Appendix A - Oxymax Calculations

A.1 Metabolic Calculations

The metabolic data reported by Oxymax is based on five empirical measurements:

- Gas concentrations measured by sensors:
  - **Reference Oxygen Concentration** ($O2_i$)
  - **Reference Carbon Dioxide Concentration** ($CO2_i$)
  - **Sample Oxygen Concentration** ($O2_o$)
  - **Sample Carbon Dioxide Concentration** ($CO2_o$)
- **Fresh Air Flow**
  - The fresh air flow measured by Oxymax for Windows depends on the ventilation system used. Positive ventilation systems throttle and measure the fresh air before delivering it to the chambers (V_i). Negative ventilation systems draw fresh air into the chamber from the atmosphere around it. The measured flow in this case is not the rate of air entering the cage, but exiting it (V_o).

The calculation of Oxygen consumption (VO_2) and Carbon Dioxide production (VCO_2) values requires the use of both the input (V_i) and output (V_o) flows to the chamber. Despite the fact that the chamber is not pressurized and does not allow gas to build up as an experiment progresses, the chamber cannot be modeled as a perfect steady state system because of the subject's unequal effect on the respiratory gases: the subject does not exhale the same volume of gas as it inhales.

Gases in an Oxymax system are broken into three categories:

- **Consumed** – Oxygen
- **Produced** – Carbon Dioxide, Methane
- **Inert** – All other gases not involved in respiration (Nitrogen, Argon, and other noble gases)

Since inert gases are not used during respiration, their rates of flow at the output (VN_o) and input (VN_i) are the same (Equation 1).

$$VN_i = VN_o$$

Equation 1

The flows of inert gases are products of the flows to and from the chamber and the concentration of inert gases (N_i and N_o) in each flow (Equation 2). The concentrations can be calculated and one of the flows is measured so the other (V_o for positive ventilation, V_i for negative ventilation) can be calculated.

$$V_i N_i = V_o N_o$$

Equation 2

The concentration of inert gases in a sample is assumed to be all gases that are not involved in respiration (Equation 3).

$$N = 100\% - O_2 - CO_2$$

Equation 3

Assuming a positive flow system, combining the previous equations yields the V_o for the system (Equation 4).

$$V_o = V_i \frac{100\% - O_{2i} - CO_{2i}}{100\% - O_{2o} - CO_{2o}}$$

Equation 4

The volumetric flow rates for consumption and production can then both be calculated. The equations are arranged such that both consumption and production are presented as positive values (Equation 5, Equation 6, Equation 7).

$$VO_{2,subject} = V_i O_{2i} - V_o O_{2o}$$

Equation 5

$$VCO_{2,subject} = V_o CO_{2o} - V_i CO_{2i}$$

Equation 6

$$VCH_{4,subject} = V_o CH_{4o} - V_i CH_{4i}$$

Equation 7

Oxymax for Windows always presents consumption and production rates normalized to the subject's body mass in kilograms. To convert the whole-body rates into mass-normalized rates just divide the whole-body rate by the mass (m) of the subject in kilograms (Equation 8).

$$V_{x,norm} = \frac{V_{x,subject}}{m}$$

Equation 8

The accumulated respiration figures (A) are calculated using the whole-body rate and the amount of time that has elapsed since the last measurement (t). The amount of gas consumed or produced in an interval is added to a running total of all sample volumes. Units are adjusted to match the ones specified in the experiment settings (Equation 9).

$$A_x[n] = A_x[n-1] + V_{x,subject} t$$

Equation 9

The respiratory exchange ratio can be calculated from either set of consumption and production rates (Equation 10).

$$RER = \frac{VCO2_{subject}}{VO2_{subject}} = \frac{VCO2_{norm}}{VO2_{norm}}$$

Equation 10

Oxymax for Windows uses one of two possible methods for calculating energy expenditure (Heat). The first uses a "calorific value" (CV) that shows the relationship between heat and the volume of consumed Oxygen. This value is derived from empirical data from Graham Lusk's "The Elements of the Science of Nutrition" (Equation 11).

RER	Kilocalories per liter of O_2
0.707	4.6862
0.75	4.7387
0.80	4.8008
0.85	4.8605
0.90	4.9226
0.95	4.9847
1.00	5.0468

$$CV = 3.815 + 1.232 * RER$$

Equation 11

The rate of energy expenditure can then be calculated using the subject's rate of Oxygen consumption (Equation 12).

$$Heat = CV * VO_{2,subject}$$

Equation 12

Oxymax for Windows also allows for the definition of a custom heat calculation equation. Coefficients for Oxygen, Carbon Dioxide and Methane rates can be specified and used to calculate heat (Equation 13).

$$Heat = \left(K_1 * VO_{2,subject}\right) + \left(K_2 * VCO_{2,subject}\right) + \left(K_3 * VCH_{4,subject}\right)$$

Equation 13