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ENERGY STAR BUILDINGS[SM] MANUAL

Stage Four
Fan System Upgrades

Fan System Upgrades Overview

The heat flow diagram (see Figure 1) illustrates how, in Stage Four—Fan System Upgrades-you can take advantage of the load reductions you have realized in Stages One through Three of the ENERGY STAR Buildings[SM] Five-Stage Approach. By doing so, you will have already reduced the energy consumption of the lighting and office equipment installed in your building and reduced cooling loads associated with their formerly inefficient mode of operation. You may have also performed a building tune-up, upgraded your windows, and upgraded your roof. The resultant opportunities for reducing your air-handling system's energy consumption are now tremendous. Continuing with the Five-Stage Approach, you can realize a 50- to 85-percent reduction in fan power consumption.

See Figure 1: Heat Flow In Buildings

Stage Four Strategy

- Rightsize your cooling system to match reduced loads
- Take advantage of improvements in air-handling technology
- Install equipment that allows for more efficient operation, lower first cost, and lower maintenance costs

The Best Ways To Save

- Fan system rightsizing
- Variable-speed drives
- Improved controls
- Energy-efficient motors
- Energy-efficient belts

If you are already planning to purchase replacement equipment, installing smaller components is less costly than replacing with larger equipment.

Potential Savings

Potential energy savings from rightsizing, energy-efficient motors, and variable speed drives:

50-85%

Source: *Variable Air Volume Systems: Maximize Energy Efficiency and Profits*, EPA 430-R-95-002.

An Easy Target

The fans that move the heating and cooling air through your building can account for 20 percent or more of energy usage in a commercial building. Any reductions in their consumption can result in significant savings for you. A recent EPA study found that almost 60 percent of building fan systems were oversized by at least 10 percent, with an average oversizing of 60 percent. By rightsizing, you can save an average of 50 percent in fan system energy. Moreover, these savings are independent of any other improvements, such as installing energy-efficient motors.

Take Action!

1. Use the pullout Fan System Survey at the end of this chapter to determine the operating characteristics of your current fan system

2. Enter this data into the EPA QuikFan software program to estimate potential savings and economic benefits

3. In most cases, the savings to be realized are quite large. Delaying the conversion of your fan system by even a few months will wind up costing you large sums of money

Air-Handling Components

The major components in your air-handling system are fans, ducts, and dampers. These components must function well individually and together in order to ensure efficient operation as well as occupant comfort.

Each component performs a task critical to the proper operation of your system. Fans circulate the air and provide the pressure required to push it through ducts and over heating or cooling coils. Ducts convey the conditioned air throughout your building, distributing the air to occupants and then returning it to the HVAC system to be conditioned and circulated again. Dampers control the flow of air through the ducts to the various parts of the building.

Fans

Fans are the heart of your building's air-handling system. Like a heart that pumps blood through a body, they distribute throughout the building the air, heat, and cold that your occupants need. There are two main types of fans, centrifugal and axial.

Centrifugal fans (see Figure 2) are by far the most prevalent type of fan used in the HVAC industry today. They are usually cheaper than axial fans and simpler in construction, but generally do not achieve the same efficiency. Centrifugal fans consist of a rotating wheel, or impeller, mounted eccentrically inside a round housing. The impeller is electrically driven by a motor, which is usually connected via a belt drive.

See Figure 2: Centrifugal Fan

Axial fans (see Figure 3) consist of a cylindrical housing with the impeller mounted inside along the axis of the housing. In an axial fan, the impeller consists of blades mounted around a central hub similar to an airplane propeller. As with an airplane, the spinning blades force the air through the fan. Typically, axial fans are more efficient than centrifugal fans.

See Figure 3: Axial Fan

Axial fan motors can be mounted externally as on a centrifugal fan. They can also be belt driven. However, they are often driven by a motor directly coupled to the impeller mounted within the central hub.

Ducts

Like the arteries and veins in your body, ducts convey the conditioned air from your heating and cooling plant out through the building and return it back to be conditioned again. They are usually constructed of sheet metal, and insulated.

Ductwork can either be round or rectangular. Rectangular duct is cheaper and more common than round duct, as it is generally easier to route, design, and install. Round duct, on the other hand, uses much less material, as it is the most efficient shape for a given cross-sectional area. It is also naturally stiffer than a rectangular duct having the same cross-sectional area. Round duct also creates less resistance as the air moves through it, reducing fan power requirements.

Duct insulation helps prevent the warming of your chilled air and the cooling of your heated air as it passes through the ducts. Ducts must be properly insulated to prevent excessive energy loss. Poorly insulated ducts also influence air leakage. Joints between ducts, registers, and the furnace can lose as much as 30 percent of the air being moved. This leaking ductwork can create positive and negative room pressures that can increase air leakage through walls, floors, and ceilings. Commercial building codes typically require 1 inch of insulation for ducts carrying hot or cold air. Proper choice of insulation can also help reduce the transmission of noise from your HVAC system to the working spaces inside your building.

Dampers

Dampers serve to modulate the flow of air through the ducts to the various parts of the building, reducing or increasing the flow of air depending upon conditions. Dampers are difficult to maintain and can affect occupant comfort as the space requirements change and as the air-handling system ages. Installing variable-speed drives (VSDs) and converting to a variable air volume (VAV) system can eliminate the need for dampers.

Air-Handling Systems

Depending on the age and design requirements of your building, you might have one or more of the following systems:

- Constant volume systems
  - Reheat system
  - Dual-duct system
  - Multizone system
- VAV systems

Compared to older systems, current air-handling systems offer much more efficient designs than may have originally been installed in your building. Today's VAV systems can handle changing load requirements by varying the amount of air circulated, as well as the amount of cooling or heating, to more accurately tailor energy consumption to the actual climate control needs of the building's occupants.

Constant Volume Systems

Constant volume, also referred to as constant air volume, systems are installed in a large number of buildings. The simplest of all the systems discussed, they circulate a constant volume of conditioned air.

Reheat Systems

In a reheat system, a constant amount of air is cooled and recirculated (see Figure 4). This amount of air is designed to be able to cool all parts of the building at peak cooling load. To cool at lighter loads or to heat the building, the circulated air, *which is still being cooled*, is reheated before being distributed to the various zones.

Reheat systems are very inefficient because the same air is being cooled and then reheated before it even reaches building occupants.

Dual-Duct Systems

Often found in buildings constructed during the 1960s and 1970s, dual-duct systems are a relatively effective means of maintaining comfort, yet an extremely inefficient method of conditioning air.

See Figure 4: Constant Volume System With Reheat

Dual-duct systems consist of two independent systems, one warm and one cool, that circulate air in parallel sets of ducts through all sections of the building. Hot and cold air are mixed in local mixing boxes in each zone or room and then fed into that area. Depending on the temperature needs of the area, the mixture of hot and cold air is adjusted until the desired temperature is reached. Unfortunately, with a dual-duct system, you must pay to cool, heat, and circulate a volume of air that is typically much larger than the actual volume required by your building.

Multizone Systems

Multizone systems are similar to dual-duct systems in that two streams of hot and cold air are mixed to produce a desired temperature. But, whereas dual-duct systems mix the air in individual boxes located at each area or room, multizone systems mix air in large mixing boxes near the fans. This conditioned air is then fed to each zone, with each zone, depending on its load, receiving air at a different temperature. As with dual-duct and reheat systems, multizone systems are quite inefficient because you must pay to heat and cool air simultaneously.

Variable Air Volume Systems

VAV systems vary the amount of circulated air in response to varying heating or cooling loads. This reduces fan power requirements, which saves energy costs.

VAV systems work either by opening or closing dampers or by modulating the airflow through VAV fan-powered mixing boxes as loads in various zones of the building change (see Figure 5). If, for example, more cooling in an area is required, the damper to that area is opened wider, increasing the flow of cold air until the desired temperature is reached. Conversely in this same example, if an area is too cool, the damper is slowly closed, reducing the flow of cold air. Used in combination with VSDs, this reduction in flow results in a reduction in the fan power needed, saving energy. Because retrofitting an existing constant volume system to a VAV system allows your system to turn itself down in response to changing demand, it is a popular option for many building owners. The inefficiency of dual-duct and terminal reheat constant volume systems can be virtually eliminated by converting the system to deliver only the volume of air needed for conditioning the actual load. Proper conversions to VAV systems include the removal of constant volume dampers and typically reduce fan horsepower requirements by 40 to 60 percent.

See Figure 5: VAV System

Thermally Powered VAVs

Thermally powered VAV systems, like standard VAV systems, regulate the volume of air that a space (usually a room) receives based upon its temperature.

Thermally powered VAVs are ceiling-mounted diffusers, each with its own damper, that replace standard diffusers. With an internal "thermostat" and a small damper, they enhance the process of reducing airflow to a certain conditioned space when its temperature is below the setpoint and increasing airflow when the temperature in that space is too warm. In addition, thermally powered VAVs are now being produced with individual controls, a feature that provides a level of control comparable to that of a standard VAV system.

Thermally powered VAV systems also:

- Provide more comfort at less cost
- Are a viable alternative to VAV fan-powered mixing boxes in terms of costs, benefits, and lessened disruption during retrofit construction

Best Opportunities

Comparison: VAV Systems Vs. Constant Volume Systems

The conversion of your older constant volume reheat, multizone, or dual-duct system to a modern, energy-efficient variable air volume system is a task to be undertaken with serious consideration and expert analysis. This would normally require the services of an engineering firm.

As discussed earlier, VAV systems are more energy efficient than constant volume systems as VAV systems can reduce airflow in response to decreasing demand. You are also cooling only the amount of air that is required to meet demand, rather than meeting demand by simultaneously heating and cooling large volumes of air.

Are Your Fans Oversized?

If your fans are oversized, fan rightsizing can be profitable. It can be implemented separately or in combination with energy-efficient motors and VSDs. In general, rightsizing with an energy-efficient motor, energy-efficient belts, and a VSD is the best alternative.

Advantages Of A Rightsized System

A rightsized system saves you energy costs; however, there are other advantages to a rightsized system that you might not have thought of:

- *Lower First Costs*

  As the capacity required from your fan system is reduced, your system can be more accurately tailored to the new flow requirements. By installing smaller, more energy-efficient equipment that meets these requirements, first costs are also reduced.

- *Comfort*

  If your fan system supplies too much air to your occupants, not only are you wasting energy, but you could also be affecting their comfort. Too much air can result in disturbing drafts, increased humidity, and noise.

- *Equipment Life*

  Prolonged operation of an oversized motor with a VSD at very low speeds can reduce the useful life of motors and other equipment. Properly sized, smaller capacity equipment will be more suited to operation at reduced capacities.

Rightsizing Your Fan System

When rightsizing your fan system, the type of system in use—constant volume or VAV—will slightly affect the methods you use.

Regardless of whether you have a constant volume system or a VAV system, when reducing your fan airflows, make sure that you maintain the proper amount of outside air to ensure occupant health and comfort (see Stage Three—Other Load Reductions, Load Sources).

VAV Systems

While VAV systems are more energy efficient than constant volume systems, the potential for rightsizing may still exist. You may be able to determine if your VAV fans are oversized by checking one of three methods: measuring the fan motor current draw (amperage), checking the fan control vanes and dampers, or measuring fan system static pressure.

Measuring Amperage

1. Measure the fan motor amperage. For a VAV system, measure the amperage when your cooling system is operating under a peak load (a hot, humid day, for example)

2. Read the full-load amperage off the motor's nameplate or from the Operations & Maintenance manual

3. Compare these two numbers. If the measured amperage is lower than 75 percent of the full-load amperage, the motor is oversized

Checking Vanes and Dampers – Check the position of the fan control vanes or dampers when the cooling system is operating under a peak load (a hot, humid day, for example). If the vanes or dampers are closed more than 20 percent, the fan is oversized.

Measuring Static Pressure

1. Measure the static pressure of the main supply fan system on a hot, humid day. Make sure that all fan vanes and dampers are fully open, and that all VAV boxes are fully open

2. Compare your static pressure reading with the static pressure setpoint. If the static pressure reading is less than the setpoint and the space in your building is sufficiently comfortable, the setpoint can be adjusted to the lower static pressure

Constant Volume Systems

If it is not economically feasible to replace your constant volume system with a VAV, rightsizing your constant volume system is generally a cost-effective choice. However, in determining the potential for rightsizing, you are typically limited to just one method—measuring fan system static pressure.

Measuring Static Pressure

1. Measure the main supply fan system static pressure on a hot, humid day. Make sure that all fan vanes and dampers are 100-percent open

2. If the measured static pressure is greater than the design pressure (found in your building's mechanical drawings), your fan is probably supplying too much air and is a good candidate for rightsizing

Three Ways To Rightsize

If you have assessed that your VAV or constant volume system is oversized, you can now rightsize it to match your building's actual flow requirements. Rightsizing your fan system can be accomplished by installing larger pulleys (sheaves), adjusting static pressure, and/or replacing the fan's motor with a smaller, energy-efficient motor.

- *Smaller, Energy-Efficient Motors*

  Once you have rightsized the fan flow rate, your existing motor is probably too big for the brake horsepower required. Replace the existing, oversized motor with a smaller, energy-efficient motor that matches the load. For example, rightsizing a 75-hp standard efficiency motor to a 50-hp energy-efficient motor will reduce your motor energy consumption by about 33 percent.

- *Larger Pulleys*

  Replacing an existing belt-driven pulley with a larger one will reduce its speed, saving energy costs. Reducing a fan's speed by 20 percent reduces its energy consumption by 50 percent.

  Note: The new pulley should operate the fan at a reduced speed that matches peak load requirements.

- *Static Pressure Adjustment (VAV Systems Only)*

  Reducing static pressure in your VAV system reduces the fan horsepower consumption. By gradually reducing the static pressure setpoint to a level low enough to keep occupants comfortable, you will reduce energy consumption.

Example: VAV System Static Pressure Reduction

A VAV fan system currently operating at a static pressure of 6 inches of water (gauge) is found to operate satisfactorily at 4 inches. This 33-percent reduction in static pressure with its accompanying reduction in flow will result in an energy savings of approximately 45 percent.

Estimating Potential Savings

You can estimate the expected benefits of rightsizing by running the EPA QuikFan program. The information required for QuikFan is gathered during the Stage Four Fan System Survey (Appendix). Instructions for running the QuikFan program are provided with the software.

Project Management Considerations

The first consideration in rightsizing your fan system is to determine which components will be involved in the process. You have the choice of replacing pulleys, adjusting static pressure, installing smaller energy-efficient motors, or a combination of these.

Note: Changes to one of these components will affect the others! Be sure to perform an analysis of the options and their effects on the system before proceeding to ensure an effective reduction.

The engineer verifying the rightsizing potential will need the information you collected for QuikFan, as well as the types and efficiencies of the air-handling units, fans, and pulleys in your building.

If you do not have a qualified engineer on staff, contract with a consulting engineering firm to verify your choices.

Once the potential for rightsizing is verified, qualified personnel should implement the changes—a controls technician should adjust static pressure, an electrician should replace motors and drives, and HVAC technicians should replace fan pulleys and belts. These upgrades might be performed by your staff, a contractor, or an energy services company.

Variable-Speed Drives

Variable-speed drives (VSDs) are an efficient and economical retrofit option and should be considered for all VAV systems. VSDs allow the motor speed of your equipment to vary depending on actual operating conditions, rather than operating at one speed. Varying the speed of your fans allows them to match more closely the actual load required. As indicated in Figure 6, reducing a fan's speed by 20 percent can reduce its energy requirements by nearly 50 percent. Installing a VSD on your fan motor allows the fan to automatically match this reduced capacity, slowing down in response to reduced demand, thereby saving energy.

See Figure 6: VSDs Reduce Maximum Power Input

A VSD is not actually a motor, but rather an electronic device that varies the frequency of the electricity to the motor. It is installed "upstream" of the motor, between the transformer and the motor.

A recent EPA study (*Variable Air Volume Systems Maximize Energy Efficiency and Profits*, EPA 430-R-95-002) showed that VSDs can greatly reduce the energy used by the same fan operating under similar airflow volumes and static pressure conditions. Overall, the study indicated that VSDs provided an average energy savings of 52 percent.

VSDs make economic sense when installed on motors that operate many hours per year at fluctuating loads, and especially on larger motors.

Table 1. VSDs: Installed Cost For Various Size Motors

hp	*Installed Cost*
5.0	$2,975
7.5	$3,400
10.0	$3,575
15.0	$4,225
20.0	$4,925
30.0	$7,225
40.0	$8,625
50.0	$11,100
60.0	$13,200
75.0	$17,700
100.0	$19,400

Source: Adapted from R.S. Means, *Electrical Cost Data*—1997 Edition.

Controls

Modifying the way your system operates, not just the system itself or its components, can also save energy. By taking advantage of such concepts as economizer cooling and night precooling, you can significantly reduce your cooling costs.

Optimized Scheduling

An optimum start and stop procedure for your system is a common-sense control philosophy that can result in significant energy savings. Normally, your system is set to automatically turn itself on and off based upon the expected occupant working hours. For example, your cooling might come on at 6 A.M. and shut off at 7 P.M. Adjusting these times for varying seasons will reduce your energy costs. In the spring and fall seasons, where cooling is required but the peak temperatures are typically lower than the summer temperatures, you can set your system to come on later in the morning and shut off earlier in the day. Of course, you can also shut down your system on weekends.

Pressure Reset

If you have installed a VSD on your fan system, pressure reset is a method by which you can increase your system's energy savings. Pressure and flow are related. Reducing pressure supplied by your fans also reduces the flow supplied, in turn reducing the power required. By reducing the duct pressure level when less air is required, instantaneous fan energy savings of 50 percent can be achieved above and beyond the application of a VSD. The desired setpoint can be found by gradually reducing the fan speed each day until the pressure is as low as possible, but occupant space is still comfortable. It is possible to have two or more pressure settings; for example, one for daytime and one for evening or one for summer and one for winter.

Economizer Cooling

As discussed in Stage Three—Other Load Reductions, air-side economizers consist of a set of dampers, filters, and sometimes a fan on the supply air side of the air-handling system. The damper is controlled so that when outside air is cooler than return air, the outside-air damper opens, allowing the outside air to be drawn into the building. When it is hotter and more humid outside than the return air, the economizer damper closes to its minimum setting, which is the minimum amount of fresh air required according to ASHRAE standards (see Stage Three, Load Sources).

Demand Ventilation

Standard ventilation specifications are based on a certain volume of outside air in cubic feet per minute (cfm). ASHRAE 62-1989 specifies a minimum of 15 cfm per occupant. This ventilation level, however, should be understood as an average value to be applied to a whole building. In other words, if your building holds 3,000 people, your air-handling system should provide 15 cfm/person x 3,000 people = 45,000 cfm of outside air.

This assumes that the occupants of your building are also equally distributed.

Case Study: Economizer Cooling

The majority of conventional air-handling units are enabled to provide 100-percent outside air. However, at one 200,000-sf office building in a Boston suburb, it was noticed that air conditioning compressors in the rooftop units operated on sunny days even when outside air temperature was as low as 35º F. The reason was that solar-heated interior air had no way to escape from the building, so that the rooftop units, even with outside air dampers wide open, could not provide enough outside air to cool the building without mechanical refrigeration.

The solution was found by installing power exhausts in the rooftop units, which exhausted all indoor air outside when the building was in economizer cooling mode. Roughly 1,000 hours per year were found to have proper conditions for free cooling. After installation of the power exhausts, cooling compressors only operated when outside air temperature was above 55º F. The installation cost $75,000 and paid for itself in under 4 years.

In some areas, such as cafeterias, auditoriums, conference rooms, and gymnasiums, the area could be empty during some portions of the day but full at others to the point that indoor air quality would suffer. For example, in a cafeteria at lunchtime, the air-handling system might not supply enough outside air to meet demand; conversely, for most of the day, the air-handling system is supplying outside air to an area with no people.

The solution to this problem is demand ventilation. By only supplying outside air when and where it is needed, you can ensure proper air quality while not wasting energy supplying the area with outside air during other parts of the day. A popular way to do this is by monitoring the concentration of CO_2 in the area. As mentioned before, CO_2 concentration is a good indicator of an area's population. As more people exhale, the concentration of CO_2 increases. By controlling the quantity of outside air based on a CO_2 setpoint, you can ventilate an area on a demand basis. When CO_2 concentration rises, dampers are opened and more outside air is allowed to flow into the area until the concentration decreases to acceptable levels.

Energy-Efficient Motors

Depending on their size, typical electrical motors are 75 percent to 95 percent efficient, with larger motors being more efficient than smaller ones. The remaining 5 percent to 25 percent of the wasted power is lost as heat to the surrounding area.

Energy-efficient motors are designed to convert a greater amount of electrical energy into useful work. After completing Stages One through Three, you will have reduced the heating and cooling loads in your building, allowing for the installation of smaller motors that better match the reduced power requirements. By installing motors that are smaller *and* more efficient, you can save further energy costs.

Table 2. Comparison Of Standard-Efficiency Motors And Energy-Efficient Motors

(1,800 RPM Totally Enclosed Fan-Cooled Motor)

hp	*Standard-Efficiency Motor*	*Energy-Efficient Motor*
5.0	83.3	89.5
7.5	85.2	91.7
10.0	86.0	91.7
15.0	86.3	92.4
20.0	88.3	93.0
30.0	89.5	93.6
40.0	90.3	94.1
50.0	91.0	94.5
60.0	91.7	95.0
75.0	91.6	95.4
100.0	92.1	95.4

Note: Older standard-efficiency models have even lower efficiencies than those shown in this table.

Source: Adapted from Washington State Energy Office, Motor Master v.2.0, and E Source, *Space Cooling Technology Atlas.*

Economic Benefits

The savings realized by installing energy-efficient motors can be particularly attractive for equipment motors that run most or all of the day and have a higher capacity, such as a fan motor.

Energy-efficient motors achieve their efficiencies from improved internals (windings, stators, etc.). Higher efficiency also offers other economic advantages. Less waste heat is generated. Excessive heat shortens motor life over time. Less heat prolongs lubricant life. At lower temperatures, bearing grease lasts longer, lengthening the required time between re-greasing. Lower temperatures translate to longer lasting insulation. Generally, motor life doubles for each 18ºF reduction in operating temperature.

Also, the higher thermal mass of energy-efficient motors allows them to tolerate heat better than standard motors. Altogether, energy-efficient motors generally last longer and require less maintenance than standard motors.

Considerations

Repair (Rewind) Vs. Replacement

Occasionally, like any type of equipment under constant use, motors fail. When they do, many people make the assumption that they should replace the unit immediately rather than repair it. Although it is generally more economical to replace, rather than repair, a failed motor, this is not always the case. Rewinding a failed motor can be more cost effective if one or more of the following situations applies:

- The motor is larger than 125 hp
- The motor operates less than 2,000 hours per year
- The failed motor is an energy-efficient motor

Premium Efficiency Vs. High Efficiency

Many motor manufacturers have three lines of motors—standard efficiency, high efficiency, and premium efficiency. Adding to the confusion, many other manufacturers offer just two lines of motors, calling their standard-efficiency motors "high efficiency" and their energy-efficient motors “premium efficiency.” Purchasers should also consider the nominal efficiency rating and the minimum efficiency rating for the design they intend to buy. Nominal efficiency, an average efficiency of motors of duplicate design, is listed in manufacturer literature and in the Motor Master Plus software (see next page). Even within a group of duplicate designs, there is some variation in actual efficiencies due to variations in motor materials and manufacturing. Minimum efficiency ratings can be used as the basis for the manufacturer’s guarantee.

Shaft Alignment

In typical fan system configurations, the motor and the fan each have shafts, which are connected with a belt or belts and two pulleys. If the pulley faces are not square with each other, then the belt and shafts are not in alignment. Improperly aligned shafts can not only result in poor efficiency and higher operating costs, but also can lead to premature failure and increased maintenance costs. Whenever you replace or rewind a motor, be sure to pay close attention to the shaft alignment.

Energy-Efficient Belt Drives

Belts are often used to transfer power from the motor to the fan system being driven. Standard V-belt drives can be found in the majority of belt applications. They are the lowest cost option of the belt family. The tradeoff, as usual, is reduced energy efficiency.

- V-belts, when new, can typically achieve efficiencies in the 90 to 95 percent range. A worn belt, however, can considerably reduce the efficiency by slippage caused by slackening and worn grip surfaces
- Cogged V-belts are similar to standard V-belts, except that the normally flat underside has longitudinal grooves in it, allowing better grip and less slip than standard V-belts. They typically offer a 2 percent to 5 percent efficiency bonus

- Synchronous belts combine toothed belts with grooved pulleys, minimizing slip and improving efficiency to a range of 97 percent to 99 percent

Economic Benefits

Drive belts should be a standard replacement part in your building's maintenance program, requiring replacement every few months. Energy-efficient belts can easily be incorporated into your standard maintenance program, and the savings generated greatly outweigh the slight increase in cost per belt.

Additional Considerations

Ventilation Requirements

As discussed in Stage Three—Other Load Reductions, building codes based on standards set by ASHRAE dictate minimum ventilation rates. Code-mandated rates have changed significantly over the years in response to events and new understanding about the impact of outside air, energy consumption, and occupant comfort.

Testing, Adjusting, And Balancing Firms

One issue to consider: After implementing some of the modifications outlined in Stage Four, your HVAC system will most likely exhibit different operating characteristics than before. Normally, the engineer or contractor who performed the work will be responsible for what is called the testing, adjusting, and balancing, or TAB, of the modified or new system. TAB involves analyzing the various flows of air, chilled water, hot water, steam, etc., and ensuring that distribution of heating and cooling throughout the building meets the required specifications as outlined in the contract documents. Recent developments in the building heating and cooling industry have led to the introduction of independent TAB firms. Under contract to the building manager, they serve as a third party to ensure accuracy of the TAB measurements and are worth retaining if further oversight is desired.

Motor Challenge

The Motor Challenge Program was developed by DOE to assist industrial customers in increasing their use of energy-efficient motor systems. Federal facility managers can also benefit from Motor Challenge through a special arrangement with FEMP and receive technical assistance, training, software, and other materials. Motor Master Plus is a PC-based software tool that helps inventory and select motors. A database of 12,000 new motors contained in the software includes horsepower, speed, enclosure type, manufacturer, model name, catalog number, voltage, nominal efficiencies at various loads, torque and current characteristics, power factor, warranty, and list price. The software allows users to simulate replacement scenarios to determine the lowest life cycle cost options for existing motors. Motor Master Plus also enables users to estimate actual motor loading using three techniques: the kilowatt technique, the amperage ratio technique, and the slip technique. Facility managers can also use Motor Master Plus to estimate operating and energy savings. FEMP is offering training to facility managers on the use of Motor Master Plus software.

QuikFan

QuikFan is an EPA software program that allows you to estimate the energy savings realized by performing the steps outlined in Stages One through Four of the ENERGY STAR Buildings program. When you enter the reductions attained in Stages One through Three as well as your existing fan system characteristics, the program helps you to select an optimized fan system for the reduced loads. You can also analyze the impact of a potential VAV system upgrade using VSDs. his and other ENERGY STAR software programs, are available free by visiting the EPA Web site at http://www.epa.gov/appdstar/appd/software.

Upgrading of Fan System—JC Penney
Atlanta, GA

The air distribution for one of JC Penney's 155,000-sf stores was provided by five air-handling units located in a penthouse equipment room. Two return fans, also located in the penthouse, vented air from the first and second floors through ductwork and back to the air-handling units. The air-handling units supplied conditioned air through ductwork to diffusers throughout the building. The fans operated at two speeds, high and low, each manually controlled with selector switches as well as on-off automatic-function switches. The fans usually operated at the high-speed setting, although they were cycled occasionally to conserve electricity. In an effort to reduce energy consumption, tests were conducted to determine the airflow from each of the fans while operating at high speed. Data collected indicated that the actual airflow for each air-handling unit was less than the design airflow; therefore the fans were larger than necessary for this facility. The testing also revealed that an accumulation of dirt on the cooling coils in air-handling units 1 and 2 was restricting air flow and wasting fan energy. The QuikFan software developed by EPA was used to estimate the energy savings potential of the various Stage Four upgrade options. Measurements of each fan motor indicated that the maximum load was less than the horsepower rating.

Another potential energy saver was minimization of the outside air brought into the building for ventilation. This air had to be heated or cooled, which required energy. By monitoring carbon dioxide levels in the building it was felt that the air intake could be safely reduced to the minimum quantity necessary.

JC Penney decided to install variable-speed drives on the supply-air and return-air fans in the building to bring the fan capacity nearer the actual load and to install carbon dioxide sensors that would enable the system to minimize the intake of air. The large open areas in the store made it impractical to install variable air volume boxes that control the speed of the fan motors with pressure sensors. Space thermostats were therefore used to regulate fan speeds directly. Before installation of the variable-speed drives, the fans cycled on at maximum electrical consumption and then cycled off regularly. The variable-speed drives eliminated this inefficient constant cycling. Peak power use was therefore less than the maximum, with projected electric demand savings of 36 kW per month.

The total cost of installation of the variable-speed drives and the carbon dioxide sensors was $17,000, which is projected to save 138,833 kWh of electricity at an annual savings of $9,726. The payback for this upgrade of the fan system is 1.75 years. JC Penney was therefore able to realize substantial annual savings with a relatively low investment, and the savings continue year after year.

Summary

Stage Four illustrates the many options that are available to you to save on your building's energy costs. To recap:

- Measure your loads
- Rightsize your fan system to match actual loads
- Install rightsized, energy-efficient motors where possible
- Install VSDs where practical
- Install energy-efficient belts
- Investigate options available for improving the control of your fan system

Next Steps

1. Using the Fan System Survey provided in the Appendix, record information on your various fan systems and measure your loads
2. Enter this data into the EPA QuikFan program to estimate what you could save
3. Using a qualified engineering firm, perform a more detailed assessment of your system to investigate further savings

Glossary

AHU
See *air-handling unit.*

air-handling unit (AHU)
Equipment used to distribute conditioned air to a space. Includes heating and cooling coils, fans, ducts, and filters.

air side systems
Equipment used to heat, cool, and transport air within building HVAC systems.

ASHRAE
American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

balancing
Process of measuring and adjusting equipment to obtain desired flows. Applies to both air side and water side systems.

boiler
Pressure vessel designed to transfer heat produced by combustion or electric resistance to a fluid. In most boilers, the fluid is water in the form of liquid or steam.

British thermal unit (Btu)
A unit of energy equivalent to the amount of heat required to raise the temperature of 1 pound of water 1 degree Fahrenheit.

Btu
See *British thermal unit*.

CAV
See *constant volume.*

CFCs
See *chlorofluorocarbons.*

cfm
Cubic feet per minute.

chiller
Mechanical device that generates cold liquid, which is circulated through cooling coils to cool the air supplied to a building.

chlorofluorocarbons
Chemical compounds consisting of carbon, hydrogen, chlorine, and fluorine, once used widely as aerosol propellants and refrigerants. Believed to cause depletion of the atmospheric ozone layer.

coefficient of performance (COP)
A measure of efficiency in which a higher value designates a more efficient system.

coil, condenser
A heat exchanger used to condense refrigerant from a gas to a liquid.

coil, cooling
Heat exchanger used to cool air under forced convection, with or without dehumidification. May consist of a single coil section or several coil sections assembled into a bank.

coil, fan
A device that combines a heat exchanger and a fan in a single unit that conditions air by forced convection.

coil, heating
Heat exchanger that heats air under forced convection. May consist of a single coil section or several coil sections assembled into a bank.

condenser
Heat exchanger used to expel building heat absorbed in the evaporator of a refrigeration system.

conditioned air
Air that serves a space that has had its temperature and/or humidity altered to meet design specifications.

constant volume (CAV, constant air volume)
Type of air-handling system that maintains comfort in buildings by providing a constant air flow and varying the air temperature.

control
Device that analyzes the difference between an actual process value and a desired process value and brings the actual value closer to the desired value.

cooling tower
Device that dissipates heat from water-cooled systems through a combination of heat and mass transfer, whereby the water to be cooled is distributed in the tower and exposed to circulated ambient air.

COP
See *coefficient of performance*.

cycling
The noncontinuous operation of equipment.

demand charges
Fees levied by a utility company for electric demand.

demand, electric
Electrical power delivered to a system at a given time or averaged over a designated period. Expressed in kilowatts.

downsizing
Process of reducing the size (capacity) of equipment so that it operates efficiently at design load conditions.

ductwork
The distribution system for air in HVAC systems. It is usually made of sheet metal or fiberglass.

efficiency
Ratio of power output to power input.

EMS
See *energy management system.*

energy management system (EMS)
The control system that monitors the environment and energy usage in a building and alters equipment operation to conserve energy while providing occupant comfort.

evaporator
Heat exchanger in a refrigeration system that absorbs heat from chilled water or building air, thus reducing the supply temperature.

fouling
The buildup of a film that reduces heat transfer.

gasket
Material used to seal a joint against leakage.

GPM
Gallons per minute. A measure of water flow rate.

heat exchanger
A device that transfers heat from one fluid to another.

heat pump
Device that extracts heat from one medium and transfers it to another portion of the same medium or to a second medium at a higher temperature.

heat, sensible
The heat required to change temperature without changing phase.

hp
Horsepower. A unit of mechanical power.

HVAC
Heating, ventilating, and air-conditioning.

impeller
The rotating element of a fan or pump used to circulate the air or water.

internal rate of return (IRR)
Compound interest rate at which the total discounted benefits become equal to total discounted costs for a particular investment.

IRR
See *internal rate of return.*

kilowatt (kW)
Unit of power equal to 1,000 watts.

kilowatt-hour (kWh)
Unit of electric consumption equal to the work done by 1 kilowatt acting for 1 hour.

kW
See *kilowatt.*

kWh
See *kilowatt-hour.*

load
The demand upon the operating resources of a system. In the case of energy loads in buildings, the word generally refers to heating, cooling, and electrical (or demand) loads.

maintenance
An ongoing process to ensure equipment operates at peak performance.

meter
A device used to measure and display or record data.

nitrogen oxides
Chemical compounds that contain nitrogen and oxygen. They react with volatile organic compounds in the presence of heat and sunlight to form ozone and are a major precursor to acid rain.

off-peak
Refers to a utility rate schedule that designates the time of day when energy and demand costs are typically less expensive.

on-peak
Refers to a utility rate schedule that designates the time of day when energy and demand costs are typically more expensive.

packaged unit
A self-contained HVAC unit that provides heating and/or cooling to a building space.

part-load
Condition when equipment operates at less than full capacity to meet the demand placed upon it.

payback
See *payback, simple*.

payback, simple
Also known as *payback*. Measurement of the elapsed time between an initial investment and the point at which accumulated savings are sufficient to offset the initial investment.

power factor
Ratio of real power to total apparent power.

pressure drop
The loss in pressure experienced by flowing water or air due to friction and obstructions.

refrigerant
Substance, such as CFCs, HCFCs, HFCs, air, ammonia, water, or carbon dioxide, used to provide cooling by evaporation and condensation.

reset, chilled water
The practice of increasing chilled water temperature to obtain higher chiller efficiency.

reset, condenser water
The practice of decreasing condenser water temperature to obtain higher chiller efficiency.

rightsizing
The process of correctly sizing equipment to the peak load.

rooftop unit
Air-handling equipment such as *packaged units* located on the roof.

scaling
See *fouling.*

schedule
A control sequence that turns equipment on and off.

seasonal energy-efficiency ratio (SEER)
Cooling capacity (Btu/hr) divided by total input power (watts) requirement where both are seasonal averages.

SEER
See *seasonal energy-efficiency ratio.*

sheave
(Pronounced shiv.) Pulley.

space
The distinct area to which conditioned air is delivered.

thermostat
A device that responds to temperature changes and controls equipment by seeking a setpoint accordingly.

timeclock
The control device used to turn equipment on and off at set times of the day.

ton
Unit of cooling capacity equal to 12,000 Btu/hr.

tune-up, building
The purposeful sequence of maintenance and operational improvements, undertaken at a specific point in time, designed to reduce energy use, heating loads, and cooling loads of existing facilities.

variable air volume (VAV)
A type of air-handling system that maintains comfort in a building by varying the quantity of air supplied through the building.

VAV
See *variable air volume.*

VSD
See *variable-speed drive.*

variable-speed drive (VSD)
A device used to adjust the speed of an AC motor to match load requirements.

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Appendix: Fan System Survey

Measure Peak Air Flows To Optimize Fan Systems

This survey will allow you to familiarize yourself with the condition of your building's fan systems. EPA's QuikFan software will enable you to estimate your energy savings potential and determine whether you can replace your fan system with an optimized fan system and rightsized, energy-efficient equipment.

You will need to compile some basic information and measurements about the fan systems in your facility. You will also need to calculate the required peak airflows for your building.

Your survey team should include the following people: a building engineer, an HVAC technician, and an electrician. You will need to evaluate your available staff resources and staff capabilities. If you do not have the means of taking these measurements, you may want to contact an independent Testing, Adjusting, and Balancing (TAB) firm or seek outside engineering services.

EPA QuikFan Software

After completing Stages One through Three of the EPA ENERGY STAR Buildings Five-Stage Approach, use QuikFan to estimate potential savings of fan system optimizing and equipment rightsizing. This program is available free and can be downloaded from the World Wide Web at www.epa.gov/appdstar/appd/download.html or by calling 1-888-STAR YES.

Before You Begin

You will need the following items to complete the survey:

- The TAB report for your building's air-handling systems and pumps
- The latest version of the mechanical drawings, also known as the "as builts." If the TAB report is not obtainable, the air-handling unit and pump schedules found in the mechanical drawings can be used instead for a rough approximation
- A pitot tube and U-tube manometer (Note: Only needed if maximum airflow is unknown and measurement is required)
- Flashlight
- Ruler (English Units)
- Calculator

Getting Started

<u>*At Your Desk*</u>

1. Use the information collected in the TAB report to begin filling out the Fan Systems Survey located on page 24. A well organized TAB report should allow you to fill out most of the following information. Note: If you have more than ten (10) fan systems in your building, you should make copies of the Fan Systems Survey sheet as needed

2. Use the "as built" mechanical drawings to fill in the remaining information. Paying close attention to the scale of the mechanical floor plans, use a ruler and a calculator to determine the floor space served in square feet (sf)

Onsite

3. Next, assemble your survey team to update and obtain any missing information. Survey each of the fan systems in your facility for the missing information. For airflow measurements you will need to measure duct dimensions (using a tape measure) and total head (using the pitot tube and U-tube manometer). If flow measurements are not possible, you can estimate oversizing by using the cooling-load calculations. Both should be done by qualified persons

QuikFan

4. Finally, back at your desk, begin inputting the data you collected into the EPA's QuikFan software. After collecting and inputting the required information, you should go to the System Sizing Worksheet, which uses either the airflow or cooling load method (at maximum load conditions) to estimate the extent of your system's oversizing

5. QuikFan will analyze your fan system and estimate the savings possible by implementing one or more of several options: installing new motors and sheaves, installing a variable-speed drive, using various pressure resets, or installing a new energy-efficient motor

Using QuikFan

System Sizing Worksheet

The system sizing worksheet is the part of the QuikFan program where you estimate the extent of your fan system's oversizing.

Ratio Of Required Airflow To Design Airflow

QuikFan asks you to calculate how oversized your system is. If your HVAC energy management system allows you to read fan airflow, compare this value on a hot summer day to the design maximum flow from the TAB report or the as-built mechanical drawings. If this information is not available, you can calculate your actual maximum load by one of two methods.

Method 1—Peak Flow-Based Calculations

Using a pitot tube and a U-tube manometer, measure airflow (cfm) at maximum load conditions (for example, on a hot summer day). Subtract the maximum airflow (cfm) from the design airflow (cfm). Divide the result by the design airflow, then multiply the result by 100.

At maximum load conditions

Measured airflow = _________cfm.

Design airflow = _________cfm.

Difference = _________cfm.
[Difference = design - measured]

Percent of design = __________%.
[(Difference ÷ design) x 100]

Example: Oversized System

The Air flow at *maximum load conditions* is measured at 8,000 cfm.

Design *airflow* is 10,000 cfm.

The difference is -2,000 cfm.

The *percent* of design cfm is: [2,000/10,000 x 100].

The unit is *oversized* by 20 percent.

Method 2—Cooling Load-Based Calculations

What is the required cooling load for the building (in tons)? This load will be compared to the chiller nameplate capacity. To determine required cooling load, take the following measurements in the afternoon on a typical hot summer day (to capture peak load effects on your system).

Note: An energy management system may also log these measurements.

- Temperature, in degrees Fahrenheit (° F), of the chilled-water supply (CHWS). A temperature gauge should be found on the pipe at the chiller's supply outlet
- Temperature, in ° F, of the chilled-water return (CHWR). A temperature gauge should be found on the pipe at the chiller's return inlet
- Flow rate (GPM) of the chilled water supply. A flow rate gauge should be found on the supply pipe. If a gauge is not available, the flow rate from the TAB report or the as-built drawings may be used.

Chiller capacity = _________tons.

CHWS = _________° F.

CHWR = _________° F.

Flow rate = _________GPM.

) T = _________° F.
[) T = (CHWR - CHWS)]

Load = _________tons.
[Load =) T x 500 x (Flow rate ÷ 12,000)]

Required load = _________tons.
[Required load = Load x 1.1]

How much of your existing chiller capacity does your building currently need? To answer this, do the following calculation:

[(Chiller capacity - Required cooling load) ÷ Chiller capacity] = Percentage of cooling system oversizing

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Example

Chilled-water supply temp: 45°F

Chilled-water return temp: 55°F

Flow rate: 180 GPM

Chiller design capacity: 100 tons

The cooling load is:(55 - 45) x 500 x (180 ÷ 12,000) = 75 tons

The required cooling load is:75 tons x 1.1 = 82.5 tons

The cooling system is oversized by:(100 - 82.5) ÷ 100 = 17.5%

Upgrade Analysis

After you have entered your system data, you will need to choose which upgrades you will be evaluating. Consider a new, *rightsized motor and pulley* if your fan is oversized. Consider a *variable-speed drive* if your system duty cycle varies during the day. You can also evaluate *combinations* of these. Knowing your actual utility charge per kWh of electricity will also help make the estimate more accurate.

Fan System Survey

Fan System Information					Motor Information			Operating Information		
Name	*Fan System Type*	*Operating Schedule*	*Fan Flow Control*	*System Duty Cycle*	*Namplate Horsepower*	*Efficiency (%)*	*Horsepower @100% cfm (hp)*	*Installed Capacity (cfm)*	*Coil Load @ Peak (tons)*	*Fan Flow @ Peak (cfm)*
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
SAF-1	Supply	Regular	Inlet Vane	Perimeter	10	91.2	10.25	22,000	50	20,000

1 From TAB reports or Mechanical Drawings. Typical examples: RAF-1, SAF-1, EF-4, VF-3.

2 Fan System Types: Supply, Return, Exhaust, or Ventilation.

3 Operating Schedule (examples): Light Use (50 hrs/week), Regular Use (68 hrs/week), Heavy Use (96 hrs/week).

4 Fan Flow Control: The fan system part-load power relationship from TAB report, Mechanical Drawings, or visual inspection (options):

VSD: Variable speed drive; reduces fan speed at part-load.

VSD 1/3 Reset: Same as above, but also has controls that adjust the static pressure set point according to air flow demand down a maximum of 1/3 of duct static pressure set point.

VSD 2/3 Reset: Same as above, except down to a maximum of 2/3 of duct static pressure.

Discharge Damper: Damper at the fan outlet regulates air flow.

Inlet Vane: Vanes at the fan inlet regulate air flow.

Variable Pitch: Vane axial fan with adjustable blade pitch regulates air flow.

5 System Duty Cycle (options):

Core Zone: Relatively stable cfm requirements due to fairly constant load without direct solar effects. Note that auditoriums, meeting halls, and classrooms may not exhibit stable loads if occupancy is highly variable.

Perimeter Zone: Fluctuating cfm requirements more widely distributed than the Core Zone, typically by time of day as a result of varying solar loads through glass.

Mixed Zone: Mix of Core and Perimeter Zone characteristics based on a more typical combination of these spaces into one zone; percentage of hours shows moderate distribution.

Exhaust Blower: Similar to Core Zone characteristics, typically found in enclosed spaces such as a restroom.

6 Nameplate Horsepower: Rated horsepower (hp) from Motor Nameplate, TAB report, or Mechanical Drawings.

7 Efficiency: Rated motor efficiency from Motor Nameplate, TAB report, or Mechanical Drawings.

8 Horsepower at 100% cfm: Actual horsepower drawn at 100 percent air flow.

9 Installed Capacity: From TAB report or Mechanical Drawings; value in cubic feet per minute (cfm).

10 Coil Load at Peak: The peak cooling load for zones served by the fan system; from Mechanical Drawings or estimated value.

11 Fan Flow at Peak: Maximum air flow for zones served by the fan system. From TAB reports and/or Mechanical Drawings.

To download EPA QuikFan, visit http://www.epa.gov/appdstar/appd/software

Figure 1: Heat Flow in Buildings

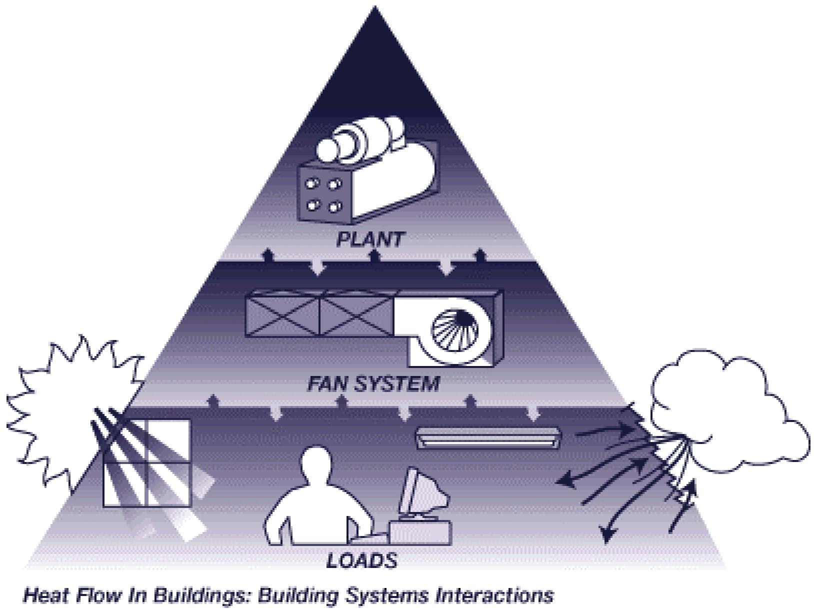

Figure 1 shows the interaction of heating, cooling, and electrical loads with the HVAC equipment. Arrows indicate heat flow pathways. Reducing heating, cooling, and electrical loads reduces the demand on HVAC equipment, thus saving energy.

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Figure 2: Centrifugal Fan

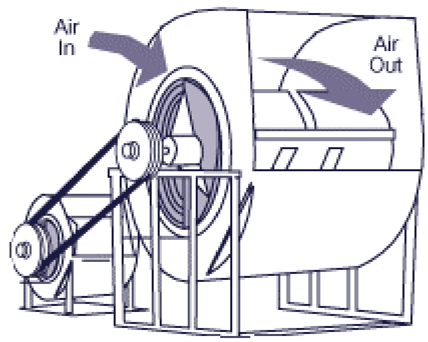

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Figure 3: Axial Fan

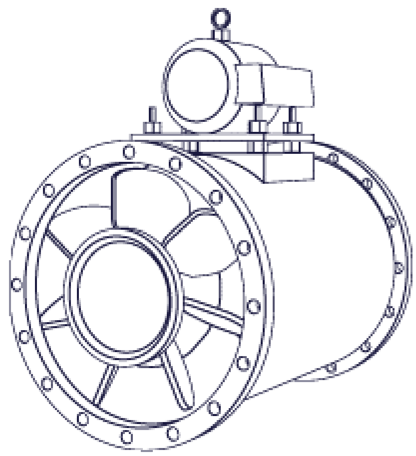

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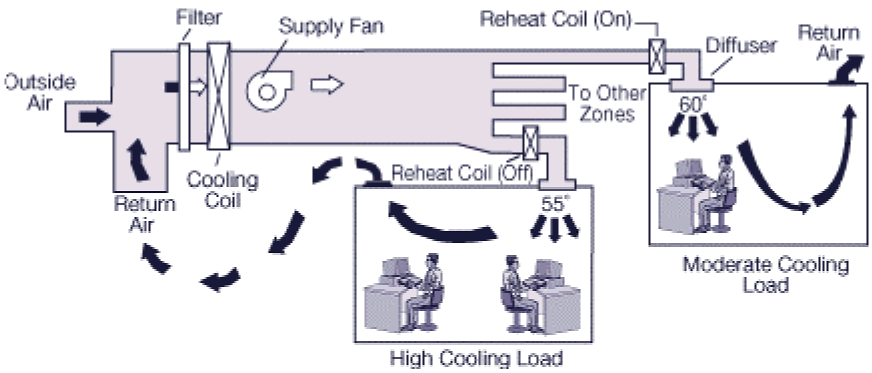
Figure 4: Constant Volume System With Reheat



In this example, the room with the moderate cooling load is reheating its air from 55º to 60º F.

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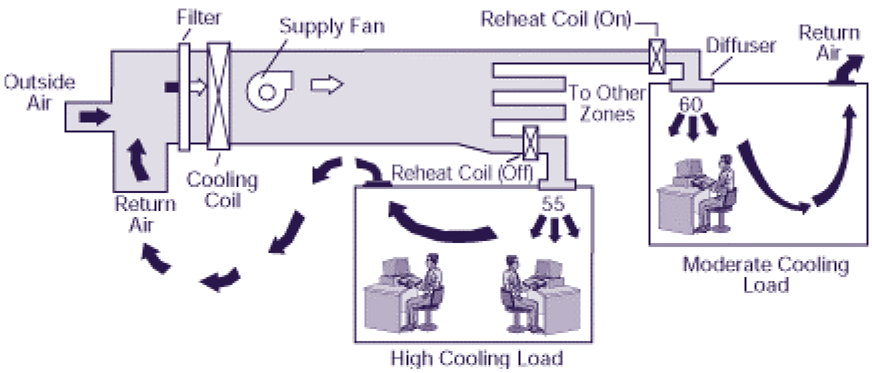
Figure 5: VAV System



In a VAV system, dampers control the flow of chilled air to respond to changes in cooling load.

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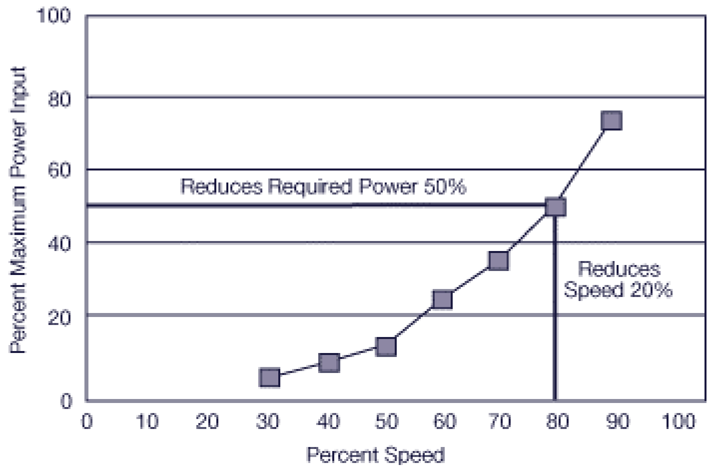
Figure 6: VSDs Reduce Maximum Power Input



Source: Electric Power Research Institute.

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