

Improving HVAC System Performance

by Charles Fafard

Heating, ventilating, and air conditioning systems consume between 40 and 60 percent of the total energy in most commercial buildings.

Building management personnel are interested in improving the performance of these systems, not only to save energy cost, but also to improve tenant comfort. Therefore, lowering the energy consumption of building systems should not be the only consideration when evaluating HVAC systems.

HVAC systems can take many forms, since they comprise all the heating, ventilating, and air conditioning systems within a building. These systems usually include an air-handling unit with integral heating and cooling coils. Normally, this unit will be connected to an outside air duct so that the unit provides ventilation as well as circulation of air within the space.

The first step in improving HVAC system performance is to evaluate the existing equipment to determine how well it meets its intended objectives. Questions to ask at this stage include: Does the unit lack adequate heating and/or cooling capacity? Is sufficient air moved, or is the air stuffy? If the answer to either of these questions is yes, then the overall system is a candidate for upgrade or replacement. If the systems meet the basic needs of the space and the occupants, then system performance and improving energy efficiency should become the focus.

There are two general guidelines to consider when evaluating the energy performance of HVAC systems: making the existing system as efficient as possible and controlling the existing system as efficiently as possible.

These principles are based on the fact that HVAC systems are expensive and may not be cost-effective to replace on the basis of improved performance or estimated annual

energy savings alone. For this reason, most systems are replaced or upgraded when they have reached the end of their useful life. At that time, various systems can be considered, including those which are more efficient than existing systems.

Inspection & Maintenance

One of the first steps is to inspect the HVAC system at least annually. The entire system should be inspected to determine if everything is working properly, and that all dampers and linkages are still connected and opening and closing as designed. All motors should be inspected, and all belts checked to determine that they are tight. Broken or damaged equipment should be replaced. Once a general inspection has been accomplished, all equipment should be cleaned and serviced. Filters should be replaced, dampers adjusted to ensure a tight seal, and linkages cleaned so that they move freely. Coils should be cleaned to remove all dirt and lint.

One study demonstrated the effect of cleaning coils on HVAC performance, showing that coils that were left uncleaned had a 27 percent loss in heat transfer after being in operation for 18 months. Even cleaned coils showed a 9 percent loss in heat transfer compared to new coils. Air conditioning systems should have their refrigerant levels checked and topped off if necessary. Steam traps should be inspected, and rebuilt or replaced if they leak. Hydronic systems should be bled to eliminate air pockets that may have accumulated, and water treatment should be verified.

Most of these are routine maintenance items. However, control systems-especially digital control systems-should be maintained, calibrated, and serviced at least once a year by a controls company that is familiar with the type of controls installed in the building. All controls should be sequenced to ensure proper operation, including verifying proper lubrication and

refrigerant charges in air conditioning equipment. If pneumatic controls are used, the pneumatic lines should be inspected to correct any leaks. Annual controls maintenance is estimated to cost about 5-10 percent of the original equipment cost.

An annual maintenance program should include tune-ups, or tuning of fuel-fired equipment. Combustion efficiency tests should be conducted, and burners adjusted to provide maximum efficiency while minimizing non-combustibles and excess air. In most cases, 5-9 percent fuel consumption savings are not unusual after tune-ups.

Boilers should have their heat transfer surfaces cleaned of scale and soot. A .03125-inch buildup of soot can reduce energy efficiency by 3 percent. When conducting annual maintenance, equipment manufacturers' operating instructions should be consulted. If operating instructions are not available, the manufacturer or vendor should be contacted to obtain recommended guidelines for routine maintenance. Failure to follow the manufacturer's recommendations may damage the equipment or cause the warranty to be canceled.

Efficiency Improvements

In addition to routine inspection and maintenance, numerous other improvements can be made without spending a lot of money. To illustrate this, a typical indoor air-handling unit with ductwork will be used. The following comments refer to various components of this system. Several of these comments refer to controls that allow the air-handling unit to operate more efficiently.

Dampers: The outside air and the exhaust dampers should be tight-sealing, insulated dampers. Ideally, these should be low-leakage dampers that limit airflow losses to 5 percent or less; airflow leakage of common dampers is in excess of 10 percent. The dampers also should have edge and jamb seals that act like weatherstripping on doors or windows. The damper between the return air duct and the

outside air duct does not need to be insulated, but should be tight-sealing.

The outside-air and exhaust-duct dampers should be located as close to the outside wall as possible, to minimize the length of ductwork open to the outside. Even when the ductwork is insulated, heat is still transferred between the room and the ductwork.

Duct Insulation: Ductwork that is exposed to outside air—including the mixed air duct, exhaust duct, and outside air duct—should be insulated to minimize heat loss from the room to the duct. Supply ductwork also should be insulated, since condensation may occur in air conditioned systems.

Seal Duct Joints: Duct joints should be sealed with silicone or duct tape, since leakage can account for at least 10 percent of the supply air that escapes.

Air Balance: Air-handling systems are mechanical devices that are subject to change during their operation. Just as a car needs to be tuned up, air-handling systems should also be balanced so that excess air is not being introduced into the building or circulated. A 5 percent savings in cubic feet of air per minute (cfm) being circulated results in a 14 percent savings in fan horsepower (see November 1996 Training Series article on piping and ducting systems for more details).

Ventilation Control: Outside air is used to provide ventilation for occupants and to offset air exhausted from toilets, kitchens, and the like. Since most buildings do not operate continuously, outside air is not needed during unoccupied periods. Heating and cooling of outside air prior to its delivery to occupied spaces can be very expensive and therefore should be controlled to match the occupied hours of the building. Energy requirements vary throughout the country, but heating each cfm of outside air can require up to 100 Btu per hour, while cooling each cfm can require up to 50 Btu per hour. Since most systems handle hundreds of cfm of outside air, heating or cooling outside air can be very expensive.

Setback Control: During occupied periods, buildings are intended to be heated and cooled to provide comfortable conditions to employees and customers. For example, during unoccupied periods, the heating temperature can be reduced by 10-15 degrees F. Savings from this control strategy are normally estimated at 1 percent per degree of setback. The temperature must be returned to the normal setting for the next occupied period.

Optimum Start: Following a setback control strategy, many systems are controlled by a time clock or an energy management system to begin their regular operation. Since building operators need to have the temperature back to normal conditions when employees arrive, this time setting is usually conservative so that the heating or cooling begins earlier than actually needed. An optimal-start strategy utilizes a database and outside temperature measurements to determine when the system should resume heating or cooling. This allows the system to remain in setback until the last possible moment, maximizing the savings from the setback controls.

Occupied/Unoccupied Control: During occupied periods, most HVAC systems are required to provide continuous air movement. However, during unoccupied periods, continuous air movement is not necessary. Therefore, one common technique is to have the air-handling unit cycle during unoccupied periods to maintain temperature. This saves fan energy, since the fan does not have to run continuously.

Hot Water Reset: In hydronic systems, reset controls allow the boiler water temperature to be reset as the outdoor temperature moderates. This saves energy by not heating the water higher than needed to heat the building, and also allows better temperature control of the system.

System Improvements

More extensive system improvements can be considered, but these are more expensive. As mentioned earlier, annual energy savings alone are usually not enough to justify making large-scale changes to HVAC systems. However, if the

system is being replaced because of age or condition, then it is time to consider systems that provide greater energy efficiency. Here are some upgrade ideas:

Economizer: High internal heat gains often require air conditioning systems to operate even during periods of mild weather. An economizer system uses large quantities of outside air to meet the cooling load rather than operating the mechanical cooling system. This involves providing additional controls to evaluate outside versus indoor air (some systems only measure temperature while others also measure humidity conditions), ductwork to allow up to 100 percent outside air to be brought into the building, and an exhaust or relief fan. Certain areas such as computer rooms should not be considered for economizers because of their special environmental requirements.

Variable Air Volume: This system was designed to be constant-volume. Constant-volume systems always deliver the same quantity of air, and air temperature is changed to control room conditions. Therefore, all spaces receive the same conditions, even rooms that are not occupied. A variable air volume (VAV) system maintains a constant supply air temperature and varies the amount of air delivered to each space. Therefore, spaces requiring less cooling receive less airflow, while those requiring more cooling receive greater airflow. VAV systems save energy because it is unusual for all spaces to require full cooling at the same time.

Heat Recovery: Heat recovery is a general term relating to the useful application of heat that normally would be wasted or exhausted from a building. Heat recovery is often cost-effective in industrial facilities, but is not usually cost-effective in commercial buildings because of the low temperature and small quantity of exhaust from them. One exception is commercial kitchens or restaurants, where exhaust from the kitchen can often be used for heat recovery. For heat recovery to be successful, three requirements must be satisfied: a heat source; a heat target, or use for the heat;

and for these two requirements to occur at the same time.

Thermal Storage: Most managers are more interested in conserving money than in conserving energy. Thermal storage systems save money in the form of monthly operating expenses. Thermal storage systems are ice-making systems that are employed at night to produce ice that can then be melted during the day to provide a chilled-water source for air conditioning.

However, in some cases thermal storage systems actually use more energy than conventional systems, since making ice is more energy-intensive than producing chilled water. However, since the system operates at night during off-peak periods, this strategy can be less expensive if it is coupled with a lower off-peak power rate.

Part-Load Boilers and Chillers: HVAC systems are selected to meet the building's heat loss and gain during design weather conditions, or the coldest and hottest times of the year. For this reason, individual boilers and chillers tend to be oversized for most of their operating times. In order to better track changes in the weather, many engineers are now designing systems with multiple boilers and chillers. One unit can be sized for 75-80 percent of the design load, while another is sized for part-load performance, or roughly 30-40 percent of the full load. This allows the operator to select which unit to operate based on energy-efficiency performance. When the weather requires full capacity, both units operate; during spring and fall, only the smaller unit operates. In addition, some systems also use the boiler to provide domestic hot water. Building operators can install and operate a summer boiler where previously they had to operate a large boiler during the summer just to produce domestic hot water.

Energy Management

Regardless of what improvements are made, none of these changes should be considered permanent, one-time improvements. HVAC systems need to be monitored at a minimum of once a year, and then adjusted as required. Even system

replacements are not permanent, since all systems need to be inspected and maintained. One of the best ways to do this is to establish an energy management program with systematic checks made of various energy-using equipment. Since most equipment is not separately metered, monthly energy bills may be the only method available for making simple checks on energy consumption.

Monthly energy use for all fuels should be plotted using separate graphs for each primary energy source, so that trends can be observed from year to year.

Weather-dependent systems, such as HVAC, should be separated out from the total monthly energy bill where possible. This can be accomplished by estimating monthly energy use for the other systems—such as lighting, electric power, and domestic water heating—that are not weather-dependent. Subtracting this energy use from the overall monthly usage yields energy use related to HVAC.

This value should then be normalized by dividing by the number of heating or cooling degree-days during that month, then graphing the data. This type of monitoring and tracking provides for early recognition of high energy use, malfunctioning equipment, or the need for maintenance.

As described in the February 1996 Training Series on energy accounting and economic analysis, an annual energy index for each building or facility can be developed and compared with similar buildings within the same geographical or climate region. This annual index should cover all fuels and should be in units of thousand Btu's per square foot of floor space per year.

There are general ranges for energy usage based on type of occupancy classification, as shown in Table 1. These values are very general, but they tend to illustrate the varying energy usage among building classifications. The large range shown within each building type is the result of differences in buildings, usage, and weather. While these ranges are broad, they still permit a comparison to be made to see where a

particular building fits in the range. When the annual energy use of a building is in the upper half of the range, there is probably an opportunity to save energy dollars by applying energy management strategies.

Improving the energy efficiency of an HVAC system is a continuous operation. In general, 10-30 percent of the energy usage can be saved in systems just by implementing good maintenance practices. What makes energy efficiency difficult is that

there are many components in an HVAC system that require annual inspection and maintenance. Savings from any one component may be small, but when all the individual components are added together the savings can be substantial. Remember, energy conservation is not necessarily the goal. Rather, the goal is to use only the energy needed and to use that energy as efficiently as possible.

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