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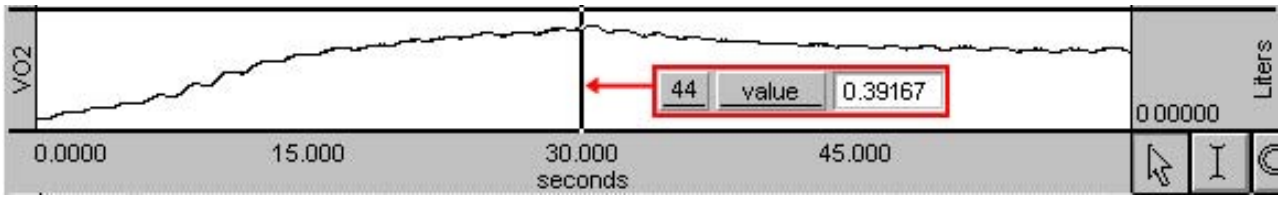
APPLICATION NOTE

7.31.13

Application Note 221 Simplified VO_2 Measurement



- This Application Note details a convenient method to measure VO_2 max without CO_2 values.
  - See AS183 for VO_2 and RER Measurement

An MP System with the O2100C and DA100C modules and some airflow accessories can be used to perform reasonably precise real-time Oxygen Consumption (VO_2) measurements. When performing tests of this kind, many factors exist to confound the measurement. For this simplified measurement, it is assumed that the volume of expired air is always the same as inspired air. This is only true when the volume of carbon dioxide expired is equal to the volume of oxygen consumed. The inspired and expired volumes are equal only when the respiratory exchange ratio (RER) equals one.

The subjects breathe through a non-rebreathing "T" valve to inspire fresh air through a pneumotach (TSD107B) and expire to a mixing chamber for gas concentration (O_2) monitoring. When using a mixing chamber to average O_2 concentrations over several breaths, there is no performance degradation (due to the module gas concentration response time) when measuring these changes for arbitrarily high breathing rates. Accordingly, a mixing chamber is typically recommended for quick, accurate and easy metabolic analysis.

Additional accessories required, but not shown, include a calibration syringe (AFT6) and calibrated gas mixture. The calibration syringe is used to calibrate the TSD107B and to flush out the mixing chamber for ambient gas concentration level calibration. The calibrated gas mixture is used to introduce known concentrations of O_2 to calibrate the upper and lower ranges of the gas measurement module.

The following values are required to convert gas at Ambient Pressure and Temperature (**APT**) to Standard Temperature and Pressure, Dry (**STPD**):

Ta: Ambient temperature in degrees C

Pb: Ambient barometric pressure in mmHg

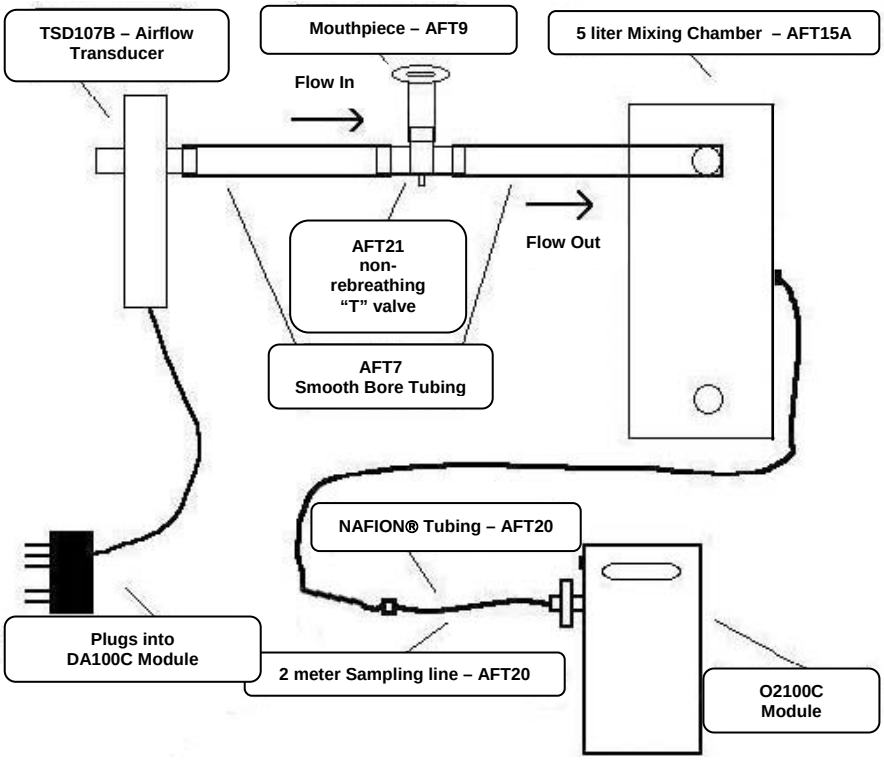
PH20: Pressure of water vapor at ambient temperature in mmHg

DEFINITIONS

O_2e	Oxygen fractional concentration in expired air
Fi	Inspired air flow (ATP)
N_2e	Nitrogen fractional concentration in expired air
Vi	Inspired air volume (ATP)
Vis	Inspired air volume (STPD)
Ves	Expired air volume (STPD)
VO_2	Volume of oxygen consumed (STPD)

Setup Procedure

Equipment Setup



Equipment Connections for Simplified VO_2 Measurement

The diagram above illustrates the typical connections when performing metabolic analysis. The subject breathes through the mouthpiece (AFT9) which attaches directly to the non-rebreathing "T" valve (AFT21). It's very important that any extraneous volumes are minimized between the subject and the "T" valve. Additional volumes affect the effective expired gas concentration levels.

When the subject inspires, air is drawn into the AFT21 as shown by the "Flow In" arrow, through the TSD107B airflow transducer. The TSD107B is placed on the inspiration side to eliminate any effects associated with expired air humidity.

When the subject expires, air is directed out to the 5 liter mixing chamber (AFT15A). The O2100C module connects to the mixing chamber via an AFT20 gas sampling interface kit. The gas sampling interface kit acts to filter and dehumidify the expired gases residing within the mixing chamber.

The non-rebreathing "T" valve directs only expired air to the 5 liter mixing chamber. Because only expired air is directed to the chamber, the mixing chamber acts to average respiratory outflows. This averaging effect causes the O_2 concentration to vary in accordance with the mean values resident in several expired breaths. The size of the mixing chamber determines the extent of the averaging effect. For example, assuming the subject's expired breath volume is typically 0.5 liter, the AFT15A mixing chamber will average about 10 expired breaths.

The TSD107B airflow transducer signal is amplified by a DA100C amplifier, which is attached to the MP System along with the O2100C module. Accordingly, two channels of analog data need to be acquired to properly measure oxygen consumption

Acq*Knowledge* Software Setup

** Download the graph template file to expedite software setup**

Acq*Knowledge* 4.X	**vo2simplified_Rescale.gtl** -- Uses the Rescale channel in conjunction with the original channels—this results in double number of calculation channels.
Acq*Knowledge* 4.X	**vo2simplified_Meta.gtl** -- embeds the original channel and the rescale channel into a Metachannel.

Templates are unique because Acq*Knowledge* 4.X performs calculation channel scaling via the Rescale calculation channel rather than directly from the dialog channel setup dialog.

Manual Graph Template Setup

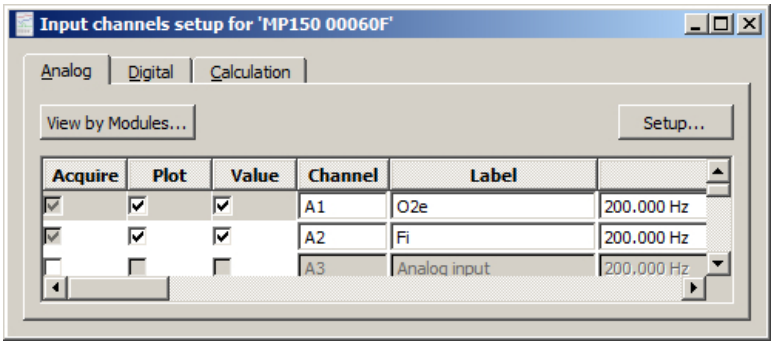
1. Set up two analog input channels.

   NOTE: For precise setup in Acq*Knowledge* 4.1 and higher, click “Add New Module” in Input channels setup and select “O2100C” (CH A1) and “DA100C” (CH A2) from the module list. After completing setup Steps 2 and 3 below, return to “View by Channels > Setup” to perform the calibration. (Page 6)

   - See the Acq*Knowledge* Software Guide for more information on Add New Module setup (available under the Help menu as a searchable pdf file).

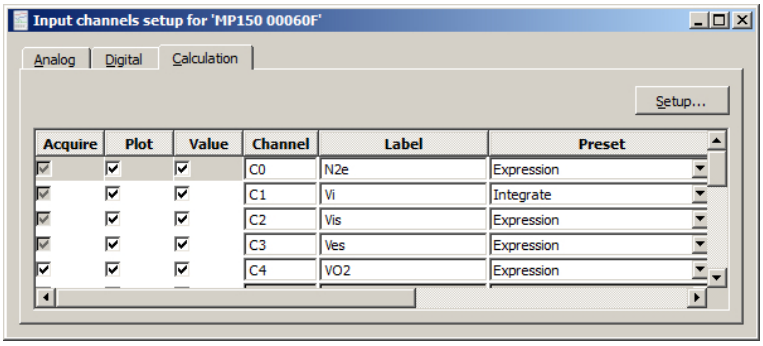
   A1: Oxygen concentration from O2100C module (O_2e)

   A2: Inspired flow from TSD107B via DA100C module (Fi)



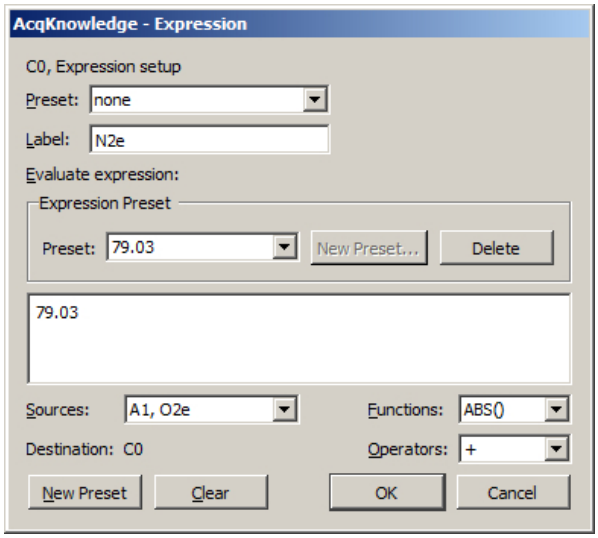
Analog Input Setup for Simplified VO_2 Measurement

2. Set up five calculation channels.



Calculation Channel Setup for Simplified VO_2 Measurement

C0 - Expression: N_2e Nitrogen fractional concentration in expired air



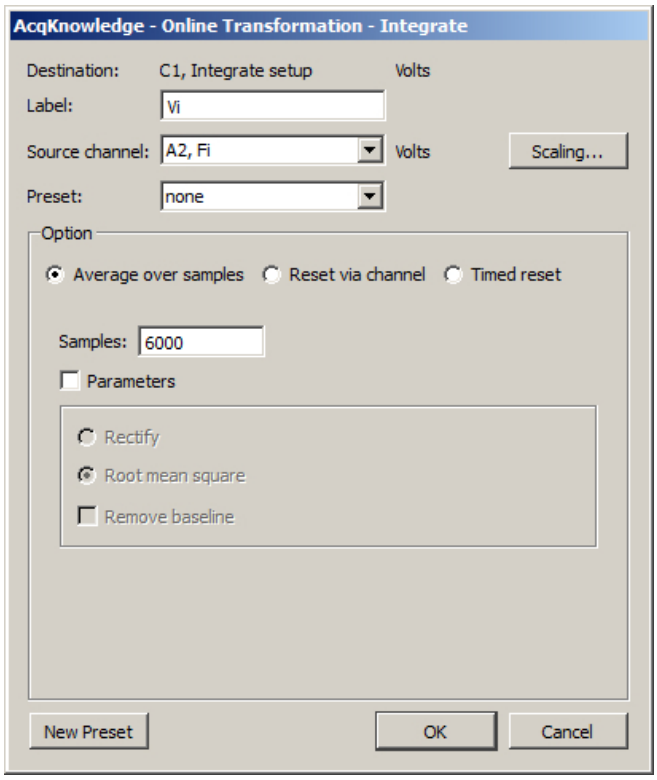
N2e calculation for Simplified VO_2 Measurement

In this simplified VO_2 measurement, the assumption is that expired nitrogen is identical to inspired nitrogen, which indicates that

$VCO_2 = VO_2$, or RER = 1

$N_2e = 79.03$

C1 - Integrate: Vi Inspired air volume (ATP)

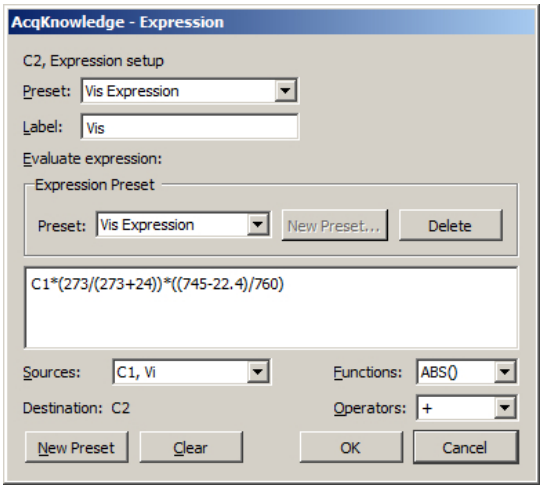


Vi calculation for Simplified VO_2 Measurement

Since the TSD107B is placed in the "Flow In" line, the flow of inspired air can be determined over a running 30 second interval, by integrating the flow signal using the expression (30 seconds equals 6000 samples at a 200 Hz sampling rate):

Vi = Integrate(Fi) over 30 second period

C2 - Expression: Vis Inspired air volume (STPD)



Vis calculation for Simplified VO_2 Measurement

Convert gas at Ambient Pressure and Temperature (**APT**) to Standard Temperature and Pressure, Dry (**STPD**):

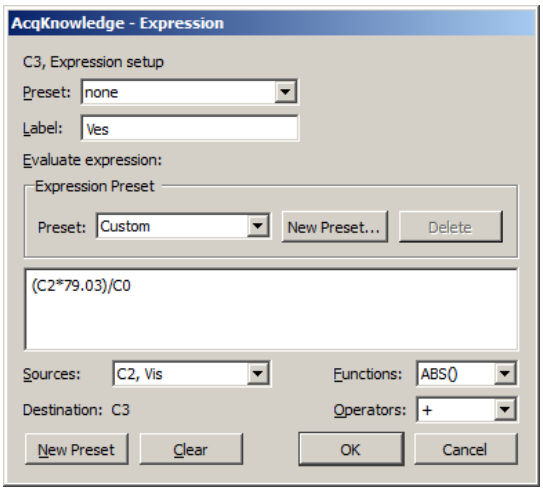
Vis = Vi*(273/(273+Ta))*((Pb-PH20)/760)

where
Ta is ambient temperature (e.g. 24 deg C)

Pb is ambient barometric pressure (e.g. 745 mmHg)

PH20 is ambient pressure of water vapor (e.g. 22.4 mmHg)

C3 - Expression: Ves Expired air volume (STPD)



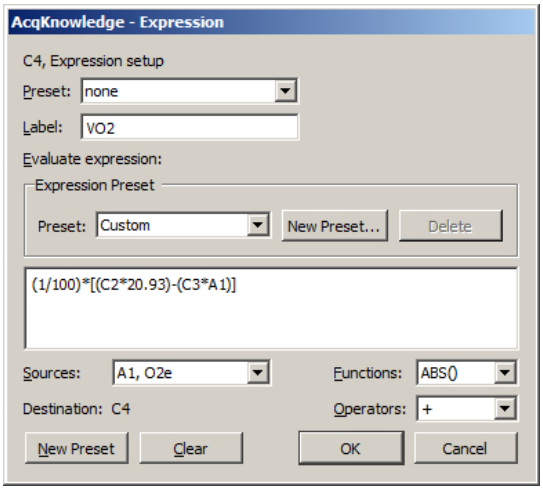
Ves calculation for Simplified VO_2 Measurement

Calculate the expired volume from the inspired volume by using the Haldane transformation (Nitrogen factor); because of the assumption for CO_2 in this setup, Ves = Vis.

Ves = (Vis*79.03) / N_2e

where the value **79.03** is the percent nitrogen in ambient air.

C4 - Expression: VO_2 Volume of oxygen consumed (STPD)



V02 calculation for Simplified VO_2 Measurement

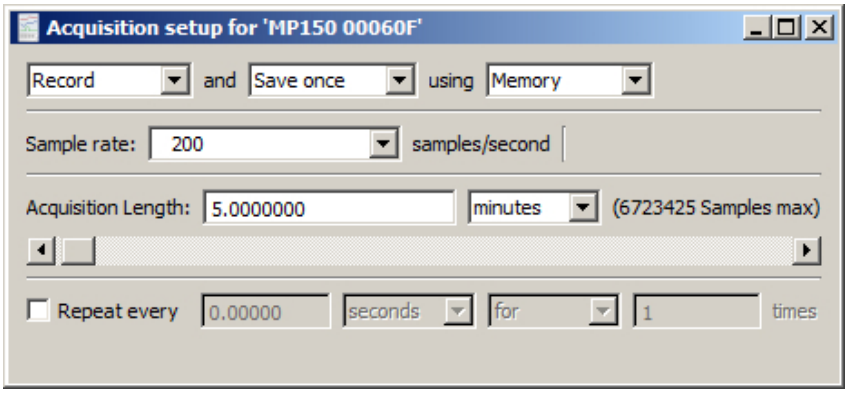
Use the following expression to determine real-time oxygen consumption volume:

VO_2 = (1/100)*[(Vis*20.93) – (Ves*O_2 e)]

where the value **20.93** is the percent oxygen in ambient air.

3. Set up acquisition as follows:

    - Record and Save Once using Memory or Disk
    - Sample rate: 200 samples/second
    - Acquisition length: 5 minutes or longer



Acquisition Setup for Simplified VO_2 Measurement

Calibration

The calibrations for this measurement are critical. Once the equipment and software setup is complete, with all the plumbing fixed and secure, gas concentration calibration can proceed. It's very important to calibrate the system for the following variables:

A. Oxygen concentration (calibrate in range of 21% to 16% O_2)
B. Inspired Flow (calibrate within the range of 0 to 13 liters/sec)

If any changes in plumbing or gas measurement module pump speed are effected, it is generally necessary to repeat the gas measurement module calibration. In this setup, the O2100C module was set to a gain of 10% O_2 per volt and the DA100C amplifier (connected to the TSD107B) was set to a gain of 1000.

- For more information on gas analysis module and flow transducer calibration, please refer to the Acq*Knowledge* Software Guide (available under the Help menu as a searchable pdf file).
- Note that the scaling shown in the following calibration screenshots are examples only. Do not set your scaling parameters to the example values.

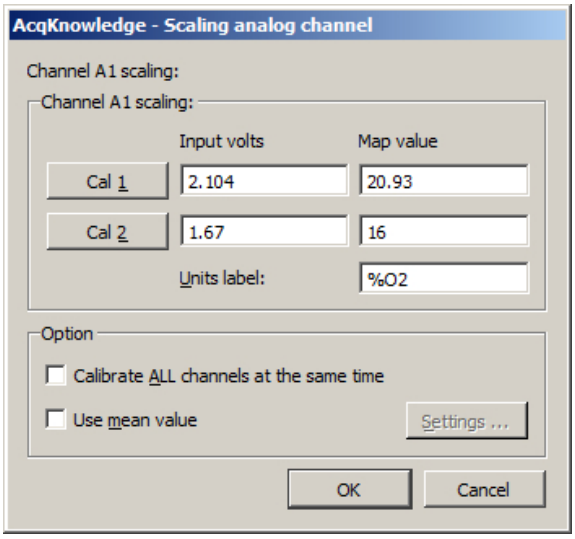
O2100C Module and Mixing Chamber (AFT15A)

1. Flood the mixing chamber with fresh (ambient) air. This can be accomplished by attaching the calibration syringe to the mouthpiece and cycling fresh air into the mixing chamber.

2. Monitor the gas concentration changes using Acq*Knowledge*. When the levels appear stabilized at ambient, obtain the first calibration point.

3. Flood the chamber with the desired gas mixture (recommended: 4% CO_2, 16% O_2 and 80% N_2).

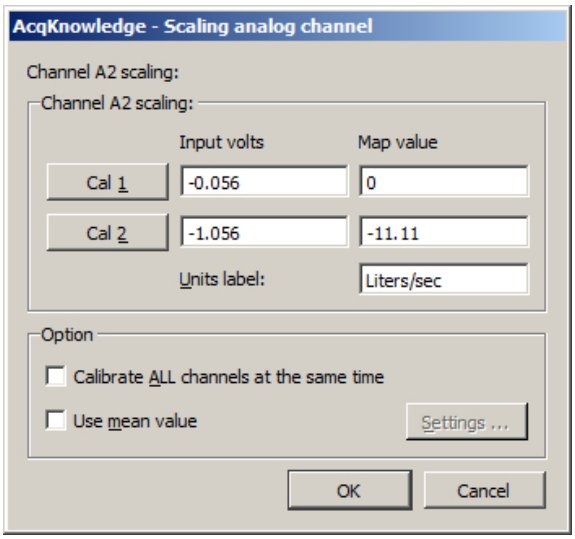
4. When the levels appear stabilized, obtain the second calibration point.



Typical Calibration values for O2100C Module

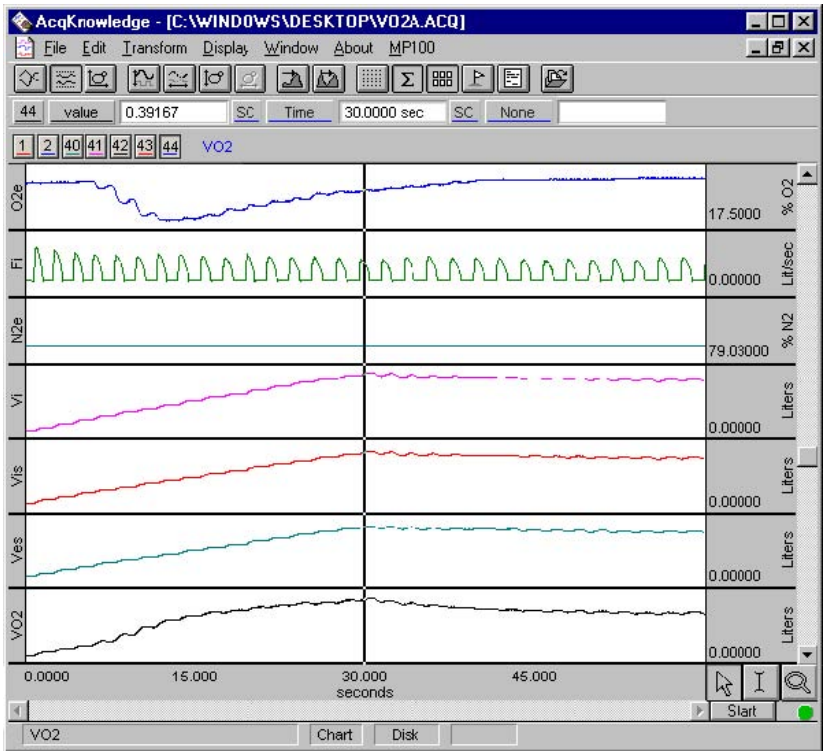
Pneumotach (TSD107B)

1. Use a calibration syringe to inject a precise volume of air through the flow transducer.
2. Determine the appropriate transducer scaling factor so the area under the recorded flow curve equals the volume injected.
3. Perform the first calibration point by recording the transducer output (from the DA100C) at zero flow.
4. Determine the second calibration point by adding the previously recorded scale factor to the offset recorded by the first calibration point.



Typical Calibration values for TSD107B Pneumotach

Analysis



Real-time Oxygen Consumption Data (with raw and calculated data displayed)

Note that the VO_2 measurement (bottom channel) varies smoothly with time. The graphical and continuous nature of this recording and calculation method provides significant information regarding the changes of VO_2 over time.

This particular setup will provide a reading that, at any point in time, indicates the oxygen consumed in the last 30 seconds. Accordingly, the VO_2 reading of 391.67 ml of oxygen consumed is indicative of the amount consumed by the subject in the last 30 seconds. This corresponds to a VO_2 measurement of 46.92 liters/hour.

As a comparison, note that in a resting state, one might use 70 cal/hour, which translates to VO_2 of 15 liters/hour. In active exercise, the same person would use 290 cal/hour, which translates to a VO_2 consumption of 62 liter/hour. A VO_2 consumption of 47 liters/hour indicates the subject is exercising moderately.