Technical Note
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Saving the Planet One Building at a Time

Energy Conservation Measures

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1. Overview

Since 2012, Earth Core Energy Services (ECES) has established a solid reputation across New England as a premier provider of comprehensive energy solutions: heating, cooling, ventilation, plumbing and lighting. ECES is a certified Energy Service Company (ESCO) providing expertise in identifying smart energy reduction solutions; referred to in the industry as Energy Conservation Measures (ECM).

ECES provides expertise in identifying ECMs for its clients that will significantly lower energy bills. In fact, most clients can expect a 30% or more decrease in building energy consumption. Many of these smart energy solutions or ECMs are recognized by the State of Connecticut and are eligible for utility incentives and rebates. Incentives and energy savings offset the cost of installation resulting in quick payback-periods typically less than 4 years and provide a significant return-on-investment (ROI).

In addition to traditional incentives for larger commercial projects, ECES is an official certified “Small Business Energy Advantage” (SBEA) vendor; allowing eligible small businesses to qualify for 0% financing and comprehensive incentives. Small Business Energy Advantage (SBEA) is a completely turnkey solution. To qualify as a "small business" for SBEA financing, a business's annual electric usage must be less than 720,000 kWh. To qualify for an SBEA loan, the project payback must be less than 8 years. The SBEA loan is 0% and is amortized over 4 years.

This paper describes some of the more common ECMs. The following is a short list,

1. Energy Management System (EMS) with load shedding
2. Setback temperature control and scheduling
3. Demand Control ventilation (DCV)
4. Dual Enthalpy Economizer (DEE)
5. Variable Speed Drives (VFD) for fan and pump motors
6. Pipe insulation
7. Kitchen Hood Units
8. Condensing Boilers and Furnaces
9. High Efficiency Heat Pumps
10. Lighting LED Retrofit

2. LED Lighting

A significant advantage of LEDs compared to traditional lighting solutions is (1) longer lifespan and (2) higher energy efficiency.

The average LED lasts 50,000 to 100,000 operating hours or more. That is 2-4 times longer than typical fluorescent, metal halide, and sodium vapor lights. It is more than 40 times longer than the average incandescent bulb. This results in less frequent fixture replacement reducing maintenance costs for both labor and material for replacement parts.

In terms of energy savings, most LED lighting retrofit projects result in a 60-75% improvement in the overall energy efficiency of the facility's lighting. Depending on the existing lights and the particular LEDs installed, the electrical energy savings could be more than 90%.

3. Economizer

3.1. Economizer (Standard)

This standard economizer accessory shall be available with or without barometric relief. The assembly includes fully modulating 0-100 percent motor and dampers, minimum position setting, preset linkage, wiring harness with plug, spring return actuator and fixed dry bulb control. The barometric relief shall provide a pressure operated damper that shall be gravity closing and shall prohibit entrance of outside air during the equipment "off" cycle. Optional solid state or differential enthalpy control shall be available for either factory or field installation. The economizer arrives in the shipping position and shall be moved to the operating position by the installing contractor. [1]

3.2. Fresh Air —Dampers and Economizer

0 - 25% manual or 0 - 50% motorized outside air hoods are available. Economizers are equipped with either dry bulb or dual enthalpy sensing. These economizers provide free cooling as the outdoor temperature and/or humidity decreases. Correctly installed, they offer a valuable energy savings. Factory-installed economizers save time and ensure proper installation. [1]

3.3. Dual Enthalpy Economizer (DEE)

Dual Enthalpy Economizer (DEE) is an economizer (EC) built in or retrofitted to Rooftop Units (RTU) or Air Handling Units (AHU). A DEE allows the use of outdoor air for cooling, provided the ambient air is below a certain temperature and the humidity is below a certain percentage. This type of cooling is often referred to as "free cooling" because it cools the building without the use of energy required to run a compressor for the AC unit. Dual Enthalpy Economizers (DEE) use two sensors; one measures the return air enthalpy, while the other measures outdoor air enthalpy. Dampers and fan speed are modulated to achieve the lowest enthalpy to be used for cooling resulting in an optimum minimal energy usage.

1. We add economizers with dual enthalpy control, and barometric relief dampers to each RTU to allow for free cooling when outside air temperature, humidity are suitable per ASHRAE standards

3.4. Integrated Differential Enthalpy Economizer (IDEE)

IDEE is the same as the DEE type except the controls communicate with the indoor multi-stage thermostat. On a call for cooling, provided the temperature and enthalpy of the outdoor air are low enough, first-stage cooling would be the economizer. If outdoor air is not sufficient enough to cool the space, second-stage cooling would come on, initiating the system's compressor

1. We typically do not install IDEE

4. Demand Control Ventilation (DCV)

Demand-controlled ventilation (DCV) is a control strategy that responds to the actual demand (need) for ventilation by regulating the rate at which the HVAC system brings outdoor air into the building. Demand Control Ventilation (DCV) systems utilize carbon dioxide (C02) sensors to measure the concentration (parts per million, ppm) of CO2 in the air which estimates the number of people in a space.

The CO2 sensor kit is available as a field installed accessory. Typically, the C02 sensors are placed in the return vent for each zone.

The C02 level rises linearly with the number of people in the space. As the CO2 concentration changes, the outside air damper modulates to meet the current ventilation needs of the zone. The system will adjust the outside air dampers to allow the minimum outside air (OA) required for the specific occupancy as specified by ASHRAE standards. When the CO2 levels are bellow a specified set-point *and* there is not a call for heating or mechanical cooling, the fan set-point will be lowered to 50%.

Legacy systems are typically designed for the worst case. So, systems *without* DCV are often set to fixed percentage of fresh air at e.g., 20%-25%, regardless of occupancy[1]. which in most cases is excessive. It requires excessive heating/cooling of unconditioned fresh outside air (OA) as opposed to heating/cooling conditioned (recirculated) air. It typically takes less energy to heat/cool conditioned air since it is closer to room temperature than outside air (OA). By minimizing the volume of outside air (OA) based on actual occupancy, significant energy savings can be achieved by reducing the amount of unconditioned outside air (OA) that needs to be heated/cooled [1]

1 The first HVAC systems were used in movie theaters and used 100% fresh air. In these early days of HVAC systems, it was soon discovered that they could not cool theaters properly in very humid weather. They realized that mixing fresh air with recirculated air could resolve the problem, since the recirculated air had less moisture than the outside air. As such the standard mix was set to 25% to reduce the amount of latent heat (humid air) needed to be conditioned. This was the norm for many years and many legacy systems encountered today still maintain a fixed 25% fresh air mixture.

5. Variable Frequency Drives (VFD)

5.1. VFD Overview

VFDs are particularly well suited for Variable Water Pressure Systems (VWP) for hydronic systems or Variable Air Volume (VAV) for ventilation systems. In such systems the active fluid (air/water) is modulated as demand from various zones changes.

Standard 3-Phase motors for fans or pumps are constant-speed motors. These systems are referred to as Constant Air Volume (CAV) or Constant Water Pressure (CWP) systems. When they are energized, they run at 100% regardless of the load. When the load required is reduced as with VAV or VWP, they adjust the flow of fluid (air or water) by *diverting* it using a mechanical barrier. For a pump this would be a rerouting switch, for a fan it would be a ventilation damper. In either case the motors continue to run at 100% and wastes energy during reduced load periods.

A Variable Frequency Drives (VFD) or variable Speed Drive (VSD) attached to a constant-speed motor reduces load fluid by reducing motor speed rather than mechanically diverting it using a baffle of damper. The electrical energy savings is significant since horsepower reduction follows the power of 3. That is, if we reduce speed by a factor of k, the horsepower is reduced by a factor of k^3. For example, if we reduce speed by a factor of 2, we reduce horsepower by a factor of 8.

5.2. VFDs for Speed Control

5.2.1. Overview

The fan speed settings are staged based on heating, cooling and ventilation modes. The sequence is based on the difference between outdoor and indoor air temperature for a given space. The minimum temperature differential between the supply and return air temp is typically maintained at 30 degrees. As the building gets hotter/cooler the stages will ramp up/down. Significant energy savings results from shutting down unused compressors and reduced fan speed.

5.2.2. Cooling

The sequence for cooling is based on outdoor air temperature and space temperature. As the building gets hotter based on internal and external heat loads the cooling stages will ramp up. The minimum temperature differential between the supply and return air temp is 30 degrees.

1. 2-Stage Cooling
    a. The 1st stage cooling on at 70 degrees ambient or space temp, drive is at 50% or 30 HZ.
    b. 2nd stage cooling on at 80 degrees ambient or space temp, drive is at 100% or 60 HZ.
2. 4-Stage Cooling
    a. 1st stage on at 70 degrees ambient or space temp, drive is on at 25% or 15 HZ
    b. 2nd stage on at 75 degrees ambient or space temp, drive is on at 50% or 30 HZ
    c. 3rd stage on at 80 degrees ambient or space temp, drive is on at is on at 75% or 45 HZ
    d. 4th stage on at 85 degrees ambient or space temp, drive is on at 100% or 60 HZ

5.2.3. Heating

The sequence for heating is based on space temperature and return air and discharge air temperature differential as the building gets colder based on internal and external heating loads the heating stages will ramp up. The minimum temperature differential between the supply and return air temp is 30 degrees.

1. 2-stage heating
    a. 1st stage is on at 70 degrees space temp; drive is at 50% or 30 HZ
    b. 2nd stage is on at 68 degrees ambient space temp; drive is at 100% or 60 HZ.
2. 4-stage heating
    a. 1st stage is on at 70 degrees space temp; drive is on at 25% or 15 HZ
    b. 2nd stage is on at 68 degrees space temp; drive is on at 50% or 30 HZ.
    c. 3rd stage is on at 66 degrees space temp; drive is on at is on at 75% or 45 HZ.
    d. 4th stage is on at 64 degrees space temp; drive is on at 100% or 60 HZ

5.3. VFDs for VAV Systems

5.3.1. Multi-Speed Indoor Fan System

The multi-speed indoor fan system is designed for use in applications for meeting the minimum requirement of CA Title 24. This system incorporates a multi-speed fan control to change the speed of the fan to 67% of full airflow based off of compressor stages. [1]

5.3.2. Multiple-Zone VAV (MZVAV)

A multiple-zone VAV (MZVAV) system consists of a packaged rooftop unit that serves several individually controlled zones. Each zone is equipped with a VAV terminal unit that varies the quantity of air delivered to maintain the desired temperature in that zone. The rooftop unit controller varies the speed of the indoor fan to maintain the static pressure in the supply ductwork at a setpoint, ensuring that all zones receive the necessary quantity of air. In addition, cooling capacity is cycled to maintain the supply air temperature at the desired setpoint. [1]

5.3.3. Single Zone VAV (SZVAV)

Single Zone VAV (SZVAV) is designed for use in single zone applications such as gymnasiums, auditoriums, manufacturing facilities, retail box stores, and any large open spaces where there is a diversity in the load profile. It is an ideal replacement to "yesterday's" constant-volume (CV) systems, as it reduces operating costs while improving occupant comfort. SZVAV systems combine Trane application, control and system integration knowledge to exactly match fan speed with cooling and heating loads, regardless of the operating condition. Trane algorithms meet and/or exceed ASHRAE 90.1- 2010 SZVAV energy-saving recommendations and those of CA Title 24. The result is an optimized balance between zone temperature control and system energy savings. Depending on your specific application, energy savings can be as much as 20+%. TRANE. [1]

5.4. VFDs for Hydronic Systems

5.4.1. Overview

3-Pipe hydronic systems are often used for chilled and hot water distribution, cf. [2] [3]. The 3-Pipe system utilizes a 3-Way Mixing Valve (MV) to take flow from either the load port or the bypass port. The by-pass flow is controlled by a 2-Way Bypass Valve (BPV). In addition, there is a Circuit Setter Valve (CCV) used to balance the pressure to meet the system flow and head requirements.

In a 3-Pipe system with a BPV installed, there is no opportunity to reduce the pump flow as the BPV is designed to open as the load is reduced; resulting in a Constant Flow System. That is, the flow and pressure are constant regardless of the number of active loads.

The implications of having a fixed CCV and BPV for constant flow are twofold. First, the since the flow is constant the pump runs at 100% regardless of demand, thus eliminating the possibility of energy savings based on variations in load. Second, a circuit setter is used to balance the flow and pressure based on existing system head and load. This mechanically restricts flow, while the pump is still at 100%. Thus, the pump is pumping with dead head even if all loads are active. This leads to reduction in the pump life as well as wasting energy by requiring to pump to run at 100% at all times.

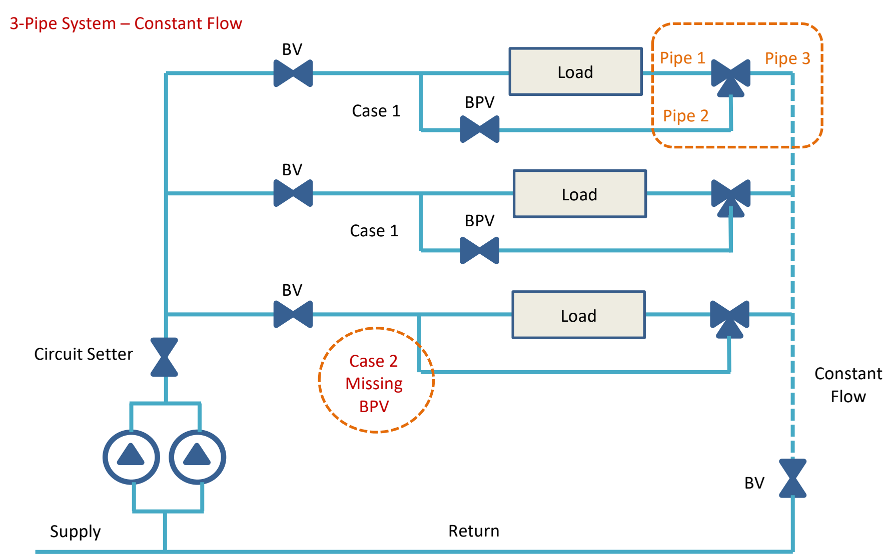

Figure 1 Standard 3-Pipe System, constant flow with circuit setter [3]

5.4.2. Converting to Variable Flow

To convert existing 3-way valve systems to 2-way valve configuration is relatively easy. Simply close the BPV in the bypass lines. With the bypass closed, the 3-way MV effectively becomes a 2-Way valve and will throttle the flow rate relative to load demand; resulting in a Variable Flow System (VFS). As the throttling reduces the system flow, the required pumping power is reduced too. In some cases, there is no BPV in the By-Pass loop. In such cases a 2-way valve must be installed.

In order to take full advantage of the variable flow system, it is also necessary to convert the existing Constant Speed Pump (CSP) to a Variable Speed Pump (VSP). Variable speed pumps, combined with a control system and pressure sensor that recognizes current system conditions, will reduce pump speed during part-load periods, reducing pressure in the system to a value that satisfies the current load flow requirements with minimum over-pumping. This will reduce pumping energy to a minimum, extends the life of the pumps and motors and increases the effectiveness of the control valves by reducing the differential pressure across them.

This is most easily achieved by installing an external Variable Speed Drive (VSD) and a Differential Pressure Sensor (DPS). The DPS detects the existing differential pressure and adjusts the drive speed of the pump to match the required pressure. The VSD adjusts the pump speed and thereby the pump horsepower (HP) by reducing the nominal AC voltage frequency of 60 Hz. Note that reducing the pump frequency by a factor of two reduces the horsepower (HP) by a factor of 8 which can result in significant energy savings. Note that the Circuit Setter is no longer needed and must be opened (100%).

So, the VSD and DPS work together to reduce pump speed to compensate for (1) the fixed Circuit Setter and (2) accommodating varying flow demands.

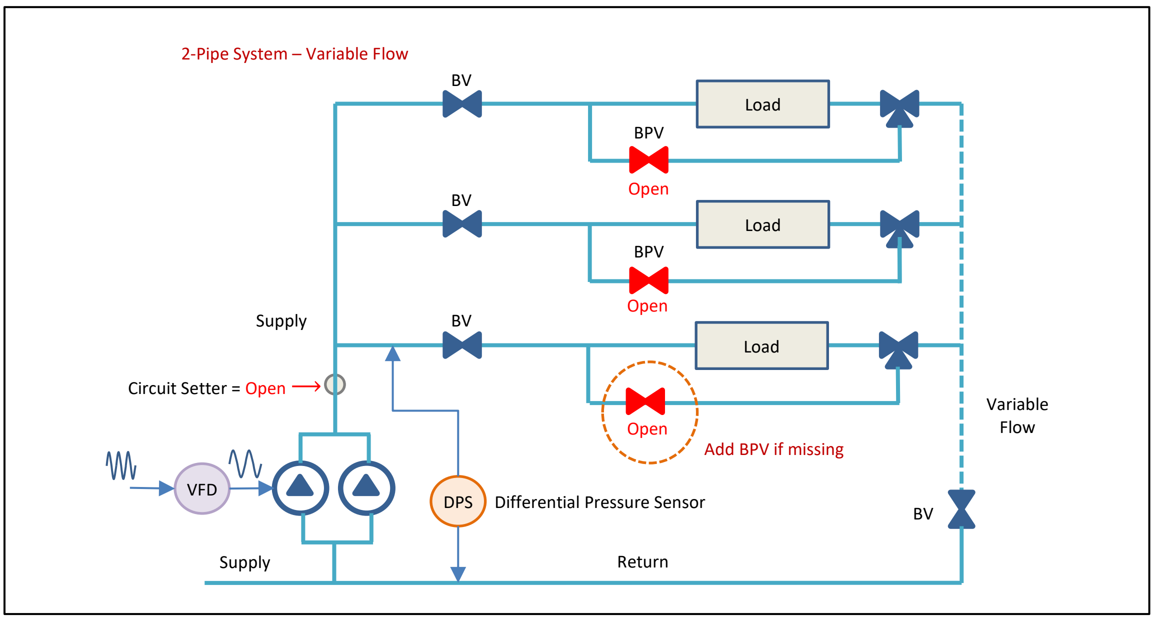

Figure 2 Converted 2-Pipe System, Variable Flow with VFD and Differential Pressure Sensor

6. Condensing Boiler/Furnace

6.1. Overview

Traditional boilers/furnaces fueled by gas or oil are built with just one heat exchanger. During the combustion process that takes place inside of this heat exchanger, a certain amount of the heat that is produced is lost up the chimney flu in the form of water vapor. This flu-heat is wasted energy you need to pay for.

Condensing boilers/furnaces have a second heat exchanger. At the beginning of the heating process, the gas burners deliver heat to the first heat exchanger and the combustion process leaves a byproduct of hot water vapor. That water vapor is next sent to the second heat exchanger where it is condensed and turned into a liquid. The resulting liquid from the condenser is then drained out of your home through a PVC pipe.

When a gas turns into a liquid, it releases latent heat. This latent heat extracted from the water vapor in the condenser is energy that would normally be vented out. The use of this residual latent heat allows a condensing boiler/furnace to utilize a greater percentage of the fuel energy which can significantly reduce operating costs. Condensing boilers/furnaces achieve high efficiency with AFUE typically greater than 90% compared to 80% for conventional designs.

6.2. Condensing Boilers Must Condense [4]

If a Condensing Boilers aren't condensing, then they are not retaining the latent heat of combustion. This means systems must be designed so that the return water temperature is at least below 130. The lower the return water temperature the better the efficiency. Figure 1 shows just how dramatically return water temperature impacts the efficiency of a condensing boiler [4].

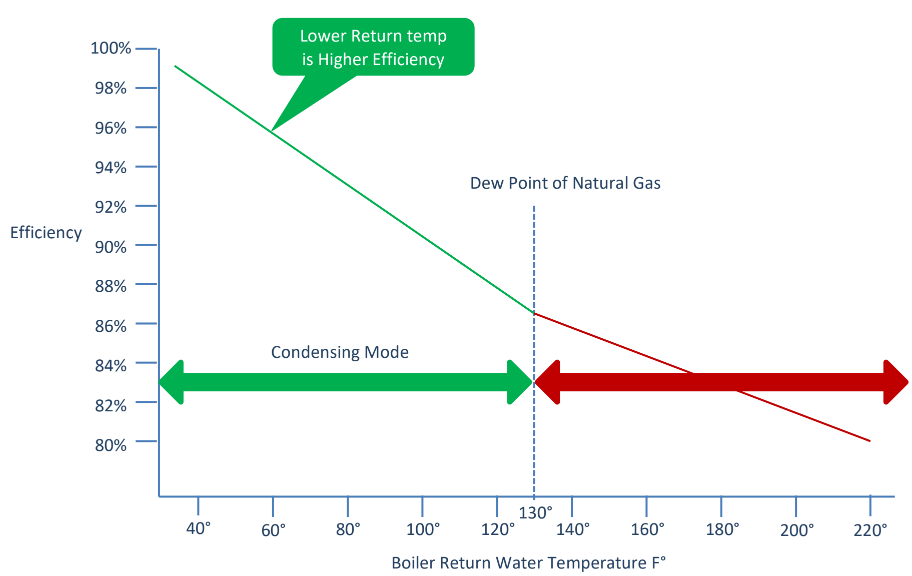

Figure 3 Efficiency vs. Return Temperature [4]

Condensing boilers are more efficient at part load! The reason for this is two-fold. As the boiler modulates toward low fire the heat exchanger capacity remains the same because the surface area has not changed. You're still generating heat and you're still condensing. As the fire rate increases, the amount of exhaust gas increases, which robs the boiler of some of its condensing capability.

With condensing boilers, the more you condense, the more efficient you are. That's why two or three boilers at low fire are always better than one at full fire. Figure 2 shows how much efficiency is gained by operating condensing boilers at part load. As the graph shows, a condensing boiler at 25% fire is approximately 8% more efficient than when it is at 100% fire.

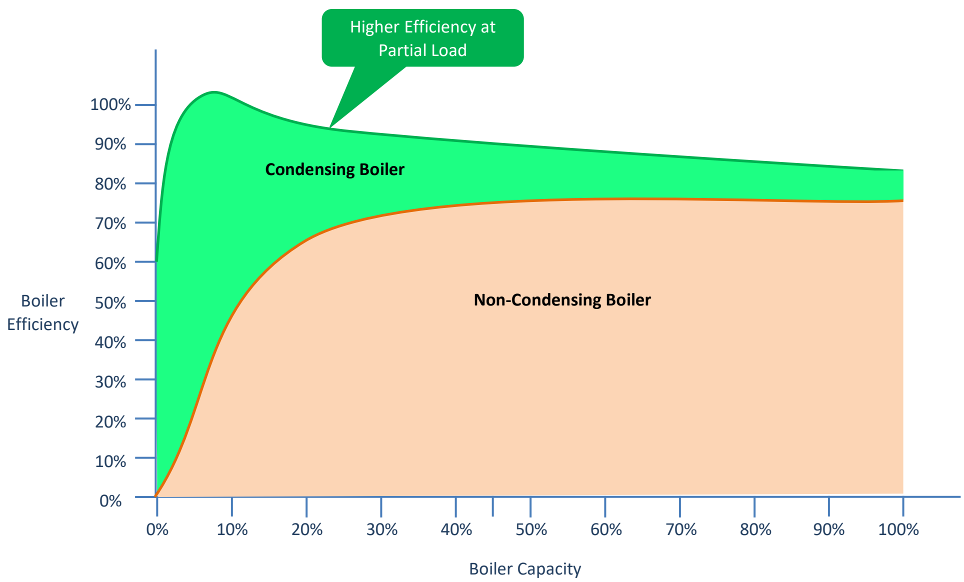

Figure 4 Efficiency vs. Load Capacity [4].

7. Setback

The amount of work that an HVAC unit has to do to maintain a steady temperature is equal to the rate at which heat is being gained or lost. The heat lost is given by $q = U \times \Delta T$, where q is the total heat transferred per hour, U is the thermal conductivity and ΔT is the difference between existing temperature and desired temperature. Thus, the greater the temperature differential, the more HVAC work is required.

An example illustrates the benefits of setback. Consider a hypothetical office with U = 2,000 BTU/hour, an ambient of 20° and a target temperature of 70°. The heat lost is q_1 = 2,000 × 50 = 100,000 BTU/hour. If ambient stays at 20° for 24 hours then the total energy lost in one day is Q_1 = 24 × 100,000 = 2,400,000 BTUs which must be replenished the next day.

Now consider the application of setback. Given the building is unoccupied from 7:00pm to 7:00am. We can setback the temperature during the 12 hours it is unoccupied. Assume after the setback is initiated it takes two hours to drop to 60°, for which the HVAC is off, and it takes two hours of heating to bring the temperature up to 70° by 7 am. We can approximate that these two periods cancel each other. So, we are left with 8 hours for which the HVAC is maintaining a temperature of 60°. Then, q_2 = 2,000 × 40 = 80,000 BTU/hour. This is a 20,000 BTU/hour savings during the 8-hour period. The total energy savings over 8 hours is 160,000 BTUs = 160 MBTU. This corresponds to an annual savings of 365 × 160 MBTU = 58,400 MBTU. There are .00964 CCF per MBTUs. So, the annual gas savings at $1.00 per CCF is 58,400 MBTU × $.0096 × $1.00 = $562.

8. Kitchen Hood Controls

Kitchen Ventilation Control System such as a Melink's Intelli-Hood system:

1. VFDs for exhaust fan and makeup air units (MAU)
2. Temperature sensors mounted in the hood to detect the cooking appliances being turned on and slow the fan to run at a min speed of 30%-50%.
3. Temperature Sensors mounted in exhaust ducts modulate the fan speeds above the min based on actual heat load demand.
4. Optic Sensors with Air Purge Units mounted on opposite ends of hoods increase fan speed to 100% upon the detection of smoke or vapors. As soon as the effluent is removed the fan speeds shall slow back down and modulate according to the actual heat load demand.
5. Touchpad is mounted on hood or convenient location to monitor and control system. Remote monitoring and control can be provided by connecting the System Controller to a building automation system via BACnet and/or Internet gateway.
6. Program and commission system

9. Bibliography

[1] TRANE, "Trane Precedent Series RTU, 3 to 10 Tons," 2019.

[2] D. Eagen, "Conversion From Constant Flow System," 2019. [Online]. Available: http://www.armstrongpumps.com.

[3] J. Pattavina, "VFDs for Variable Flow Hydronic Systems," 2019.

[4] C. Edmondson, "Energy Efficient Hot Water Boiler Plant Design Part 2: Golden Rules of Condensing Boilers," [Online]. Available: http://jmpcoblog.com/hvac-blog/energy-efficient-hot-water-boiler-plant-design-part-2-golden-rules-of-condensing-boiler-technology.