Introduction

Expired Gas Analysis or indirect calorimetry, can be used to measure ventilation and the fractions of oxygen and carbon dioxide in expired air. From these measurements, the body's oxygen consumption and carbon dioxide production can be calculated.

Two basic measuring techniques are in general use : Breath-by-breath analysis and Mixed expired gas analysis.

Breath-by-breath techniques are viewed by some to be potentially inaccurate owing to sensing expired gas concentration as it leaves the mouth, as well as the air that is inhaled. The errors of this approach relate to the decreasing time available for analysis as exercise intensity increases, often less than 500 ms. This is accentuated by the relatively slow response time of both oxygen and carbon dioxide sensors, typically 100 ms.

Mixed expired gas analysis makes use of a mixing chamber, where the expired gasses are collected and allowed to mix before before being presented to the gas sensors for analysis. The disadvantage of using mixing chambers is attributed to the relatively large chamber volume, (usually between 5 - 7 litres) needed to overcome end tidal volume bias. This may limit the reliable sampling frequency, thus decreasing the sensitivity to rapid changes in metabolism. The accumulation of moisture may also cause problems. Nevertheless mixing chambers enable reliable and **repeatable** expired gas analyses.

Unlike some manufacturers, we don't claim that our metabolic cart is better than all others. We believe however, that our innovative **bespoke** manufacturing approach, provides a practical alternative to respiratory gas analysers found in today's market place.

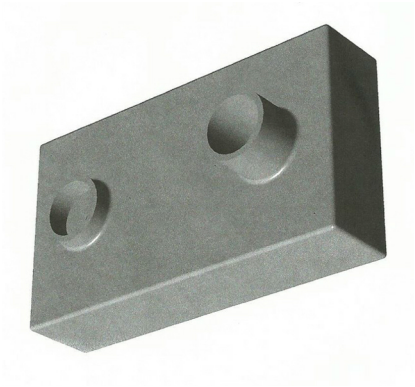
In general health and rehabilitation it's desirable not only to be able to monitor cardiovascular fitness improvement, but also respiratory lung function. The COVOX Metabolic Cart provides for an integrated spirometer, resulting in a ***multi-functional respiratory gas analyser*.**

In human performance teaching laboratories it's customary to introduce students to gas analysis using Douglas bags, and then using separate gas analysers and a gas meter for the analysis. COVOX has the capability to allow students to manually analyse the gas concentrations, and expired gas volume of Douglas bags - resulting in significant cost savings in laboratory equipment.

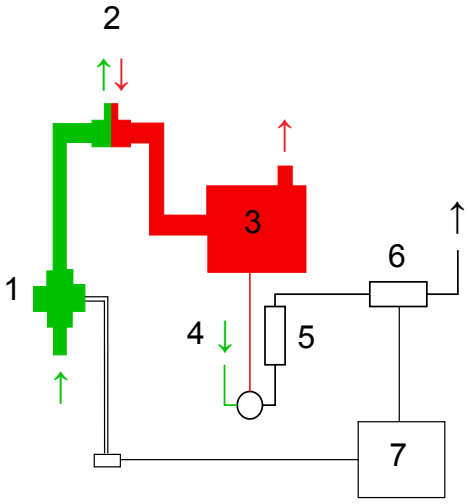
In longitudinal Undergraduate and Post Graduate studies, repeatability will be of prime importance. The COVOX fundamental design ensures excellent long term repeatability.

The COVOX Approach is to use breath-by-breath measurement of pulmonary ventilation in combination with our proprietary mixed expired gas mixing chamber.

We have overcome the disadvantages associated with mixing chambers.



The COVOX Mixed Expired Gas Chamber measures just 18 cm x 4 cm x 10 cm with an internal capacity of just 500 ml. The small size allows fitment within the analyser enclosure. The design eliminates end tidal volume bias. The chamber is constructed of thin walled thermoplastic, which quickly assumes the temperature of the exhaled air and therefore prevents condensation within the chamber itself.



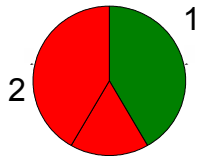
The Breathing Circuit

The non re-breathing valve ***2*** allows air to be inhaled through the pneumotach ***1***, and then vented through the mixing chamber ***3***. The mixing chamber is sampled and the mixed expired gas presented for analysis ***6***.

4 Calibration Gas inlet

5 Sample Gas Flow Control

7 Differential Pressure Transducer



Gas Sampling Sequence

(CO_2 analysis optional)

Calibration phase ***1***: This is where room air is drawn through the gas sampling circuit and analysed for oxygen concentration to establish F_iO_2 (F_iCO_2). This period can be set between 10 and 25 seconds.

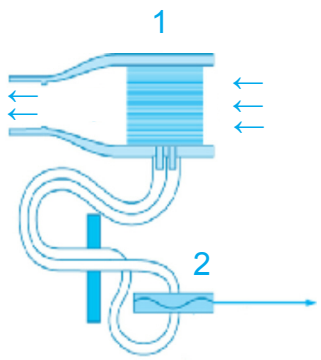
After the calibration phase ***2***, expired gas is taken from the mixing chamber for analysis. Actual or Predictive minute VO_2 is updated and displayed after each Breath. *Note that during the calibration phase expired gas continues to be mixed.*

Predictive Mode Sampling Option

When selected this option predicts minute VO2 after each breath, after calibration phase has elapsed. The advantage of using this mode is that a useful measurement can be made if the person under test is unable to complete the full minute measuring period when close to exhaustion.

Airflow measurement

Stator-rotor and turbine systems have difficulty measuring low flows because of the compromise with flow impedance. The COVOX Metabolic Cart however detects instantaneous inspired respiratory air during each breath using a Fleisch pneumotachograph, which due to its excellent linearity, allows accurate measurement of pulmonary ventilation (Ve) from rest to VO_2max, using a single flow head.



Inside the flowhead (1) is a bundle of capillary tubes that create a pattern of laminar air flow, and introduces a very slight resistance to the air flow causing a differential pressure. This differential pressure, which is measured by a pressure sensor (2), is directly proportional to the flow rate. The output from the pressure sensor is passed through an A-D converter, the signals from which are used to give calibrated flow and volume measurements.

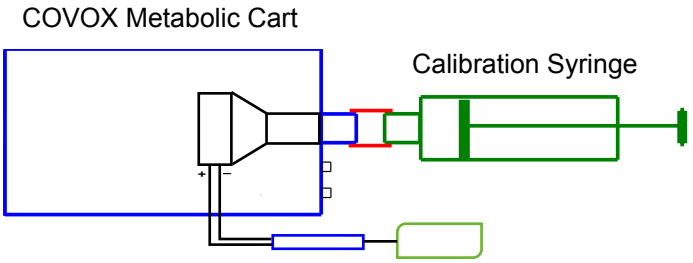
Accuracy: Better than +/- 3% (typically +/- 1.5%)

Maximum flow 16 L/s : Minimum Flow 0.02 L/s

Linearity: +/- 1% in range 0.1 L/s to 16 L/s

The advantages of Fleisch diagnostic flow measuring systems include: Accurate and linear measurements throughout the flow range, robustness and no moving parts. Pneumotach moisture contamination is avoided by measuring inspired respiratory air, thereby eliminating surface condensation and contamination from moisture in the breath.

Good practice dictates regular calibration checks. If pneumoach accuracy is compromised, for example if ambient testing conditions change significantly, COVOX software allows quick and simple re-calibration that takes less than a minute to perform.



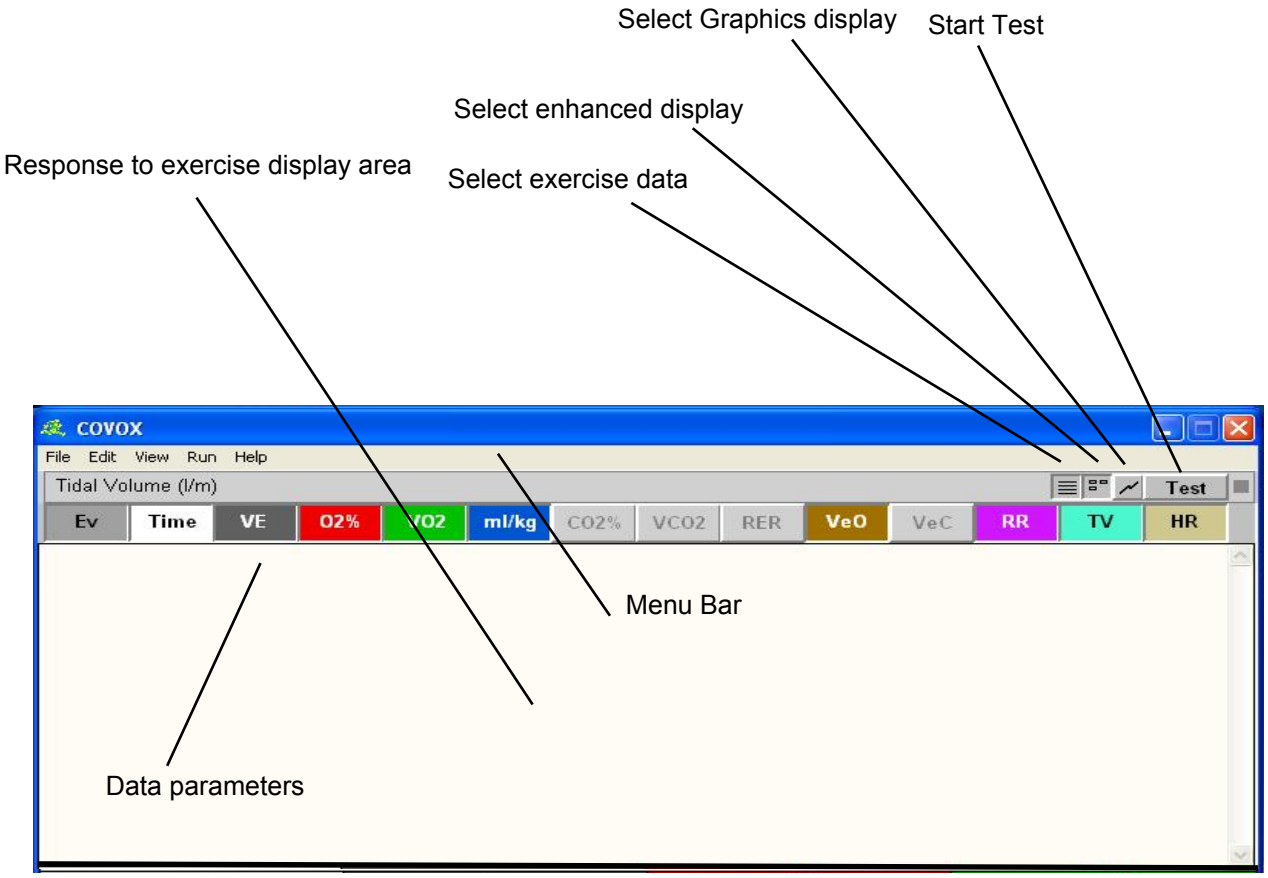
Flow L/min	Back Pressure mm H2O
5	0.1
10	0.2
20	0.4
35	0.8
50	1.1
65	1.4
80	1.8
100	2.2
200	4.3
300	6.6
400	8.9
500	11.1
600	13.4
700	15.6

Data rounded to one significant digit

The table shows a typical example of raw data used in the calibration of the flow head.

The excellent linearity of this device allows accurate measurement of flow rates from rest to VO_2max, using a single flow head.

The COVOX Screen



Data Display Options

Three display options are available and any two can be displayed at the same time. Screen display options can be changed during an actual data run by selecting or deselecting the option.

Ev	Time	VE	O2%	VO2	ml/kg	CO2%	VCO2	RER	VeO	VeC	RR	TV	HR
	1:00	23.5	19.25	0.39	5	1.34	0.29	0.74	60	82	23	1.02	
	2:00	26.3	16.70	1.08	14	3.51	0.85	0.79	24	31	20	1.31	
1	3:00	28.9	16.45	1.24	17	4.02	1.08	0.87	23	27	21	1.38	
	4:00	34.9	16.51	1.46	19	4.14	1.34	0.91	24	26	23	1.52	
2	5:00	35.6	16.58	1.46	19	4.19	1.38	0.95	24	26	22	1.62	
	6:00	42.7	16.44	1.80	24	4.39	1.74	0.96	24	25	25	1.71	
3	7:00	51.2	16.50	2.11	28	4.46	2.11	1.00	24	24	27	1.90	
	8:00	57.5	16.58	2.33	31	4.42	2.35	1.01	25	24	30	1.92	
4	9:00	66.8	16.65	2.65	35	4.40	2.72	1.03	25	25	31	2.15	

Exercise Data : This is the raw data, which is updated after each breath during the measuring cycle.

Enhanced Display:

Data parameters can be shown enlarged at the foot of the screen.

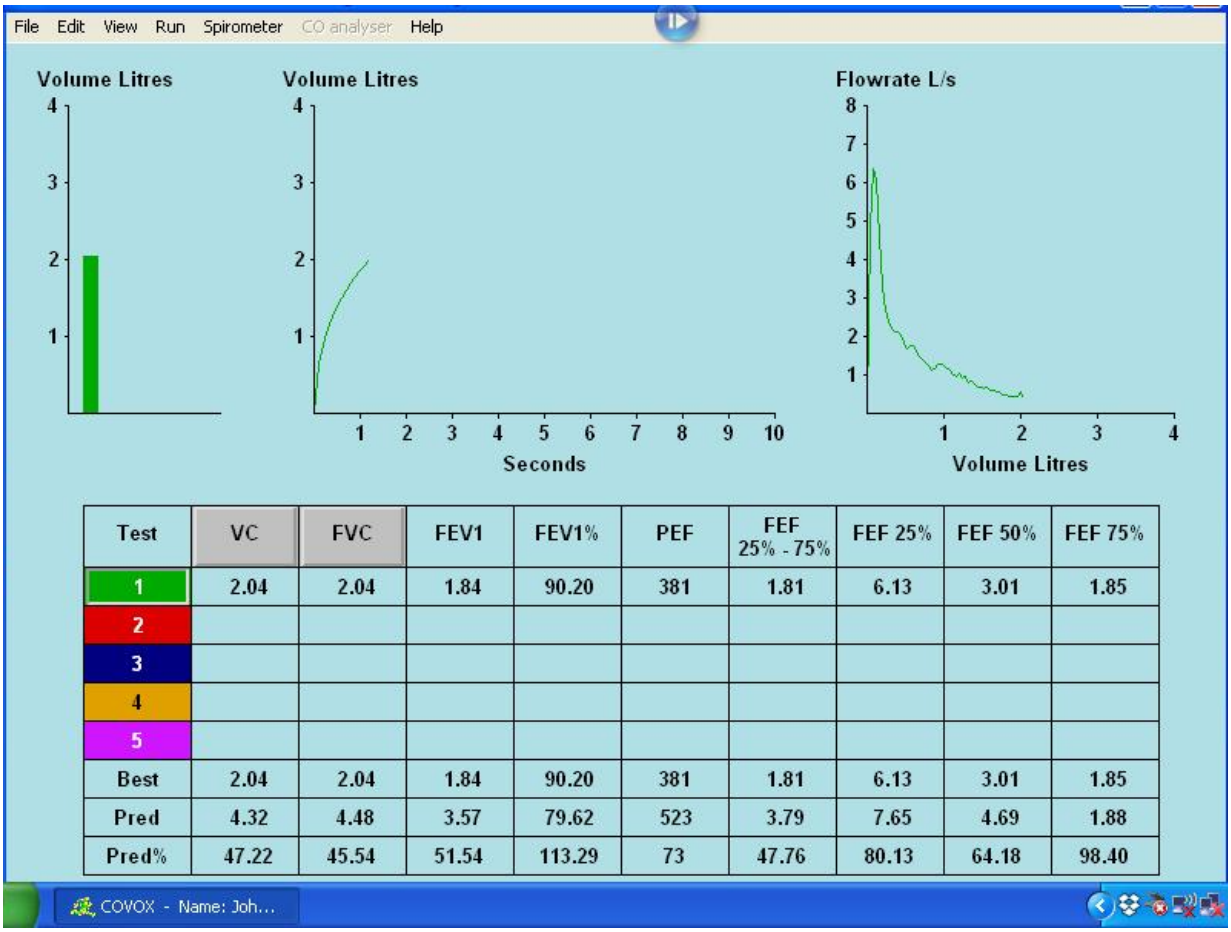
Time	VE	O2%	VO2
9:00	66.8	16.65	2.65
ml/kg	CO2%	VCO2	RER
35	4.40	2.72	1.03
VeO	VeC	RR	TV

Graphics Display.

Exercise data can be shown in graphical format. Similarly to all data graphs can be displayed or hidden during a data run by clicking the

The Spirometry work station

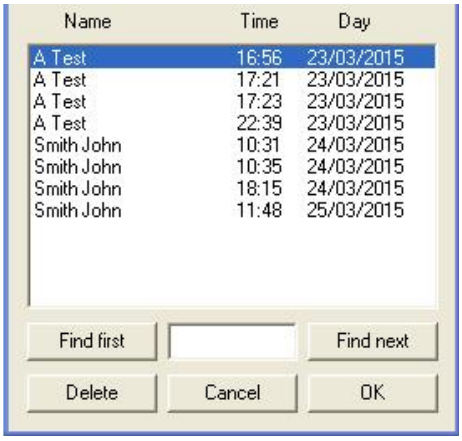
All the spirometer functions are available from this single screen.



Test	VC	FVC	FEV1	FEV1%	PEF	FEF 25% - 75%	FEF 25%	FEF 50%	FEF 75%
1	2.04	2.04	1.84	90.20	381	1.81	6.13	3.01	1.85
2									
3									
4									
5									
Best	2.04	2.04	1.84	90.20	381	1.81	6.13	3.01	1.85
Pred	4.32	4.48	3.57	79.62	523	3.79	7.65	4.69	1.88
Pred%	47.22	45.54	51.54	113.29	73	47.76	80.13	64.18	98.40

The VC and FVC buttons initiate the relevant test. Five attempts are available. By convention the VC (vital capacity test) is performed first, which in this case also sets the measurement range to either 4 or 8 litres. When a button is clicked, a prompt will let you know when the spirometer is ready.

The FVC (forced vital capacity test) generates the graphs. The graphs can be displayed or hidden by clicking the relevant test button 1 - 5. For a hard copy when you have finished testing, go to ***Spirometer*** then click ***Print***. The hard copy will be a complete screen dump of whatever is showing at the time. The print file is in pdf format and suitable for emailing.



Spirometry Database

To retrieve a record simply select ***Spirometer*** from the menu bar and click ***Recall***.