HYSYS

In this exercise you will simulate the respiration process using a chemical process simulation package from Hyprotech Inc. This program is used by industry to design and simulate process plants such as oil and gas refineries, chemical and pharmaceuticals production facilities. A typical sampling of well-known companies using this software are given below:

DuPont	Amoco	Arthur D. Little
Eastman Kodak	Exxon Chemical	Ballard
Monsanto	Olin	Koch
Hoechst Celanese	Conoco	Hoffman LaRoche
Rohm & Haas	Phillips	International Flavors
Shell	Foster Wheeler	and Fragrances

This software is written in C++, which is a language that you will learn next semester. The cost of this software is approximately $45,000 for the dynamic version and $20,000 for the steady-state version. This price is for only one user! For more information on Hyprotech go to www.hyprotech.com.

In this computer laboratory experiment, you will simulate the process of respiration

HEAT TRANSFER THROUGH RESPIRATION

In this lab, you will simulate the process of respiration using HYSYS. The software is capable of performing mass balances on the lungs, just as you did in your hand calculations for the Respiration Experiment. In the respiration experiment, you explored the gas exchange that occurs during respiration (i.e., oxygen and carbon dioxide transfer). In this experiment you will investigate the role of respiration in heat transfer.

The Body's Thermoregulatory System

In order to function properly, the body's internal temperature must be kept very close to 98.6 °C, or 37 °C. The energy generated by chemical reactions in your body must eventually be released as heat. The most obvious mechanism for removing heat from the body, as you are well aware, is through perspiration.

As we discovered in the metabolism lab, energy is required for the basic maintenance of the internal organs (basal metabolic rate, BMR), as well as for physical activity. To maintain a constant temperature, this heat must be released from the body at an equal rate. Heat losses occur (under normal conditions, for a seated nude body) by radiation (60%), evaporation from the skin and respiratory tract (25%), convection (12%, and conduction (3%)[i].

ENGINEERING CONCEPTS

The analysis of heat transfer through respiration involves an energy balance on the air flowing in and out of the lungs during respiration. There are two types of energy changes involved in this system: **sensible heat and latent heat**.

> **Sensible heat** is the amount of heat energy that must be supplied to (or removed from) a system in order to raise the temperature a certain amount.

> **Latent heat** is the amount of heat that must be supplied to (or removed from) a system in order to change its phase, without changing the temperature.

The property associated with a change in temperature (sensible heat) or a change in phase (latent heat) of a substance is called **enthalpy**.

Sensible heat change

When a system experiences a change in temperature (at constant pressure), the enthalpy change is:

$$\Delta H = mC_p \Delta T \tag{1}$$

Where ΔH is the enthalpy change of the substance, m is the mass of the substance, C_p is the heat capacity, and ΔT is the temperature change. In the system of units we have used for respiration, H has units of kcal, m has units of g, Cp has units of kcal/g°C, and T has units of temperature.

Latent heat change

When a substance undergoes a phase change, heat energy must be supplied even if there is no change in temperature. Consider liquid water at 100°C. Heat energy must be supplied to it in order to boil it and change the water to a vapor. The enthalpy change associated with the phase from a liquid to a vapor is the latent heat of vaporization:

$$\Delta H_{vap} = H_{vapor} - H_{liq} \tag{2}$$

Where ΔH_{vap} is the enthalpy change associated with vaporization at a particular temperature; H_{vapor} is the enthalpy of the vapor at that temperature, and H_{liq} is the enthalpy of the liquid at the same temperature. For example, consider water at 100°C: The enthalpy of the liquid is 0.1 kcal/g and the enthalpy of the vapor is 0.64 kcal/g°C. The energy that must be supplied to change the liquid to a vapor (at 100°C) is (0.64-0.1) = 0.54 kcal/g. This is **evaporative heat transfer**.

Process simulation, Heat Transfer, and Respiration

In this experiment, we will explore the heat transfer involved in the respiration process. The heat transfer occurs in two ways: The inhaled air is first heated to body temperature (sensible heat change), and is then humidified by evaporating liquid water from the lung tissue (latent heat change). The total heat transfer rate is the combined contributions of the sensible heat transfer and the latent heat transfer.

Using the process simulator, the inhaled air is first heated using a heater. The inlet temperature, pressure, and relative humidity are simply the ambient conditions of the surrounding air. The air is heated to body temperature (37°C) and the same pressure using a heater. This air, at 37°C is then humidified until it is completely saturated (100% relative humidity).

Heat exchange is associated with each step. Energy is removed from the body to heat the air from ambient temperature to body temperature. Then, to humidify this air, water in the lung tissue removes heat energy from the body to become a vapor. This energy is ultimately removed with the saturated air as it is exhaled from the lungs. We can write an energy balance on the heater (sensible heat exchange),or for the humidifier (evaporative heat exchange), or for the entire process:

$$H_{sensible} = H_2 - H_1$$

$$H_{evvap} = H_3 - H_2 - H_{moisture} \tag{3}$$

$$\Delta H_{total} = H_{sensible} - H_{evap}$$
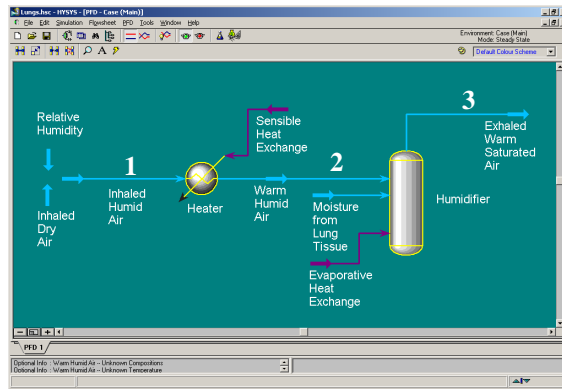
Where stream 1 is the inhaled air at ambient conditions, stream 2 is the inhaled air heated to body temperature, and stream 3 is the exhaled saturated air at body temperature.

Analysis

You will determine the rate of heat transfer due to respiration and compare it to the total heat loss of the body. You will also examine the relative contributions of sensible heat transfer and evaporative heat transfer, under conditions of varying ambient temperature and humidity.

RESPIRATION PROCESS SIMULATION INSTRUCTIONS

For your in class assignment, you will repeat this procedure for three cases:

1. Ambient conditions measured at the weather station on the day of your experiment.
2. Cold and Dry: T=0°C, ambient pressure and relative humidity of 30%.
3. Warm and Humid: Temperature = 30 °C and ambient pressure, 100% relative humidity.

1) Start your computer:

   a) Log on to the Engineering Network
   b) Start HYSYS using the menu bar (Start…Programs…Hyprotech…HYSYS3.1…Hysys)

2) Follow the steps below to save the two email attachments that were sent to you during class.

   a) Open your email
   b) Open the email message from me.
   c) Click on the attachment called Lung.prf
      i) When a window appears offering you the choice to open or save this file, choose Save. Save the file on your Engineering drive.
      ii) Repeat the process for the file called lungs.hsc

3) Follow the steps to open the HYSYS case lungs.hsc…

   a) From the menu bar, click File-open-case... Then browse to find the file lungs.hsc that you just saved on your Engineering Drive.
   b) The process flow diagram for respiration should appear as shown in Figure 1.

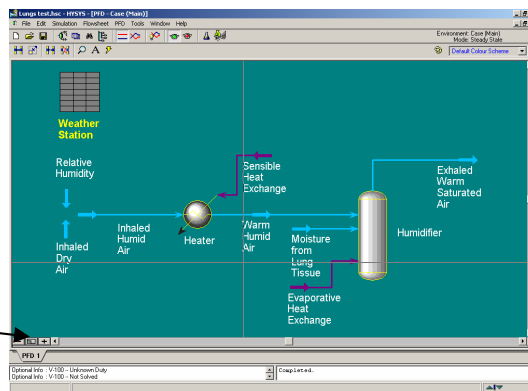You can center the diagram at any time by clicking the center button here.

Figure 1. The process flow diagram for respiration.

   c) Rename the file by clicking File… Save As… Provide a filename such as case1. When you repeat the procedure next time, use a different filename such as case2.
   d) Click the Save button.

4) Follow the steps below to choose the preferred system of units for your calculations. A set of units has already been created for the units commonly used in respiration calculations (Temperature [=] °C, Pressure [=] mm Hg; gas volumetric flow rate [=] L/min; power [=] kcal/h)…*Ignore any error messages regarding an old version of HYSYS.*

    a) From the menu bar, choose Tools-Preferences…

    b) A pop-up window appears. Click the button that says load preference set.

    c) Browse to find the folder for preference set: public1\farrell\hysys.

    d) Double-click on the file name lungs.prf.

5) In this step you will provide the general ambient weather conditions for the test case. Enter the appropriate ambient conditions (T, P, Relative Humidity) into the Weather Station. (Note: These are the room conditions for each simulation case mentioned above).

    a) Double Click on the Weather Station

    b) Enter the appropriate values of T, P, RH in column B. The relative humidity should be expressed as a decimal (e.g., 0.45) rather than a percentage.

    c) Click the X in the top right corner of the window to close it.

6) Now you will enter the same Temperature and Pressure again, specifically for the dry inhaled air. Follow the steps below to enter the T, P, the dry inhaled air….

    a) Double-click on the Dry Inhaled Air stream.

    b) A pop-up window appears. The stream variables are listed in the left-hand column (Temperature, pressure, flowrate, etc.).

    c) Click on the right column and enter values as shown in Figure 2. Notice that the units are displayed in the drop-down box to the right of the data entry box.
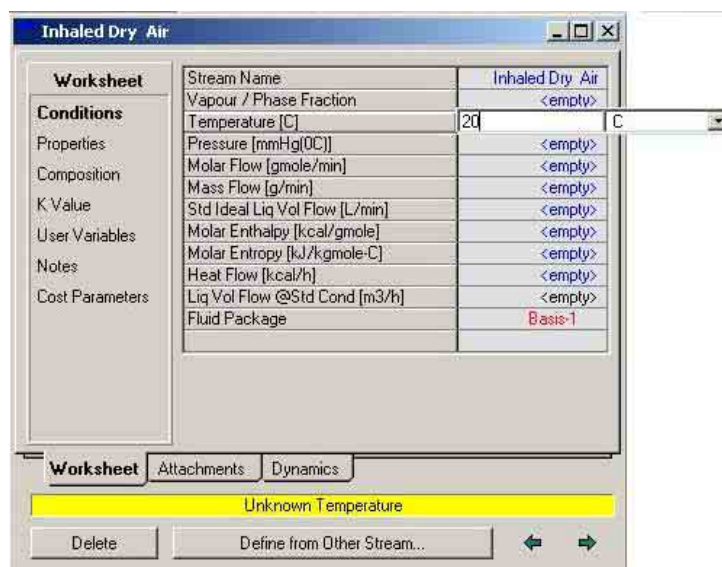

Figure 2. Entering Stream Information

d) Enter the Temperature and Pressure for your simulation case. Also enter your calculated value of the molar Flowrate of air that you obtained from experimental data (same for each simulation case).

e) Notice that when these three values have been entered (shown in blue), all the cells in the table automatically fill up with numbers (in black). The black numbers are automatically calculated by HYSYS when sufficient information has been supplied.

f) Click the X in the top right corner of the window to close it.

g) Click the Save button.

7) Just observe. Notice stream labeled Inhaled Humid Air. HYSYS has performed calculations (based on the information supplied for the dry air and RH), to determine the total flowrate of inhaled humid air. This is the air that is actually inhaled.

a) Double-click on the stream arrow, the pop-up window provides values for all the stream variables (T, P, flowrate, etc.).

b) Notice that the Temperature and Pressure of this stream are the same as the ambient conditions that you entered for the dry air stream.

c) Click the X in the top right corner of the window to close it.

8) Follow the steps below to enter the Temperature (body temperature) and Pressure of the Warm Humid Air stream…

a) Follow the procedure in 6)c) to enter the temperature and pressure.

b) Click the X in the top right corner of the window to close it.

c) Click the Save button.

9) Follow the steps below to enter the Temperature (body temperature) and Pressure of the Moisture from Lung Tissue stream…

a) Follow the procedure in 6)c) to enter the Temperature (body temperature) and pressure.

b) Click the X in the top right corner of the window to close it.

c) Click the Save button.

10) Enter the Temperature (body temperature) of the Exhaled Warm Saturated Air stream…

a) Follow the procedure in 6)c) to enter the temperature.

b) Click the X in the top right corner of the window to close it.

c) Click the Save button.

11) Print your results…

a) Set up the printer for graphics: From the menu bar, choose File-Printer Setup and select graphic printer. When the popup window appears, choose 1st floor printer in the drop down box. Click OK.

b) Set up the printer for reports. From the menu bar, choose File-Printer Setup and select reports printer. When the popup window appears, choose 1st floor printer (labs-eng131-hp4200-g) in the drop down box. Click OK.

c) Print the process flow diagram. With the process flowsheet window on the screen, go to the menu bar and click File-print.

d) Print the Stream information…

   i) From the Menu Bar, click Tools – Workbooks. When the pop-up window appears, double-click on Case (Main). When the workbook appears, make sure the "Streams" tab is selected at the bottom of the window.

   ii) From the main menu bar, click File-Print.

Check only the Streams box.
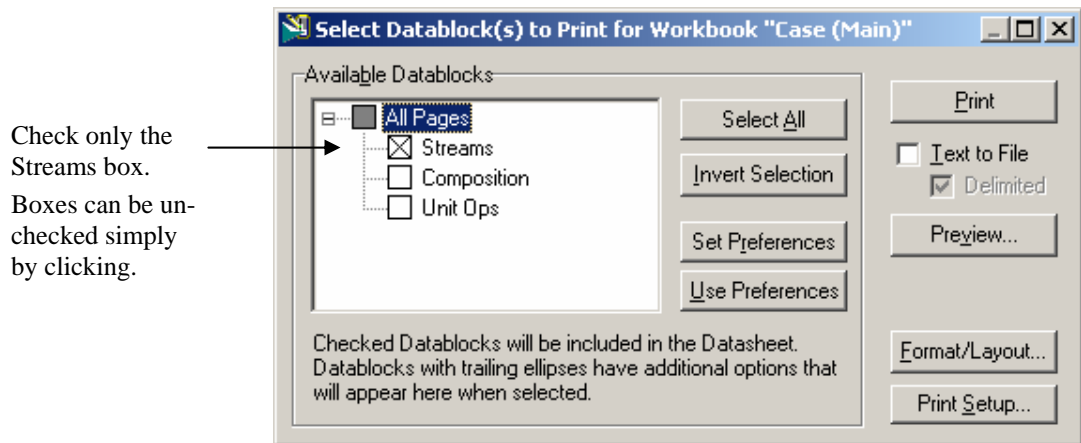
Boxes can be un-checked simply by clicking.

Figure 3. Selecting data to print.

   iii) Check the Worksheet Conditions box (only) as shown in Figure 3. To uncheck a box, simply click it if it is already checked.

   iv) Click the Print button.

12) Close the case and exit the program. From the menu bar, click File-Close Case. Then Click File-Exit to exit the program.

ASSIGNMENT

At the end of the class, turn in (1) your HYSYS printouts and (2) your calculations along with the requested comments and observations. Be sure to include units on all your calculations.

CALCULATIONS AND ANALYSIS

1) Calculate your BMR as you did in the Metabolism Lab. (The equation is given on the following page). You may simply reference your Metabolism assignment if you take the BMR value that you calculated in that assignment.

2) Construct a table of your simulation results for the rates of sensible- and evaporative-heat transfer for each simulation case. Notice that the Heat Transfer Rates for each simulation case are calculated by HYSYS, and are displayed in the Worksheet as separate "streams".

	T (°C)	P (mm Hg)	RH (fraction)	Sensible Heat Exchange (kcal/h)	Evaporative Heat Exchange (kcal/h)
Case 1					
Case 2					
Case 3					

3) How much does each of the above heat transfer rates in #2 contribute to the total heat transfer rate (BMR)?

4) For simulation case 1 and simulation case 2 (warm day vs. cold day), compare the following heat transfer rates.

   a) The sensible heat transfer rate (Case 1 vs. Case 2). Does the ambient temperature have a significant effect on the sensible heat transfer rate? Compare and explain why.

   b) The evaporative heat transfer rate (Case 1 vs. Case 2). Does the ambient temperature have a significant effect on the rate of evaporative heat transfer? Compare and explain why.

5) For simulation case 1 and simulation case 3 (normal humidity vs. high humidity), compare the following heat transfer rates:

   a) The sensible heat transfer rate (Case 1 vs. Case 3). Does the relative humidity have a significant effect on the sensible heat transfer rate? Compare and explain why.

   b) The evaporative heat transfer rate (Case 1 vs. Case 3). Does the relative humidity have a significant effect on the rate of evaporative heat transfer? Compare and explain why.

Male

$$\frac{(BMR)}{(SA)} = \left[54.79\,\frac{kcal}{m^2 \cdot h}\right] - \left[1.303\,\frac{kcal}{m^2 \cdot h \cdot yr}\right] * Y + \left[0.0294\,\frac{kcal}{m^2 \cdot h \cdot yr^2}\right] * Y^2$$

$$- \left[0.0001228\,\frac{kcal}{m^2 \cdot h \cdot yr^3}\right] * Y^3 - \left[3.3558*10^{-6}\,\frac{kcal}{m^2 \cdot h \cdot yr^4}\right] * Y^4 \qquad (4)$$

$$+ \left[2.903*10^{-8}\,\frac{kcal}{m^2 \cdot h \cdot yr^5}\right] * Y^5$$

Female:

$$\frac{BMR}{SA} = \left[55.73\,\frac{kcal}{m^2 \cdot h}\right] - \left[1.757\,\frac{kcal}{m^2 \cdot h \cdot yr}\right] * Y + \left[0.0414\,\frac{kcal}{m^2 \cdot h \cdot yr^2}\right] * Y^2$$

$$+ \left[5.216*10^{-6}\,\frac{kcal}{m^2 \cdot h \cdot yr^3}\right] * Y^3 - \left[1*10^{-5}\,\frac{kcal}{m^2 \cdot h \cdot yr^4}\right] * Y^4 \qquad (5)$$

$$+ \left[7.979*10^{-8}\,\frac{kcal}{m^2 \cdot h \cdot yr^5}\right] * Y^5$$

Surface Area can be found from the following correlation, which relates SA to mass, and height [ii]:

$$SA = \left[0.202\,\frac{m^{1.275}}{kg^{0.425}}\right] * m^{0.425} * h^{0.725} \qquad (6)$$

where SA is in units of (m^2), m is mass in kg and h is height in meters.

REFERENCES

[i] Cooney, David O., Biomedical Engineering Principles, Marcel Dekker, NY 1976.

[ii] Cameron, J., J. Skofronick, and R. Grant, <u>Physics of the Body</u>, Medical Physics Publishing, Madison, WI, 1992.