ENERGY SAVINGS ESTIMATE—CONSTANT VOLUME VS. VARIABLE AIR VOLUME FUME HOODS

APPLICATION NOTE LC-120

When designing or retrofitting a laboratory, consideration should be given to variable air volume (VAV) versus constant volume (CV) fume hoods. The use of variable air volume fume hoods has two distinct advantages over constant volume hoods: 1) Increased safety due to having a constant face velocity at a value that provides optimal containment, 2) energy savings due to reduced amounts of conditioned air being exhausted through the fume hoods. The disadvantage is the added initial cost of VAV controls. This cost, in most cases, can be offset by the energy savings that will result. In a retrofit application, energy savings might be used to justify the cost of the renovation.

Potential energy savings come from the reduced amount of conditioned air exhausted through the fume hoods. A CV hood exhausts the same volume of air regardless of sash position. A VAV hood only exhausts the amount of air required to maintain a specified face velocity setpoint. Additional energy savings come from reduction in fan horsepower due to the ability to reduce the supply fan speed, and possibly exhaust, during low hood usage. In many situations energy savings can also be realized by the reduction in the amount of reheat required to satisfy space temperature at lower airflow rates.

This paper will use a simple and conservative approach that calculates energy savings based on a reduction of airflow and costs associated with conditioning and moving that air. This method only considers sensible heating and cooling. In climates needing dehumidification, or those that require humidification in winter months, there could be significantly more energy savings. For new facilities or major retrofits, a consulting engineer may be able to provide a more detailed study by using computer modeling to simulate actual laboratory operation.

The following pages provide a step by step procedure to determine energy costs of operating a laboratory containing fume hoods. The Energy Analysis first gives $/CFM*Yr based on degree days and energy costs. Potential energy savings can then be determined by evaluating the anticipated use of the VAV hoods verses the CV system. If the cost per CFM has already been determined, go directly to Step 4.

TSI has also created a spreadsheet to perform the calculations explained in this Application Note. To obtain a copy of the spreadsheet please contact your local representative or TSI Incorporated.

Step 1: Determine Heating and Cooling Degree Days

Degree Day: A degree day is based on a balance temperature in which the difference between mean outdoor ambient temperature and indoor temperature setpoint balances any loads due to temperature difference, solar gains, lights, occupants and so forth. When the mean temperature varies from the balance point, either a heating or cooling load occurs. The balance temperature is commonly defined as 65°F. Tabulated data is readily available for this value.

The heating and cooling degree days can be obtained from the local weather service or at a local library in the reference section under the heading Local Climatological Data:

Cooling Degree Days = __________

Heating Degree Days = __________

Step 2: Determine Fuel or Energy Costs

Determine the average cost of the energy sources used to move and condition air in the facility. The equations to follow use electricity in $ per Kwh, natural gas in $ per ccf and steam in $ per Lb.

Energy costs can be obtained from the local utility company or the physical plant:

Average Electrical Costs = __________ per Kwh

Average Natural Gas Cost = __________ per ccf

Average Steam Costs = __________ per Lb.

Step 3: Calculate Cost Per CFM Per Year

Some simple equations can determine the cost to condition and move an average CFM through the facility based on degree days and energy costs. Below are the basic equations:

$$\text{Cost} \cong \text{Load} \bullet \text{Energy Cost} \bullet \frac{\text{Sensible Energy Load}}{\text{CFM}} \bullet \text{Equipment Efficiency}$$

Natural Gas Heating Cost per CFM per Year:

$$Cost_{htg} \cong DD_{htg65}\frac{F \bullet Day}{Yr} \bullet E_{gas}\frac{\$}{CCF} \bullet \frac{1.08Btu}{Hr \bullet CFM \bullet F} \bullet \frac{24Hr}{Day} \bullet \frac{1}{0.8} \bullet \frac{CCF}{1x10^{-6}BTU} = \frac{\$}{CFM \bullet Yr}$$

$$Cost_{htg} = DegreeDays \bullet EnergyCost \bullet 3.24x10^{-4} = \$\_\_\_\_/\,cfm \bullet yr$$

Steam Heating Cost per CFM per Year:

$$Cost_{htg} \cong DD_{htg65}\frac{F \bullet Day}{Yr} \bullet E_{steam}\frac{\$}{1000Lb} \bullet \frac{1.08Btu}{Hr \bullet CFM \bullet F} \bullet \frac{24Hr}{Day} \bullet \frac{1000Lb}{1x10^{-6}Btu} = \frac{\$}{CFM \bullet Yr}$$

$$Cost_{htg} = DegreeDays \bullet EnergyCost \bullet 2.6x10^{-5} = \$\_\_\_\_/\,cfm \bullet yr$$

Electric Cooling Cost per CFM per Year:

$$Cost_{clg} \cong DD_{clg65}\frac{F \bullet Day}{Yr} \bullet E_{elect}\frac{\$}{KwH} \bullet \frac{1.08Btu}{Hr \bullet CFM \bullet F} \bullet \frac{24Hr}{Day} \bullet \frac{1}{4.5} \bullet \frac{KwH}{3.414x10^{3}Btu} = \frac{\$}{CFM \bullet Yr}$$

$$Cost_{clg} = DegreeDays \bullet EnergyCost \bullet 1.69x10^{-3} = \$\_\_\_\_/\,cfm \bullet yr$$

Fluid Moving Cost per CFM per Year:

$$Cost_{fluidmoving} \cong E_{elect}\frac{\$}{KwH} \bullet 0.746\frac{Kw}{Hp} \bullet 1.75x10^{-3}\frac{Hp}{CFM} \bullet 8760\frac{Hr}{Yr}$$

$$Cost_{fluidmoving} = EnergyCost \bullet 11.4 = \$\_\_\_\_\_/\,cfm \bullet yr$$

Total Cost per CFM per Year:

To determine the cost per CFM on a yearly basis simply add up the associated cost from each of the equations above that apply.

Total Cost per CFM = Cost of Cooling + Cost of Heating + Cost of Fluid Moving

Step 4: Determine Operating Criteria

To calculate operating costs, the current and anticipated laboratory volumes (CFM) and the number of days and hours the hoods are operating must be known. In most cases, the flow volume of a constant volume hood is the volume required to maintain 100 fpm face velocity with the sash fully open.

Current Fume Hood Exhaust Volume:	_________	CFM
Maximum VAV Fume Hood Exhaust Volume:	_________	CFM
Fume Hood Turn Down Ratio:	_________	:1
Hours of Operation Per Day:	_________	hrs/day
Days of Operation Per Year:	_________	days/yr
Diversity Factor:	_________	%

Current Fume Hood Exhaust Volume: The volume at which constant volume hoods are currently operating or the manufacturer's maximum volume rating for new fume hoods

Maximum VAV Fume Hood Exhaust Volume: Obtained from the manufacturer's specifications or by multiplying the desired face velocity by the full open area of the hood (may be the same as the Current Fume Hood Exhaust Volume)

Turn Down Ratio: The allowable maximum flow through the hoods in ratio to the minimum flow (common turndown rations are 4:1 to 5:1, or minimum hood flow is either 25% of full flow (4:1) or 20% (5:1))

Hours of Operation Per Day: Normally 24 hours (in some instances the fume hoods may be turned off at night or when not in use)

Days of Operation Per Year: Normally 365 days (in some instances the fume hoods may be turned off on weekends or holidays)

Diversity Factor: Anticipated percentage of hoods that would be open and operating at any one time

Step 5: Current Constant Volume Operation

Operating cost = CFM × ($/CFM per yr) × (#hrs per day/24 hrs) × (#Days/365 days)

For the purpose of this paper, the laboratory is assumed to follow standard lab codes, standards and practices, all hoods will be operating twenty-four hours per day 365 days per year.

Operating cost = CFM × ($/CFM per yr)

Operating cost = ________ cfm × $________/cfm yr = $__________/yr

Step 6: Determine VAV Operation[1]

To determine operating cost of a VAV hood, we must first decide how the hoods will operate. What turndown ratio can be expected from each hood? What diversity factor, or what percentage of hoods can be assumed open and operating on the average?

$$OperatingCost = \left\{ \left(CFM \cdot \frac{Diversity}{100} \right) + \left[CFM \cdot \frac{1}{turndownratio} \cdot \left(1 - \frac{Diversity}{100} \right) \right] \right\} \cdot \frac{\$}{CFM \cdot yr}$$

Step 7: Determine Cost Savings of CV vs. VAV Operation

Cost Savings = Operating cost of VAV – Operating cost of CV

Cost Savings = $_______/yr – $_______/yr = $_______/yr

To aid in calculation, TSI has a spreadsheet to calculate potential energy savings. Simply enter degree days and energy costs. On the next page is an example showing results using TSI's Energy Estimate spreadsheet.

Additional Energy Savings Device: Sash Stops

An additional energy saving device is a sash stop, usually mounted so the sash can only open half way without intentionally disabling the stop. This restricts the sash operation to 50% of the normal full flow, allowing the use of a greater diversity factor.

CV operation with sash stops:

$$OperatingCost = CFM \cdot 0.5 \cdot \frac{\$}{cfm \cdot yr}$$

VAV operation with sash stops:

$$OperatingCost = \left\{\left(CFM \cdot 0.5 \cdot \frac{Diversity}{100}\right) + \left[CFM \cdot \frac{1}{turndownratio} \cdot \left(1 - \frac{Diversity}{100}\right)\right]\right\} \cdot \frac{\$}{CFM \cdot yr}$$

Additional Energy Saving Practice: Night Setback

An additional energy saving practice is night setback, which is to reduce the exhaust through the fume hoods when the laboratory is unoccupied. Typically, during night setback periods the fume hood exhaust is reduced to achieve a face velocity of 60 ft/min from the standard 100 ft/min.

The first step of calculating costs with any setback scheme is to determine the number of setback hours. The setback hours are a function of the number of hours per day, weekends, and holidays during which the lab will be operating under setback conditions.

$$setbackhours = \left\{\left[\left(\frac{104 weekenddays}{year} + \frac{10 holidays}{yr}\right) \cdot \frac{24 hours}{day}\right] + \left[\left(\frac{365 days}{yr} - \frac{104 weekenddays}{yr} - \frac{10 holidays}{yr}\right) \cdot \frac{12 hours}{day}\right]\right\}$$

CV Operation with Night Setback

$$Operatingcost = CFM \cdot \left\{(setbackhours \cdot 100\%) + \left[\left(\frac{365 days}{yr} \cdot \frac{24 hours}{day} - setbackhours\right) \cdot 50\%\right]\right\} \cdot \frac{\$}{CFM \cdot yr}$$

VAV Operation with Night Setback

$$Operatingcost = \left\{\left(CFM \cdot \frac{Diversity}{100}\right) + \left[CFM \cdot \frac{1}{turndownratio} \cdot \left(1 - \frac{Diversity}{100}\right)\right]\right\} \cdot \left\{(setbackhours \cdot 100\%) + \left[\left(\frac{365 days}{yr} \cdot \frac{24 hours}{day} - setbackhours\right) \cdot 50\%\right]\right\} \cdot \frac{\$}{CFM \cdot yr}$$

VAV Operation with Night Setback and Sash Stops

$$OperatingCost = \left\{\left(CFM \cdot 0.5 \cdot \frac{Diversity}{100}\right) + \left[CFM \cdot \frac{1}{turndownratio} \cdot \left(1 - \frac{Diversity}{100}\right)\right]\right\} \cdot \left\{(setbackhours \cdot 100\%) + \left[\left(\frac{365 days}{yr} \cdot \frac{24 hours}{day} - setbackhours\right) \cdot 50\%\right]\right\}$$

[1] These are only estimates. Actual savings will depend on how hoods are operated, ventilation requirements and other issues. However, these numbers give a good estimate of payback when comparing constant volume to variable air volume fume hood systems.

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