SAINT MARY'S COLLEGE OF CALIFORNIA

Building Operations Awareness

HVAC

Building Occupant Awareness Manual

HVAC Equipment Guide

2008

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HVAC

Introduction

This document is intended to supplement the HVAC Efficiency training workshop. It contains all the material covered in the workshop and supplementary detail. Those who attended the workshop are encouraged to read this manual afterwards to reinforce the principles that were learned.

Goals

The goals of this section are to:

- elaborate on why conservation, recycling, and energy efficiency are beneficial and important.
- provide a basic understanding of the most common efficiency issues related to HVAC equipment.
- provide a brief overview of indoor air quality issues, since they are very much related to HVAC systems.
- discuss relevant maintenance issues.

Consequences of HVAC Efficiency

- Reduced energy use and associated costs.
- Improved quality and comfort.
- Less maintenance is required.
- Longer equipment life.
- Scheduling and complex control strategies are easily programmed into building automation systems.
- Positive impact on climate change issues.

Expectations of Comfort

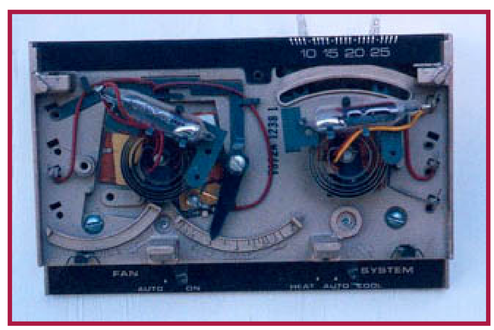
Under typical conditions, an average of 20 per cent of the people will be slightly uncomfortable while the remaining 80 per cent will be comfortable. It is not always possible to satisfy everyone at the same time. What is cold for one person can be just right or too hot for another. A person's level of activity, age, and type of clothing are contributing factors.

HVAC systems and buildings are not perfect; therefore, it is not realistic to expect flawless and absolute comfort through the entire range of temperature and humidity extremes typical of this climate. For example: many older buildings have minimal insulation and windows, which would be fine in place like Arizona. As the outdoor temperature drops below -5 °F, the inside surface of exterior walls and windows become colder, and a person's body radiates more heat to the cold surface.

Thermostats

<u>What is a thermostat?</u>
Thermostats are used to control furnaces, radiation heating valves, heat pumps, unit ventilators, and cooling units.

Using an electric thermostat as an example, this thermostat consists of 1) an internal sensor and thermometer which measures the space temperature, and 2) a set of contacts to start or stop HVAC equipment. The thermostat compares the space temperature to the setpoint, which is the temperature at which the user sets the thermostat. For example, in heating mode, when the space temperature drops below the temperature setpoint, the thermostat senses a drop in that temperature, closes its contacts, and sends a signal to start the furnace or open a hot water heating valve. When the space temperature is above the set point, the thermostat signals the furnace to shut off or the hot water heating valve to close.



<u>Types of Thermostats</u>
The most common types of thermostats include pneumatic, electric, and electronic.

> *Pneumatic thermostats* operate from compressed air, and characteristic hissing sounds can be heard as compressed air is frequently bled off in response to changes in the space temperature.
>
> *Electric thermostats* consist of a bi-metal strip which expands and contracts according to space temperature and opens or closes a mercury-bulb switch.
>
> *Electronic thermostats* employ solid state circuitry to achieve the same objective.

Some electronic thermostats are also equipped with a microprocessor which can provide programmable schedules and temperature setpoints, thus making temperature setback simple and easy to program. This can save 15 per cent or more on heating costs.

For each degree Fahrenheit that the space temperature is reduced during an eight-hour period, the cost of heating can be reduced by 1 per cent.

Correct Use of a Thermostat

A thermostat should never be covered with posters or have boxes and furniture stacked in front of it. Impeding air circulation around the thermostat will often cause it to sense a false temperature (not measuring the actual room temperature). This often results in a room becoming too hot or too cold.

Once the best setpoint has been determined, there is no need to change it on a daily or hourly basis; this only results in the space temperature fluctuating and causing discomfort. Adjustments should normally be made for different seasons or if weather conditions change quickly. For example, increase the setpoint by 2 or 3 °F in cold weather to compensate for colder walls and windows, and dryer air. In warm weather, if there is a cooling mode, increase setpoint to 75 °F instead of 70 or 72 °F.

There seems to be a placebo effect with thermostats. Sometimes dummy thermostats are installed to alleviate complaints, with satisfactory results. Other thermostats have a maximum setpoint range of plus or minus 3 °F regardless of the dial setting shown.

Thermostat Calibration

A thermostat is out of calibration when the setpoint and the temperature sensor differ by more than 3 °F. All thermostats can eventually fail or go out of calibration; regular maintenance is necessary.

Three Common Misconceptions About Thermostats

1. *Setting the thermostat to a high temperature will result in quicker warm-up....* In XXXXXXX, the heating output of most furnaces is 100 per cent on or 100 per cent off, and a typical hot water heating valve is either fully open or fully closed. The thermostat cannot make the furnace heat up the space quicker or force more hot water through the hot water pipes.

Setting the thermostat too high will result in overheating and wasting energy.

Note: some new high efficiency furnaces do have variable heat output capability; even so, similar principles would apply. Since the vast majority of furnaces in XXXXXXX are the 100 per cent output type, and for reasons of simplicity, the interaction of variable output furnaces and thermostats will not be addressed further in this module.

Temperature setback does produce energy savings.

2. Temperature setback does not save because the furnace must work harder afterwards.... A typical furnace does not work harder if the space temperature has been setback; its output is always the same regardless of the room temperature. Heat loss is directly proportional to the temperature differential between the outside wall and the inside wall, and the outside and inside ventilation air. The colder it becomes outdoors, the greater the heat loss. Reducing the indoor temperature reduces the temperature differential between inside and outside; thus lower heat loss results. Temperature setback is a proven method of energy savings, with the exception of heavy mass buildings or concrete underfloor heating where there is a significant flywheel effect.

Some have argued that since all building materials and furnishing have cooled down from temperature setback, the furnace must work harder to heat everything back up again. This premise is false because an equivalent amount of energy was saved when the building was cooling down at the beginning of temperature setback; the net result is zero.

3. Adjusting the thermostat will ameliorate a faulty HVAC system.... A thermostat cannot compensate for HVAC system deficiencies. For example: a thermostat cannot make a broken heating valve close if it is stuck open; or a thermostat cannot generate more heat if the boiler or furnace is undersized. Sometimes frustrations with HVAC system problems are taken out on thermostats. These are delicate instruments that are easily damaged by careless use or intentional vandalism.

HVAC in Portables

Most portables are equipped with a self-contained forced-air furnace or rooftop unit; some portables also have cooling units. All of these units have a thermostat to control them. It is important to realize that there are some major differences between HVAC systems in portables (or any classroom that has a self-contained HVAC systems such as heat pumps or unit ventilators) and the centralized system in the main school.

There are important differences between HVAC systems in portables and the centralized system in the main facility.

In a portable, the thermostat controls the ventilation fan as well as heating and cooling; in a centralized HVAC system, the thermostat normally controls the heating and cooling controls only.

<u>The Flywheel Effect</u>

Flywheel effect occurs in all buildings to a greater or lesser degree. It occurs more in heavy mass buildings and less in lighter mass buildings. Heavy mass construction would include older buildings with thick walls – as much as 3 feet – consisting of solid concrete, brick, or limestone, often with no insulation. Alternately, most modern construction materials are lighter-weight consisting of wood-framing or steel studs, 8” hollow concrete block, fiberglass or rigid styrofoam insulation, and some drywall.

Heavy mass material, such as brick, takes much longer to heat up than wood or styrofoam. The corollary is that the brick will also take longer to cool down than either wood or styrofoam. This delay in heating up and cooling down the building materials is known as the *flywheel effect*. Each building will have its own specific flywheel effect, depending on construction materials and interior furnishings. If the flywheel effect is large, then temperature setback may not be effective, given usual occupancy schedules.

Tips for Saving Energy During Vacant Periods

Unoccupied Cooling Season	
1	Set the furnace fan to the "Off" position.
2	Adjust cooling setpoint as high as possible
3	Adjust heating setpoint to 60 °F
Unoccupied Heating Season	
4	Furnace fan should be set to "Auto" position
5	Adjust heating setpoint to 60 °F
6	Adjust cooling as high as possible

Furnace Fan Settings

Most thermostats have a separate "Auto/On" fan setting:

In Auto setting, the fan will cycle on call for heating or cooling by the thermostat.
With On setting, the fan will operate continuously.

Use **Auto** setting during vacant periods. The fan will cycle on a call for heating.
Use **On** setting during occupied periods to allow the furnace fan to operate continuously for improved indoor air quality. If the fan is off, no outside air is entering the system.

If temperature set-up is programmed correctly, the fan should not operate at all during vacant periods in the cooling season. Temperature set-up is cooling season equivalent of temperature setback during the heating season. The temperature setpoint is adjusted to 82°F or higher to save on cooling costs.

In the case of thermostats with programmable schedules and setpoints, it is best to let qualified staff do the programming. If programming is incorrectly done, it can lead to excessive energy use and even potential equipment damage.

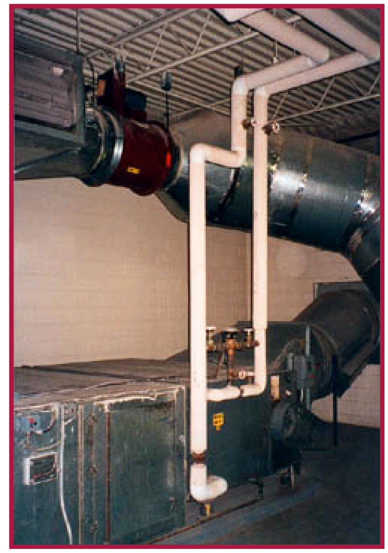
If thermostats are programmable, is temperature setback working? Since custodians are often working in the facility during essentially vacant periods, they can easily notice if thermostats setback modes are actually setting-back the temperature in winter or setting-up in summer. Advise maintenance staff if programmable thermostats need adjustment.

Considerations for Cooling Mode

Adjusting the cooling setpoint too low (70 °F or less) not only wastes energy, but can damage HVAC equipment. The DX (direct expansion) coil can become so cold that ice forms on it from water vapor in the air, because of insufficient load. When the ice melts, it can cause a small flood and serious damage to a furnace unit and compressor. Expensive repairs and inconvenience can result.

Ventilation Fans

Efficient Use of Ventilation Fans



Shutting off ventilation fans during vacant periods is critical to saving energy, as they are large energy users of both fuel for heating outside air and electricity for large electric motors and refrigeration systems – as much as 30 per cent of total building energy use. Ensuring that ventilation fans are off during vacant periods is one of the most important energy savings strategies.

Operate fans only when needed. Consider the cost of operating large fans for the comfort of a few people during summer vacation. If fans must be on, only operate the fan for those specific areas in which people are working.
Infiltration will normally provide plenty of fresh air for a small number of people in a facility. Full mechanical ventilation is necessary only during times when occupants are present.

Except during free-cooling or mild weather, any outside air must either be heated or cooled, and humidified or dehumidified (where a humidifier has been installed). This requires energy: cooling requires additional electricity use to drive refrigeration compressors and condensers; heating incurs fuel use.

Ventilation Fans and Night Purge

During hot weather, the free-cooling capability of ventilation fans can be optimized by starting the fans prior to occupancy to pre-cool the building, thus taking advantage of the flywheel effect and lower outdoor temperatures in the morning. This is quite effective in continental climates where it can become very hot during daytime, but cools down nicely between 4 a.m. and 7 a.m. The fans don't need to run all night to cool-down the facility (night purge). The entire volume of air in the facility can easily be replaced in less than one hour. Start the fans no more than two hours before occupied periods.

HOA Switches and Ventilation Fans

HOA (Hand-Off-Auto) switches are typically used to control HVAC motors, car plugs, and sometimes lighting. They consist of a round knob selector switch usually located in mechanical or electrical rooms directly on electric motor starter panels.

Free-Cooling

At outside temperatures of approximately 50 °F to 70 °F, and in most buildings, outside ventilation air does not need to be heated or cooled. The outside air is cool enough such that additional mechanical cooling is not required or is at least reduced. HVAC controls can be designed to take advantage of the cooler outside air for building cooling, varying the percentage of outside air from 10 per cent to 100 per cent, depending on conditions. This avoids or limits the use of the refrigeration system, or provides additional comfort where there is no refrigeration system; hence the term free-cooling.

Hand position is selected when:

- It is the only means of overriding the automatic controls i.e. if the automatic control system is not working.
- Auto mode has malfunctioned.

Hand position is essentially a manual bypass of the building automation systems or fan time clock. Remember that the equipment will operate continuously in hand position. Using it as an after-hours override can result in equipment being left running and forgotten about. It is recommended to have a separate override method with a time limitation (See Ventilation Fans and Override Switches for more information).

Auto is the usual position and links the fan to the energy savings controls including time clocks or building automation system. Off position is used to completely shut off electricity to the fans, for safety reasons or when repairs are being made. If in *Off* position, do not switch to *On* or *Auto* unless you have verified that it is safe to do so.

System Overrides

Dedicated system overrides are a simple way for custodians and teachers to activate HVAC systems during normally vacant periods, such as weekends. Intended for short-term intermittent use, system overrides are best for those times which are not easily predicted – outside of regularly scheduled activities, at times which are not convenient for programming through time clocks or building automation systems.

Common types of overrides include spring-wound timers which are often used for fans; and push-button switches which are sometimes used on thermostats

Examples of Applying Overrides

1.	A button located on or near a thermostat is pushed which temporarily bypasses temperature set-back, avoiding the hassle of trying to reprogram a thermostat every time a teacher comes into the classroom for a couple of hours on the occasional weekend. This also reduces inadvertently changing or deleting the existing programmed schedule and setpoint.
2.	A gymnasium is used for two hours on the occasional weekend. A spring-wound timer with a two-hour limit is used to activate the fans for adequate ventilation. Note: If the gymnasium is vacant for a large portion of the day, the same timer could also be used, rather than automatically running the fans all day from a time clock or building automation system.
3.	A silk screen exhaust fan is activated by a two-hour spring-wound timer on an as-needed basis; if forgotten about, the fan is automatically shut off after two hours.

It is best if overrides have a time limit of two to three hours or less – short-term and intermittent usage. Longer time periods can negate the benefits of an override by allowing equipment to operate far longer than necessary.

- Ask to have an override switch installed if one is needed.
- Day/night thermostats may already have push-button overrides: are they being used?
- Dedicated override switches are preferred over use of HOA switches.

Time Clocks

Time clocks have been commonly used to automatically switch HVAC equipment according to a pre-programmed schedule. *Electro-mechanical* time clocks are the most common type and have a tendency to go out-of-time. They normally have the 24-hour or seven-day configuration. *Electronic* time clocks are more accurate but are less common. They offer a wider range of scheduling options. Time clocks are a simple and economical way to start and stop equipment according to an efficient schedule. However, with the advent of building automation systems, most will gradually be phased out as facilities are retrofitted.

Time clocks usually need to be reset or checked for:

- Changing schedules
- Correct schedule for the application
- Clock eventually going out-of-time
- Daylight savings time
- Pins that have been removed or changed

Building Automation Systems (BAS)

<u>What is a Building Automation System?</u>

A building automation system (BAS) is a centralized computer control system which uses digital technology to operate HVAC systems, alarms, and lighting. Based on inputs from sensors and microprocessors, computer programs make automatic decisions to optimize HVAC and building systems. Energy use is reduced while maintaining or even improving comfort and reliability.

Desktop computers and graphical software programs are used to access the system.

Also referred to as EMS (Energy Management System) or DDC (Direct Digital Control), a BAS is used to replace old systems usually consisting of mechanical time clocks and pneumatic or electric controls. Portables are usually not connected to the BAS, but have individual thermostats.

Figure 1 is a schematic illustrating how a BAS is networked. The on-site Operator Work Station is a personal computer with applicable software and graphical interface which provides access to the system through the computer network. The operator may have off-site access via modem and telephone lines. Other buildings can also be networked through a HUB and WAN (Wide Area Network). Remote control units (RCUs) manage inputs and

outputs for field devices, sensors, actuators, and mechanical equipment such as boilers, fans, and pumps. The RCU panel houses microprocessors and instrumentation that controls the HVAC system. A building may have one or more RCU panels, depending on the size of the system. The panels are stand-alone but are networked to each other. Each panel can be accessed directly with a portable laptop computer.
Terminal control units (TCUs) are a sub-network of an RCU. These are zone controllers which operate terminal units, variable air volume boxes, and reheat coils.

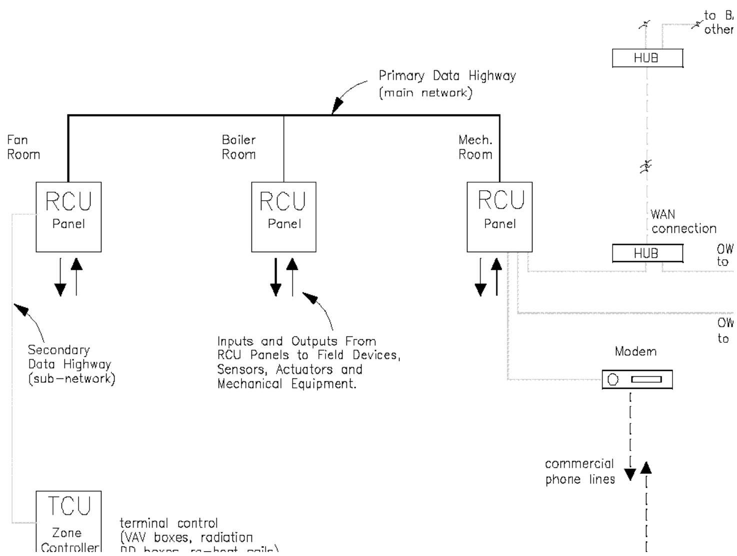


Figure 1

Figure 2 is a drawing of a standard air handling unit with mixed-air dampers, a heating coil, humidifier, and control devices. All input and output information from the mechanical equipment feeds into an RCU shown in Figure 1. For example, the RCU receives input information on the supply air temperature from a sensor in the discharge air supply and send back a signal to heating valve to maintain discharge air temperature setpoint.

Note: The main objectives in describing Figures 1 and 2 is to assist custodians in gaining a conceptual understanding of how a BAS is networked together and the system's architectural configuration.

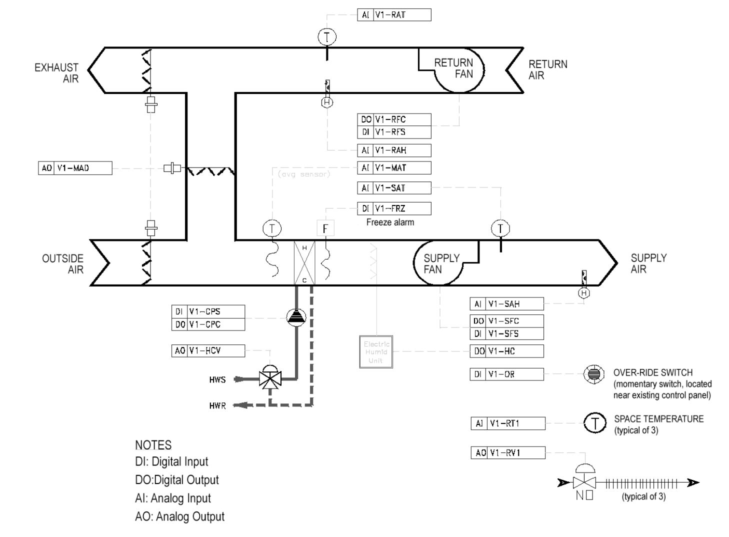


Figure 2

Advantages of a BAS

1. Optimum start/stop
The BAS automatically adjusts the start time of HVAC equipment based on indicators of heating or cooling load. It also advances equipment stop time by taking advantage of the thermal mass of the building. For example, temperature setback can begin a half hour before the building is vacant, or the amount of time between fan start-up and building occupancy can be varied according to outside weather conditions and building load.

2. Temperature reset
The temperature of supply air, hot water, and chilled water is reset according to inputs such as outside air temperature, building mass temperature, and worst zone temperature.

3. Economizer control
100 per cent outside air used for free-cooling when the system is calling for cooling and return air is warmer than outside air, usually when outside air is between 55 °F and 65 °F. Outside air dampers normally go back to minimum positions outside this range.

4. Night purge
Fans supply 100 per cent outside air to pre-cool the building and its mass during the cooling season and during vacant periods. The amount of time fans need to run is optimized.

5. Intelligent control
How quickly is a gymnasium heating up? Information like this can be used to avoid problems and energy waste such as overheating. Algorithms are normally included in BAS software that can improve control by predicting or anticipating HVAC loads. These computer programs adjust and adapt based on changing conditions, “learning” from past performance – a combination of historical data and incoming information from sensors located throughout the facility – and correction of previous errors.

6. Trend logging
Trend logging provides useful historical data such as equipment run times and space temperatures – valuable information that can help identify problem areas.

Other Benefits Include

- Complex routines (holiday and other schedules) are easily programmed to optimize savings.
- Should have fewer complaints. Solid state hardware has greater reliability and lower maintenance; old pneumatic controllers required regular maintenance and recalibration.
- Provides maintenance staff with a powerful tool for monitoring, alarming, and reporting building conditions and HVAC equipment status.
- Computer technology offers the advantages of a global networked system. Remote control is especially useful in rural areas where XXXXXXX are widely spaced. HVAC systems can be monitored and adjusted from remote locations via modem.

Indoor Air Quality (IAQ)

IAQ is achieved by maintaining the following within acceptable levels:
- Carbon dioxide
- Carbon monoxide
- Temperature and humidity
- Respirable particulates
- Fungi and bacteria

Miscellaneous contaminants such as chemicals *Carbon monoxide* indicates that combustion byproducts from fuel-fired appliances or outdoor sources are infiltrating the building.

Respirable particulates are defined as being small enough to be inhaled (less than 5 microns diameter). They are an indicator of ventilation system filtration efficiency and the presence of cigarette smoke.

Thermal comfort and relative humidity ranges: If indoor temperatures and relative humidity are not maintained within recommended ranges (see below), discomfort and suspicions about IAQ problems can result. Many IAQ complaints can be solved with improvements to thermal comfort or humidity.

<u>Recommended Temperature and Humidity Ranges</u>
66 °F to 76 °F (winter)
72 °F to 80 °F (summer)
40 per cent to 60 per cent relative humidity
(40 per cent to 60 per cent relative humidity has been found to be the ideal range; above 60 per cent tends to increase mold and fungi growth; below 40 per cent is

more conducive to viruses and bacteria.)

- IAQ is a complex issue.
- Increasing attention is being focused on IAQ. Regulations and standards are being developed.
- IAQ can be blamed for unrelated health problems.
- The custodian has an important role in watching for potential IAQ problems. Avoiding sources of contamination is one of main ways to improve IAQ.

Some Ways IAQ is Affected

Inadequate fresh air...ventilation systems are sometimes shut off due to noise concerns ventilation fans running on a call for heating only outside air dampers not opening sufficiently; advise maintenance that - -- adjustment and repair may be needed.

Inadequate local exhaust... are local exhaust fans actually exhausting air? Fan belts could be broken or exhaust grilles plugged with lint or blocked by storage materials.

Contamination of outdoor air intakes... vehicle exhaust in loading bays exhaust fan outlets too close to air intakes trash located by air intakes.

Low efficiency or dirty filters... should be changed regularly use higher efficiency type where possible.

Mold and bacteria growth... fungal growth can develop in drain pans, evaporative humidifiers, cooling towers, and any area of excessive moisture. Use appropriate maintenance to reduce or eliminate fungal growth.

Polluting sources near occupants...

- Cleaning solutions and chemicals should be properly stored in sealed containers and in rooms with exhaust fans. Are they used according to directions and so as to minimize contamination of air?
- Consider stripping and waxing floors so that floor products have time to off-gas.
- Don't store trash in mechanical rooms.
- Install new carpets and furniture during vacation to allow time for off-gassing.
- Sewer traps will dry out if not used. Periodically fill them with water or add cooking oil to reduce evaporation.
- Avoid, isolate, or eliminate tobacco smoke. To be most effective, smoking rooms must be under a negative pressure, with 100 per cent exhaust to prevent smoke from returning into the main air handling system and dispersing into the entire school.

Other Energy Savings Tips

Entrance vestibule heaters

There is no need to keep entrance vestibules at 70 °F or higher. Vestibule heaters can easily be set to 60 °F, and even shut off completely once there is no chance of freeze-up. This is a very common area of overheating and energy waste.

Use vestibule doors effectively
The inside set of vestibule doors should normally be kept closed to minimize cold air infiltration. Type face is larger than previous

Note if temperature setback is working
Note any rooms (especially portables) with programmable thermostats that are not setting back or setting-up during vacant periods, and report to maintenance staff.

Effective use of blinds and curtains
Use blinds and curtains effectively during cooling season to reduce solar load. In winter, take advantage of the solar heating effect during sunny periods – also reducing the need for indoor lighting.

Shut off exhaust fans if not required
A facility can have many small exhaust fans scattered throughout storage and other rooms. Often they are on a simple toggle switch control, independent of the BAS; shut them off if they are not required. If needed, ask maintenance staff to install a spring-wound timer.

Maintain weather-stripping and caulking
Weather-stripping and caulking requires periodic upgrading. Regular maintenance reduces drafts, condensation, and cold air infiltration.

Effectively use ceiling destratification fans
Many gyms, libraries, lobbies and high bay rooms are equipped with ceiling destratification fans. They improve circulation and prevent excessive heat build-up at the ceiling level. They should be on in winter, off in summer.

Use electric heaters sparingly
Use electric heaters sparingly because electricity usually costs more than natural gas and other heating fuels (five times or more). Ensure they are shut off during vacant periods (if there is no danger of pipe freeze-up).

Avoid stacking materials on HVAC grilles
Using horizontal heating grilles for storage blocks air circulation and reduces heating/cooling efficiency. Advise teachers that comfort would improve if grilles are kept free of obstruction.

Check outside air intakes for lint, paper and leaves etc.
Poplar seeds, lint, leaves, and paper can obstruct outside air intakes reducing IAQ and free cooling capability; these are easily cleaned.

Close doors to isolate some HVAC zones
In some cases, often during summer when only parts of the facility are in use, certain zones can be isolated by shutting doors to preventing escape of conditioned and pressurized air into vacant areas.

Other Energy Savings Ideas?

This is not intended as a complete list. Custodians often have many other valuable energy savings ideas.

Maintenance Issues

1. Keeping records

Recording boiler temperatures and pressures is important. Operation outside of normal ranges can be a sign of: impending equipment failure safety hazards (boiler could explode for example) specific maintenance needed energy wastage

2. Report unusual noise, vibration, and acrid odours

Excessive noise and vibration from HVAC equipment can be an indication of imminent failure. Prompt response can avoid inconvenience and unnecessary equipment damage. A deteriorating fan bearing or worn V-belt are good examples. Likewise, a burning electrical odour can indicate that motor windings or other equipment are failing or overheating, which could cause a fire.

3. Change filters as needed

Proper filter maintenance is critical to the optimum performance of the HVAC system.

HVAC Notes:

Appendix A: Definitions of HVAC Acronyms

AI	Analog input
AO	Analog output
DI	Digital input
DO	Digital output
HVAC	Heating, ventilation, and air conditioning
IAQ	Indoor air quality
OWS	Operator work station
RH	Relative humidity
RCU	Remote control unit
TCU	Terminal control unit