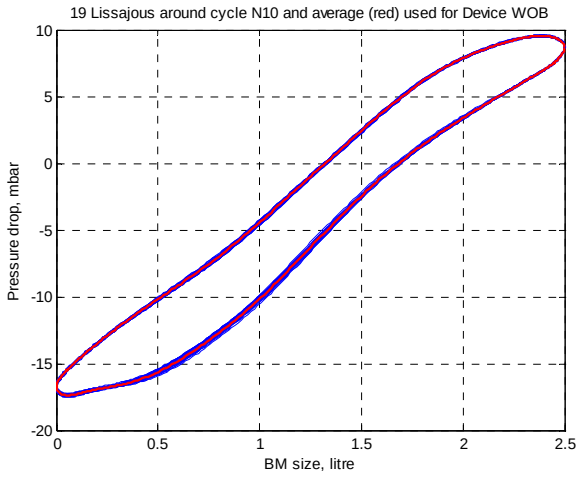
CONDITIONS OF TEST

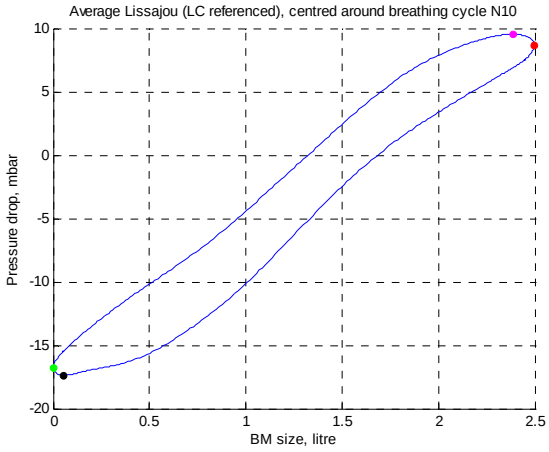
ATTITIDE: PITCH & ROLL	:	0/-90	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	22.0 / 4.2	℃
EHXALE GAS TEMPERATURE	:	15.5	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/24.9bpm/62.4lpm	standard

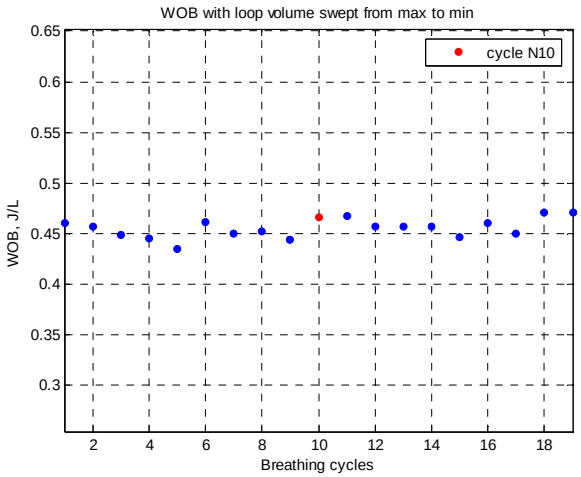
RESULTS

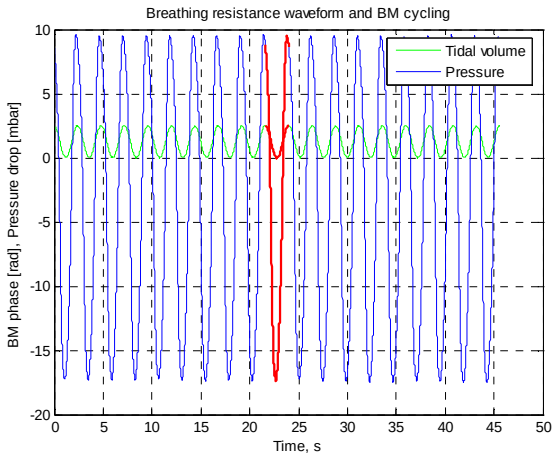
PRESSURE@END EXHALE/INHALE	=	8.6 / -16.7	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	8.6	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)	=	8.6	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	9.5 / -17.4	mbar
INHALE/EXHALE RESP PRESSURE	=	26.0 / 26.3	mbar
PEAK TO PEAK PRESSURE	=	26.9	mbar
ELASTANCE	=	10.2	mbar/litre
WORK OF BREATHING	=	0.47	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_SRB01_62_5lpm_101029_opt









8.2 Empirical Results for OR_Umbilical model

RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL DRB SN12 (ALVBOV equipped)	
TEST METHOD	:	EN14143:2003	SINE FLOW
DATE AND TIME	:	29/10/2010 11:17	
TEST CARRIED OUT BY	VS	WITNESS: MS	

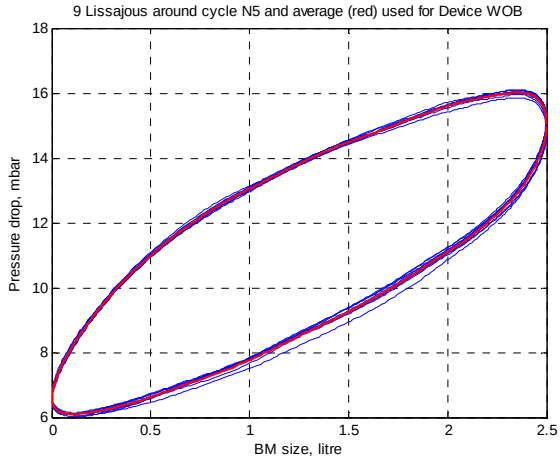
CONDITIONS OF TEST

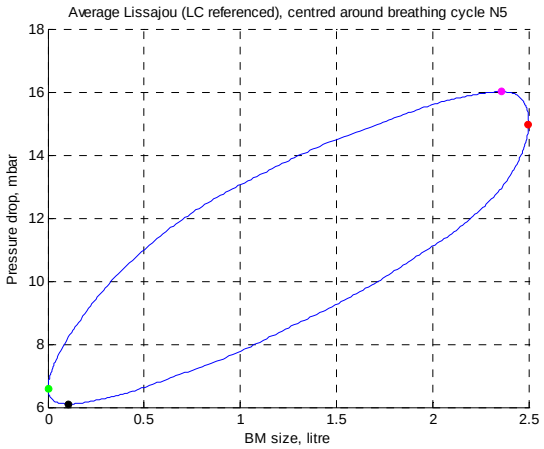
ATTITIDE: PITCH & ROLL	:	180/0	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	24.0 / 4.1	℃
EHXALE GAS TEMPERATURE	:	14.8	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/25.0bpm/62.5lpm	standard

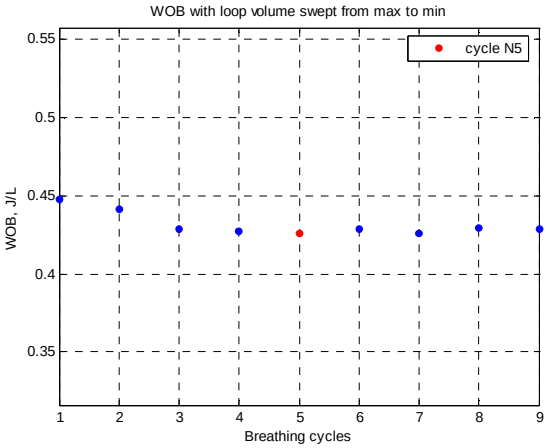
RESULTS

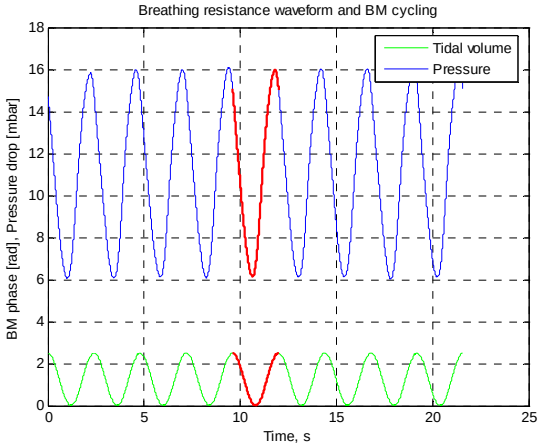
PRESSURE@END EXHALE/INHALE	=	15.0 / 6.6	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	15.0	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)		22.0	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	16.0 / 6.1	mbar
INHALE/EXHALE RESP PRESSURE	=	8.9 / 9.4	mbar
PEAK TO PEAK PRESSURE	=	9.9	mbar
ELASTANCE	=	3.4	mbar/litre
WORK OF BREATHING	=	0.43	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_DRB01_62_5lpm_101029_opt









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL DRB SN12 (ALVBOV equipped)	
TEST METHOD	:	EN14143:2003	SINE FLOW
DATE AND TIME	:	29/10/2010 11:22	
TEST CARRIED OUT BY		VS WITNESS: MS	

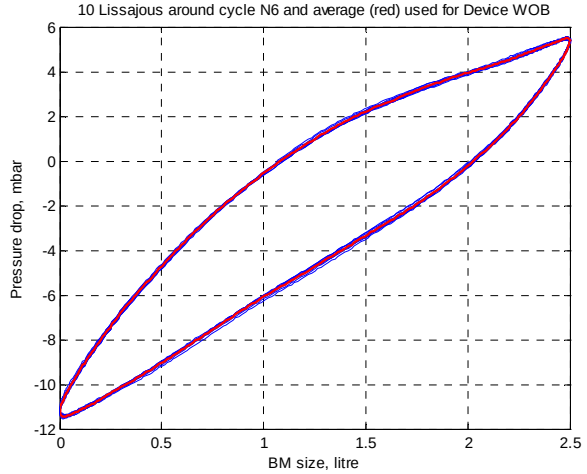
CONDITIONS OF TEST

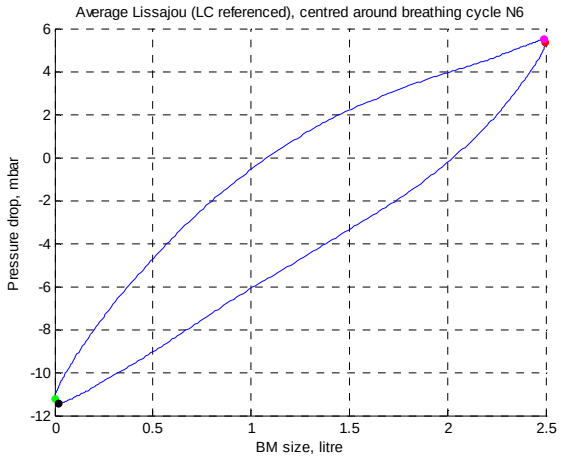
ATTITIDE: PITCH & ROLL	:	90/0	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	24.0 / 4.1	℃
EHXALE GAS TEMPERATURE	:	14.8	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/25.0bpm/62.5lpm	standard

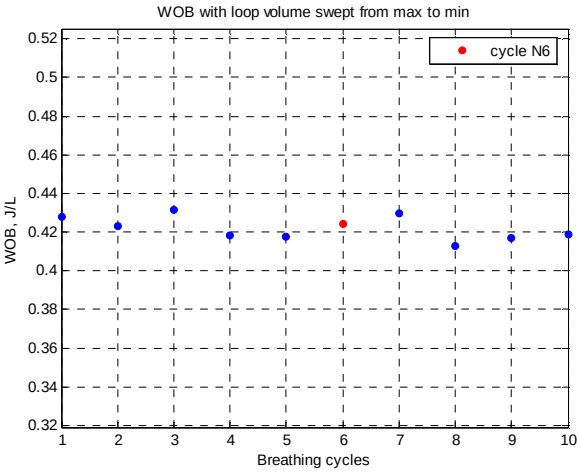
RESULTS

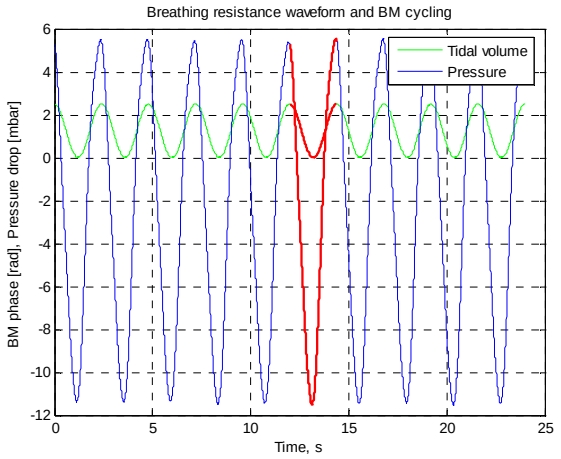
PRESSURE@END EXHALE/INHALE	=	5.4 / -11.2	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	5.4	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)		18.9	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	5.5 / -11.4	mbar
INHALE/EXHALE RESP PRESSURE	=	16.8 / 16.7	mbar
PEAK TO PEAK PRESSURE	=	16.9	mbar
ELASTANCE	=	6.6	mbar/litre
WORK OF BREATHING	=	0.42	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_DRB01_62_5lpm_101029_opt









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL DRB SN12 (ALVBOV equipped)	
TEST METHOD	:	EN14143:2003	SINE FLOW
DATE AND TIME	:	29/10/2010 11:26	
TEST CARRIED OUT BY		VS WITNESS: MS	

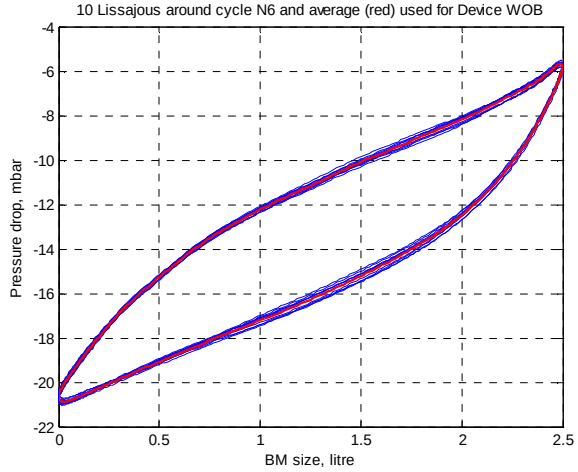
CONDITIONS OF TEST

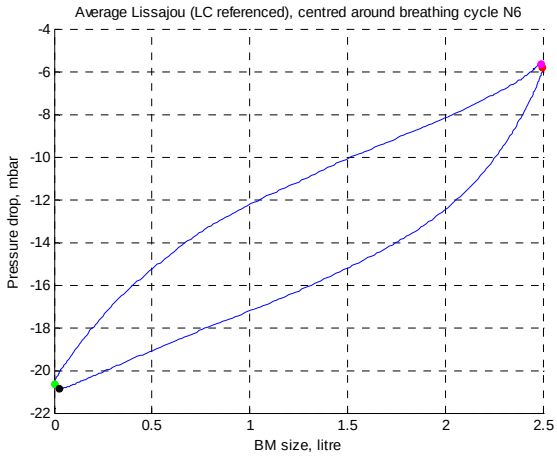
ATTITIDE: PITCH & ROLL	:	45/0	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	24.0 / 4.1	℃
EHXALE GAS TEMPERATURE	:	14.8	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/25.0bpm/62.5lpm	standard

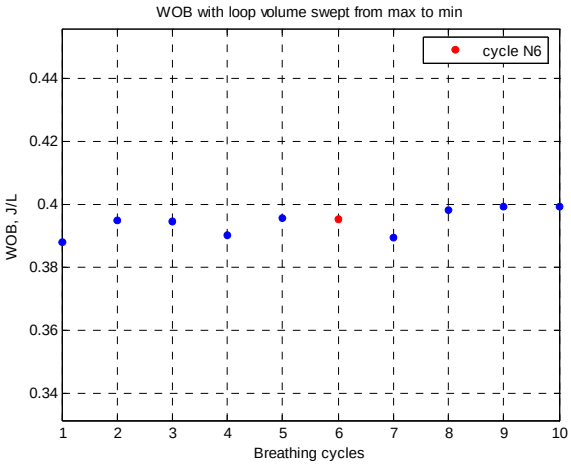
RESULTS

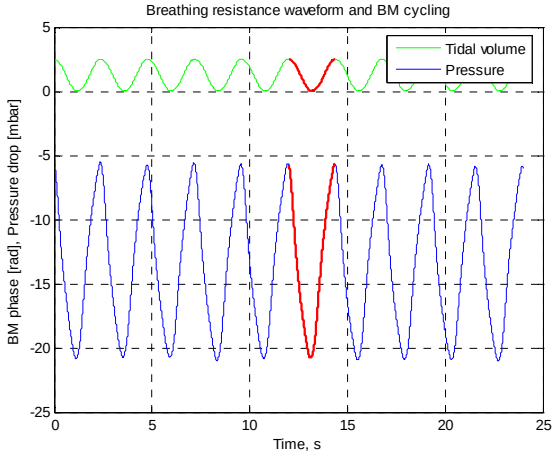
PRESSURE@END EXHALE/INHALE	=	-5.8 / -20.7	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	-5.8	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)		-1.2	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	-5.7 / -20.9	mbar
INHALE/EXHALE RESP PRESSURE	=	15.1 / 15.0	mbar
PEAK TO PEAK PRESSURE	=	15.2	mbar
ELASTANCE	=	5.9	mbar/litre
WORK OF BREATHING	=	0.39	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_DRB01_62_5lpm_101029_opt









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL DRB SN12 (ALVBOV equipped)	
TEST METHOD	:	EN14143:2003	SINE FLOW
DATE AND TIME	:	29/10/2010 11:26	
TEST CARRIED OUT BY		VS WITNESS: MS	

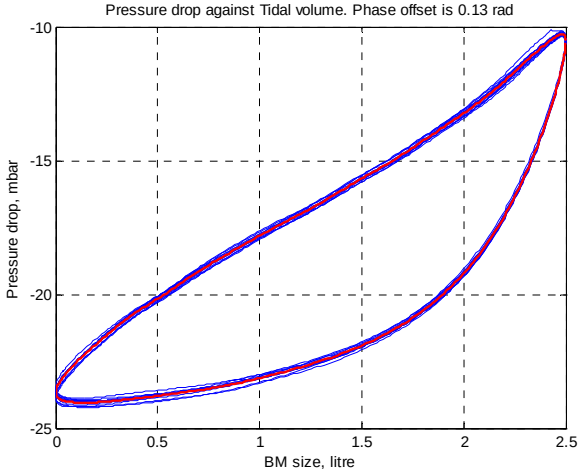
CONDITIONS OF TEST

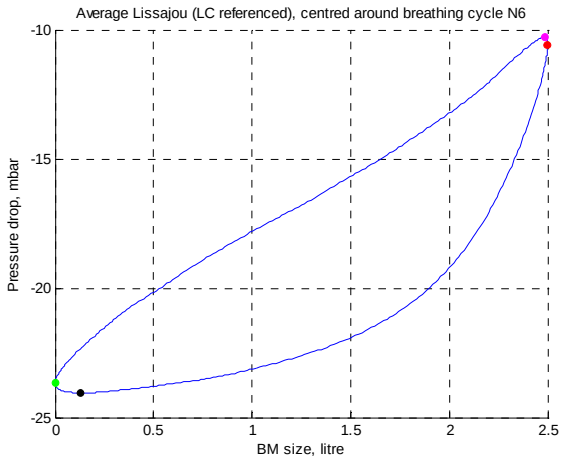
ATTITIDE: PITCH & ROLL	:	0/0	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	24.0 / 4.1	℃
EHXALE GAS TEMPERATURE	:	14.8	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/25.0bpm/62.5lpm	standard

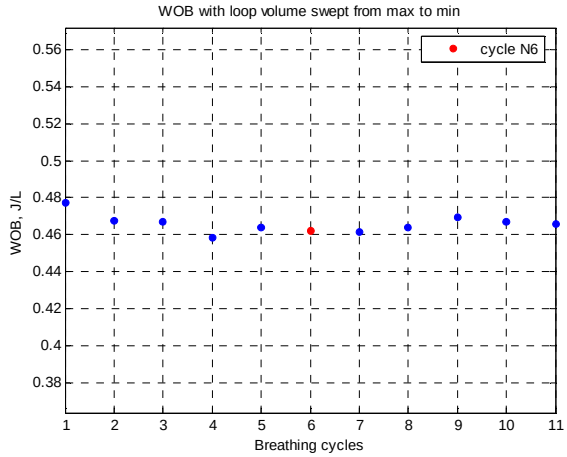
RESULTS

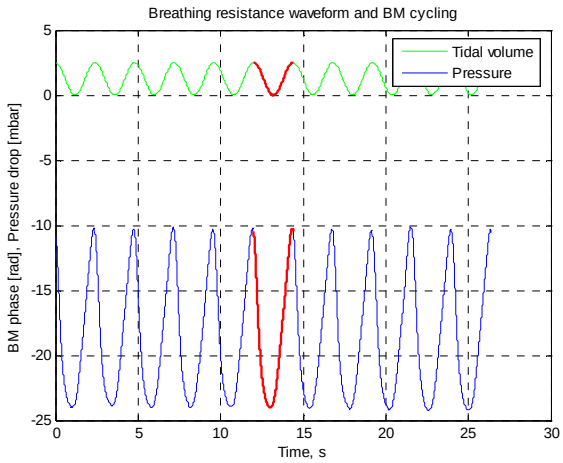
PRESSURE@END EXHALE/INHALE	=	-10.6 / -23.7	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	-10.6	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)		-17.6	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	-10.3 / -24.1	mbar
INHALE/EXHALE RESP PRESSURE	=	13.5 / 13.4	mbar
PEAK TO PEAK PRESSURE	=	13.8	mbar
ELASTANCE	=	5.2	mbar/litre
WORK OF BREATHING	=	0.47	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_DRB01_62_5lpm_101029_opt









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL DRB SN12 (ALVBOV equipped)	
TEST METHOD	:	EN14143:2003	SINE FLOW
DATE AND TIME	:	29/10/2010 11:31	
TEST CARRIED OUT BY		VS WITNESS: MS	

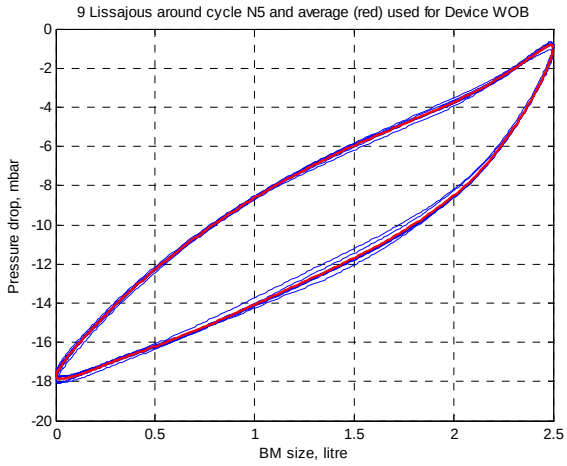
CONDITIONS OF TEST

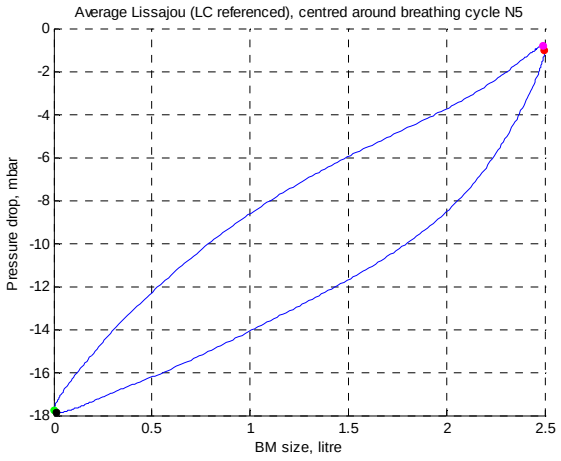
ATTITIDE: PITCH & ROLL	:	-45/0	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	24.0 / 4.1	℃
EHXALE GAS TEMPERATURE	:	14.8	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/25.0bpm/62.5lpm	standard

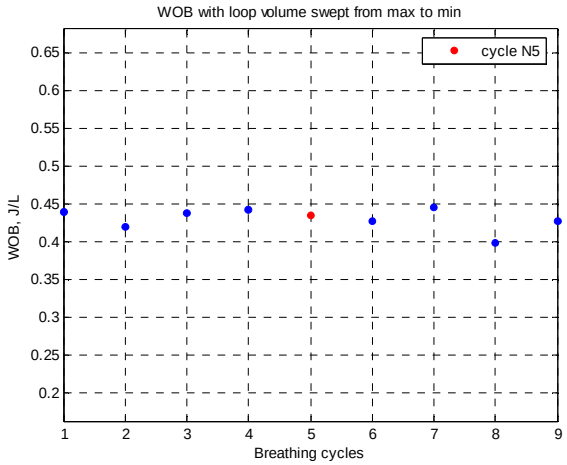
RESULTS

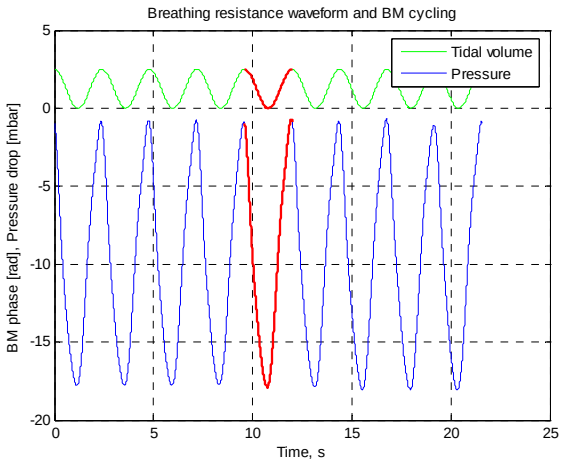
PRESSURE@END EXHALE/INHALE	=	-1.0 / -17.8	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	-1.0	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)		-15.5	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	-0.8 / -17.9	mbar
INHALE/EXHALE RESP PRESSURE	=	16.9 / 17.0	mbar
PEAK TO PEAK PRESSURE	=	17.1	mbar
ELASTANCE	=	6.7	mbar/litre
WORK OF BREATHING	=	0.44	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_DRB01_62_5lpm_101029_opt









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL DRB SN12 (ALVBOV equipped)	
TEST METHOD	:	EN14143:2003	SINE FLOW
DATE AND TIME	:	29/10/2010 11:35	
TEST CARRIED OUT BY		VS WITNESS: MS	

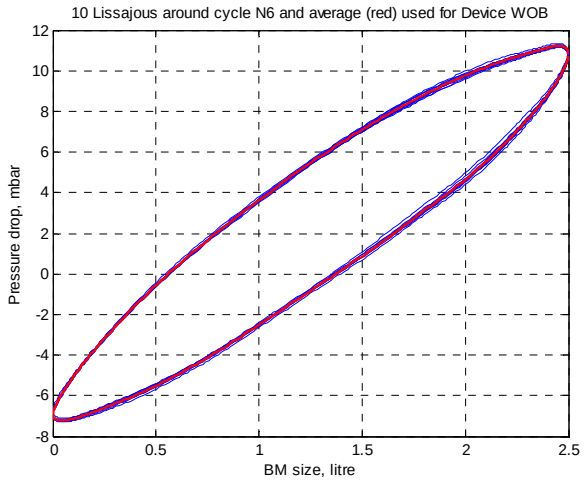
CONDITIONS OF TEST

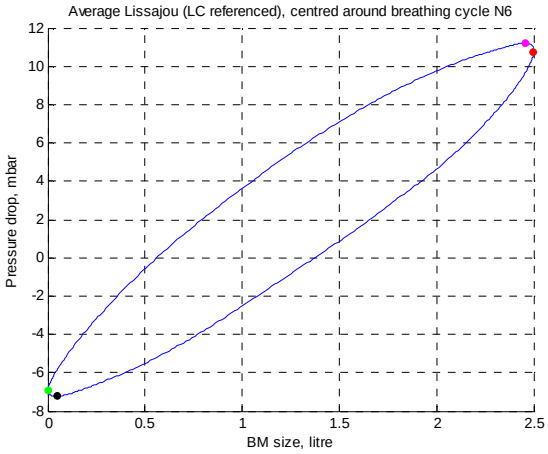
ATTITIDE: PITCH & ROLL	:	-90/0	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	24.0 / 4.1	℃
EHXALE GAS TEMPERATURE	:	14.8	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/25.0bpm/62.5lpm	standard

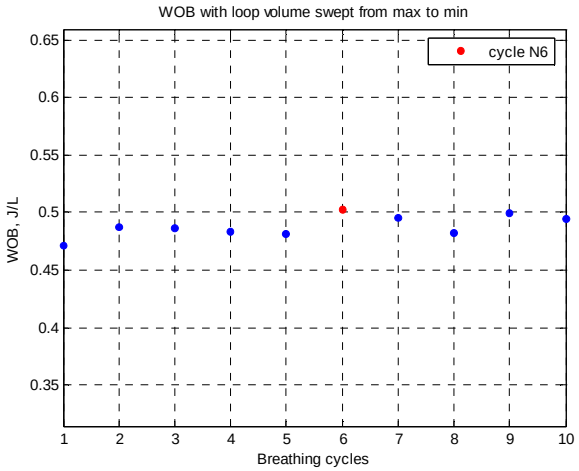
RESULTS

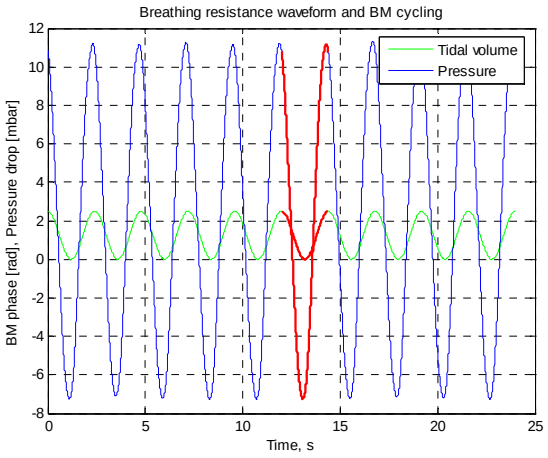
PRESSURE@END EXHALE/INHALE	=	10.8 / -6.9	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	10.8	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)		-2.7	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	11.2 / -7.2	mbar
INHALE/EXHALE RESP PRESSURE	=	18.0 / 18.1	mbar
PEAK TO PEAK PRESSURE	=	18.5	mbar
ELASTANCE	=	7.1	mbar/litre
WORK OF BREATHING	=	0.5	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_DRB01_62_5lpm_101029_opt









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL DRB SN12 (ALVBOV equipped)	
TEST METHOD	:	EN14143:2003	SINE FLOW
DATE AND TIME	:	29/10/2010 11:39	
TEST CARRIED OUT BY		VS WITNESS: MS	

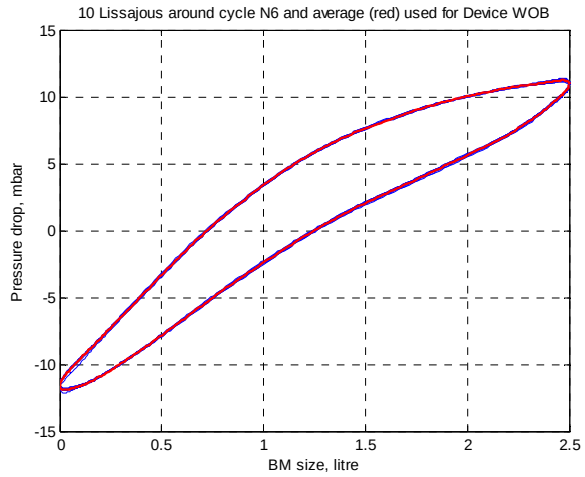
CONDITIONS OF TEST

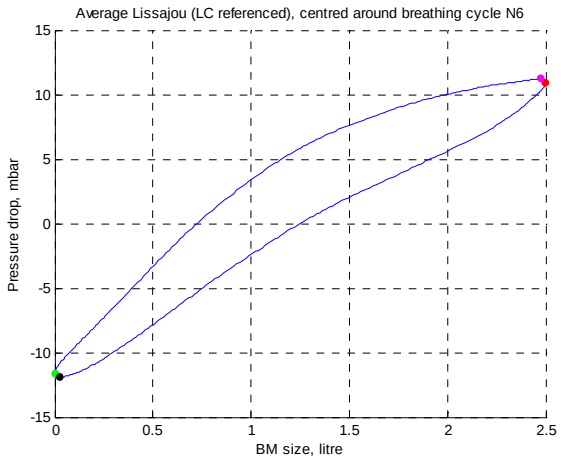
ATTITIDE: PITCH & ROLL	:	0/90	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	24.0 / 4.1	℃
EHXALE GAS TEMPERATURE	:	14.8	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/25.0bpm/62.5lpm	standard

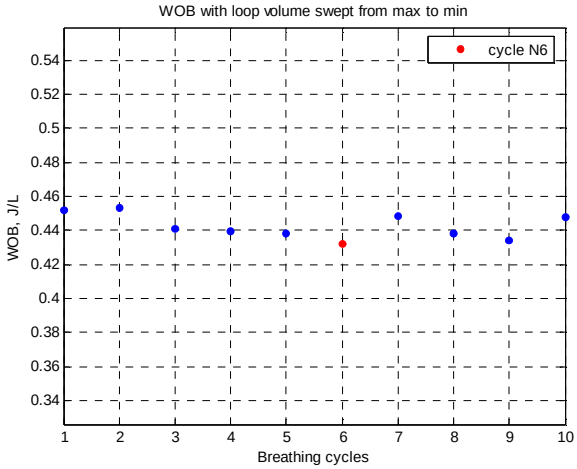
RESULTS

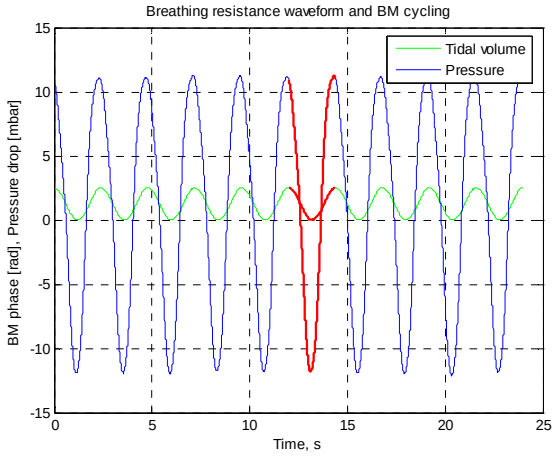
PRESSURE@END EXHALE/INHALE	=	10.9 / -11.6	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	10.9	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)		10.9	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	11.2 / -11.9	mbar
INHALE/EXHALE RESP PRESSURE	=	22.8 / 22.9	mbar
PEAK TO PEAK PRESSURE	=	23.1	mbar
ELASTANCE	=	9.0	mbar/litre
WORK OF BREATHING	=	0.46	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_DRB01_62_5lpm_101029_opt









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL DRB SN12 (ALVBOV equipped)	
TEST METHOD	:	EN14143:2003	SINE FLOW
DATE AND TIME	:	29/10/2010 11:44	
TEST CARRIED OUT BY		VS WITNESS: MS	

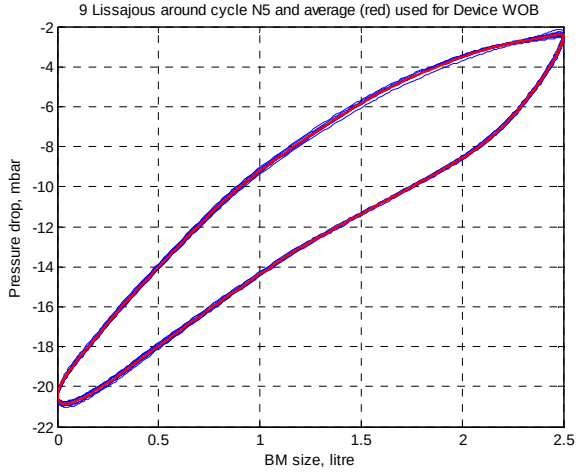
CONDITIONS OF TEST

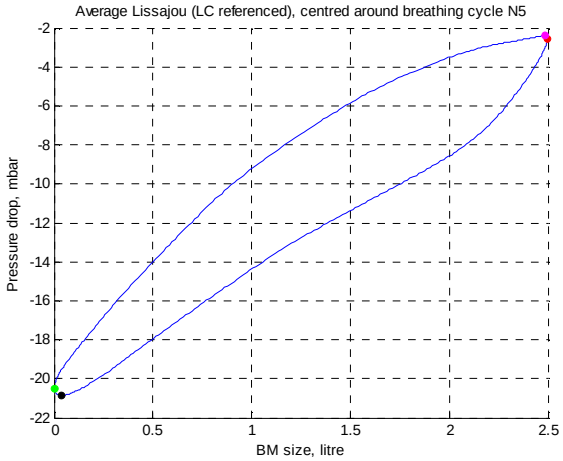
ATTITIDE: PITCH & ROLL	:	0/45	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	24.0 / 4.1	℃
EHXALE GAS TEMPERATURE	:	14.8	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/25.0bpm/62.5lpm	standard

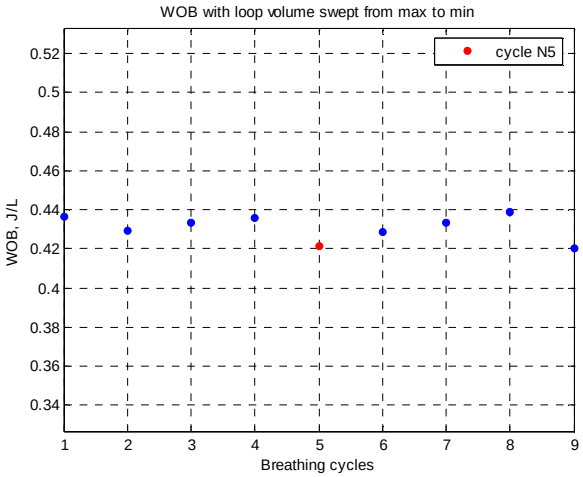
RESULTS

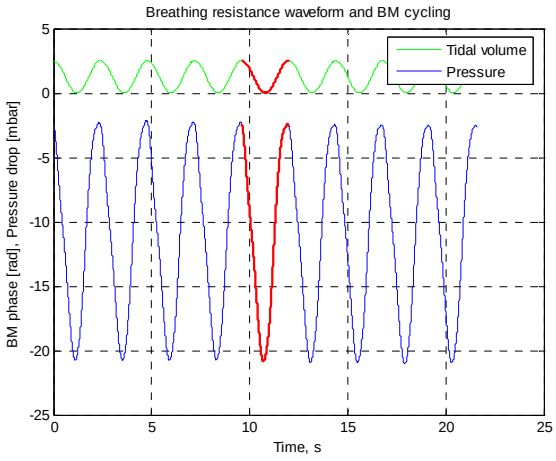
PRESSURE@END EXHALE/INHALE	=	-2.5 / -20.5	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	-2.5	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)		2.4	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	-2.4 / -20.9	mbar
INHALE/EXHALE RESP PRESSURE	=	18.3 / 18.1	mbar
PEAK TO PEAK PRESSURE	=	18.5	mbar
ELASTANCE	=	7.2	mbar/litre
WORK OF BREATHING	=	0.44	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_DRB01_62_5lpm_101029_opt









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL DRB SN12 (ALVBOV equipped)	
TEST METHOD	:	EN14143:2003	SINE FLOW
DATE AND TIME	:	29/10/2010 11:48	
TEST CARRIED OUT BY		VS WITNESS: MS	

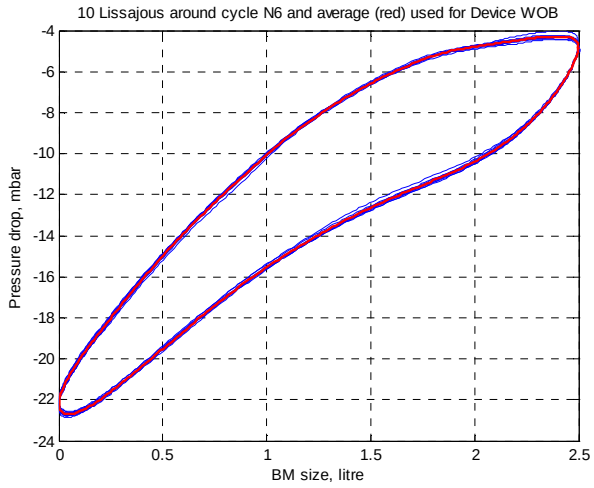
CONDITIONS OF TEST

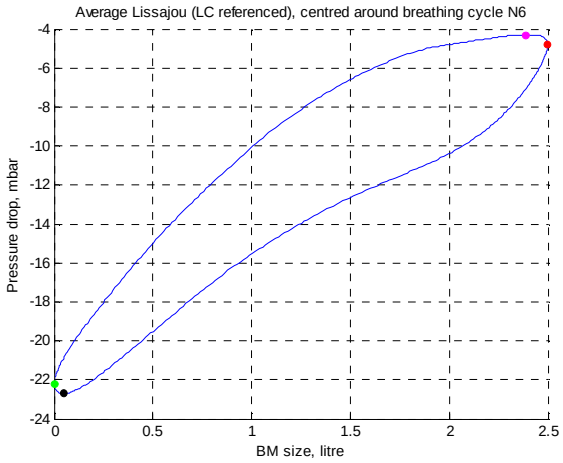
ATTITIDE: PITCH & ROLL	:	0/-45	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	24.0 / 4.1	℃
EHXALE GAS TEMPERATURE	:	14.8	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/25.0bpm/62.5lpm	standard

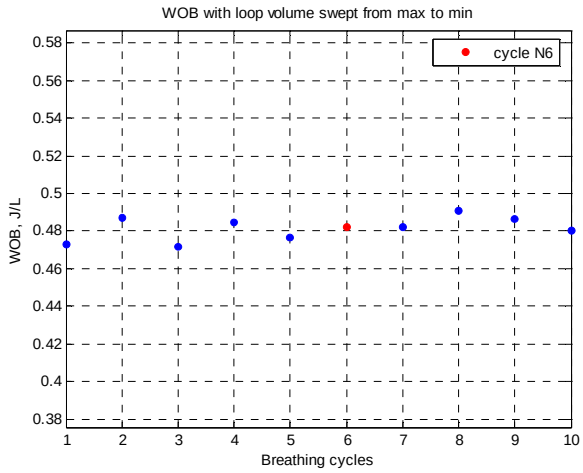
RESULTS

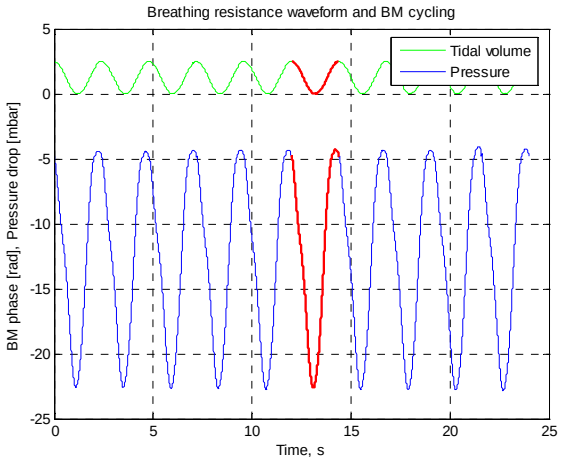
PRESSURE@END EXHALE/INHALE	=	-4.8 / -22.3	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	-4.8	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)		0.1	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	-4.3 / -22.7	mbar
INHALE/EXHALE RESP PRESSURE	=	17.9 / 18.0	mbar
PEAK TO PEAK PRESSURE	=	18.4	mbar
ELASTANCE	=	7.0	mbar/litre
WORK OF BREATHING	=	0.46	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_DRB01_62_5lpm_101029_opt









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL DRB SN12 (ALVBOV equipped)	
TEST METHOD	:	EN14143:2003	SINE FLOW
DATE AND TIME	:	29/10/2010 11:53	
TEST CARRIED OUT BY		VS WITNESS: MS	

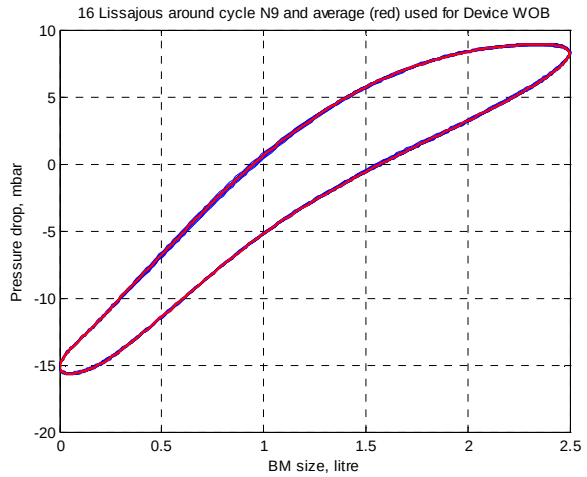
CONDITIONS OF TEST

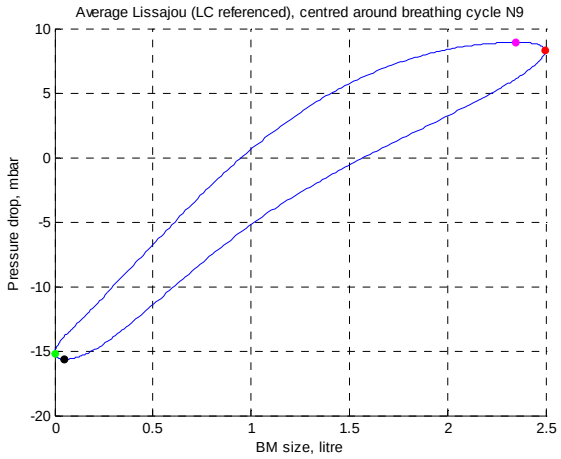
ATTITIDE: PITCH & ROLL	:	0/-90	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	24.0 / 4.1	℃
EHXALE GAS TEMPERATURE	:	14.8	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/25.0bpm/62.5lpm	standard

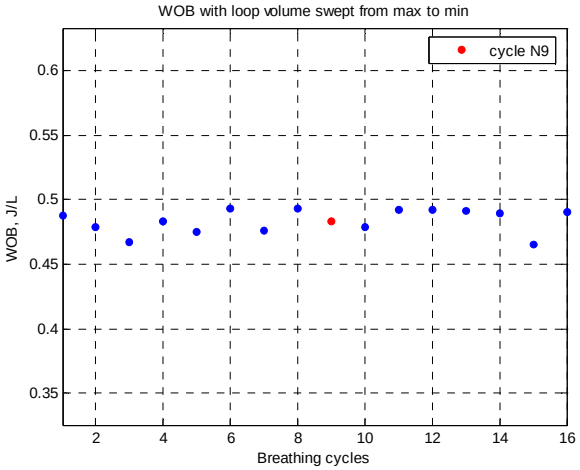
RESULTS

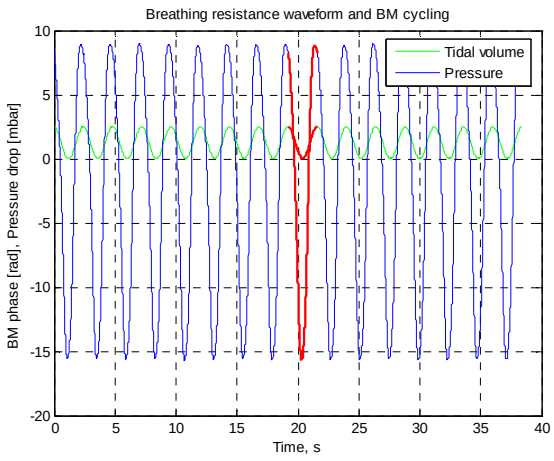
PRESSURE@END EXHALE/INHALE	=	8.3 / -15.2	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	8.3	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)		8.3	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	8.9 / -15.6	mbar
INHALE/EXHALE RESP PRESSURE	=	23.9 / 24.1	mbar
PEAK TO PEAK PRESSURE	=	24.5	mbar
ELASTANCE	=	9.4	mbar/litre
WORK OF BREATHING	=	0.47	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_DRB01_62_5lpm_101029_opt









8.3 Tabulation of Results Optimised Fixed Loop Volume

The tables below are for one loop volume. Retest can produce other tables depending on the exact loop volume, but with any loop volume using the procedure optimised as set down in the method, all models of the rebreathers meet all limits.

Test Num.	Position		EN14143: 2003 (relative to LC)	OR Incursion / Apocalypse Type IV iCCR	OR Umbilical	Status
	Pitch	Roll				
1	+180	0	-20 +20	18.5	15.0	Both OR pass
2	+90	0	-20 +20	5.3	5.4	Both OR pass
3	+45	0	-20 +20	-5.9	-5.8	Both OR pass
4	0	0	-25 +20	-12.3	-10.6	Both OR pass
5	-45	0	-20 +20	-5.3	-1.0	Both OR pass
6	-90	0	-20 +20	9.0	10.8	Both OR pass
7	0	+90	-20 +20	8.1	10.9	Both OR pass
8	0	+45	-23 +23	-5.5	-2.5	Both OR pass
9	0	-45	-23 +23	-4.6	-4.8	Both OR pass
10	0	-90	-20 +20	8.6	8.3	Both OR pass

9 RESULTS FOR BOUNDARY CASE FIXED LOOP VOLUME

9.1 Empirical Results for OR Incursion / Apocalypse Type IV Models

RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL SRB SN1 (ALVBOV equipped)	
TEST METHOD	:	EN14143:2003	SINE FLOW
DATE AND TIME	:	01/10/2009 16:24	
TEST CARRIED OUT BY		MS WITNESS: VS	

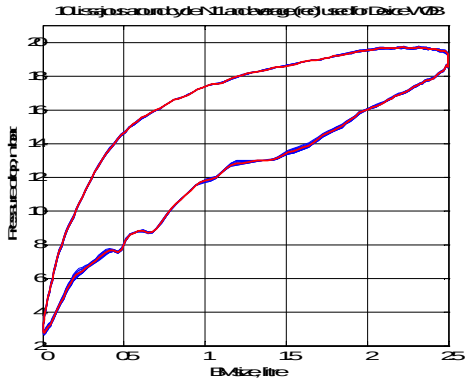
CONDITIONS OF TEST

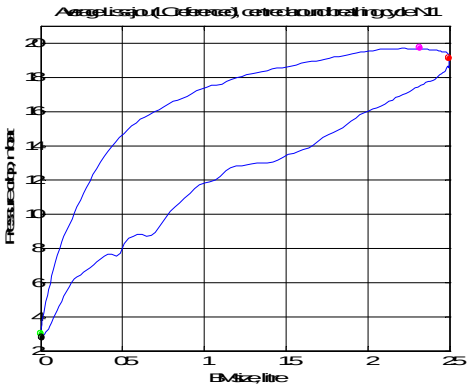
ATTITIDE: PITCH & ROLL	:	180/0	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	18.0 / 4.5	℃
EHXALE GAS TEMPERATURE	:	15.5	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/24.9bpm/62.4lpm	standard

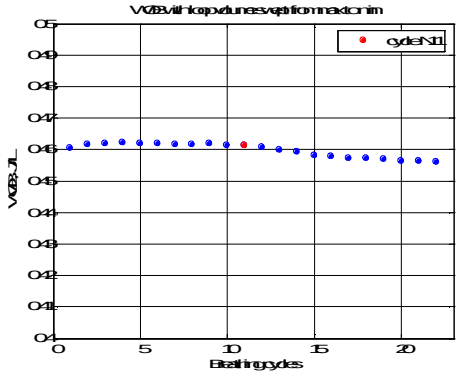
RESULTS

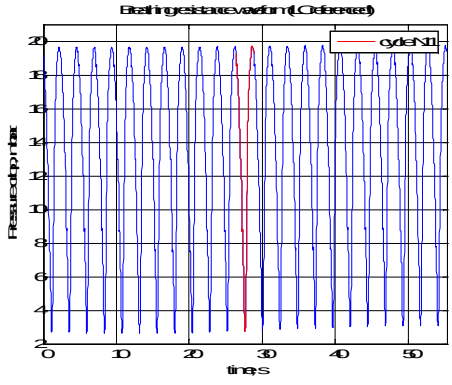
PRESSURE@END EXHALE/INHALE	=	19.1 / 3.0	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	19.1	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)	=	26.1	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	19.7 / 2.8	mbar
INHALE/EXHALE RESP PRESSURE	=	16.3 / 16.7	mbar
PEAK TO PEAK PRESSURE	=	16.9	mbar
ELASTANCE	=	6.5	mbar/litre
WORK OF BREATHING	=	0.46	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_SRB01_62_5lpm_101029_opt









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL SRB SN1 (ALVBOV equipped)	
TEST METHOD		EN14143:2003	SINE FLOW
DATE AND TIME		01/10/2009 16:29	
TEST CARRIED OUT BY		MS WITNESS: VS	

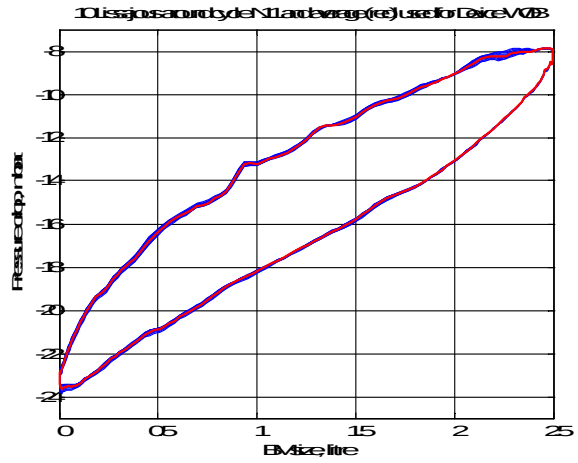
CONDITIONS OF TEST

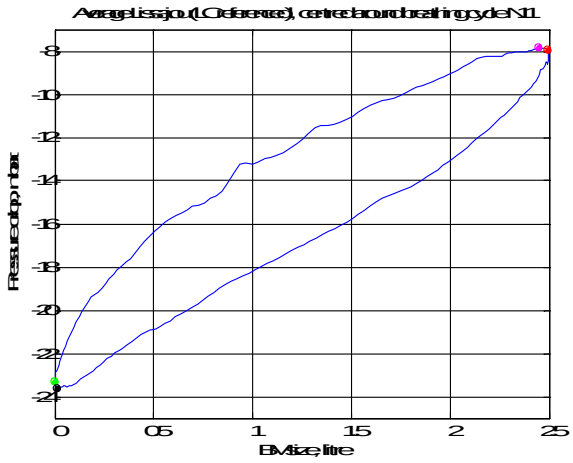
ATTITIDE: PITCH & ROLL	:	90/0	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	18.0 / 4.5	℃
EHXALE GAS TEMPERATURE	:	15.5	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/24.9bpm/62.4lpm	standard

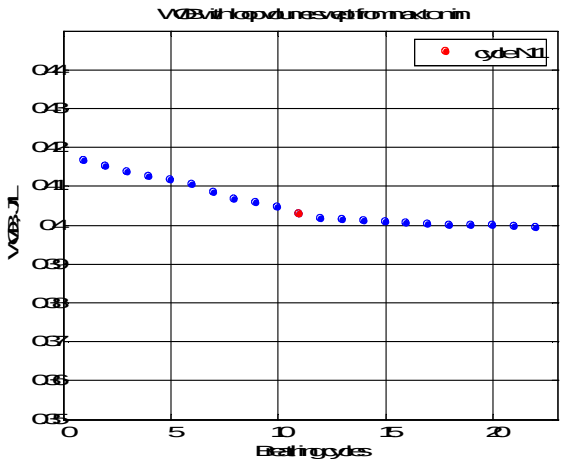
RESULTS

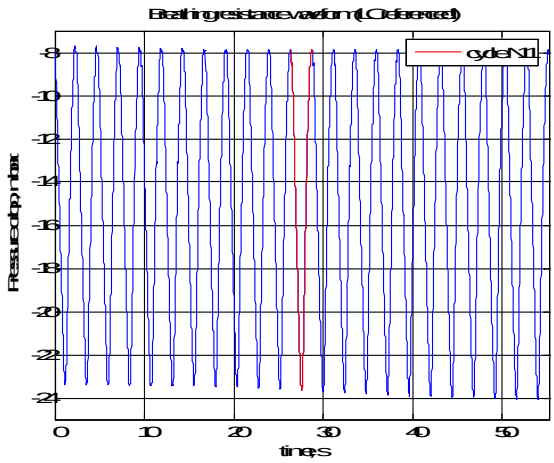
PRESSURE@END EXHALE/INHALE	=	-8.0 / -23.4	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	-8.0	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)	=	5.5	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	-7.9 / -23.6	mbar
INHALE/EXHALE RESP PRESSURE	=	15.7 / 15.5	mbar
PEAK TO PEAK PRESSURE	=	15.8	mbar
ELASTANCE	=	6.2	mbar/litre
WORK OF BREATHING	=	0.40	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_SRB01_62_5lpm_90_0_091001_opt









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL SRB SN1 (ALVBOV equipped)	
TEST METHOD		EN14143:2003	SINE FLOW
DATE AND TIME		01/10/2009 16:32	
TEST CARRIED OUT BY		MS WITNESS: VS	

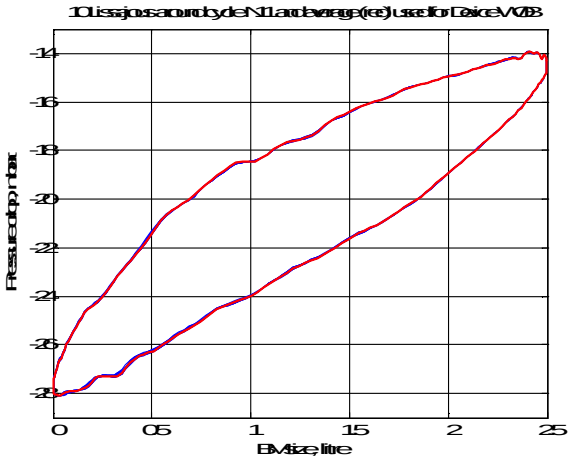
CONDITIONS OF TEST

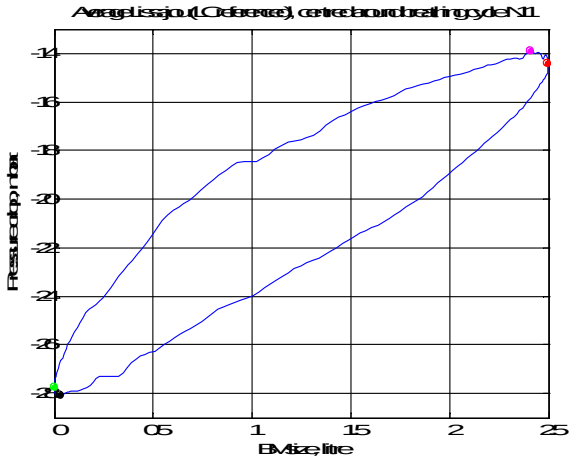
ATTITIDE: PITCH & ROLL	:	45/0	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	18.0 / 4.5	℃
EHXALE GAS TEMPERATURE	:	15.5	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/24.9bpm/62.4lpm	standard

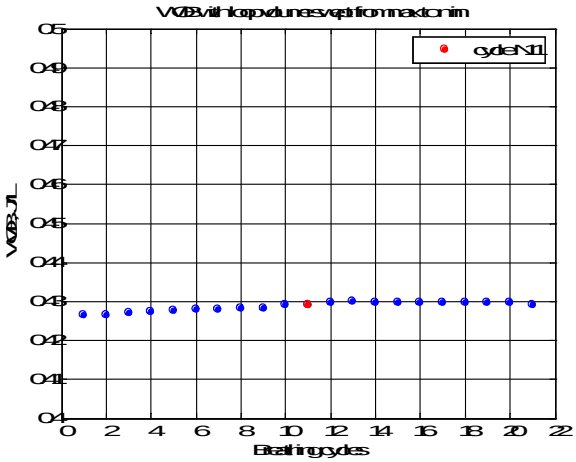
RESULTS

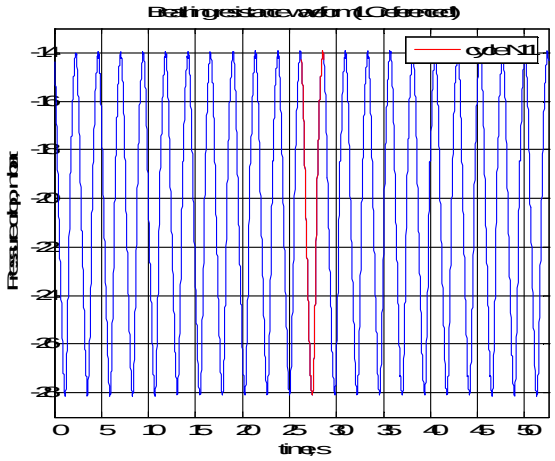
PRESSURE@END EXHALE/INHALE	=	-14.4 / -27.7	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	-14.4	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)	=	-9.8	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	-13.9 / -28.1	mbar
INHALE/EXHALE RESP PRESSURE	=	13.6 / 13.8	mbar
PEAK TO PEAK PRESSURE	=	14.2	mbar
ELASTANCE	=	5.3	mbar/litre
WORK OF BREATHING	=	0.43	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_SRB01_62_5lpm_45_0_091001_opt









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL SRB SN1 (ALVBOV equipped)	
TEST METHOD		EN14143:2003	SINE FLOW
DATE AND TIME		01/10/2009 16:21	
TEST CARRIED OUT BY		MS WITNESS: VS	

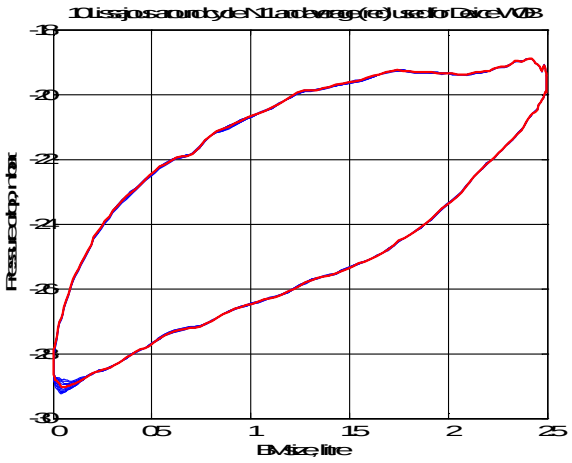
CONDITIONS OF TEST

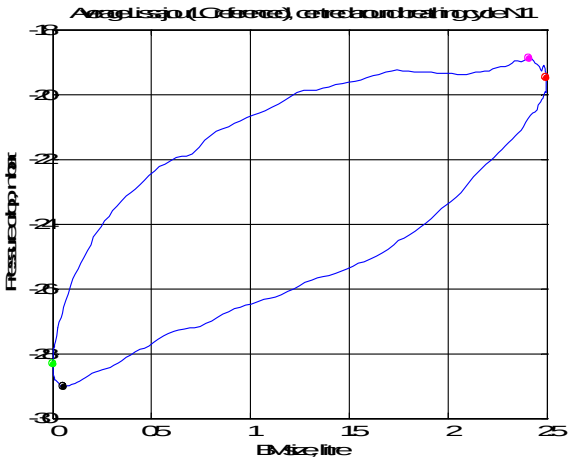
ATTITIDE: PITCH & ROLL	:	0/0	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	18.0 / 4.5	℃
EHXALE GAS TEMPERATURE	:	15.5	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/24.9bpm/62.4lpm	standard

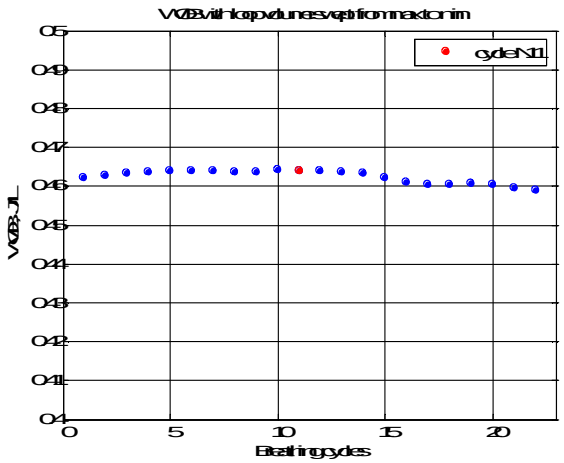
RESULTS

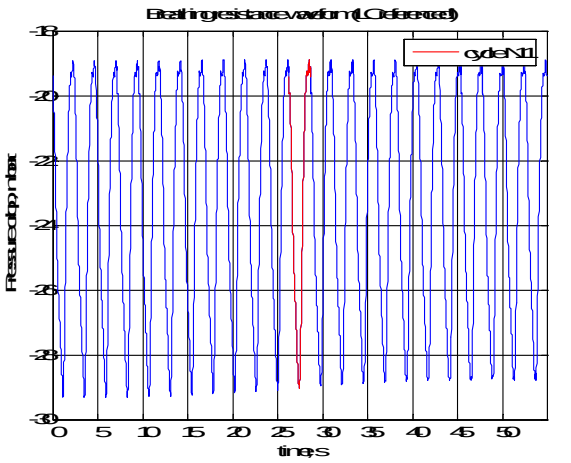
PRESSURE@END EXHALE/INHALE	=	-19.5 / -28.3	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	-19.5	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)	=	-26.5	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	-18.9 / -29.0	mbar
INHALE/EXHALE RESP PRESSURE	=	9.5 / 9.4	mbar
PEAK TO PEAK PRESSURE	=	10.2	mbar
ELASTANCE	=	3.5	mbar/litre
WORK OF BREATHING	=	0.46	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_SRB01_62_5lpm_0_0_091001_opt









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL SRB SN1 (ALVBOV equipped)	
TEST METHOD		EN14143:2003	SINE FLOW
DATE AND TIME		01/10/2009 16:35	
TEST CARRIED OUT BY	MS	WITNESS: VS	

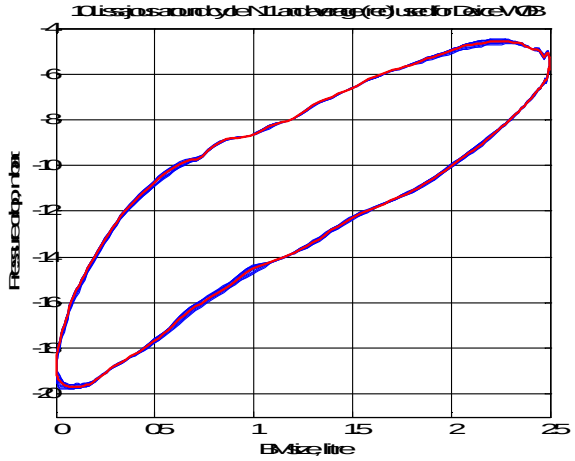
CONDITIONS OF TEST

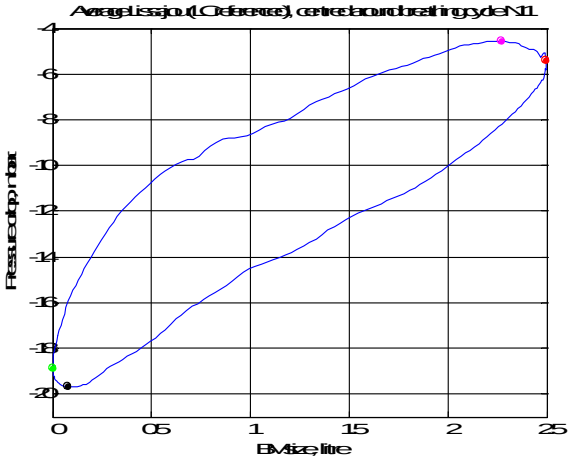
ATTITIDE: PITCH & ROLL	:	-45/0	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	18.0 / 4.5	℃
EHXALE GAS TEMPERATURE	:	15.5	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/24.9bpm/62.4lpm	standard

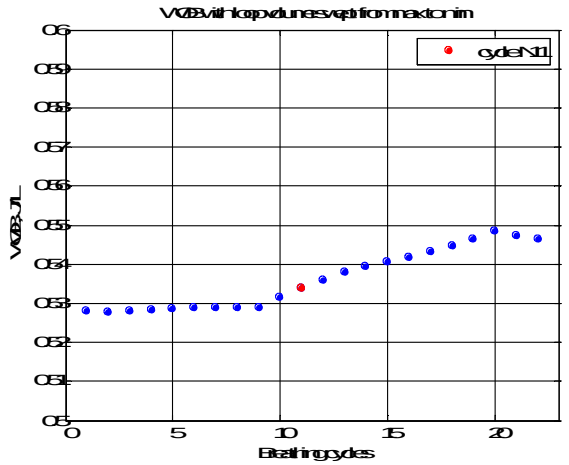
RESULTS

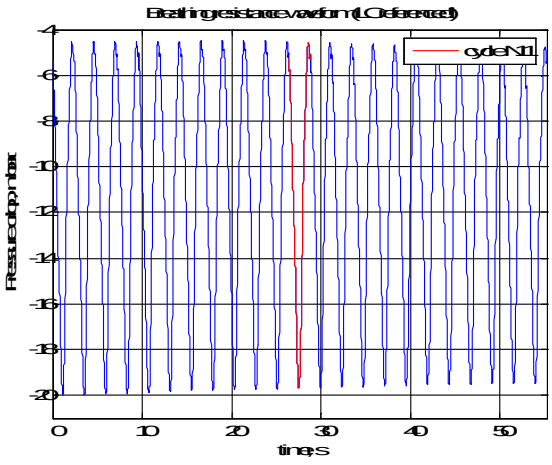
PRESSURE@END EXHALE/INHALE	=	-5.4 / -18.9	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	-5.4	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)	=	-19.9	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	-4.6 / -19.7	mbar
INHALE/EXHALE RESP PRESSURE	=	14.3 / 14.3	mbar
PEAK TO PEAK PRESSURE	=	15.1	mbar
ELASTANCE	=	5.4	mbar/litre
WORK OF BREATHING	=	0.53	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_SRB01_62_5lpm_-45_0_091001_opt









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL SRB SN1 (ALVBOV equipped)	
TEST METHOD		EN14143:2003	SINE FLOW
DATE AND TIME		01/10/2009 16:39	
TEST CARRIED OUT BY		MS WITNESS: VS	

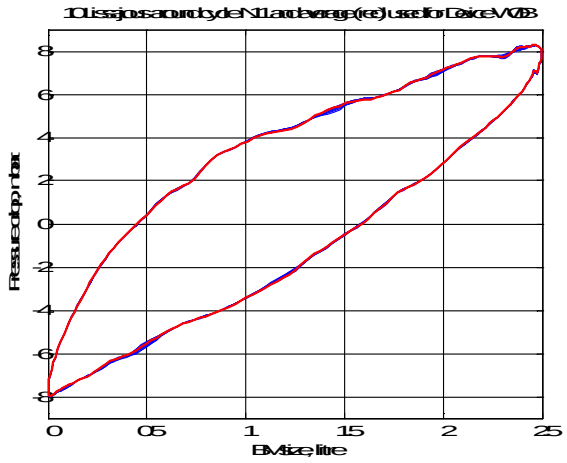
CONDITIONS OF TEST

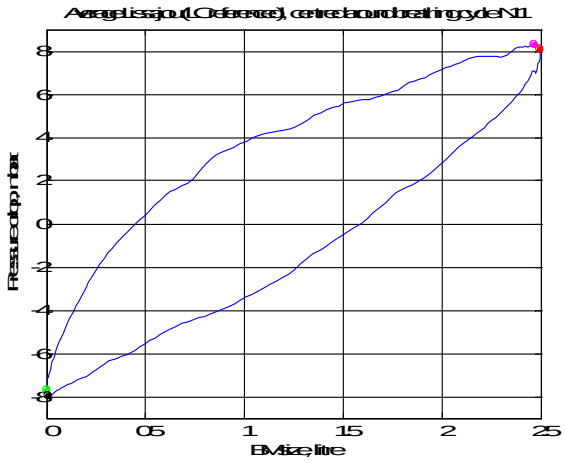
ATTITIDE: PITCH & ROLL	:	-90/0	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	18.0 / 4.5	℃
EHXALE GAS TEMPERATURE	:	15.5	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/24.9bpm/62.4lpm	standard

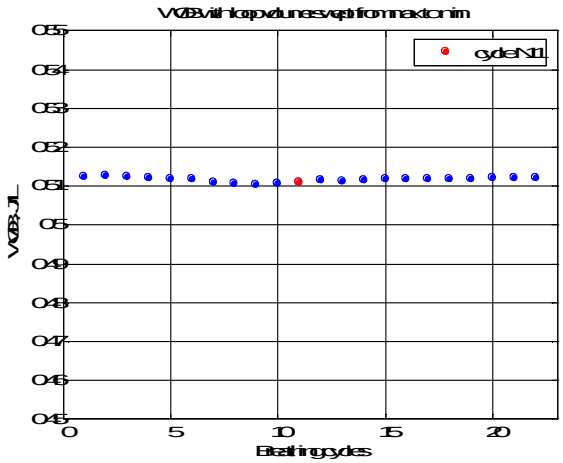
RESULTS

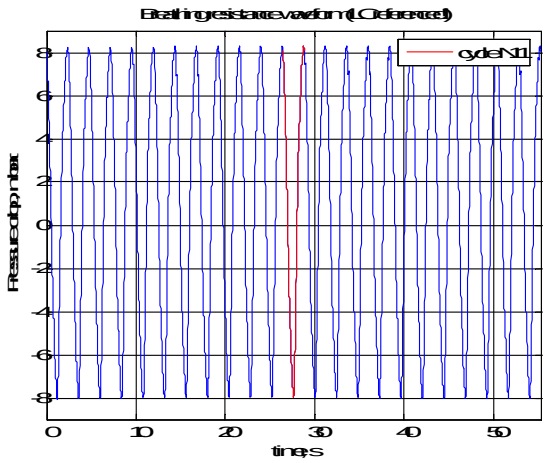
PRESSURE@END EXHALE/INHALE	=	8.1 / -7.7	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	8.1	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)	=	-5.4	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	8.3 / -8.0	mbar
INHALE/EXHALE RESP PRESSURE	=	16.0 / 16.0	mbar
PEAK TO PEAK PRESSURE	=	16.3	mbar
ELASTANCE	=	6.3	mbar/litre
WORK OF BREATHING	=	0.51	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_SRB01_62_5lpm_-90_0_091001_opt









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL SRB SN1 (ALVBOV equipped)	
TEST METHOD		EN14143:2003	SINE FLOW
DATE AND TIME		01/10/2009 16:41	
TEST CARRIED OUT BY	MS	WITNESS: VS	

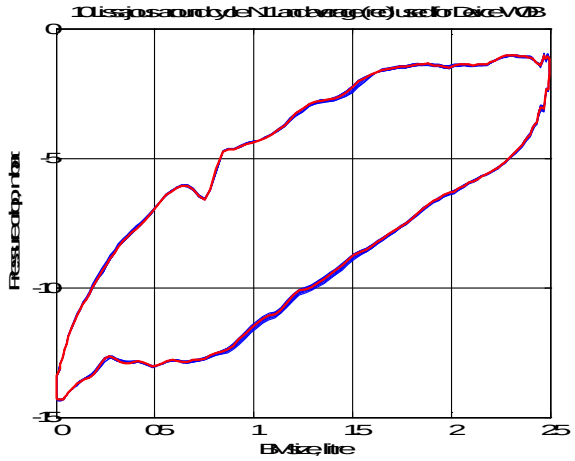
CONDITIONS OF TEST

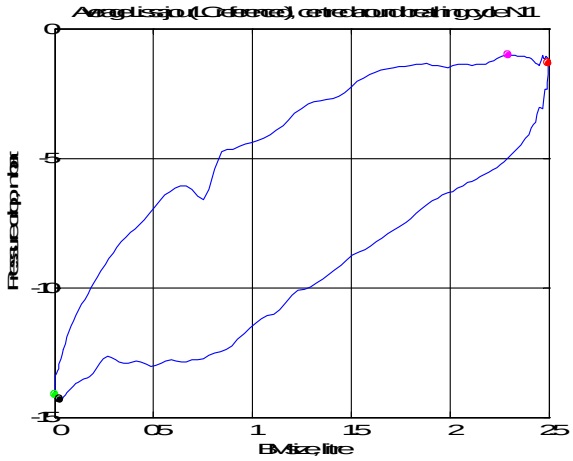
ATTITIDE: PITCH & ROLL	:	0/90	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	18.0 / 4.5	℃
EHXALE GAS TEMPERATURE	:	15.5	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/25.0bpm/62.5lpm	standard

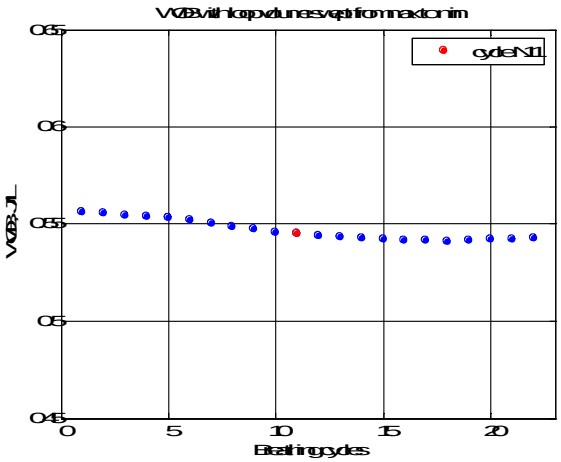
RESULTS

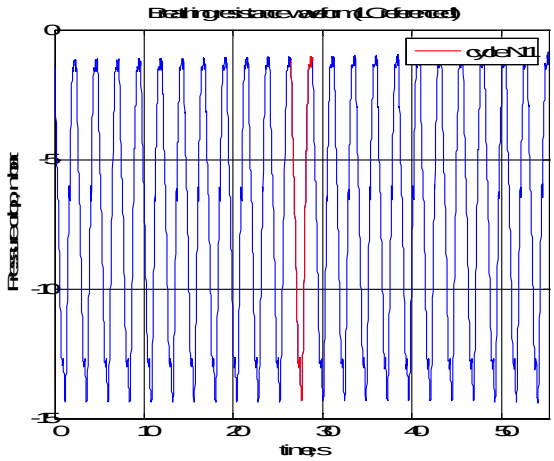
PRESSURE@END EXHALE/INHALE	=	-1.3 / -14.2	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	-1.3	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)	=	-1.3	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	-1.0 / -14.3	mbar
INHALE/EXHALE RESP PRESSURE	=	13.0 / 13.1	mbar
PEAK TO PEAK PRESSURE	=	13.3	mbar
ELASTANCE	=	5.1	mbar/litre
WORK OF BREATHING	=	0.54	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_SRB01_62_5lpm_0_90_091001_opt









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL SRB SN1 (ALVBOV equipped)	
TEST METHOD		EN14143:2003	SINE FLOW
DATE AND TIME		01/10/2009 16:44	
TEST CARRIED OUT BY		MS WITNESS: VS	

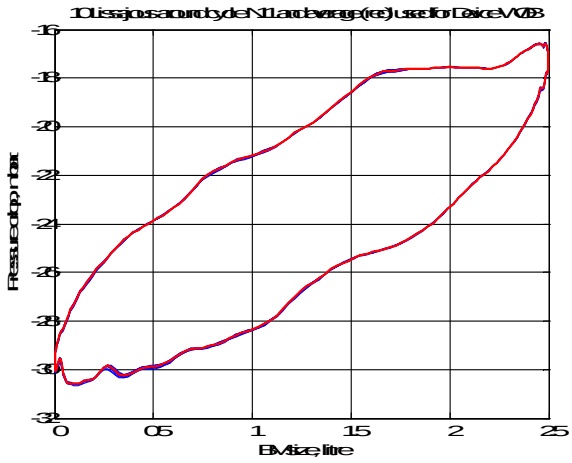
CONDITIONS OF TEST

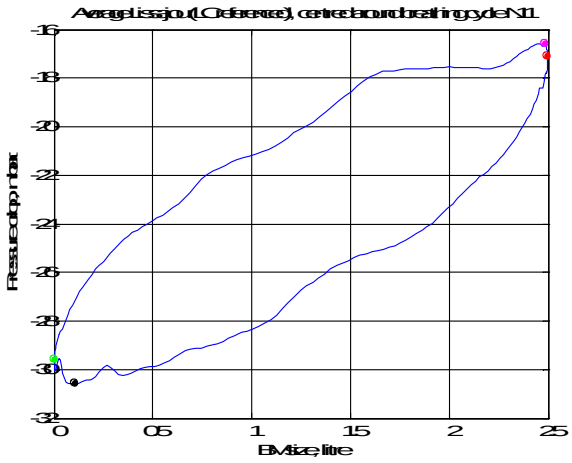
ATTITIDE: PITCH & ROLL	:	0/45	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	18.0 / 4.5	℃
EHXALE GAS TEMPERATURE	:	15.5	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/25.0bpm/62.4lpm	standard

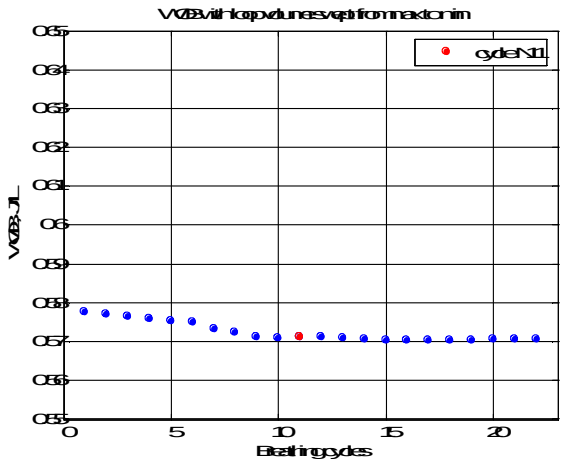
RESULTS

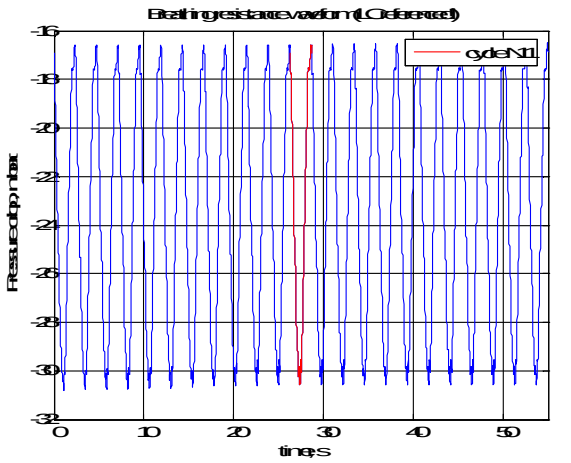
PRESSURE@END EXHALE/INHALE	=	-17.1 / -29.6	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	-17.1	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)	=	-12.2	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	-16.6 / -30.6	mbar
INHALE/EXHALE RESP PRESSURE	=	13.5 / 13.0	mbar
PEAK TO PEAK PRESSURE	=	14.0	mbar
ELASTANCE	=	5.0	mbar/litre
WORK OF BREATHING	=	0.57	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_SRB01_62_5lpm_0_45_091001_opt









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL SRB SN1 (ALVBOV equipped)	
TEST METHOD		EN14143:2003	SINE FLOW
DATE AND TIME		01/10/2009 17:00	
TEST CARRIED OUT BY	MS	WITNESS: VS	

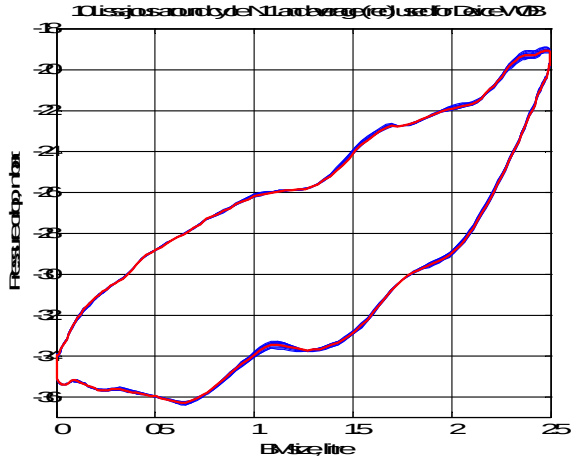
CONDITIONS OF TEST

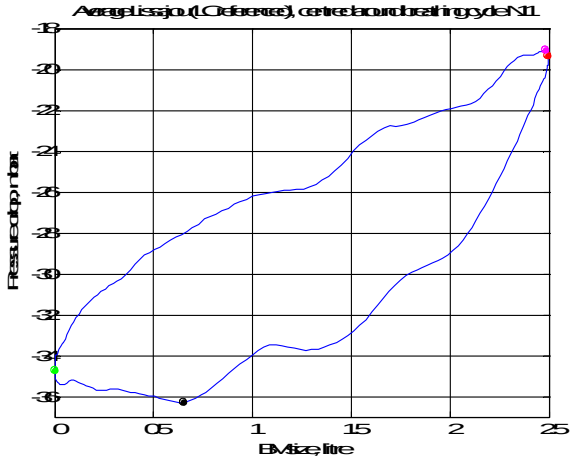
ATTITIDE: PITCH & ROLL	:	0/-45	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	18.0 / 4.5	℃
EHXALE GAS TEMPERATURE	:	15.5	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/25.0bpm/62.4lpm	standard

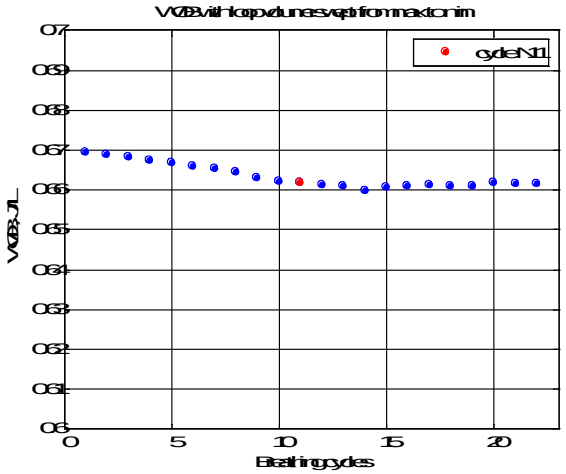
RESULTS

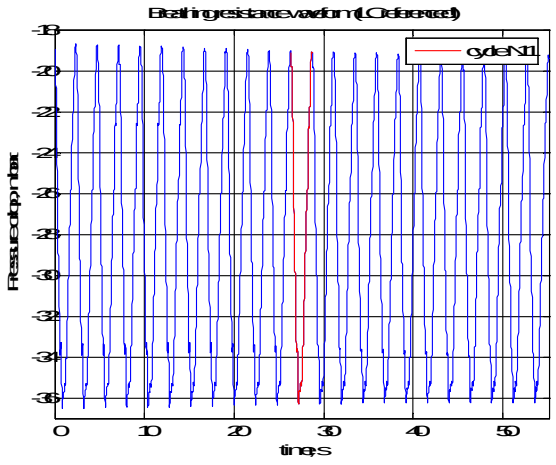
PRESSURE@END EXHALE/INHALE	=	-19.4 / -34.8	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	-19.4	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)	=	-14.5	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	-19.1 / -36.3	mbar
INHALE/EXHALE RESP PRESSURE	=	17.0 / 15.7	mbar
PEAK TO PEAK PRESSURE	=	17.2	mbar
ELASTANCE	=	6.2	mbar/litre
WORK OF BREATHING	=	0.66	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_SRB01_62_5lpm_0_-45_091001_opt









RESPIRATORY PERFORMANCE MEASUREMENT

QUIPMENT TYPE & SERIAL NUMBER	:	DL SRB SN1 (ALVBOV equipped)	
TEST METHOD		EN14143:2003	SINE FLOW
DATE AND TIME		01/10/2009 16:55	
TEST CARRIED OUT BY		MS WITNESS: VS	

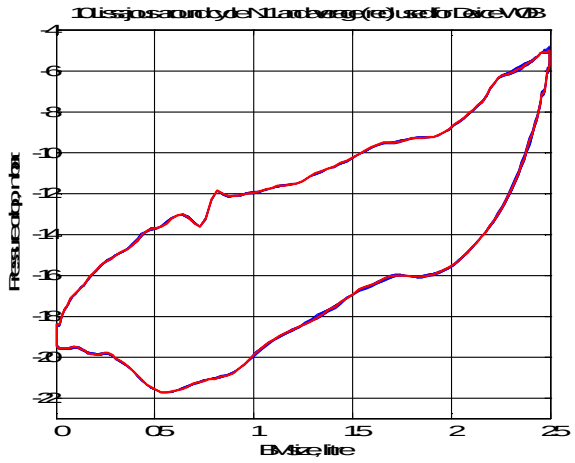
CONDITIONS OF TEST

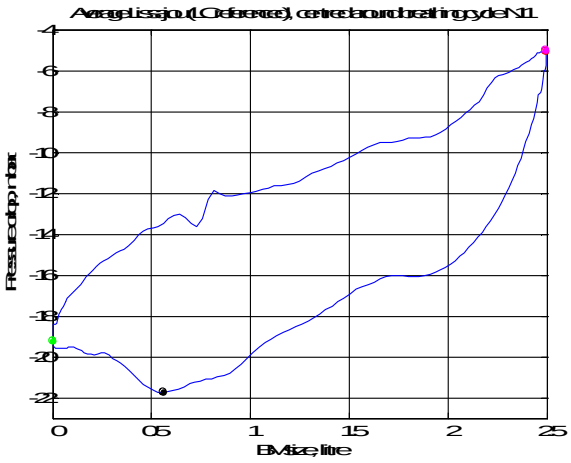
ATTITIDE: PITCH & ROLL	:	0/-90	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	18.0 / 4.5	℃
EHXALE GAS TEMPERATURE	:	15.5	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/25.0bpm/62.4lpm	standard

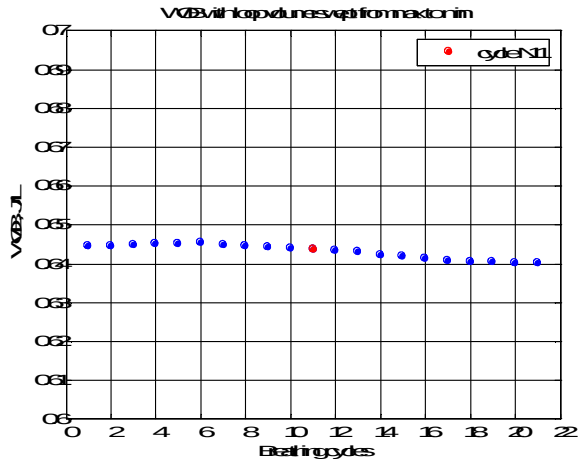
RESULTS

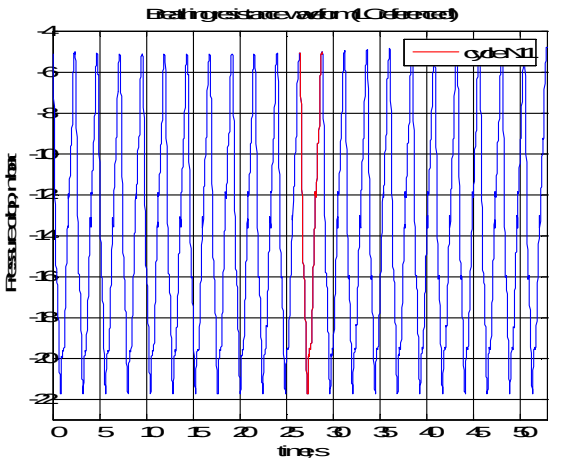
PRESSURE@END EXHALE/INHALE	=	-5.1 / -19.2	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	-5.1	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)	=	-5.1	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	-5.0 / -21.8	mbar
INHALE/EXHALE RESP PRESSURE	=	16.6 / 14.2	mbar
PEAK TO PEAK PRESSURE	=	16.7	mbar
ELASTANCE	=	5.6	mbar/litre
WORK OF BREATHING	=	0.64	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_SRB01_62_5lpm_0_-90_091001_opt









9.2 Empirical Results for OR Umbilical Model

RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL DRB SN1112 (ALVBOV equipped)	
TEST METHOD	:	EN14143:2003	SINE FLOW
DATE AND TIME	:	01/10/2009 11:17	
TEST CARRIED OUT BY		MS WITNESS: VS	

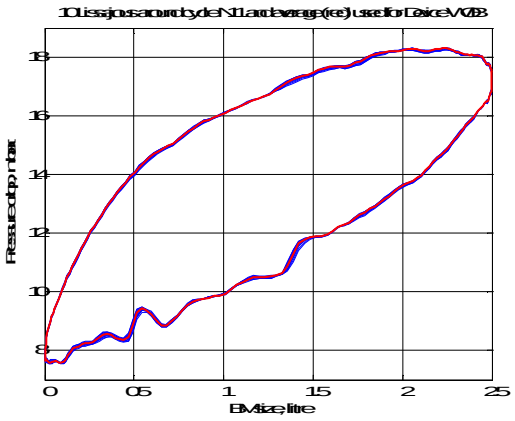
CONDITIONS OF TEST

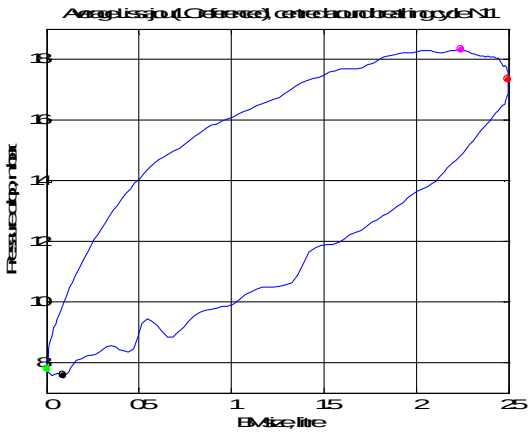
ATTITIDE: PITCH & ROLL	:	180/0	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	24.0 / 4.1	℃
EHXALE GAS TEMPERATURE	:	14.8	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/25.0bpm/62.5lpm	standard

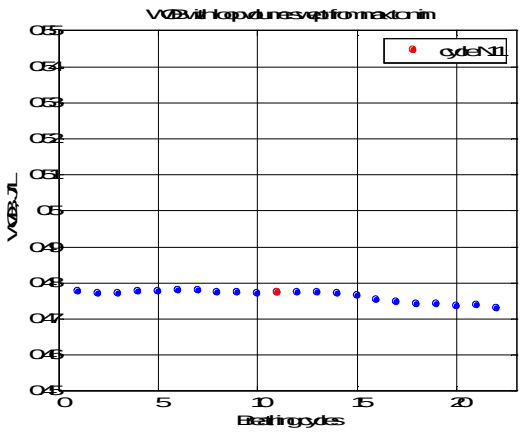
RESULTS

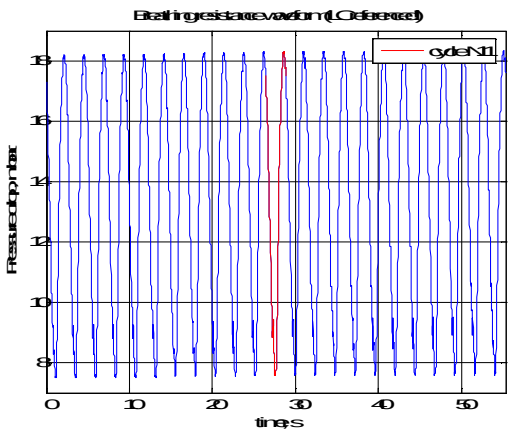
PRESSURE@END EXHALE/INHALE	=	17.3 / 7.8	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	17.3	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)		24.3	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	18.3 / 7.6	mbar
INHALE/EXHALE RESP PRESSURE	=	9.8 / 10.5	mbar
PEAK TO PEAK PRESSURE	=	10.7	mbar
ELASTANCE	=	3.8	mbar/litre
WORK OF BREATHING	=	0.48	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_DRB01_62_5lpm_101029_opt









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL DRB SN1112 (ALVBOV equipped)	
TEST METHOD	:	EN14143:2003	SINE FLOW
DATE AND TIME	:	01/10/2009 11:21	
TEST CARRIED OUT BY		MS WITNESS: VS	

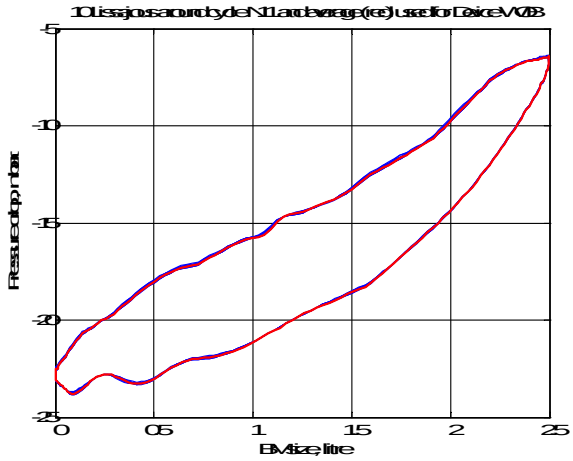
CONDITIONS OF TEST

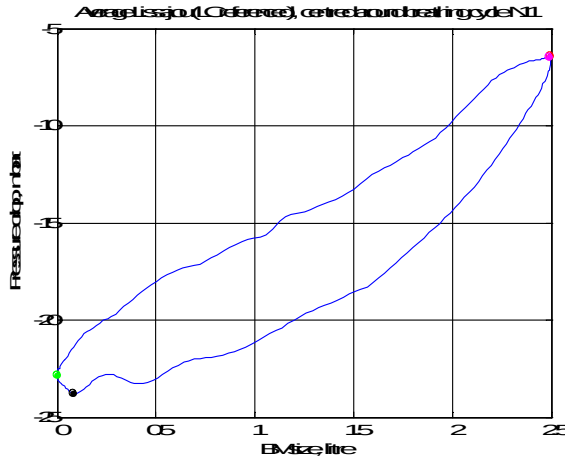
ATTITIDE: PITCH & ROLL	:	90/0	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	24.0 / 4.1	℃
EHXALE GAS TEMPERATURE	:	14.8	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/25.0bpm/62.5lpm	standard

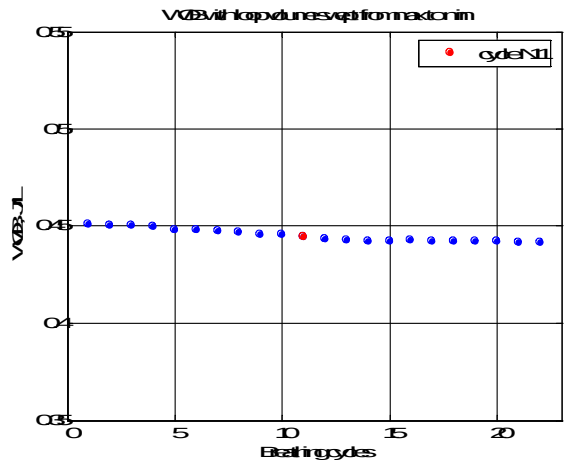
RESULTS

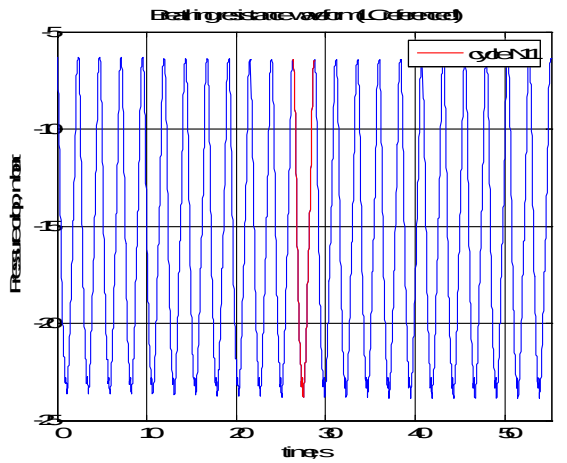
PRESSURE@END EXHALE/INHALE	=	-6.4 / -22.9	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	-6.4	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)		7.1	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	-6.5 / -23.8	mbar
INHALE/EXHALE RESP PRESSURE	=	17.3 / 16.4	mbar
PEAK TO PEAK PRESSURE	=	17.3	mbar
ELASTANCE	=	6.6	mbar/litre
WORK OF BREATHING	=	0.44	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_DRB01_62_5lpm_90_0_091001_opt









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL DRB SN1112 (ALVBOV equipped)	
TEST METHOD	:	EN14143:2003	SINE FLOW
DATE AND TIME	:	01/10/2009 11:27	
TEST CARRIED OUT BY		MS WITNESS: VS	

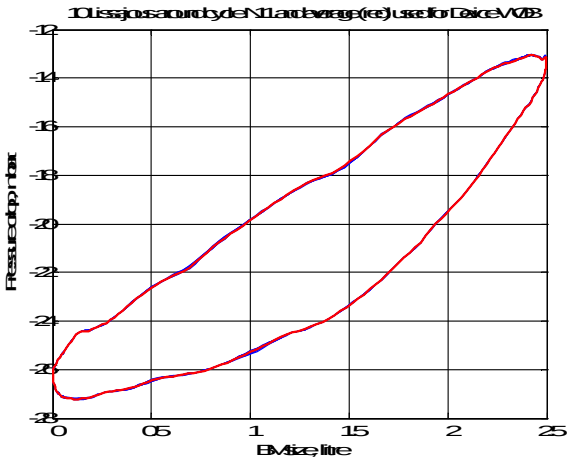
CONDITIONS OF TEST

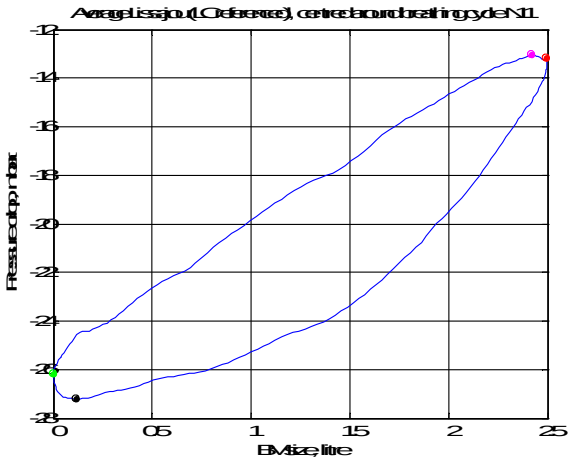
ATTITIDE: PITCH & ROLL	:	45/0	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	24.0 / 4.1	℃
EHXALE GAS TEMPERATURE	:	14.8	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/25.0bpm/62.5lpm	standard

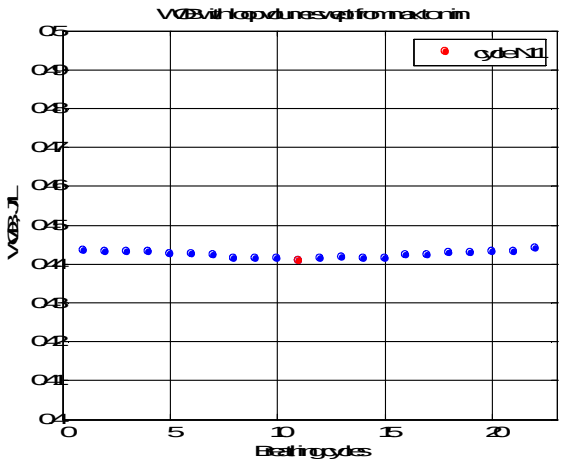
RESULTS

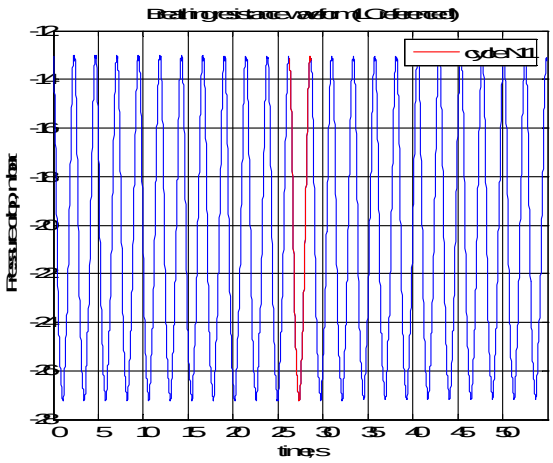
PRESSURE@END EXHALE/INHALE	=	-13.2 / -26.2	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	-13.2	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)		-8.6	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	-13.0 / -27.2	mbar
INHALE/EXHALE RESP PRESSURE	=	14.0 / 13.2	mbar
PEAK TO PEAK PRESSURE	=	14.2	mbar
ELASTANCE	=	5.2	mbar/litre
WORK OF BREATHING	=	0.44	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_DRB01_62_5lpm_45_0_091001_opt









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL DRB SN1112 (ALVBOV equipped)	
TEST METHOD	:	EN14143:2003	SINE FLOW
DATE AND TIME	:	01/10/2009 11:11	
TEST CARRIED OUT BY		MS WITNESS: VS	

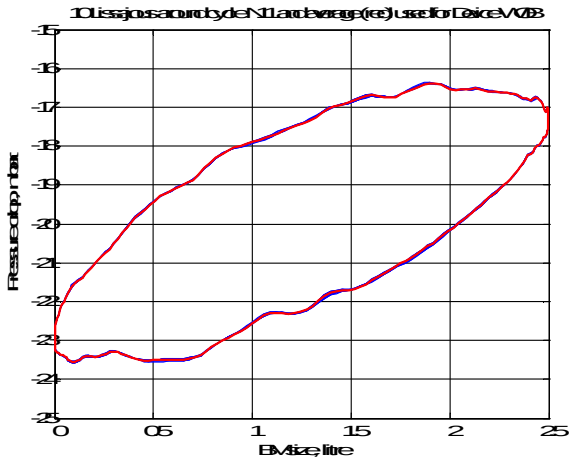
CONDITIONS OF TEST

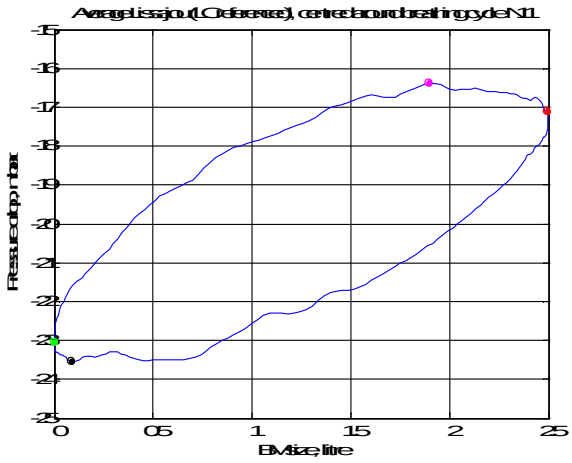
ATTITIDE: PITCH & ROLL	:	0/0	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	24.0 / 4.1	℃
EHXALE GAS TEMPERATURE	:	14.8	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/25.0bpm/62.5lpm	standard

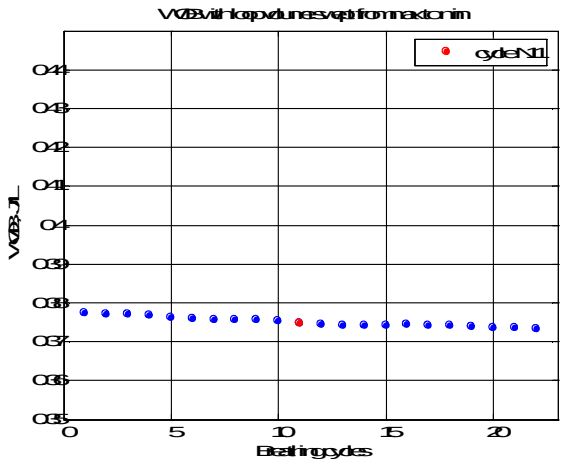
RESULTS

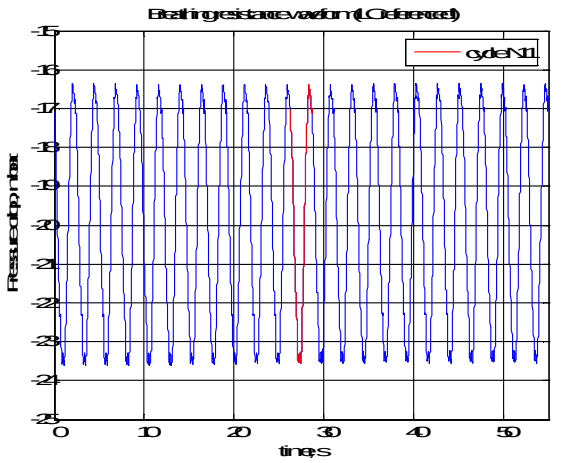
PRESSURE@END EXHALE/INHALE	=	-17.1 / -23.1	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	-17.1	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)	=	-24.1	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	-16.4 / -23.6	mbar
INHALE/EXHALE RESP PRESSURE	=	6.4 / 6.7	mbar
PEAK TO PEAK PRESSURE	=	7.2	mbar
ELASTANCE	=	2.4	mbar/litre
WORK OF BREATHING	=	0.37	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_DRB01_62_5lpm_0_0_091001_opt









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL DRB SN1112 (ALVBOV equipped)	
TEST METHOD	:	EN14143:2003	SINE FLOW
DATE AND TIME	:	01/10/2009 11:31	
TEST CARRIED OUT BY	MS	WITNESS: VS	

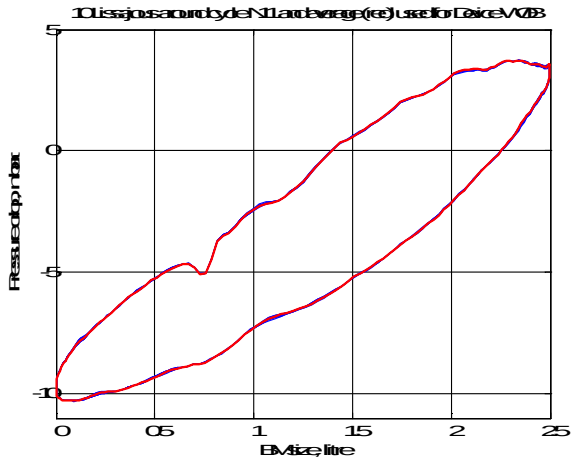
CONDITIONS OF TEST

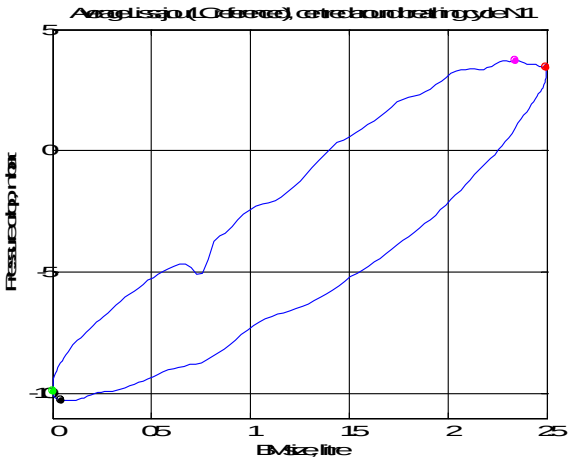
ATTITIDE: PITCH & ROLL	:	-45/0	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	24.0 / 4.1	℃
EHXALE GAS TEMPERATURE	:	14.8	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/25.0bpm/62.5lpm	standard

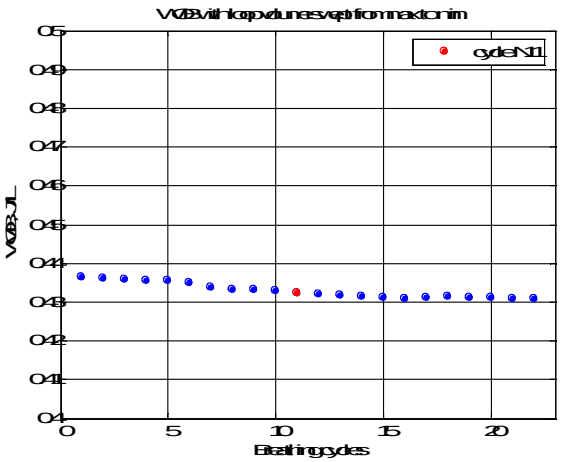
RESULTS

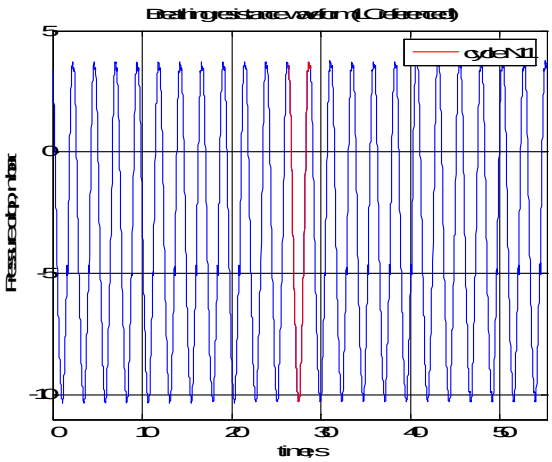
PRESSURE@END EXHALE/INHALE	=	3.4 / -9.9	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	3.4	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)	=	-11.1	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	3.7 / -10.3	mbar
INHALE/EXHALE RESP PRESSURE	=	13.7 / 13.6	mbar
PEAK TO PEAK PRESSURE	=	14.0	mbar
ELASTANCE	=	5.3	mbar/litre
WORK OF BREATHING	=	0.43	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_DRB01_62_5lpm_-45_0_091001_opt









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL DRB SN1112 (ALVBOV equipped)	
TEST METHOD	:	EN14143:2003	SINE FLOW
DATE AND TIME	:	01/10/2009 11:36	
TEST CARRIED OUT BY		MS WITNESS: VS	

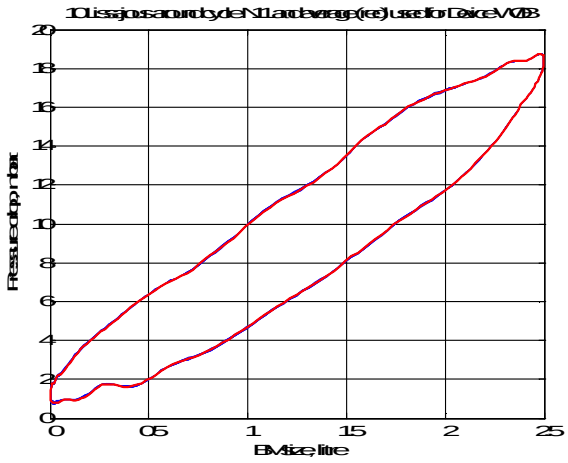
CONDITIONS OF TEST

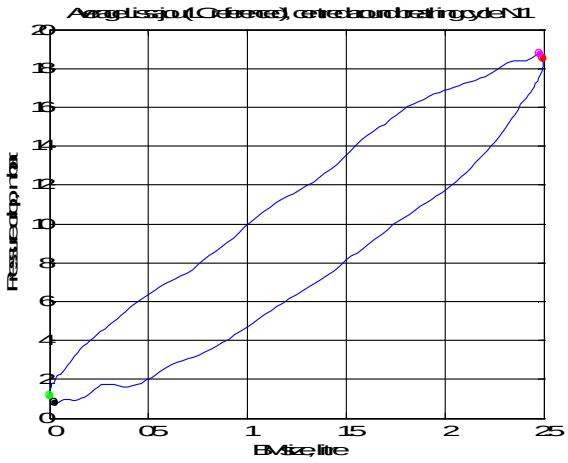
ATTITIDE: PITCH & ROLL	:	-90/0	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	24.0 / 4.1	℃
EHXALE GAS TEMPERATURE	:	14.8	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/25.0bpm/62.5lpm	standard

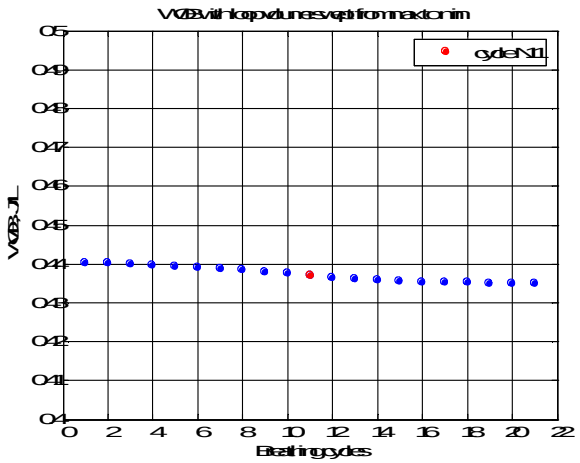
RESULTS

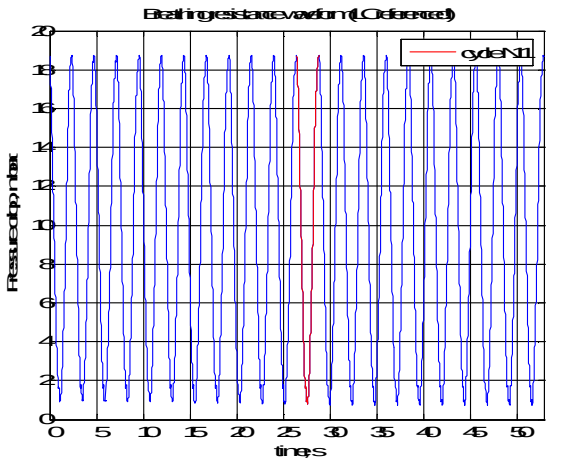
PRESSURE@END EXHALE/INHALE	=	18.5 / 1.1	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	18.5	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)	=	5.0	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	18.8 / 0.8	mbar
INHALE/EXHALE RESP PRESSURE	=	17.8 / 17.6	mbar
PEAK TO PEAK PRESSURE	=	18.0	mbar
ELASTANCE	=	7.0	mbar/litre
WORK OF BREATHING	=	0.44	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_DRB01_62_5lpm_-90_0_091001_opt









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL DRB SN1112 (ALVBOV equipped)	
TEST METHOD	:	EN14143:2003	SINE FLOW
DATE AND TIME	:	01/10/2009 11:41	
TEST CARRIED OUT BY	MS	WITNESS: VS	

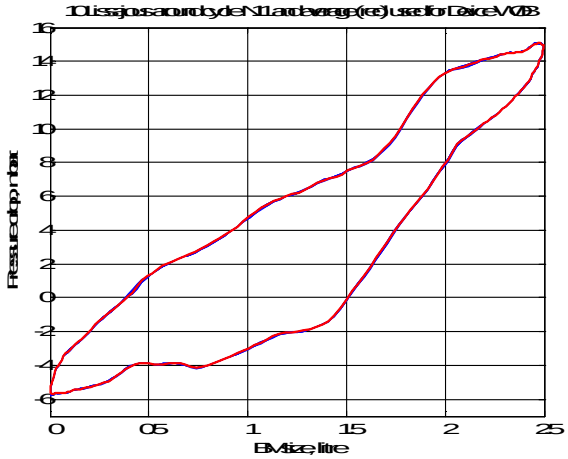
CONDITIONS OF TEST

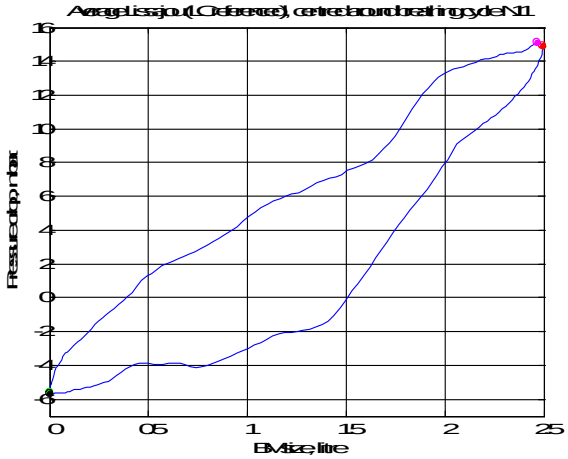
ATTITIDE: PITCH & ROLL	:	0/90	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	24.0 / 4.1	℃
EHXALE GAS TEMPERATURE	:	14.8	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/25.0bpm/62.5lpm	standard

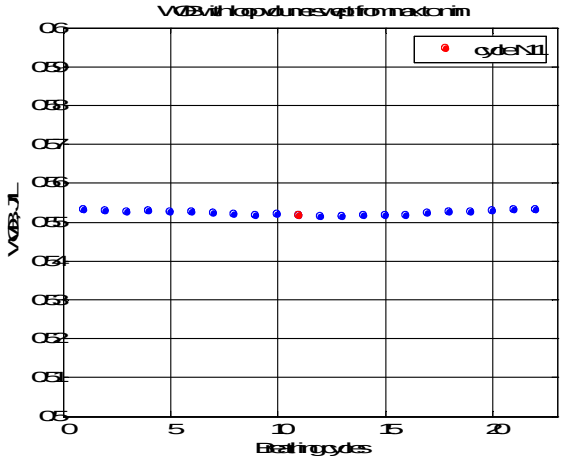
RESULTS

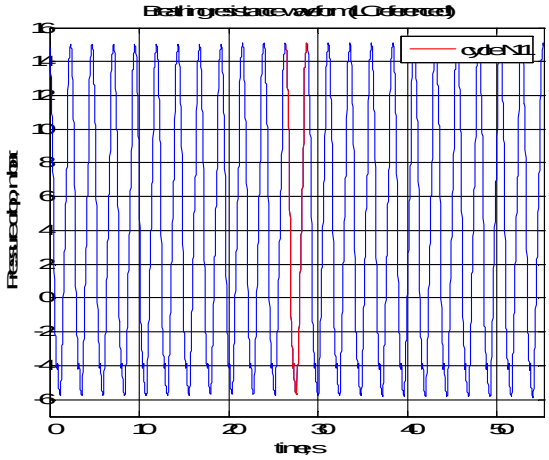
PRESSURE@END EXHALE/INHALE	=	14.9 / -5.6	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	14.9	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)	=	14.9	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	15.1 / -5.7	mbar
INHALE/EXHALE RESP PRESSURE	=	20.6 / 20.7	mbar
PEAK TO PEAK PRESSURE	=	20.8	mbar
ELASTANCE	=	8.2	mbar/litre
WORK OF BREATHING	=	0.55	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_DRB01_62_5lpm_0_90_091001_opt









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL DRB SN1112 (ALVBOV equipped)	
TEST METHOD	:	EN14143:2003	SINE FLOW
DATE AND TIME	:	01/10/2009 11:44	
TEST CARRIED OUT BY		MS WITNESS: VS	

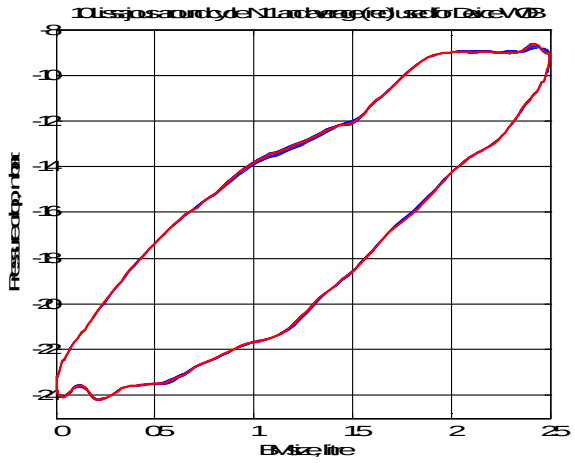
CONDITIONS OF TEST

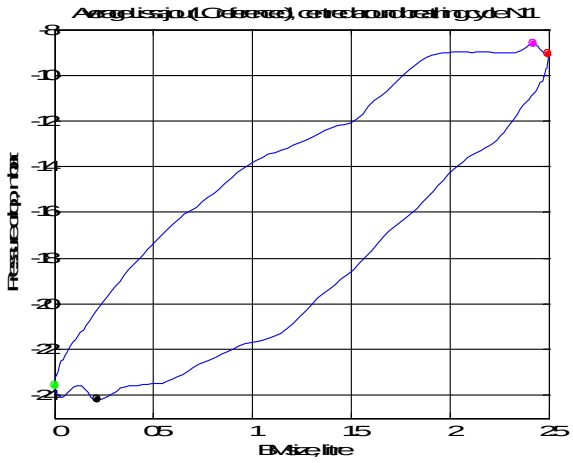
ATTITIDE: PITCH & ROLL	:	0/45	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	24.0 / 4.1	℃
EHXALE GAS TEMPERATURE	:	14.8	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/25.0bpm/62.5lpm	standard

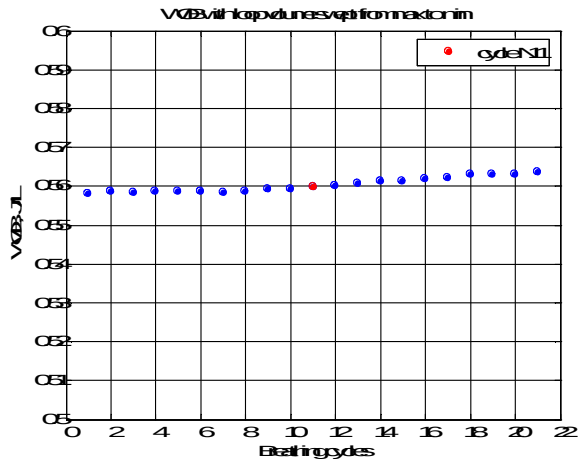
RESULTS

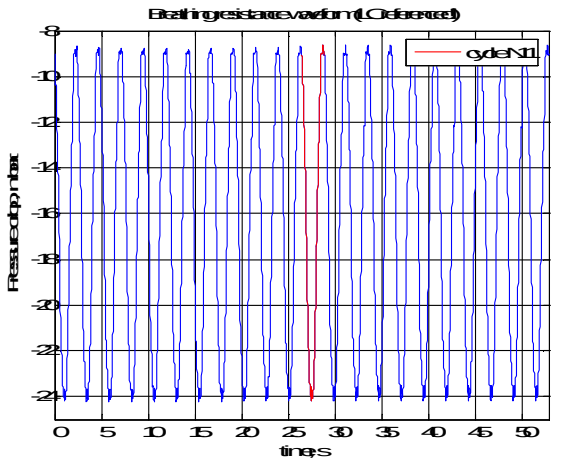
PRESSURE@END EXHALE/INHALE	=	-9.1 / -23.6	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	-9.1	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)	=	-4.2	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	-8.6 / -24.2	mbar
INHALE/EXHALE RESP PRESSURE	=	15.1 / 15.0	mbar
PEAK TO PEAK PRESSURE	=	15.6	mbar
ELASTANCE	=	5.8	mbar/litre
WORK OF BREATHING	=	0.56	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_DRB01_62_5lpm_0_45_091001_opt









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL DRB SN1112 (ALVBOV equipped)	
TEST METHOD	:	EN14143:2003	SINE FLOW
DATE AND TIME	:	01/10/2009 11:49	
TEST CARRIED OUT BY		MS WITNESS: VS	

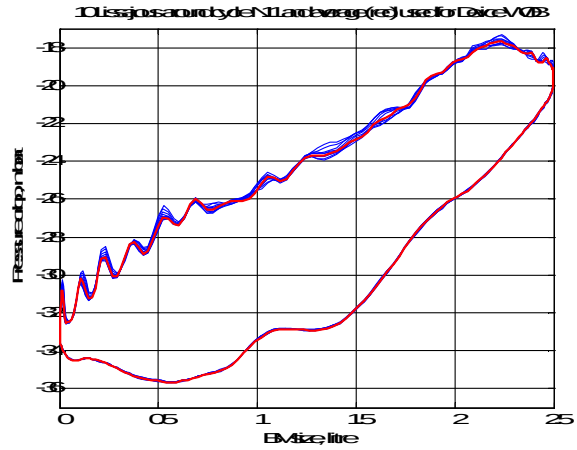
CONDITIONS OF TEST

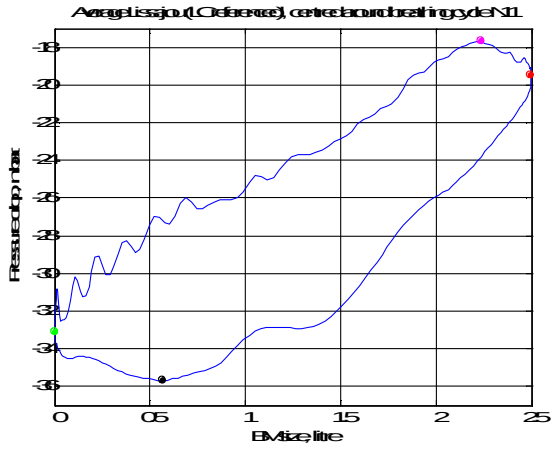
ATTITIDE: PITCH & ROLL	:	0/-45	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	24.0 / 4.1	℃
EHXALE GAS TEMPERATURE	:	14.8	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/25.0bpm/62.5lpm	standard

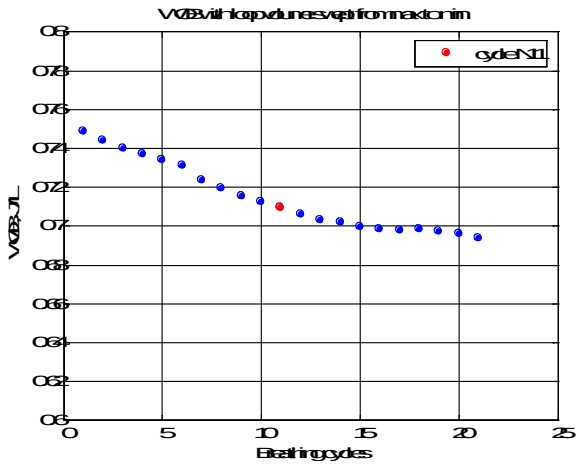
RESULTS

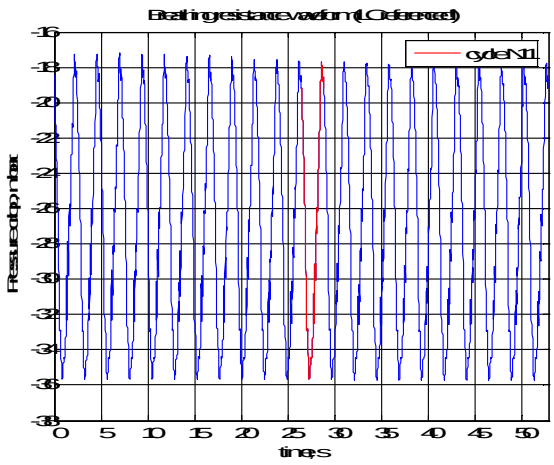
PRESSURE@END EXHALE/INHALE	=	-19.5 / -33.1	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	-19.5	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)	=	-14.6	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	-17.7 / -35.7	mbar
INHALE/EXHALE RESP PRESSURE	=	16.2 / 15.5	mbar
PEAK TO PEAK PRESSURE	=	18.0	mbar
ELASTANCE	=	5.5	mbar/litre
WORK OF BREATHING	=	0.71	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_DRB01_62_5lpm_0_-45_091001_opt









RESPIRATORY PERFORMANCE MEASUREMENT

EQUIPMENT TYPE & SERIAL NUMBER	:	DL DRB SN1112 (ALVBOV equipped)	
TEST METHOD	:	EN14143:2003	SINE FLOW
DATE AND TIME	:	01/10/2009 11:56	
TEST CARRIED OUT BY		MS WITNESS: VS	

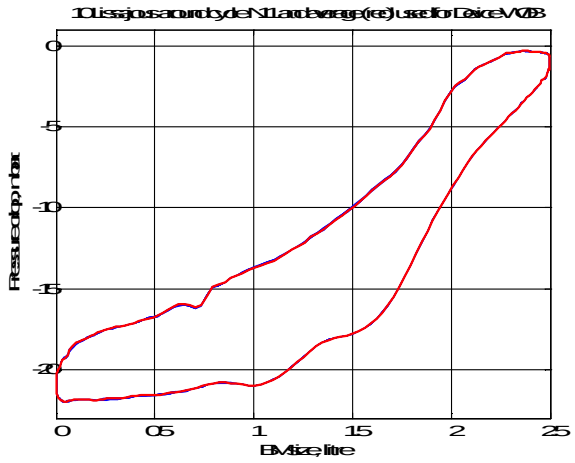
CONDITIONS OF TEST

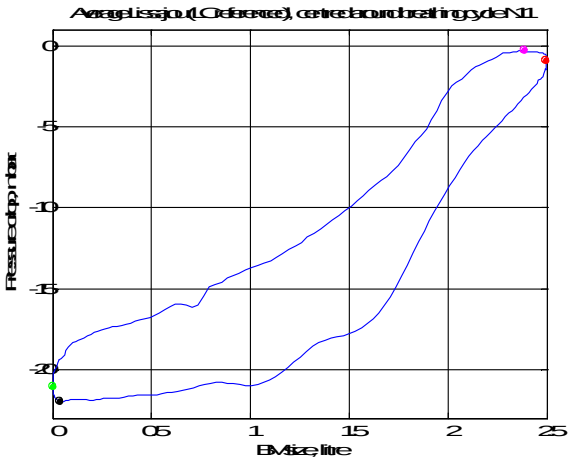
ATTITIDE: PITCH & ROLL	:	0/-90	Deg.
GAS MIXTURE	:	Air	
DEPTH	:	0.0	msw
ROOM / WATER TEMPERATURE	:	24.0 / 4.1	℃
EHXALE GAS TEMPERATURE	:	14.8	℃
GAS SUPPLY PRESSURE	:	10	barg
TIDAL VOL, RESP RATE, RMV	:	2.5L/25.0bpm/62.5lpm	standard

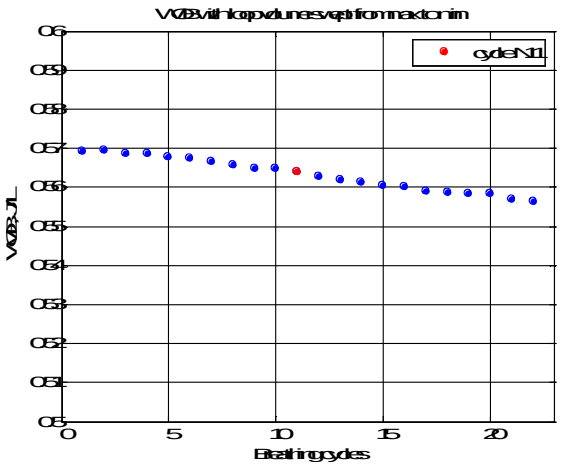
RESULTS

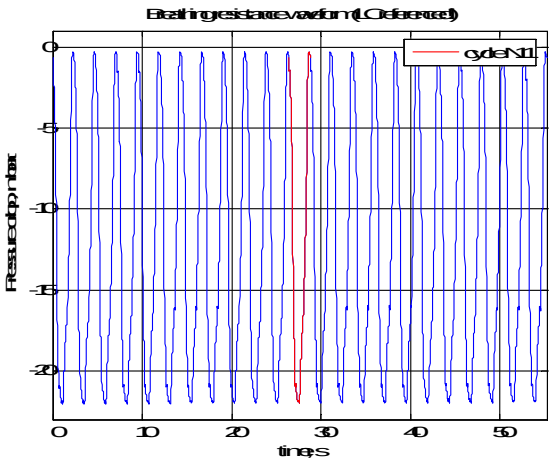
PRESSURE@END EXHALE/INHALE	=	-0.9 / -21.1	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO LC)	=	-0.9	mbar
HYDROSTATIC IMBALANCE (RELATIVE TO SN)	=	-0.9	mbar
PHYSIOLOGICAL PEAK PRESSURES	=	-0.3 / -22.0	mbar
INHALE/EXHALE RESP PRESSURE	=	21.0 / 20.8	mbar
PEAK TO PEAK PRESSURE	=	21.7	mbar
ELASTANCE	=	8.1	mbar/litre
WORK OF BREATHING	=	0.56	J/litre

ALL DATA STORED AS # (DATA FILE): Hydr_DRB01_62_5lpm_0_-90_091001_opt









9.3 Tabulation of Results, Boundary Case Fixed Volume

The tables below are for one loop volume. Retest can produce other tables depending on the exact loop volume, but with any loop volume using the procedure optimised as set down in the method, all models of the rebreathers meet all limits.

Test Num.	Position		EN14143: 2003 (relative to LC)	OR Incursion / Apocalypse Type IV iCCR	OR Umbilical	Status
	Pitch	Roll				
1	+180	0	-20 +20	+19.1	+17.3	Both OR pass
2	+90	0	-20 +20	-8.0	-6.4	Both OR pass
3	+45	0	-20 +20	-14.4	-13.2	Both OR pass
4	0	0	-25 +20	-19.5	-17.1	Both OR pass
5	-45	0	-20 +20	-5.4	+3.4	Both OR pass
6	-90	0	-20 +20	8.1	+18.5	Both OR pass
7	0	+90	-20 +20	-1.3	+14.9	Both OR pass
8	0	+45	-23 +23	-17.1	-9.1	Both OR pass
9	0	-45	-23 +23	-19.4	-19.5	Both OR pass
10	0	-90	-20 +20	-5.1	-0.9	Both OR pass

Both models tested also pass the prEN14143:2010 proposed standard in the boundary case.

Test Num.	Position		EN14143: 2003 respiratory pressures limits, mbar	Inhale/Exhale respiratory pressures, mbar		Status
	Pitch	Roll		OR Incursion / Apocalypse Type IV iCCR	OR Umbilical	
1	180	0	25	16.3 / 16.7	9.8 / 10.5	Both OR pass
2	90	0		15.7 / 15.5	17.3 / 16.4	Both OR pass
3	45	0		13.6 / 13.8	14.0 / 13.2	Both OR pass
4	0	0		9.5 / 9.4	6.4 / 6.7	Both OR pass
5	-45	0		14.3 / 14.3	13.7 / 13.6	Both OR pass
6	-90	0		16.0 / 16.0	17.8 / 17.6	Both OR pass
7	0	+90		13.0 / 13.1	20.6 / 20.7	Both OR pass
8	0	+45		13.5 / 13.0	15.1 / 15.0	Both OR pass
9	0	-45		17.0 / 15.7	16.2 / 15.5	Both OR pass
10	0	-90		16.6 / 14.2	21.0 / 20.8	Both OR pass

Both models tested also pass the inhale/exhale limits in the prEN14143:2010 proposed standard using the boundary case fixed loop volume. There appears to be no requirement for Deep Life to provide any disclaimer in respect to the error in the EN 14143:2003 standard for

the OR_Apocalypse and OR_Incursion models, as they pass under both correct and erroneous conditions.

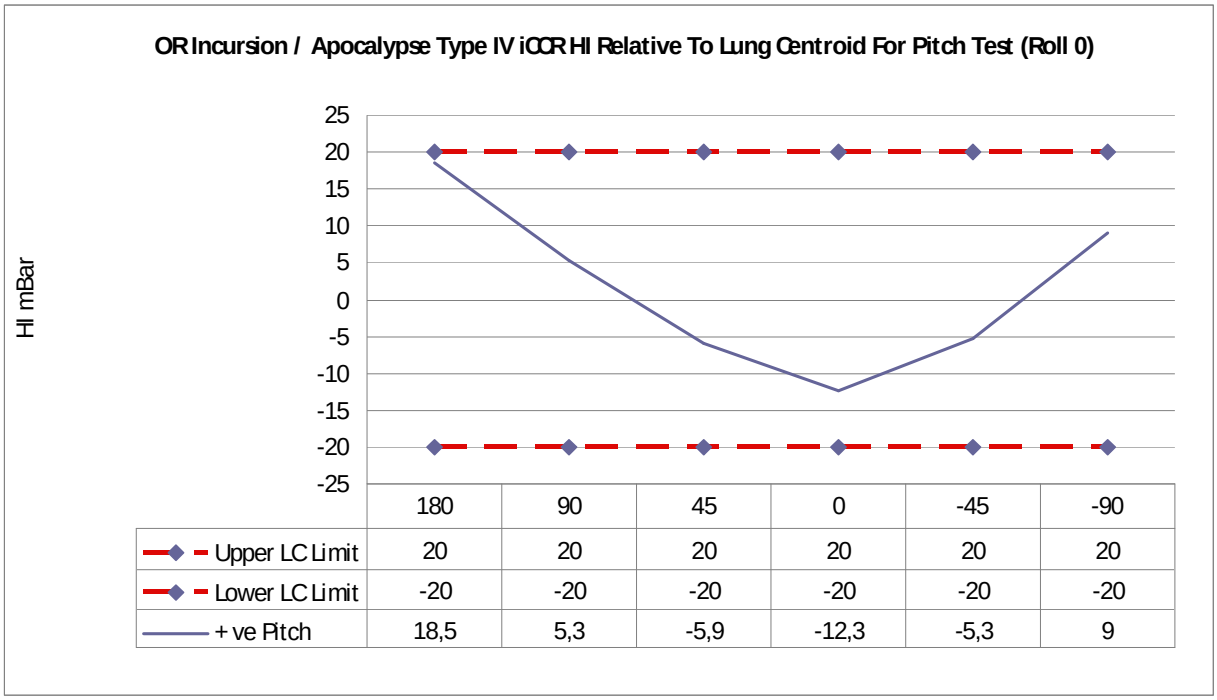
Test Num.	Position		EN14143: 2003 peak to peak pressure limits, mbar	OR Incursion / Apocalypse Type IV iCCR	OR Umbilical	Status
	Pitch	Roll				
1	180	0	50	16.9	10.7	Both OR pass
2	90	0		15.8	17.3	Both OR pass
3	45	0		14.2	14.2	Both OR pass
4	0	0		10.2	7.2	Both OR pass
5	-45	0		15.1	14.0	Both OR pass
6	-90	0		16.3	18.0	Both OR pass
7	0	+90		13.3	20.8	Both OR pass
8	0	+45		14.0	15.6	Both OR pass
9	0	-45		17.2	18.0	Both OR pass
10	0	-90		16.7	21.7	Both OR pass

10 COMPLIANCE OF FIXED VOLUME RESULTS

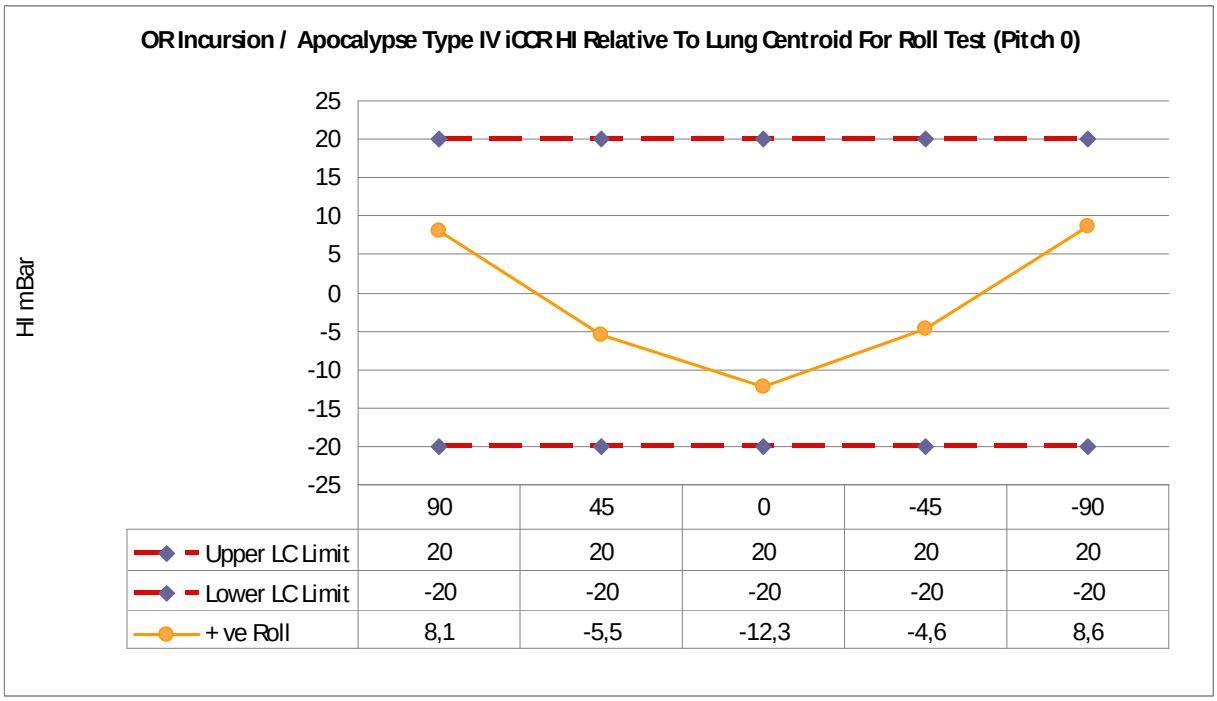
The following subsections consider the fixed volume results that were tabulated in the previous chapters, with respect to both Lung Centroid and the erroneous Table 1 Suprasternal Notch in EN 14143:2003, for the purpose of determining whether it can be claimed that the equipment meets EN 14143:2003 regardless of its errors in Table 1, or whether compliance can be claimed only against the corrected Table 1.

10.1 Plots of Results Optimised Fixed Loop Volume, w.r.t. Lung Centroid

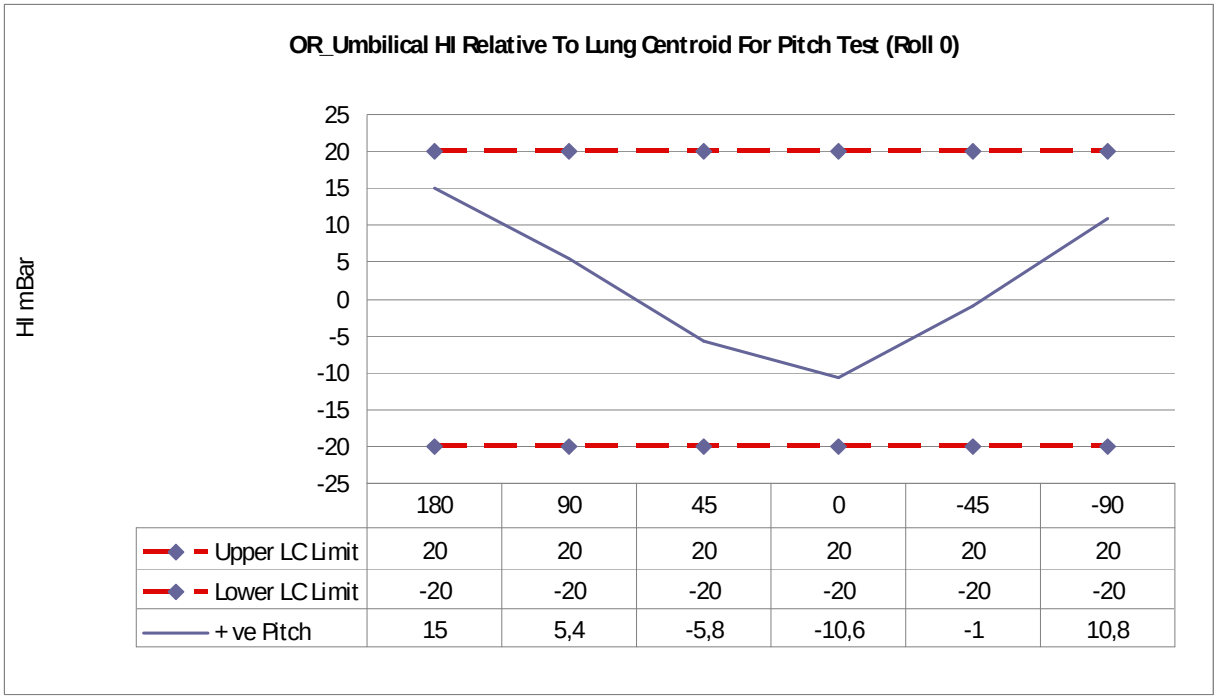
The data in the plots below is that tabulated in Chapter 8.3, with the limits in EN 14143:2003 Table 1 read as being the Lung Centroid (i.e. the corrected Table 1).



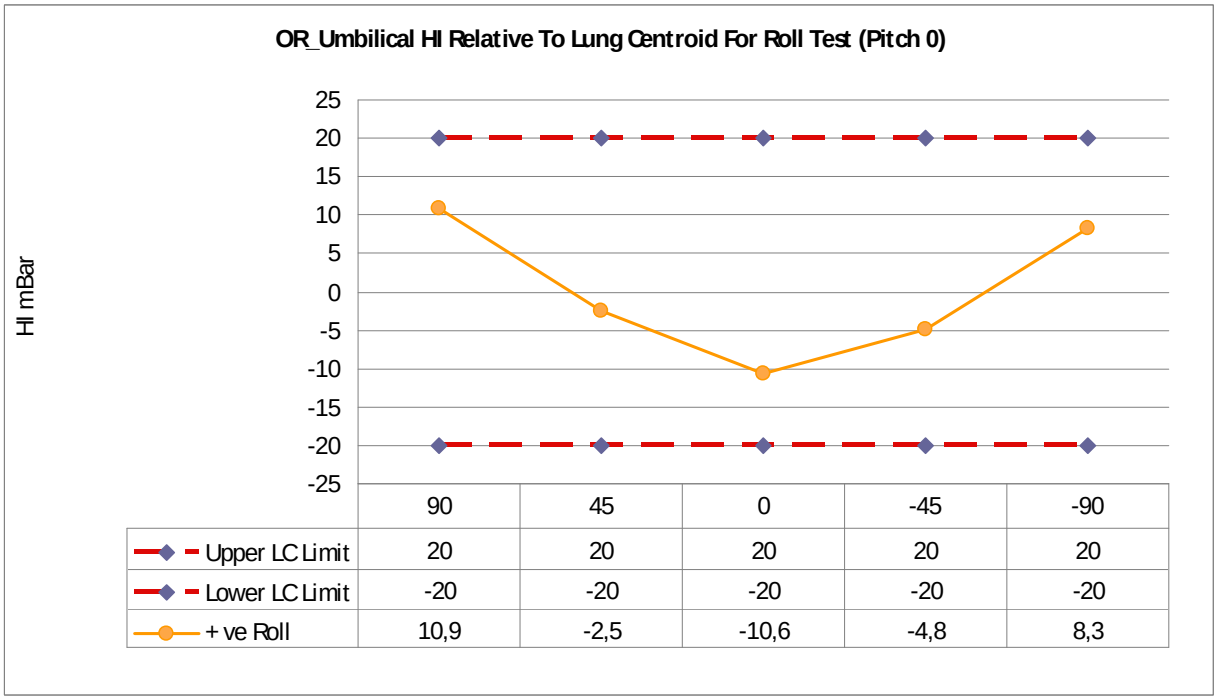
	180	90	45	0	-45	-90
Upper LC Limit	20	20	20	20	20	20
Lower LC Limit	-20	-20	-20	-20	-20	-20
+ ve Pitch	18,5	5,3	-5,9	-12,3	-5,3	9



	90	45	0	-45	-90
Upper LC Limit	20	20	20	20	20
Lower LC Limit	-20	-20	-20	-20	-20
+ ve Roll	8,1	-5,5	-12,3	-4,6	8,6



	180	90	45	0	-45	-90
Upper LC Limit	20	20	20	20	20	20
Lower LC Limit	-20	-20	-20	-20	-20	-20
+ ve Pitch	15	5,4	-5,8	-10,6	-1	10,8

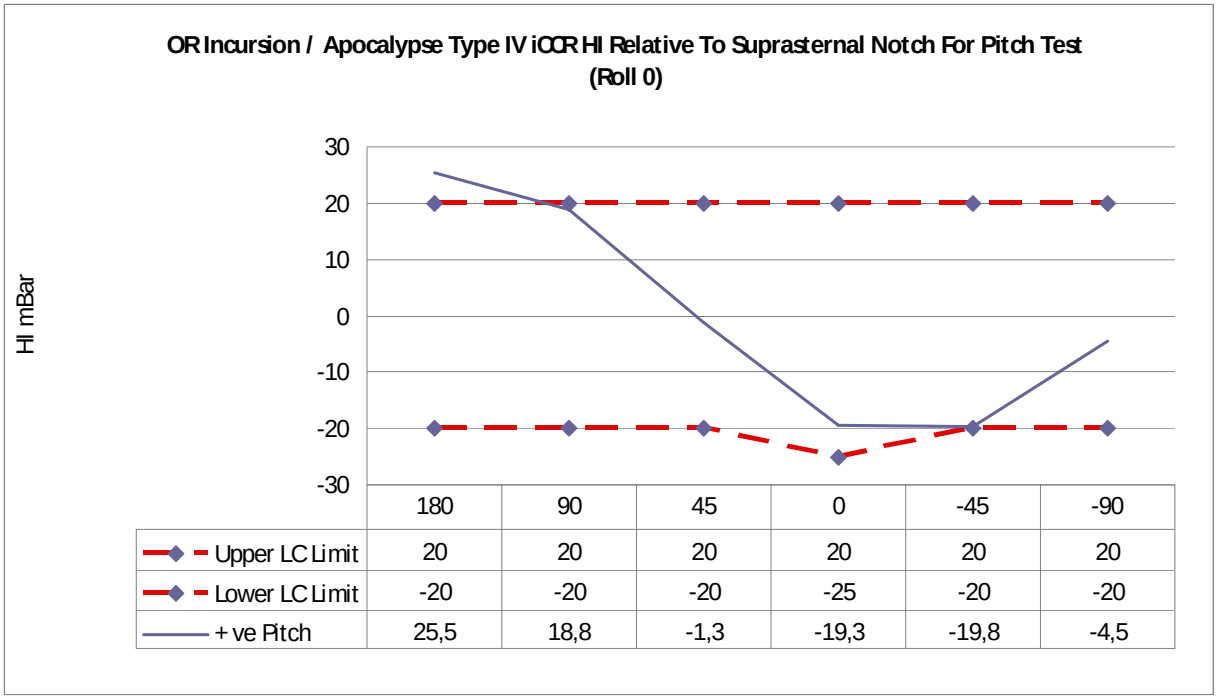


	90	45	0	-45	-90
Upper LC Limit	20	20	20	20	20
Lower LC Limit	-20	-20	-20	-20	-20
+ ve Roll	10,9	-2,5	-10,6	-4,8	8,3

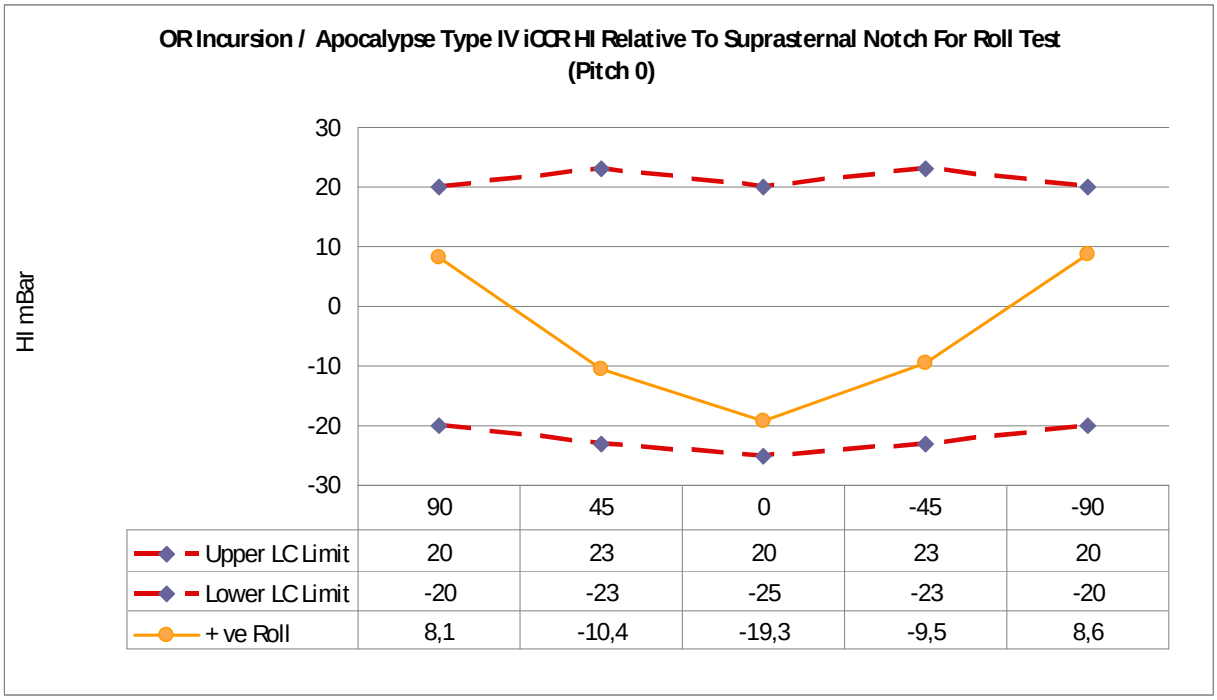
It is clear from the above plots that all models meet the hydrostatic imbalance limits of EN 14143:2003 Table 1 with the corrected table label (i.e. Lung Centroid).

10.2 Plots of Results, Optimised Fixed Volume w.r.t. SSN with Erroneous Table 1

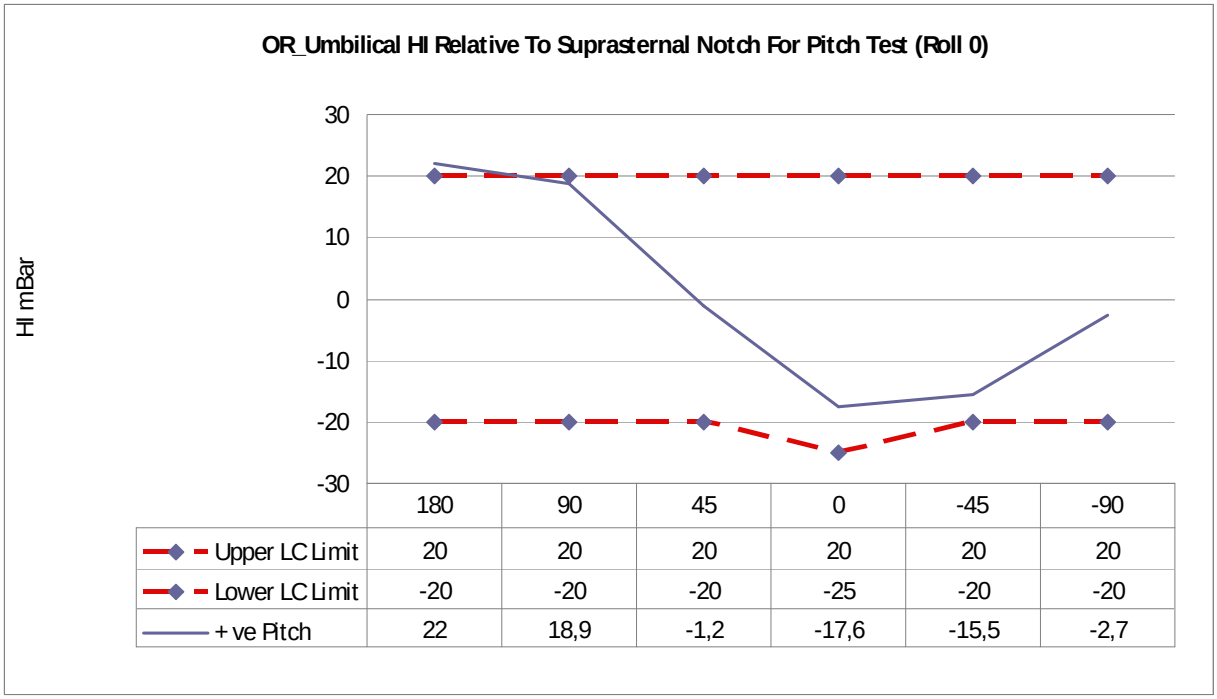
The plots below is the same data with respect to the Suprasternal Notch limits in EN 14143:2003 Table 1 as printed, i.e. containing the incorrect label. In order to claim compliance with EN 14143:2003 it is necessary to meet both the corrected and as printed table.



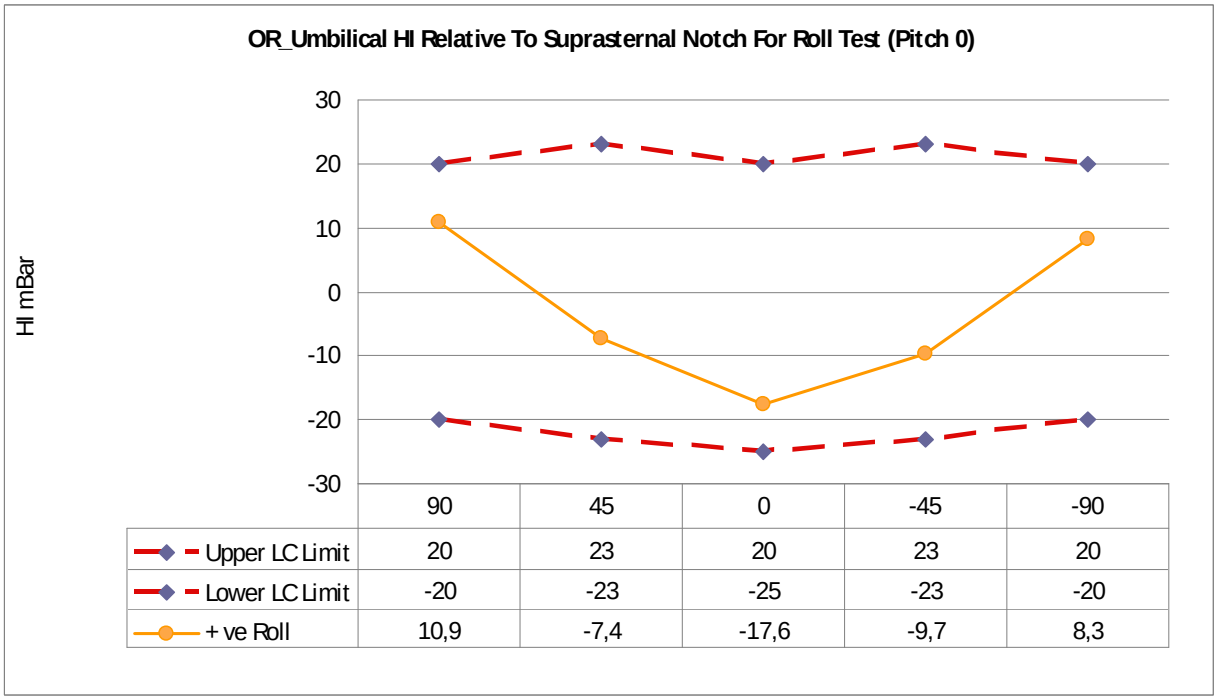
	180	90	45	0	-45	-90
Upper LC Limit	20	20	20	20	20	20
Lower LC Limit	-20	-20	-20	-25	-20	-20
+ ve Pitch	25,5	18,8	-1,3	-19,3	-19,8	-4,5



	90	45	0	-45	-90
Upper LC Limit	20	23	20	23	20
Lower LC Limit	-20	-23	-25	-23	-20
+ ve Roll	8,1	-10,4	-19,3	-9,5	8,6



	180	90	45	0	-45	-90
Upper LC Limit	20	20	20	20	20	20
Lower LC Limit	-20	-20	-20	-25	-20	-20
+ ve Pitch	22	18,9	-1,2	-17,6	-15,5	-2,7

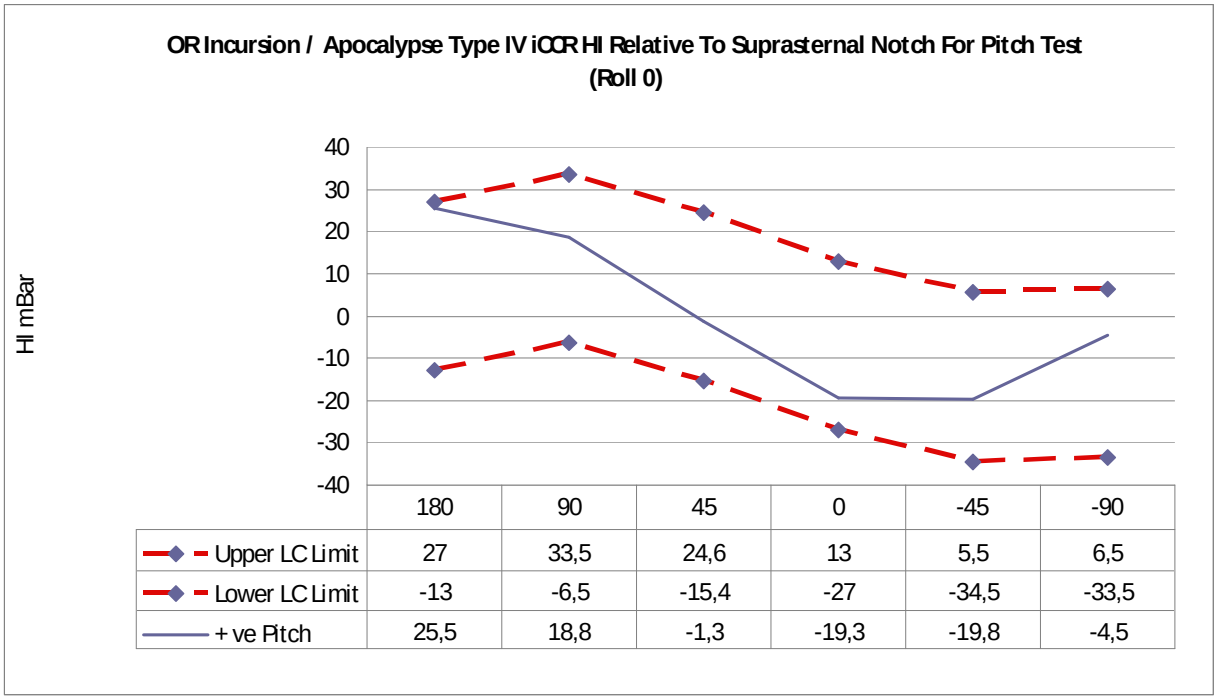


	90	45	0	-45	-90
Upper LC Limit	20	23	20	23	20
Lower LC Limit	-20	-23	-25	-23	-20
+ ve Roll	10,9	-7,4	-17,6	-9,7	8,3

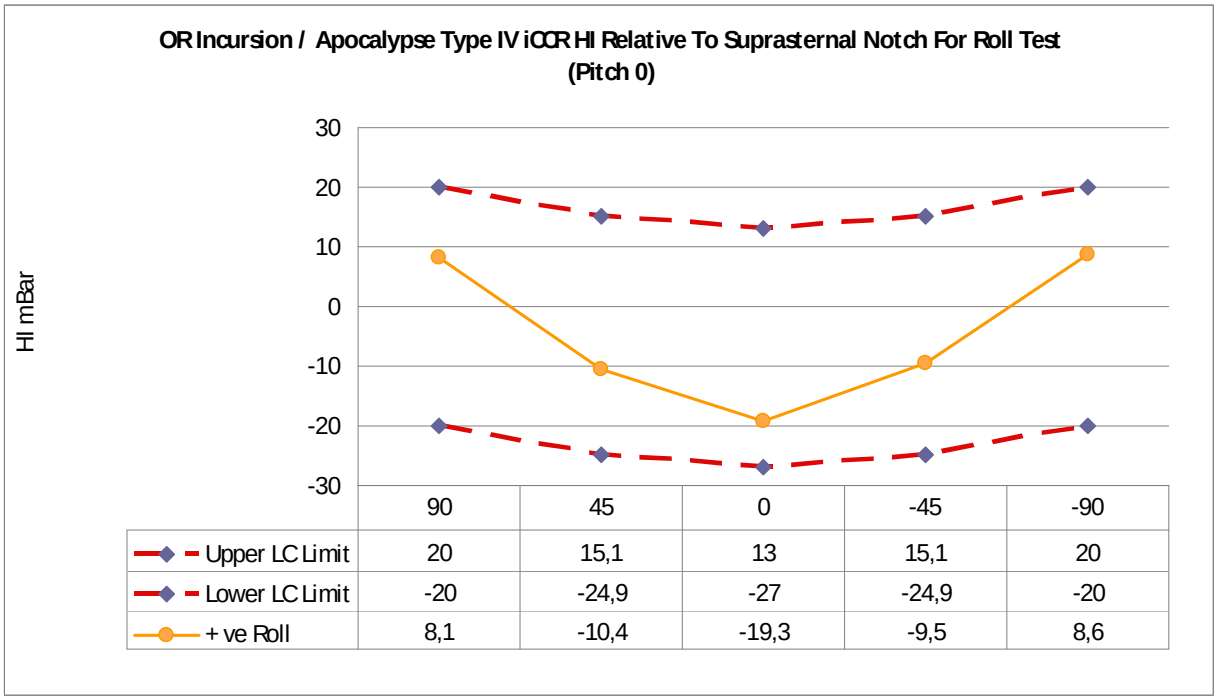
From the above plot, it can be seen that the Incursion/Apocalypse will not meet the EN 14143:2003 with the loop volume used in this test, but for OR_Umbilical there is only one point outside the EN 14143:2003 Table 1 with the erroneous reference to the Suprasternal notch, at Pitch 180, Roll 0, and the amount by which it is out is less than the distance available to shift the curve down by adding gas to the loop, i.e. the space between the lower limit and the Pitch -45, Roll 0 is greater. The OR_Umblical can therefore meet EN 14143:2003 with the erroneous label using a loop volume optimised for that purpose.

10.3 Plots of Results, Optimised Fixed Volume w.r.t. SSN with Correct Table 1

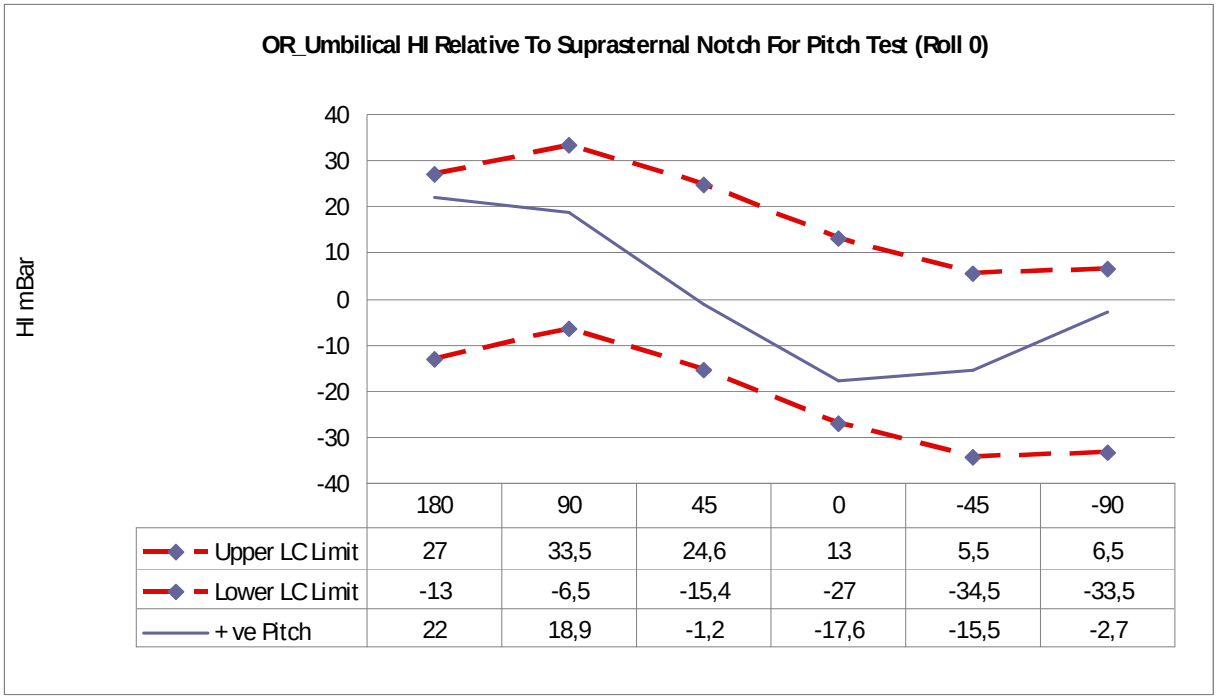
The corrected limits for the Suprasternal Notch reference for EN 14143:2003 Table 1 using the correction values on Page 10 of this document is shown in the plots below: it can be seen there is a clear pass for all models of the rebreather.



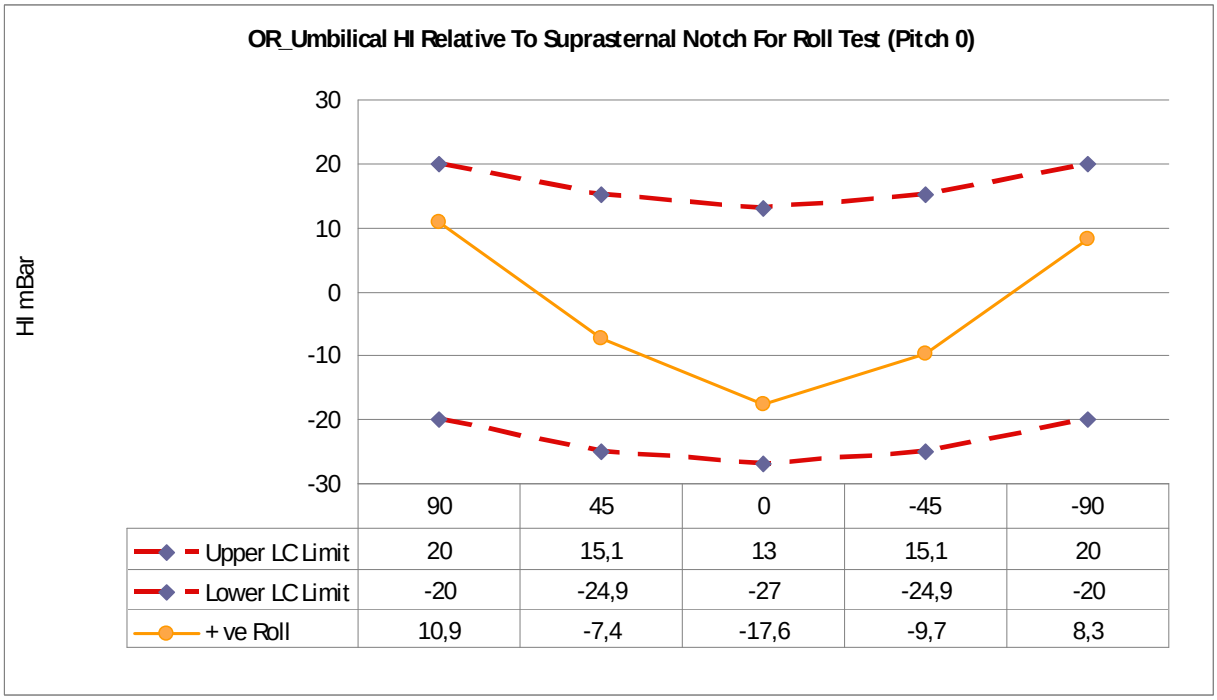
	180	90	45	0	-45	-90
Upper LC Limit	27	33,5	24,6	13	5,5	6,5
Lower LC Limit	-13	-6,5	-15,4	-27	-34,5	-33,5
+ ve Pitch	25,5	18,8	-1,3	-19,3	-19,8	-4,5



	90	45	0	-45	-90
Upper LC Limit	20	15,1	13	15,1	20
Lower LC Limit	-20	-24,9	-27	-24,9	-20
+ ve Roll	8,1	-10,4	-19,3	-9,5	8,6



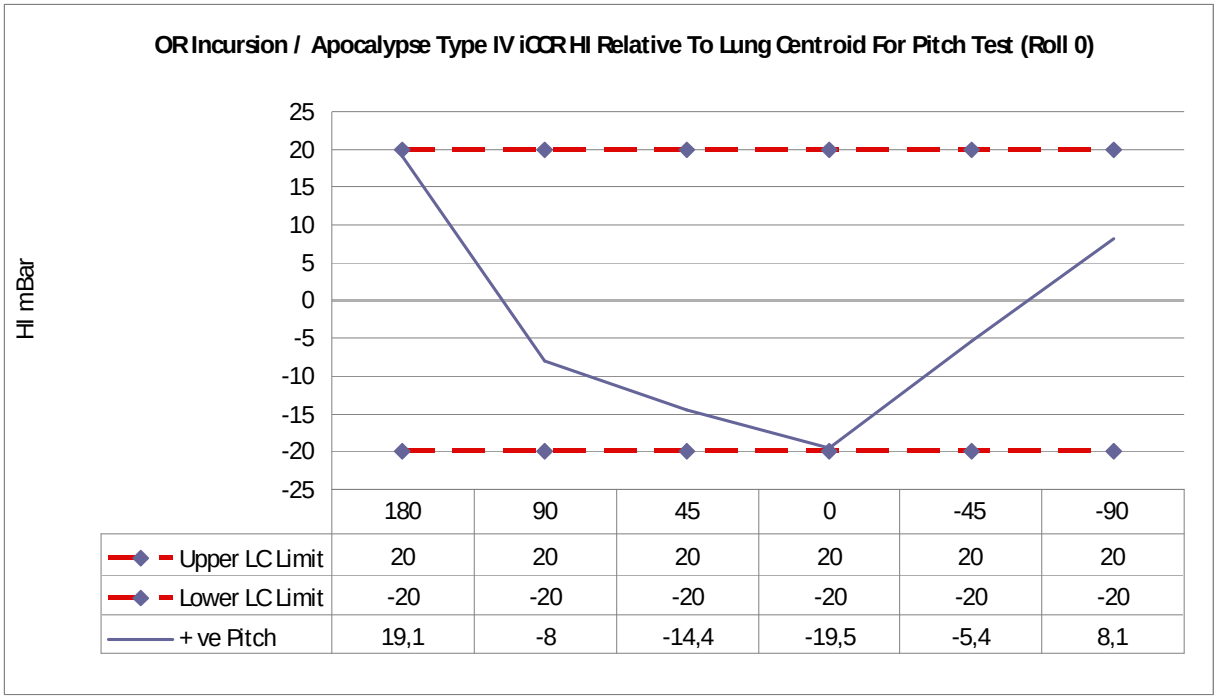
	180	90	45	0	-45	-90
Upper LC Limit	27	33,5	24,6	13	5,5	6,5
Lower LC Limit	-13	-6,5	-15,4	-27	-34,5	-33,5
+ ve Pitch	22	18,9	-1,2	-17,6	-15,5	-2,7



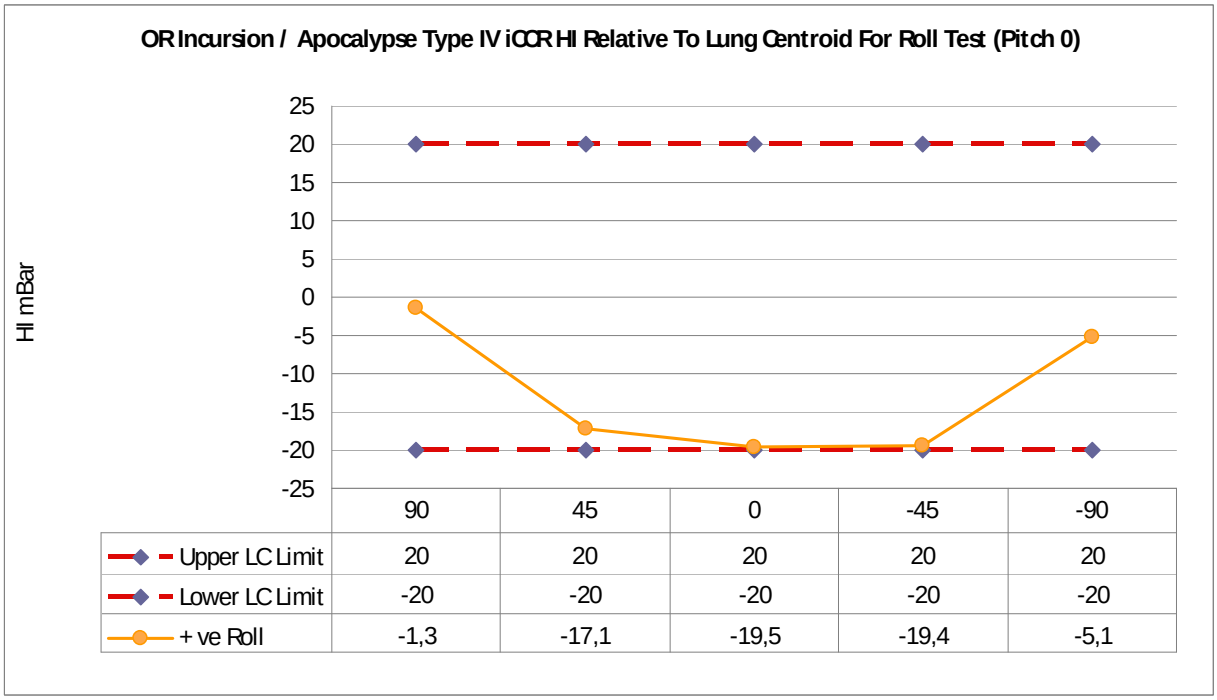
	90	45	0	-45	-90
Upper LC Limit	20	15,1	13	15,1	20
Lower LC Limit	-20	-24,9	-27	-24,9	-20
+ ve Roll	10,9	-7,4	-17,6	-9,7	8,3

10.4 Plots of Results, Boundary Case Fixed Volume w.r.t. Lung Centroid

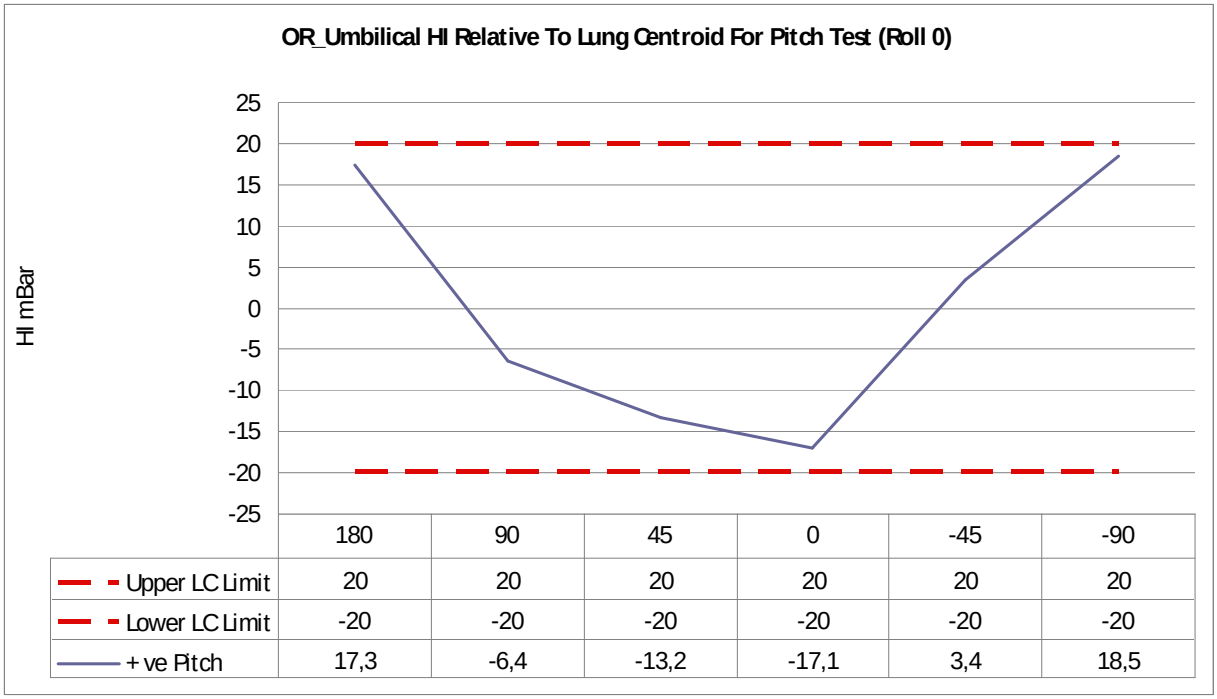
The data in the plots below is that tabulated in Chapter 8.3, with the limits in EN 14143:2003 Table 1 read as being the Lung Centroid (i.e. the corrected Table 1). These are not optimised loop volumes by definition, so are compared only with the limits in the corrected Table 1.



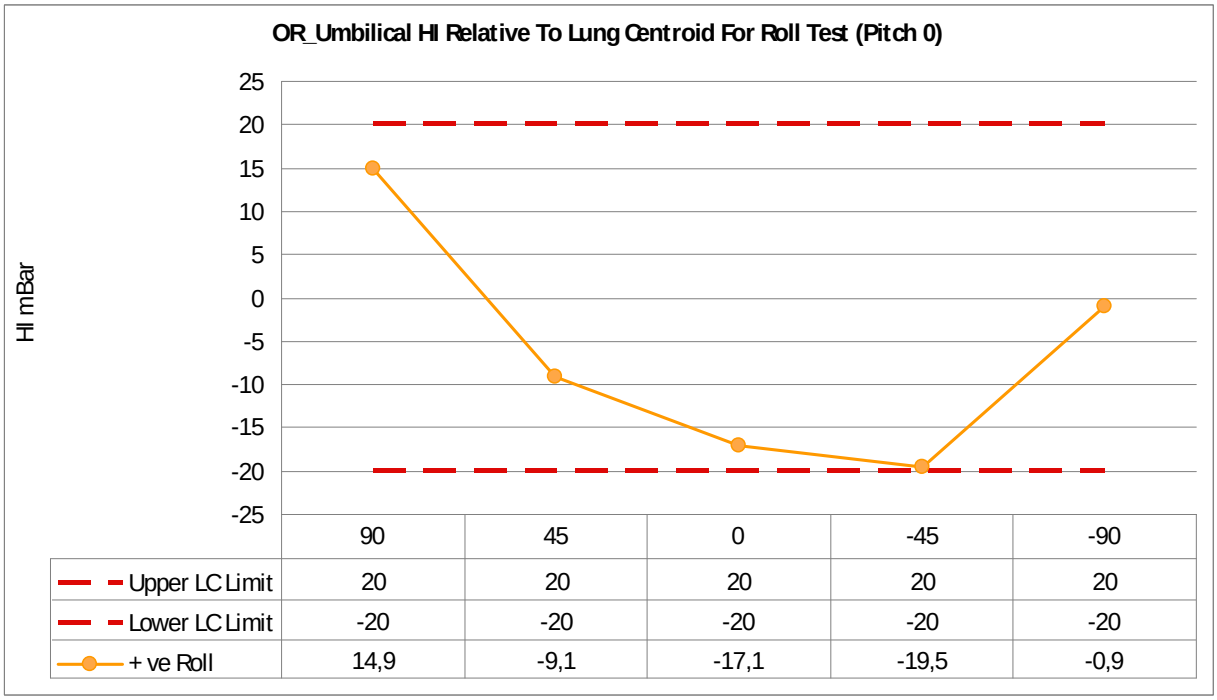
	180	90	45	0	-45	-90
Upper LC Limit	20	20	20	20	20	20
Lower LC Limit	-20	-20	-20	-20	-20	-20
+ ve Pitch	19,1	-8	-14,4	-19,5	-5,4	8,1



	90	45	0	-45	-90
Upper LC Limit	20	20	20	20	20
Lower LC Limit	-20	-20	-20	-20	-20
+ ve Roll	-1,3	-17,1	-19,5	-19,4	-5,1



	180	90	45	0	-45	-90
Upper LC Limit	20	20	20	20	20	20
Lower LC Limit	-20	-20	-20	-20	-20	-20
+ ve Pitch	17,3	-6,4	-13,2	-17,1	3,4	18,5



	90	45	0	-45	-90
Upper LC Limit	20	20	20	20	20
Lower LC Limit	-20	-20	-20	-20	-20
+ ve Roll	14,9	-9,1	-17,1	-19,5	-0,9

The above plots are for information only, in that they define the limits of loop volume that will meet the EN 14143:2003 Table 1 (Corrected) and prEN14143:2010.

11 CONCLUSION

All models of the Open Revolution rebreather apparatus comply with all Hydrostatic Imbalance requirements, hydrostatic respiratory pressure and elastance requirements of:

A) EN 14143:2003 with the error in Table 1 of the standard corrected,

B) EN 14143:2003 without the error in Table 1 corrected, OR_Umbilical only

C) prEN 14143:2010

D) NORSOK U101:1999,

E) NATO STANAG 1410:2006

F) NEDU TR 05-17 2007 recommendations.

Using the optimised loop volumes in the tests reported herein, the OR_Umbilical rebreather can also claim compliance with the erroneous EN14143:2003 Table 1 values if they are treated as Suprasternal notch valves by providing a fixed loop volume optimised for that condition. It is not clear if such a loop optimisation exists for the Incursion or Apocalypse models within the limits created by the errors in Table 1.

There is a clear margin of compliance if the Table 1 figures are treated as the values they actually are, i.e. they are Lung centroid values so must be measured against the Lung centroid and not the Suprasternal notch. This means all rebreathers pass the prEN14143:2010 hydrostatic imbalance limits with ease.

A full discussion of other methods of measuring hydrostatic imbalance in rebreathers and their likely effect on results has been presented.

<End of Document>