This appendix presents a brief introduction to energy calculations for operators of rinks and arenas.

Energy calculations can be easily done for the heat loss that occurs in winter and the amount of heat input required in maintaining the temperature. Calculations to estimate the amount of cooling required for ice making, or to maintain a cold building during the summer, are more difficult and should only be attempted by a qualified consultant.

The rate at which heat flows through different materials is called that material's conductivity, which is determined by the make-up of the material.

A building board such as plywood or drywall sheathing has a certain thickness and conductivity, and will conduct heat at a fairly consistent rate. This is called the conductance of the building board. The higher the conductance value, the more heat will be transported (by conduction) through the board. As an example, three-quarter inch plywood has a conductance value of 1.07, where as one-half inch drywall has a conductance value of 2.25.

A common method of expressing conductance (U) is by taking its inverse (1/U), which is the familiar resistance (R-value in imperial units, RSI in metric units) to heat flow.

Calculating heat loss from conduction

To calculate heat loss due to conduction, use the following equation:

$$\textbf{Heat flow} = \frac{\textbf{(Area) x (Temperature difference)}}{\textbf{(Thermal resistance)}}$$

OR

$$Q_k = (A \times \Delta T) / (R)$$

When using this equation to calculate heat flow in imperial units:

Q_k = heat flow in Btu/hour

A = area in square feet (ft^2)

ΔT = temperature difference in degrees F

R = thermal resistance in R-value

When using metric units:

Q_k = heat flow in watts (W)

A = area in square meter (m^2)

ΔT = temperature difference in degrees C

R = thermal resistance in RSI

The degree at which insulation is minimized is related to how much of the structure or framing goes through the insulation. The calculation that is required to determine the exact effect is somewhat complicated and should be carried out by a consultant, but there are counterbalancing factors as well. The resistance of the interior and exterior sheathing, and even the resistance of the still air on the interior and exterior surface of the building, add to the overall resistance. The result is that quite often the nominal resistance – the resistance of the insulation alone – is fairly close to the assembly resistance.

The resistance of the assembly is also affected by the quality of its construction and installation of the insulation. This often affects the overall result more than the difference between the nominal and assembly resistance.

The amount of heat carried by air currents brushing against the interior and exterior surfaces of the building is best calculated by estimating the equivalent conductive resistance. This is termed the surface film resistance and can be used in the calculation of the assembly conductive resistance, although the added effect will be small.

Radiant barriers on insulation do not add much resistance to a well-insulated building envelope. The reason is that a well-insulated building envelope in winter will have interior and exterior surface temperatures close to the ambient conditions on either side. There will be some benefit from radiant barriers that protect against heat gain.

Heat transfer through windows

The exception to radiant barriers is windows. Making the window opaque or reflective to heat radiation decreases the amount of heat transmission through the window and increases the comfort level next to the window.

The R-value of windows have improved over the years with common upgrades such as; low emissivity (low-E) coating on the glass, inert gas fill (i.e. argon or krypton) between glass layers, and insulating spacers between panes of glass. All of these are designed to reduce heat transfer from the warmest to the coldest parts of the window. This also helps reduce window condensation caused by increased humidity, allowing the space to be more comfortable. Other upgrade options include additional glass layers and improved frame design using fiberglass and PVC materials.

The Energy Rating (ER) label is a positive or minus rating system that makes it easy to compare performance among different quality windows by evaluating solar heat gain; heat loss through frames, spacer and glass; and heat loss due to air leakage. A few high-efficiency windows rate positive, which means they can actually contribute to heating the space through passive solar heat gain.

Look for the ENERGY STAR® label and climate zone rating on windows for the best in energy efficiency. Four climate zones have been determined in Canada (A-B-C-D), from warmest to coldest. Saskatchewan’s climate zone is C. ENERGY STAR qualified windows will show the climate zone on the label or on its sales literature.

Generally speaking, windows that are fixed or non-opening are more energy efficient than operable windows.

Calculating heat flow caused by air leakage

To calculate the amount of heat flow due to air leakage, use the following equation:

Heat flow = (Volume flow rate) x (Air density)
x (heat capacity of the air) x (temp. difference)

OR

$$Q_a = (V) \times (d) \times (cp) \times (\Delta T)$$

Where:

Q_a = heat loss in watts (W)

V = flow rate volume in litres per second (L/s)

d = air density at standard conditions in kilograms per cubic metre (kg/m^3)

cp = specific heat capacity of air in kilojoule per kilogram degree Kelvin (kJ/kg °K)

ΔT = temperature difference in degrees C

The heat capacity of the air is the amount of heat that the air can hold per degree of temperature. It is expressed in pounds or kilograms of air per degree of temperature.

Using imperial units and average temperatures for the equation above yields:

$Q_a = (V) \times (d) \times (cp) \times (\Delta T)$

$Q_a = (V) \times [(0.075) \times (0.24)] \times (\Delta T)$

$Q_a = (V) \times (0.018) \times (\Delta T)$

Where:

Q_a = heat loss in Btu/h

V = flow rate volume in cubic feet per hour (cf/h)

d = air density at 70°F - 0.075 pounds per cubic foot (lb/cf)

cp = specific heat capacity of air - 0.24 btu per pound degree F (Btu/lb °F)

ΔT = temperature difference in degrees F

Calculating the amount of energy loss in ventilation is exactly the same as for air leakage. If heat recovery is used on the ventilation exhaust air, then you must multiply the total air volume by the fraction of unrecovered energy.

Heat recovery ventilators (HRV) are becoming common appliances in energy efficient homes, and similar units are available for larger municipal and institutional facilities. HRV’s are rated according to their effectiveness in recovering exhaust heat. The higher the effectiveness, the higher the heat recovery. Check the main body and Appendix vi of the manual for details on HRV’s and other mechanical equipment that can reduce energy consumption.

Heat flow methods

There are basically four methods of heat flow that have to be considered for buildings:

- Conduction across all the building assemblies, such as walls, ceilings, floors, windows and doors
- Air leakage (infiltration)
- Ventilation heat losses
- Radiation (solar)

The effect of radiation on the building envelope can be calculated using the SolAir temperature in the conduction calculations. This is explained in the 2001 ASHRAE Handbook of Fundamentals.

Calculations for energy transfer between interior surfaces by radiation should be done when the surface temperatures differ between assemblies, such as for the ceiling and ice surface. Detailed calculations, where required, should be done by a qualified consultant.

Energy software programs

Simplified energy programs can be run on most personal computers. These generally work best and most accurately for buildings that require heating only. This is because it is too difficult to estimate the exact effect of heat gains from people, who give off heat depending on their activities, and equipment, which may run only intermittently.

The simplest programs require information about the building envelope, such as the areas of the walls and various R-values. This type of information is required for all the different components that make up the building envelope; that is, all the walls, the ceiling or roof, the different areas of the floor, and such elements as the windows and doors.

One of the most popular software programs is used in the R-2000 housing series, called HOT2000™. The software is available on-line and free to download from Natural Resources Canada – Buildings Group. The HOT2000™ program is a computer simulation tool that is used as the reference calculation application for the R-2000 Program. The building simulation tool helps you build comfort, sustained energy performance and lower operating costs into all your new construction and major renovation projects.

The tool was designed to model houses, but can be used for buildings that have little or no ventilation systems and are less than 8,000 square feet.

Other simulation tools available from Natural Resources Canada – Buildings Group include software applications in areas such as lighting and daylighting, HVAC, Building Envelope and Windows, Whole House Design and Performance, and Whole Building Performance.