Fact Sheet No. 4

Simplified Laboratory Energy Cost Calculations

Our clients often ask, “what is the yearly cost to condition one CFM of air?” This is an important figure to know if you are attempting to predict energy usage for a new facility or evaluate the economics of engineering modifications to an existing laboratory such as heat recovery systems or fume hood face velocity controls. You can easily calculate approximate costs if you know four things:

- Heating Degree Days
- Cooling Degree Days
- Average Electrical Costs
- Average Natural Gas or Steam Costs

FACTS:

The costs to condition a CFM of air may be divided into five major categories: heating, cooling, fluid moving, humidification and dehumidification.

To accurately predict these costs, many consultants simulate the building, mechanical systems and the weather using a computer model. This type of accurate analysis is recommended when designing a new facility in order to size the mechanical equipment and determine power distribution and emergency generating capacity. If, however you just need a relatively close and conservative figure then there is a simpler way of calculating energy costs. It utilizes the first three components mentioned above, heating, cooling and fluid moving, since these can be easily approximated using simple formulae and data which is easy to obtain.

Weather data may be obtained either through the public library in the reference section under the heading *local climatological data* or directly through the National Oceanic and Atmospheric Administration, U.S. Department of Commerce, National Climatic Data Center, Federal Building,

Eq. 1.A.: Heating Costs
Using natural gas as the fuel in either direct-fired equipment or in a steam boiler and assuming an 80% efficiency yields the following:

$$Cost_{HTG} \cong \left(DD_{HTG\,65^\circ}\frac{^\circ F\bullet Day}{Yr}\right)\left(E_{GAS}\frac{\$}{CCF}\right)\left(\frac{1.08\ Btu}{Hr\bullet CFM\bullet {}^\circ F}\right)\left(\frac{24\ Hr}{Day}\right)\left(\frac{1}{0.8}\right)\left(\frac{CCF}{1x10^{5}\ Btu}\right)$$

Combining terms:

$$Cost_{HTG} \cong \left(DD_{HTG\,65^\circ}\frac{^\circ F\bullet Day}{Yr}\right)\left(E_{GAS}\frac{\$}{CCF}\right)\left(3.24x10^{-4}\frac{CCF}{Day\bullet CFM\bullet {}^\circ F}\right) \cong \left(\frac{\$}{CFM\bullet Yr}\right)$$

Eq. 1.B.: Heating Costs
Using steam as the heat source yields the following:

$$Cost_{HTG} \cong \left(DD_{HTG\,65^\circ}\frac{^\circ F\bullet Day}{Yr}\right)\left(E_{STEAM}\frac{\$}{1000\ Lb}\right)\left(\frac{1.08\ Btu}{Hr\bullet CFM\bullet {}^\circ F}\right)\left(\frac{24\ Hr}{Day}\right)\left(\frac{1000\ Lb}{1x10^{6}\ Btu}\right)$$

Combining terms:

$$Cost_{HTG} \cong \left(DD_{HTG\,65^\circ}\frac{^\circ F\bullet Day}{Yr}\right)\left(E_{STEAM}\frac{\$}{1000\ Lb}\right)\left(.026\frac{Lb}{Day\bullet CFM\bullet {}^\circ F}\right) \cong \left(\frac{\$}{CFM\bullet Yr}\right)$$

Where:
$DD_{HTG\,65^\circ}$ = Heating Degree Days, 65°F base.
E_{GAS} = Average Natural Gas Costs
E_{STEAM} = Average Steam Costs

Eq. 2.: Cooling Costs
Using electricity as the power source for a mecanical refrigeration system operaing at a C.O.P. of 4.5 yields the following:

$$Cost_{CLG} \cong \left(DD_{CLG\,65^\circ}\frac{^\circ F\bullet Day}{Yr}\right)\left(E_{ELECT}\frac{\$}{KwH}\right)\left(\frac{1.08\ Btu}{Hr\bullet CFM\bullet {}^\circ F}\right)\left(\frac{24\ Hr}{Day}\right)\left(\frac{1}{4.5}\right)\left(\frac{3.41x10^{-3}\ KwH}{Btu}\right)$$

Combining Terms:

$$Cost_{CLG} \cong \left(DD_{CLG\,65^\circ}\frac{^\circ F\bullet Day}{Yr}\right)\left(E_{ELECT}\frac{\$}{KwH}\right)\left(.0196\frac{KwH}{Day\bullet CFM\bullet {}^\circ F}\right) \cong \left(\frac{\$}{CFM\bullet Yr}\right)$$

Where:
C.O.P. = Coefficient of Performance of the mechanical refrigeration. Btu of Cooling / Btu of Energy Input (dimensionless)
$DD_{CLG\,65^\circ}$ = Cooling Degree Days, 65°F base.
E_{ELECT} = Average Electrical Costs

Asheville, NC. Utility costs can be obtained through your local utility, or in the case of a large facility, your plant engineering or power department.

The first step is to calculate the heating costs. If your heating system uses natural gas apply equation 1. A., if it uses steam apply equation 1.B.

The next step is to calculate the cooling costs. See equation 2.

The third step is to calculate the fluid moving costs. Use equation 3.

The final step is to to combine all of these to get the total cost. See equation 4.

For example, in Midland, Michigan which has 6847 heating degree days, 555 cooling degree days, an average natural gas cost of \$0.80/CCF, and an average electrical cost of \$0.15/KwH will yield an annual cost of \$5.02 to condition one CFM of air per year. This is shown in example 1.

Eq. 3.: Fluid Moving Costs

Using electricity as the power source for supply fans, exhaust fans, air-cooled condenser fans or cooling tower fans, and hot/chilled water pumps for a typical laboratory mechanical system yields the following:

$$Cost_{FLUID\ MOVING} \cong \left(E_{ELECT}\frac{\$}{KwH}\right)\left(.746\ \frac{Kw}{Hp}\right)\left(1.75\text{x}10^{-3}\frac{Hp}{CFM}\right)\left(8760\ \frac{Hr}{Yr}\right)$$

Combining Terms:

$$Cost_{FLUID\ MOVING} \cong \left(E_{ELECT}\frac{\$}{KwH}\right)\left(11.4\ \frac{KwH}{CFM\bullet Yr}\right) \cong \left(\frac{\$}{CFM\bullet Yr}\right)$$

Where: E_{ELECT} = Average Electrical Costs

Eq. 4.: Total Costs

$$Cost_{TOTAL} \cong Cost_{HTG} + Cost_{CLG} + Cost_{FLUID\ MOVING}$$

Example 1. Total Cost

$$Cost_{TOTAL} \cong \left(6847\ \frac{°F\bullet Day}{Yr}\right)\left(0.80\ \frac{\$}{CCF}\right)\left(3.24\text{x}10^{-4}\ \frac{CCF}{Day\bullet CFM\bullet °F}\right) = \$1.68\ \text{(Heating)}$$

$$+\left(555\ \frac{°F\bullet Day}{Yr}\right)\left(0.15\ \frac{\$}{KwH}\right)\left(.0196\ \frac{KwH}{Day\bullet CFM\bullet °F}\right) = \$1.63\ \text{(Cooling)}$$

$$+\left(0.15\ \frac{\$}{KwH}\right)\left(11.4\ \frac{KwH}{CFM\bullet Yr}\right) = \$1.71\ \text{(Fluid Mvg)}$$

$$= 5.02\ \frac{\$}{CFM\bullet Yr}$$

CAUTIONS:

Note that these formulas are, in some cases fairly conservative because they only estimate sensible heating and cooling loads and do not take into account latent heat in the form of dehumidification and humidification. Actual costs in most applications and locations will be higher. In hot and humid locations (Florida, Louisiana, etc.) requiring extensive dehumidification and in extremely cold areas (Minnesota, etc.) which require significant humidification this method may yield results as much as 25-30% lower than actual.

CONCLUSION:

The average four foot benchtop fume hood consumes approximately 800 CFM of air from the laboratory space. In the above example, this one hood, operated in a constant volume fashion, would cost over \$1,800 per year to operate. In a medium sized educational or research laboratory facility with 100 fume hoods of different sizes, the yearly energy costs to operate the facility can exceed a quarter of a million dollars.

There are many ways to conserve energy in laboratories without sacrificing safety. For example, heat recovery and variable air volume laboratory airflow controls can result in a savings of more than 50% of your annual energy consumption and costs. An experienced laboratory consultant can assist you when building a new facility, renovating an existing facility or examining the options to reduce your operating costs.

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Contact Us:

SAFELAB Corporation
5350 West 79th Street
Indianapolis, Indiana 46268-1631
U.S.A.
Phone: 1-888-SAFELAB
(1-888-753-3522)
1-317-872-6600
E-Mail: dhitchings@saflab.com