Demand Ventilation in Commercial Kitchens
An Emerging Technology Case Study

Melink *Intelli-Hood® Controls*
Commercial Kitchen Ventilation System
Intercontinental Mark Hopkins Hotel

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The FSTC extends a "thank you" to Robin Lamont of the Intercontinental Mark Hopkins Hotel for the opportunity to conduct this energy-monitoring project.

The FSTC recognizes the dedicated effort by Melink® in pioneering demand ventilation controls for commercial kitchens.

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The objective of this study was to evaluate the Melink *Intelli-Hood® Controls*, a demand-ventilation control package that had been installed on the commercial kitchen ventilation (CKV) system at the Intercontinental Mark Hopkins Hotel in San Francisco, California. The exhaust system comprised a 30-foot double-island, canopy hood with a design ventilation rate of 22,500 cfm and dedicated makeup air unit with a design rate of 19,500 cfm. Within the scope of the State-Wide Emerging Technologies Program and under the direction of PG&E, the study examined the energy use and demand of two exhaust fans and one makeup air unit (MAU) fan with and without the operation of the Melink *Intelli-Hood Controls.* In addition, air temperatures were monitored upstream and downstream of the MAU (outdoor and supply air temperatures) in order to calculate the associated makeup air heating load savings.

The Melink *Intelli-Hood Controls* modulate the speed of the exhaust and MAU fan motors with variable frequency drives (VFDs). The VFDs receive commands from a central controller, which receives its input from two sources: (1) an infrared (IR) beam that spans the length of the exhaust hood and (2) a temperature sensor mounted in the exhaust duct. A disturbance in the IR beam or an increase in the exhaust duct temperature signals the controller to increase the exhaust system fan speed from a predetermined minimum to full speed.

The Melink *Intelli-Hood* demand ventilation strategy at the Intercontinental Mark Hopkins Hotel Kitchen was shown to significantly reduce the energy consumption and electrical demand associated with operating the CKV system. The *Intelli-Hood Controls* reduced the combined three-fan electrical demand from 14 kW to 5.3 kW for a savings of 8.7 kW. This 62% reduction in electrical demand was concurrent with the statewide, summertime, peak demand hours of 12:00 noon to 6:00 pm. The demand reduction over the course of a typical operating day is illustrated in Figure ES-1. The average daily energy consumption for all three fans combined without the demand ventilation controls was 336 kWh/d. With the demand controls, the daily energy consumption dropped to 127 kWh/d. This represents an annual reduction of 76,285 kWh for a cost savings of $9,910 (based on $0.13 per kWh).

In addition to the electrical energy savings at the three fans, there was energy savings gained from the reduced heating load at the MAU. The average fan speed (and associated airflow) of the MAU

dropped by 30%, which resulted in an average reduction of 5,750 cfm in the volume of outdoor air that was being heated. This saved a calculated 11,826 therms of natural gas a year, which translated to an annual cost savings of $9460 (based on $0.80 per therm).

Combining the total fan energy and demand savings of $9,910 and the MAU gas savings of $9,460, the estimated total annual savings for the Mark Hopkins Hotel was $19,500. The estimated cost of the Melink *Intelli-Hood Controls* including installation was approximately $15,000, which resulted in a return on the investment of less than 1 year.

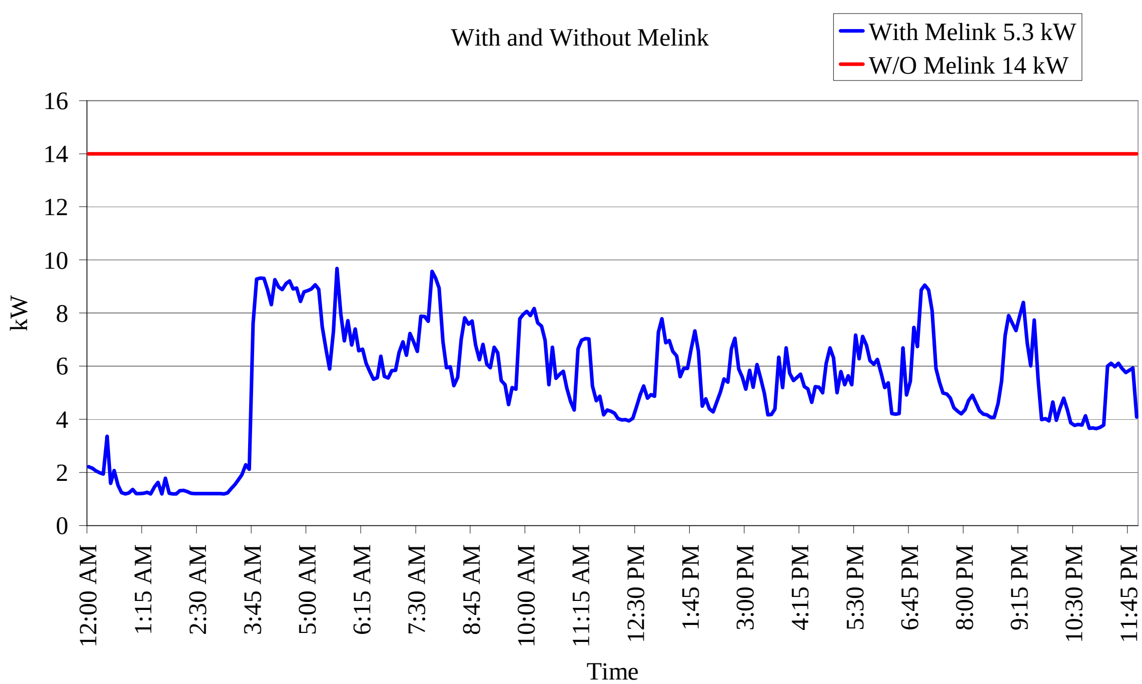

Figure ES-1. Exhaust and Makeup Fan Power With and Without the Melink Intelli-Hood® Controls

As with most HVAC controls, commissioning can be very important to the success of the project. Although the FSTC team determined that the Melink *Intelli-Hood Controls* had been programmed correctly for this application, a faulty wiring harness (discovered during the monitoring phase of the project) effectively disabled one half of the control system. This partial system failure emphasizes the importance of commissioning, as well as the need for facility managers to periodically inspect energy management systems to ensure proper operation.

Executive Summary

The Mark Hopkins kitchen represented a good application for demand-control ventilation because of three primary factors:

- The exhaust and makeup fans were large enough (in terms of air flow, pressure drop and associated horsepower) that any significant energy savings (expressed as a percentage) would produce a significant cost savings.
- The kitchen had scheduled cooking times, which meant there were also many slow periods with little cooking and therefore little demand for full-speed operation of the exhaust hood.
- The kitchen operated 24 hours a day, 7 days per week, which increased the number of hours in which the fans could run at low speed.

Table ES-1 presents an economic summary of the demand ventilation control system.

Table ES-1. Energy & Cost Summary.

Case Study: Mark Hopkins Hotel	
Without Melink Intelli-Hood Controls	
Design Exhaust Ventilation Rate	22,500 cfm
Exhaust & Makeup Fan Power	14 kW
Exhaust & Makeup Fan Energy	336 kWh/d
With Melink Intelli-Hood Controls	
Reduced (Average) Exhaust Rate	13,750 cfm
Reduced (Average) Fan Power	5.3 kW
Reduced Fan Energy	127 kWh/d
Energy Savings	
Effective Exhaust Reduction	5,750 cfm
Makeup Air Heating Saving	11,826 therms
Average Demand Reduction	8.7 kW
Average Fan Energy Saving	209 kWh/d
Cost Savings	
Fan Energy Savings*	$9,910
Makeup Air Heating Savings*	$9,460
Total Cost Savings with Melink Control	$19,370
Installed Cost of Intelli-Hood Controls	$15,000
Payback	**< 1 year**
* based on $0.80/therm and $0.13/kWh	

In conclusion, kitchen exhaust ventilation systems in large hotels and institutional kitchens (such as hospitals and prisons) may represent one of the more cost-effective applications for demand ventilation control. It is recommended that California utilities encourage market transformation through targeted education and/or incentives for this emerging technology, particularly for the larger institutional-style kitchens.

Introduction

Demand Ventilation

Today's kitchen ventilation systems are about more than heat and smoke removal at the lowest first cost. Food-service establishment owners and operators have become more sophisticated and demanding, wanting systems that are more energy efficient and require less maintenance. In addition, they want kitchens to be more comfortable while complying with more stringent indoor air quality standards. Finally, owners and operators want reduced noise levels and improved fire safety.

Until a few years ago, kitchen ventilation controls mainly consisted of a manual on/off switch and a magnetic relay or motor starter for each fan. Exhaust and makeup fans either operated at 100% speed or not at all. In a world of automated HVAC control, the commercial kitchen ventilation (CKV) system is still operating in the dark ages**—***you turn it on***,** *you turn it off, and in between it operates at full speed!* The occasional independent operator has upgraded to a manual two-speed system that relies on cooks to switch from low to high-speed and vice versa, which is an improvement but not a global solution for the lack of control over kitchen exhaust. Today's state-of-the-art system is equipped with microprocessor-based controls with sensors that automatically vary fan speed based on cooking load and/or time of day. Clearly in the category of emerging technologies, these demand-control ventilation strategies are split into four general categories[1].

Control Strategy 1. The first strategy is based on the energy *input to* the cooking appliances. The idea is that the more energy appliances use, the more ventilation probably is needed. This involves installing sensors/transmitters on the gas and/or electric lines to monitor energy consumption, and variable-frequency drives to vary the fan speeds accordingly.

Control Strategy 2. The second control strategy is based on the energy and effluent *output from* the cooking appliances (i.e., the more heat and smoke/vapors generated, the more ventilation needed). This involves installing a temperature sensor in the hood exhaust collar and an optic sensor on the end of the hood, and variable-frequency drives to adjust the fan speed accordingly.

[1] Melink,S,K., Kitchen Hood Using Demand Ventilation, ASHRAE Journal, 2003.

Control Strategy 3. The third control strategy is based on time of day. While time of day is the most indirect control variable of the three strategies, it is the simplest approach if the cooking schedule is very predictable with little or no part-load conditions. A user override can be incorporated within the strategy.

Control Strategy 4. The fourth control strategy is based on the cook manually turning appliances on and off, or opening lids to clamshell griddles, kettles, and ovens where this change in appliance operation is integrated (through dedicated controls) with the exhaust system. This was a strategy previously reported on by the FSTC within the scope of monitoring an energy efficient quick-service restaurant[2]. This approach is more dependent on the number and type of appliances than the other three and therefore somewhat limited in application. The main drawback is the field integration required between the cooking appliances and the hood control system, and possibly the need for operator assistance.

The demand ventilation control strategy used by the Mark Hopkins Hotel in this study was Control Strategy #2.

In summary, demand ventilation controls for commercial kitchen hoods have been installed in recent years, but the market is still relatively young. Supermarkets have been especially progressive because their deli/bakery departments have highly variable cooking loads. Institutions such as hospitals, nursing homes, schools, and universities also are suitable applications because of their typically large hoods and long operating hours. Restaurant chains are more application-specific since many have smaller hoods and more steady-state cooking operations. However, as energy costs continue to increase and restaurant chains become more aware of the secondary benefits of demand ventilation, smart hoods gradually will become the standard.[3]

[2] Fisher, D.R., Schmid, F., Spata, A.J. 1999. *Estimating the Energy-Saving Benefit of Reduced-Flow and/or Multi-Speed Commercial Kitchen Ventilation Systems.* ASHRAE Transactions, V. 105, Pt. 1.
[3] Melink,S,K., Kitchen Hood Using Demand Ventilation, ASHRAE Journal, 2003.

Introduction

Objective and Scope

The objective of this field study was to monitor the energy and electric demand savings realized from the Melink *Intelli-Hood Controls* system—an emerging demand-ventilation technology.

The *Intelli-Hood* system previously had been installed at the Intercontinental Mark Hopkins Hotel in San Francisco, CA (Figure 1). Within the scope of the State-Wide Emerging Technologies Program and under the direction of PG&E, the FSTC monitored the energy usage of the two exhaust hood fans and the makeup air unit (MAU) fan. In addition, the FSTC monitored the air temperatures of the outdoor air entering and exiting the MAU, which allowed for calculating the associated gas heating load and determining energy savings realized by reducing the heating load of the MAU.

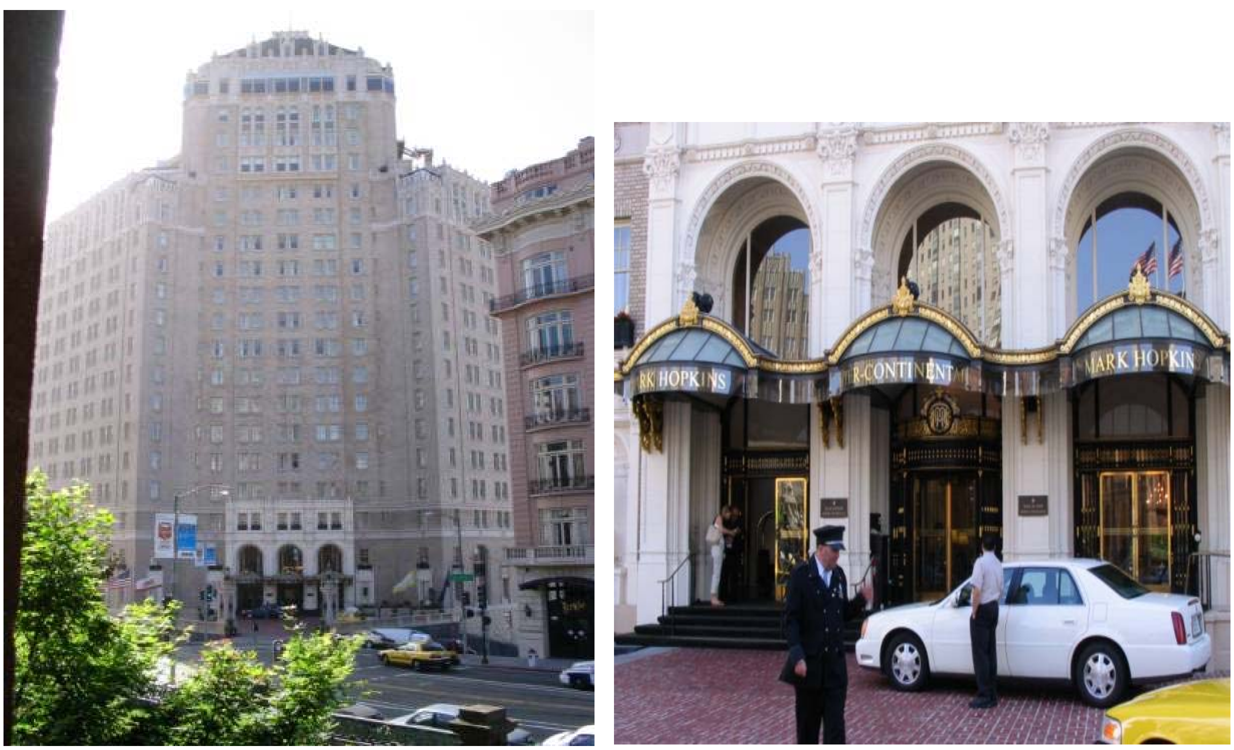

Figure 1. The Interncontinental Mark Hopkins Hotel.

CKV System Description

The Intercontinental Mark Hopkins Hotel Kitchen

The Intercontinental Mark Hopkins Hotel kitchen never closes – operating 24 hours per day, 365 days per year. The kitchen provides breakfast, lunch, dinner, room service and all of the hotel's catering needs (Figure 2). As a 24/7, hotel operation, there are many hours during the day that the appliances are not being used to cook food, providing potential for demand-controlled ventilation.

Figure 2. The Mark Hopkins Hotel Kitchen

CKV System Description

A Gaylord Industries 30-foot, double-island canopy exhaust hood removes the cooking effluent from a front and back appliance line. The front line provides the majority of the short-order cooking, while the back line accommodates most of the batch cooking (Figures 3 & 4). The design ventilation rate of the exhaust hood was 22,500 cfm. The makeup air unit was rated at 19,500 cfm, approximately 87% of the exhaust flow.

Figure 3. The Front Cook Line

Front Line (left to right):

- ½ size HFHC
- 4-burner range w/oven
- 4-burner range w/oven
- Fryer (electric)
- Griddle w/oven & salamander
- 1.5 ft broiler
- Fryer (electric)
- 8-burner range w/oven & salamander
- Over-fired broiler

Figure 4. The Back Cook Line

Back Line (left to right):

- 4-steam jacketed kettles, three 60 gallon and one 30 gallon
- Skillet
- 6-burner range w/oven
- 2 roll-in ovens

CKV System Description

Exhaust and Makeup Air Fan Descriptions

The two exhaust hood fans were Greenheck belt driven models. The fan motors were 3-phase, 208V, rated at 7.5 horsepower each. These fans operated 24/7 and were only shut down for a few hours during the monthly hood cleaning (Figure 5 and Table 1).

Figure 5. The Two Greenheck Exhaust Fans

The Temtrol makeup air unit (MAU) included a belt driven, 3-phase, 208V fan rated at 20 horsepower (Figure 6 and Table 1). The operation of this unit was interlocked with the exhaust fans. The unit only provided heating and the heat exchanger used hot water from the hotel's hydronic system. There was no cooling of the makeup air supplied to this kitchen, which is acceptable due to the cool coastal climate in San Francisco.

Figure 6. The Temtrol MAU

Table 1. Fan Specifications.

Greenheck Exhaust Fans	
Model	SWB-230-75-CW-TAU-6
Rated hp	7.5 (each)
Phases	3
Voltage	208
Design airflow (cfm)	22,500 (combined)
Temtrol MAU	
Model	ITF-RD 12
Rated hp	20
Phases	3
Voltage	208
Design airflow (cfm)	19,500

Melink *Intelli-Hood*® *Controls* Description

The Melink *Intelli-Hood Controls* package is a demand-ventilation-based energy management system for commercial kitchen exhaust hoods (Figure 7). The *Intelli-Hood* controls the speed of the exhaust fans and MAU fan through variable frequency drives (VFDs). The VFDs receive a signal from a controller, which receives input for controlling the exhaust and MAU from two sources. First is an infrared (IR) beam that crosses the bottom of the exhaust hood. When this beam is obstructed (reducing its intensity to less than 95% of full input), the exhaust hood and MAU will go to 100 percent speed. The IR beam can be broken by either smoke or steam produced by the cooking process (Figure 8). The second control input comes from temperature probes placed in the exhaust duct collars (Figure 9). If the temperature probe senses a predetermined temperature activation point, the hood will go to 100 percent. An appliance in either a cooking or a standby mode of operation can generate this heat.

The *Intelli-Hood Controls* optimize energy efficiency by reducing the exhaust and make-up air fan speed when no cooking occurs. In addition, the noise level in the kitchen is reduced significantly when the fans slow down and the airflow through the hood is reduced. When the system starts up for the first time each day, the controller performs a self-diagnostic test to ensure that the system is correctly calibrated. If all is okay, the fans reach a preset minimum speed of between 10 and 50 percent. If not, the system will go into a fail-safe mode and operate at 100% to ensure that all smoke and heat is removed.

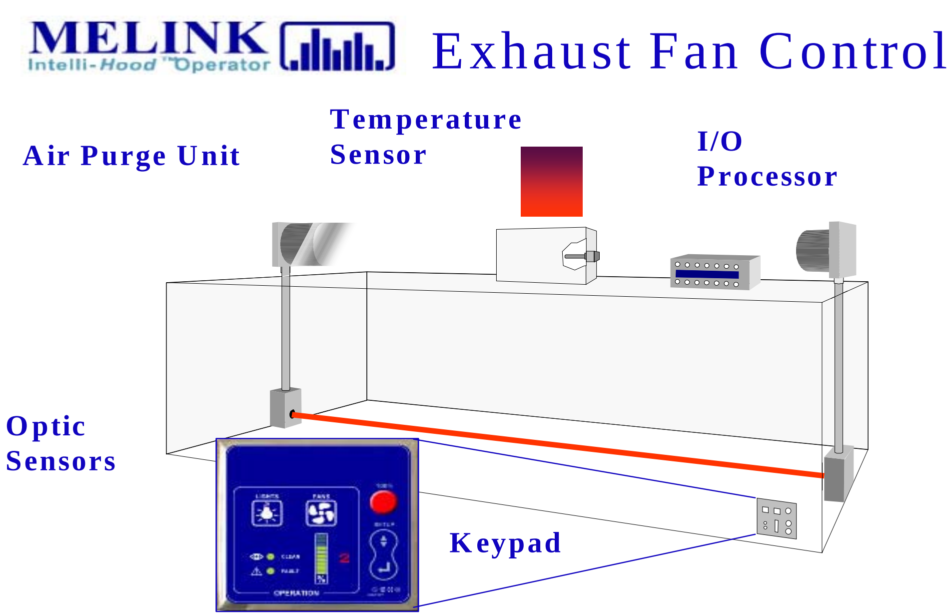

Figure 7. Intelli-Hood – Exhaust Fan Control (Courtesy of Melink®).

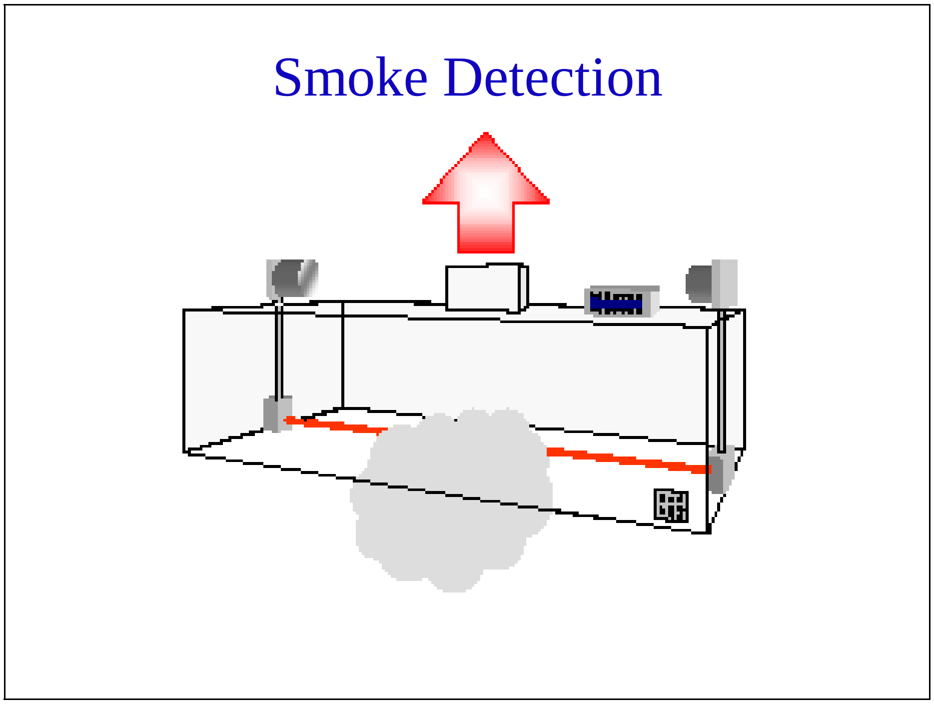

Figure 8. Intelli-Hood – Smoke Detection (Courtesy of Melink®).

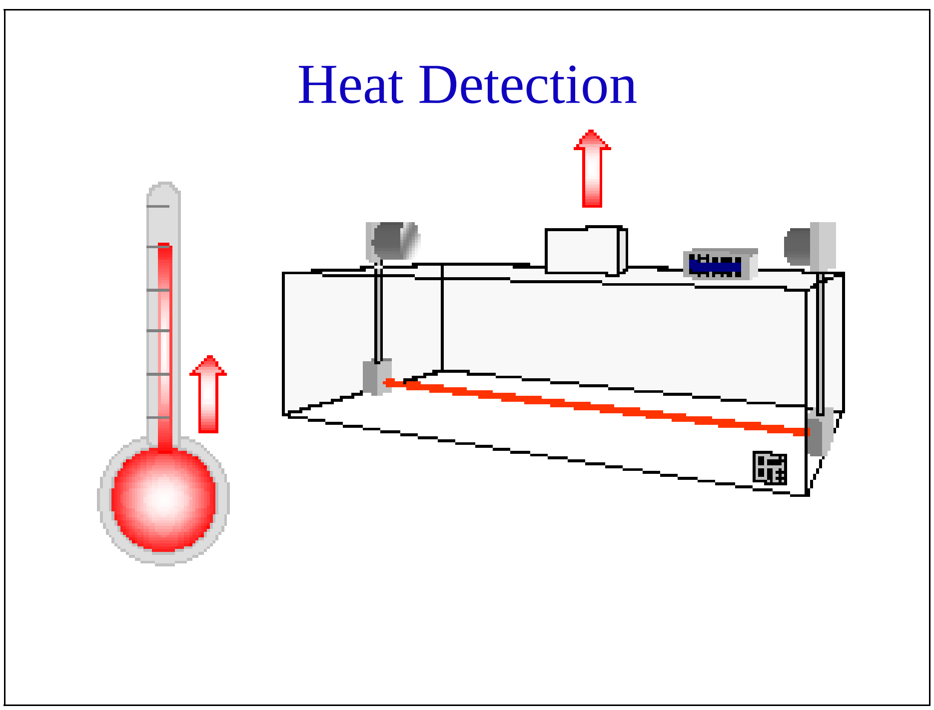

Figure 9. Intelli-Hood – Heat Detection (Courtesy of Melink®).

Variable Frequency Drives

Many electric motors operate at full speed even though the devices that they are driving may have varying load requirements. A technique that is used to make electric motors responsive to diverse loading conditions is the application of variable speed drives (VSDs), which reduce the operating speed of the electric motor to some fraction of the full speed. One of the most accepted ways of controlling the speed of existing three-phase AC motors is with a type of VSD know as a variable frequency drive (VFD). The following excerpt[4] describes the theory behind VFDs:

The VFD accomplishes part load control by varying electric motor speed. The stator and rotor contain pole pairs wound with copper wire. When a current is applied, a magnetic field is generated and the north/south field rotates through the stationary stator as the rotor spins to catch up to the rotating field. The spinning of the rotor provides the torque necessary to drive a load. An electric motor turns at a given speed depending on the number of poles in the motor and the frequency of the alternating current applied. Thus, changing the alternating current frequency can change the motor speed. Nearly all variable frequency drives manufactured today are referred to as pulse width modulation drives. These drives contain electronic circuitry that converts the 60 Hertz line power to direct current, then pulses the output voltage for varying lengths of time to mimic an alternating current at the frequency desired.

The VFDs used at the Intercontinental Mark Hopkins Hotel, were manufactured by ABB. These VFDs enabled the Melink *Intelli-Hood Controls* to increase and decrease the kitchen exhaust fan speed as the controller monitored and responded to the cooking process (Figure 10).

Figure 10. Variable Frequency Drives (VFDs)

[4] Energy Expertise: Energy Efficiency *Variable Frequency Drives* Retrieved September 20, 2004, from http://www.alliantenergy.com/stellent/groups/public/documents/pub/bus_exp_eff_012399.hcsp

Setup and Instrumentation

FSTC researchers used two types of data loggers for the monitoring project. For the electrical measurements, Dent Elite Pro data loggers were installed, and for the temperature measurements, HOBO External Temperature loggers were used (Figure 11).

The Dent Elite Pro data loggers measure single or three phase loads, AC or DC, kWh, kW, Volts, Amps, kVA, kVAR, Watts, VA, VAR, and Power Factor. The accuracy of these loggers is ± 1% of reading, exclusive of sensor (current transducer – CT) accuracy. The Magnelab model number SCT-0750-050 split core CTs used to record the measurements were rated from 5 to 50 amps with a ± 1% accuracy. The data loggers were installed in the VFD enclosure and the CTs were installed between the VFDs and the upstream motor breakers. Measurements were recorded in 5-minute intervals and data was collected for 30 days.

The Onset HOBO External Temperature loggers, model number H08-002-02, were used to record air temperatures. Temperature measurements are based on voltage (0-2.5 V DC) readings received from an external sensor. The logger can record up to 7943 total readings, available in nonvolatile memory. These loggers have a temperature range from -40°F to 212°F. The accuracy of these loggers is ±1.27°F at 70°F. The outside air temperature measurement was taken on the rooftop at the MAU filters, where the outdoor air enters the unit. The second measurement was taken in the kitchen as air exited the MAU through the 4-way diffusers. Measurements were recorded in 5-minute intervals and data was collected for 30 days.

Figure 11. The HOBO Temperature Logger and the Dent Power Meter

Results and Discussion

The FSTC monitored the Melink *Intelli-Hood* System at the Intercontinental Mark Hopkins Hotel for 30 days. The monitoring was separated into two phases. The first phase covered the initial monitoring of the system, while the second phase covered performance after a repair had been made to a faulty wiring harness within the control system. During the initial system evaluation, the FSTC only collected data and monitored the exhaust hood fans and the MAU. During this phase, no adjustments or operational changes to the *Intelli-Hood* control panel occurred. During this time, it was discovered that one of the six wiring harnesses for the duct temperature probes, on the back cooking line, was faulty. As a result, the Melink *Intelli-Hood* was operating the back cooking line in a fail-safe mode and the exhaust hood fan was running at 100 percent all day. The second monitoring phase occurred after a new wiring harness had been installed and the controller's programming was checked. No re-programming was required, as the Melink *Intelli-Hood* System had been setup for maximum exhaust reduction upon initial installation.

The monitoring project at the hotel consisted of installing three data loggers, one for each exhaust fan motor and one for the MAU. Each of the graphs in this section will reference the following fan designation:

- KEF 1 is the fan that exhausts the front cooking line where the majority of the cooking occurs.
- KEF 2 is the fan that exhausts the back cooking line that is mostly dedicated to food prep and other batch cooking.
- MAU is the fan that provides the make up air for the kitchen, replacing the air that has been removed through the exhaust hood by the two exhaust fans. This fan supplies air for both sides of the exhaust hood.

Results and Discussion

Initial Results – Phase 1

The two exhaust hood fans were each rated at 7.5 hp and the MAU at 20 hp. In Table 2, the fan nameplate ratings are presented along with recorded maximum power (kW) and the initial daily energy (kWh) consumption from the first monitoring phase of the project.

It should be noted that there is often a discrepancy between a fan motor nameplate rating and the actual measured kW, which can lead to over estimating a fan's energy consumption. Fans do not typically operate at their maximum rated horsepower (and equivalent kW) because of safety factors built into the specification. With this understood, the maximum measured power (kW) of each fan is presented in Table 2, as well as the initial monitoring results. As shown, the fans were drawing significantly less power than their rated capacity at 100% speed.

Table 2. Fan Nameplate HP, Measured Maximum kW and Daily kWh – Phase 1.

KEF 1	
Nameplate HP Rating	7.5
Measured Maximum kW	3.8
Measured Daily Average kWh	43.4
Measured Daily Average kW	1.8
KEF 2	
Nameplate HP Rating	7.5
Measured Maximum kW	3.8
Measured Daily Average kWh	88.7
Measured Daily Average kW	3.7
MAU	
Nameplate HP Rating	20.0
Measured Maximum kW	6.4
Measured Daily Average kWh	91.2
Measured Daily Average kW	3.8

Figures 12, 13 and 14 illustrate the measured typical daily electricity use for each fan. The profile for KEF 1, which is the front-line fan, shows an exhaust fan that is modulating throughout the day in response to cooking activities. However, as shown on Figure 13, KEF 2 did not display any variation in exhaust rate throughout the day. This led the FSTC researchers to investigate and determine a problem with the hood/controller. In Figure 14, the MAU had a similar pattern to KEF 1 where it's fan motor adjusted throughout the day in sequence with KEF 1.

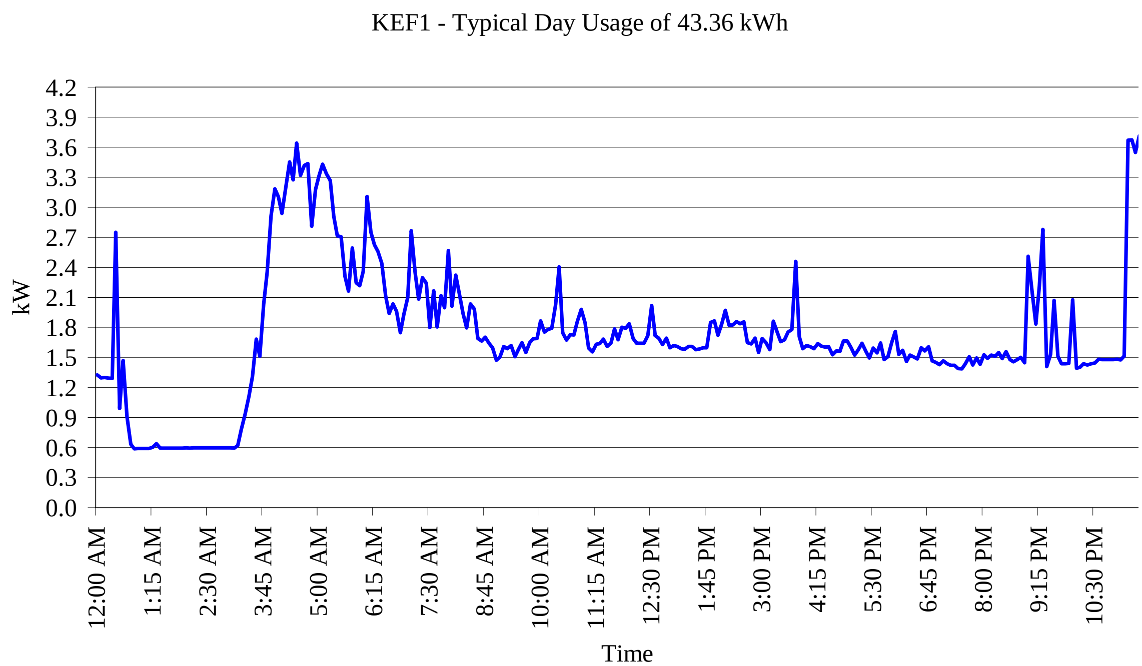

Figure 12. Typical Electric Demand (kW) of KEF 1 – Phase 1

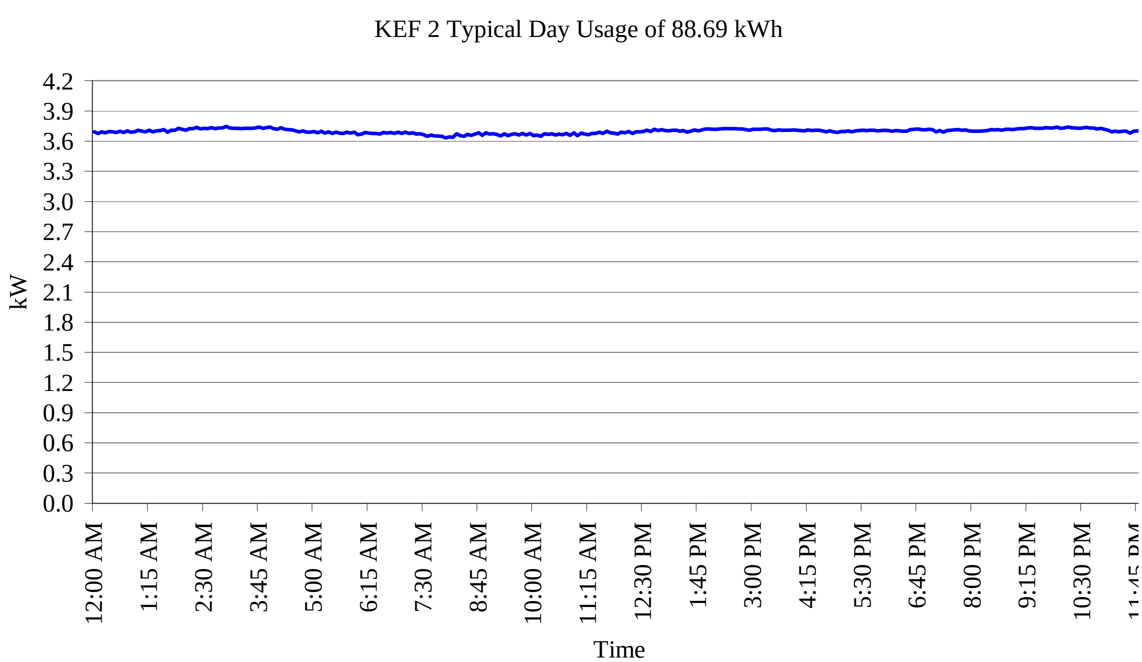

Figure 13. Typical Electric Demand (kW) of KEF 2 – Phase 1

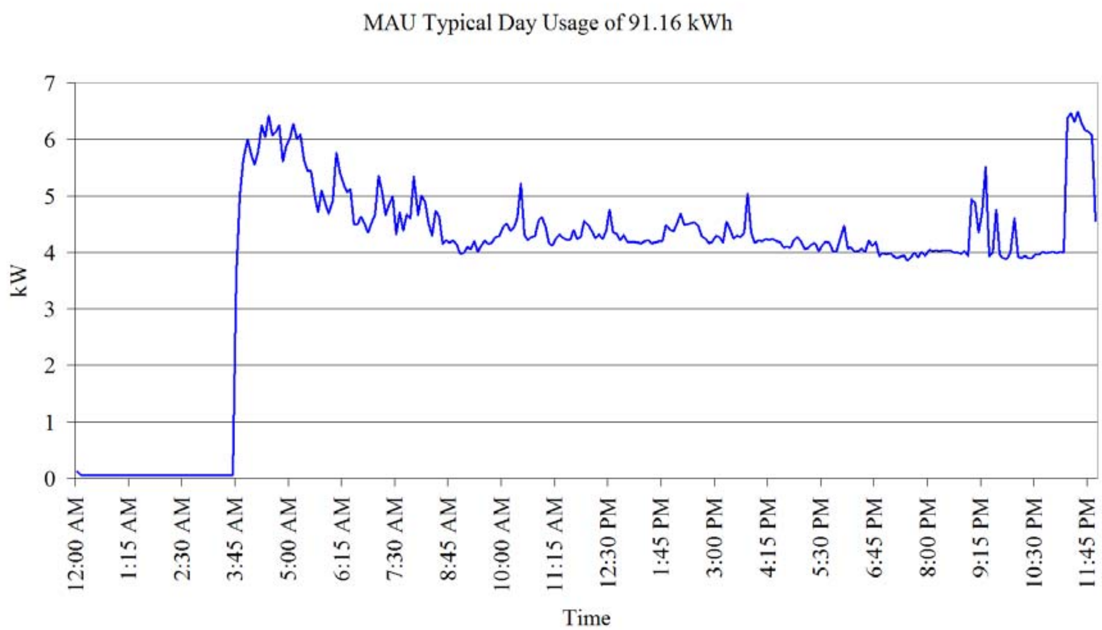

Figure 14. Typical Electrical Demand (kW) of MAU – Phase 1

Figure 15 shows the location of the faulty wiring harness for KEF 2. The controller was not receiving a duct temperature for the back line exhaust hood and, as a result, the fan operated at 100% in the fail-safe mode.

Figure 15. View of the Melink Intelli-Hood Controller, Temperature Probes and Wiring Harness

Results After the New Wiring Harness Was Installed – Phase 2.

After the new wiring harness had been installed for the temperature probes on the back-line exhaust hood, immediate results were seen. KEF 2 responded by modulating as the cooking activity increased or decreased. Figure 16, which illustrates energy use before and after installation of the new wiring harness, clearly distinguishes the difference in energy usage patterns and the resulting reduction in demand and consumption. The average kWh usage with the faulty wiring harness was 88.7 kWh per day. After the new harness was installed, KEF 2 averaged only 30.5 kWh per day, which represents a 66% reduction in fan energy. Also affected by this change was the MAU. Before the wiring harness was installed on KEF 2, the MAU averaged 91.2 kWh a day. Once the new harness was installed, the MAU energy use dropped by 40% to an average of 54.7 kWh per day (Figure 17). The percent reduction at the MAU fan was lower than the reduction at KEF2 because the MAU serves both sides of the exhaust hood and the unit was already partially responding to the cooking loads as seen in the "before" profile in Figure 17. As for KEF 1, no changes in average kWh occurred, which is what was expected since the wiring harness problem did not affect the front cooking line. Table 3 lists the "before and after" energy use and corresponding % changes.

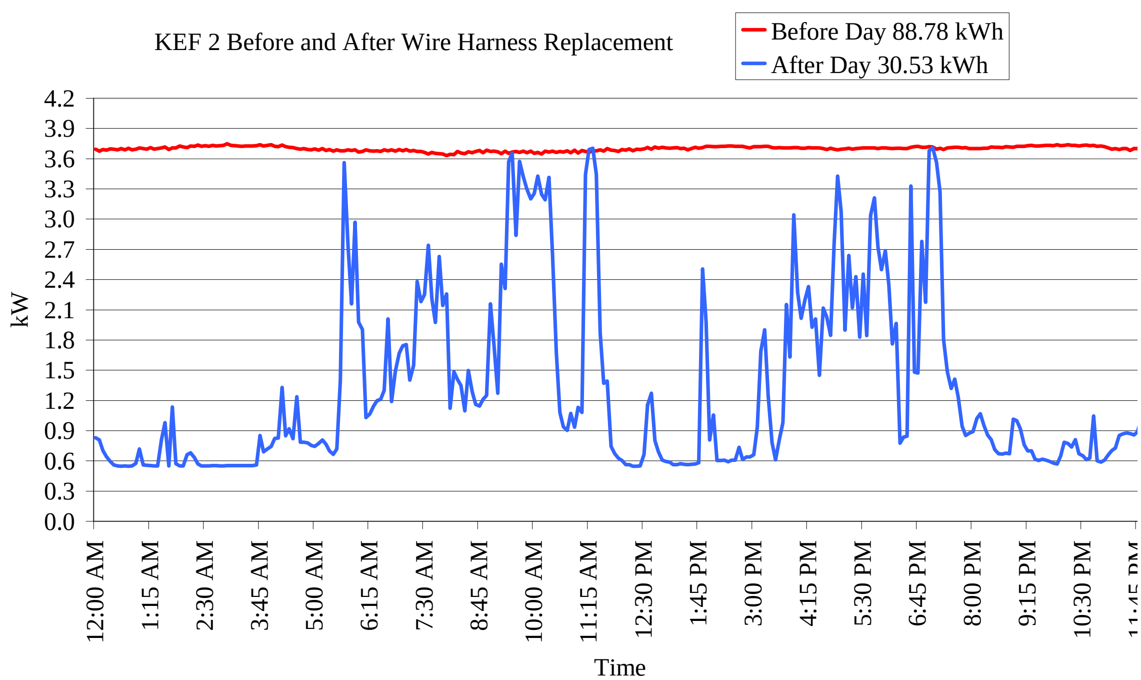

Figure 16. KEF 2 After the Wiring Harness Replacement – Phase 2

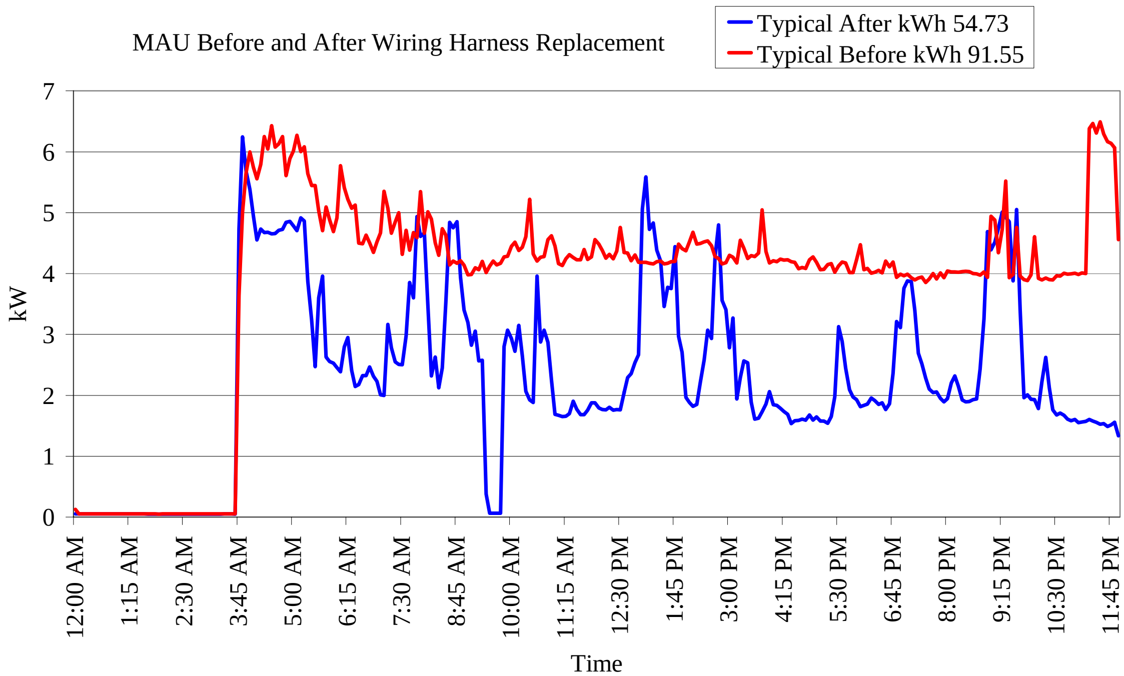

Figure 17. MAU After the Wire Harness Replacement – Phase 2

Table 3. Results for the Three Fans After the New Wiring Harness Installation – Phase 2.

	KEF 1	KEF 2	MAU
Measured Daily Average (kW)	1.80	1.3	2.2
Before Harness Installation (kWh/d)	43.6	88.7	91.5
After New Wire Harness (kWh/d)	43.6	30.5	54.7
Percent Change (%)	0.0%	65.6%	40.2%

Daily Energy Use of Each Fan During the Monitoring Project

The following graphs illustrate the daily kWh usage during the monitoring project. As detailed in Figure 18, KEF1 consistently modulated fan speed in response to the cooking load every day with the exception of two days at the beginning of the project when the hotel was performing scheduled hood cleaning and the Melink *Intelli-Hood* was left on “override.”

In Figure 19, the daily energy consumption for KEF 2 changed dramatically after the new temperature probe wiring harness was installed. The graph displays this change as it occurred on 4.17.04 when the energy consumption dropped by 66%. A similar change occurred in the MAU, where the daily kWh consumption dropped by 40% after the wiring harness was installed (Figure 20).

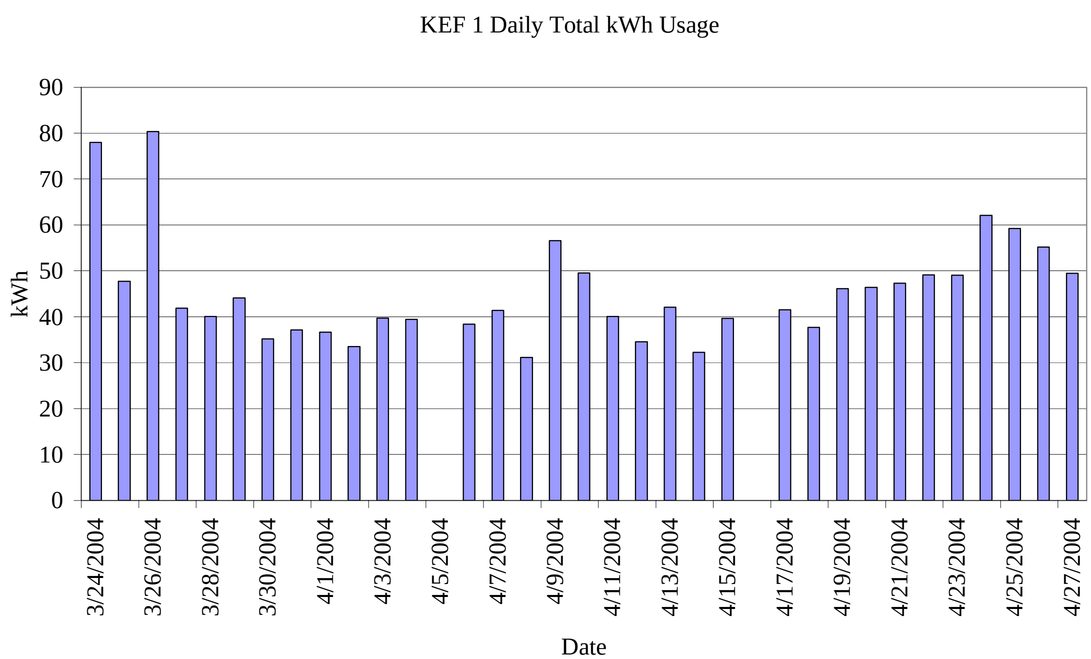

Figure 18. KEF 1 Daily Usage During The Monitoring Project

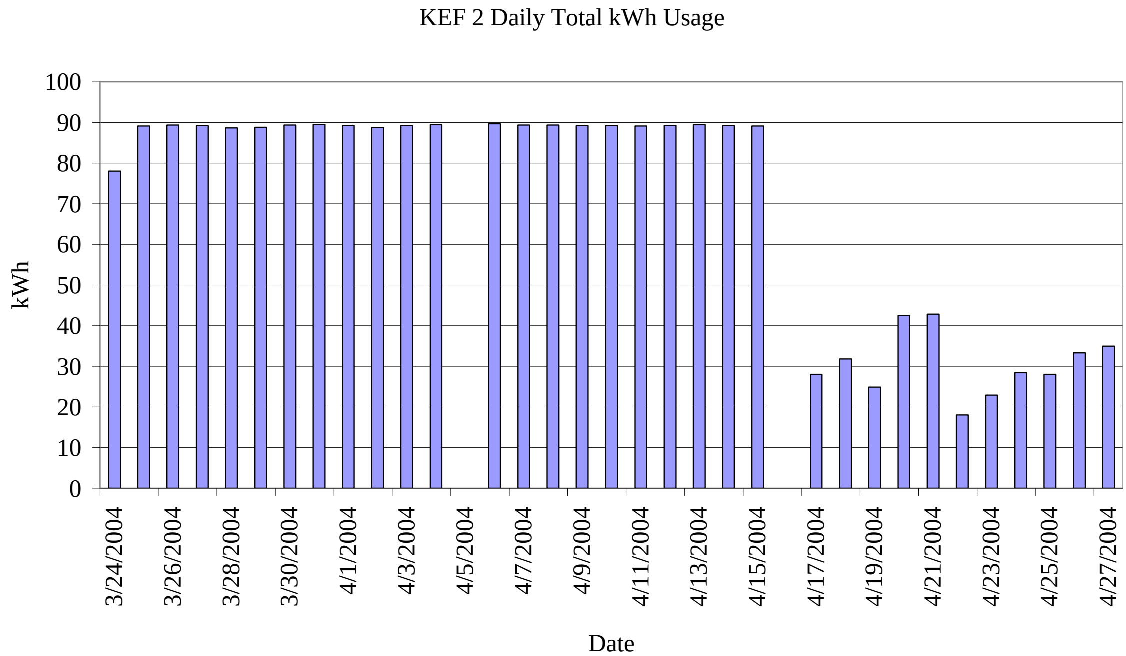

Figure 19. KEF 2 Daily Usage During The Monitoring Project

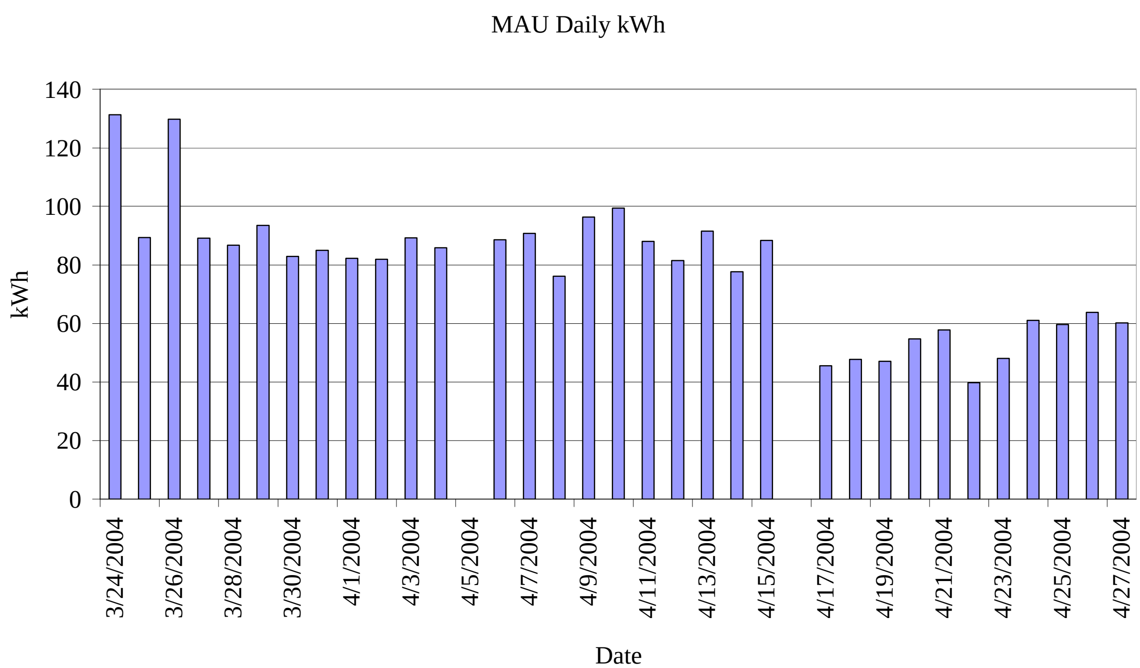

Figure 20. MAU Daily Usage During The Monitoring Project

System Demand Comparison With and Without the Melink *Intelli-Hood Controls*

Figure 21 graphically illustrates the total reduction in demand (kW) achieved by applying the *Intelli-Hood Controls* to the exhaust and makeup air system at the Mark Hopkins kitchen. Without the *Intelli-Hood Controls*, the entire kitchen ventilation system (two exhaust fans and the MAU fan) ran at full speed all the time and drew a continuous 14 kW. With the controls, the three fans changed speed in response to the cooking process and the average demand of the entire system dropped to 5.3 kW. This 8.7 kW demand reduction was also coincident with the statewide, summertime, peak demand hours of 12:00 noon to 6:00 pm. Table 4 lists the demand for each fan with and without the *Intelli-Hood Controls* as well as the kW and percent change.

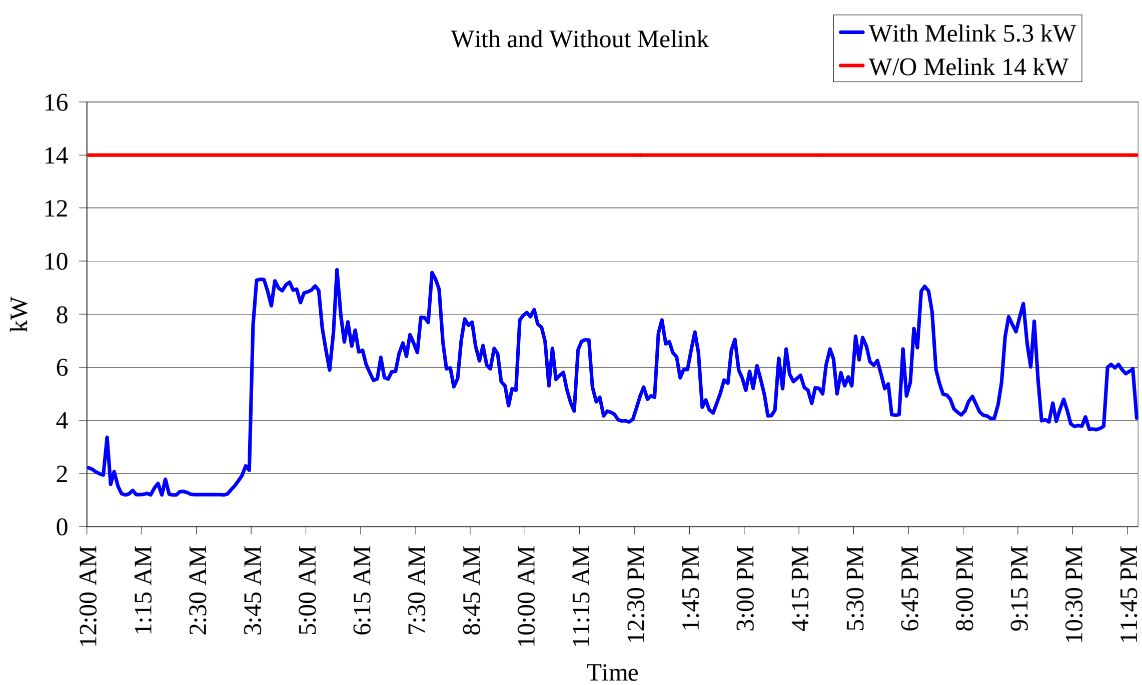

Figure 21. Exhaust and Makeup Fan Power With and Without the Melink Intelli-Hood® Controls

Table 4. Demand Reduction with the Melink Intelli-Hood System.

	KEF 1	KEF 2	MAU
Measured Daily Average Without Melink (kW)	3.8	3.8	6.4
Measured Daily Average With Melink (kW)	1.8	1.3	2.2
Average Reduction (kW)	2.0	2.5	4.2
Percentage Reduction (%)	53	66	66

Reduction in Makeup Air Heating Load

The air that typically enters a commercial kitchen through a MAU is tempered with the assistance of a mechanical heating or cooling system (an evaporative cooler can also be used in appropriate climates). The Mark Hopkins Hotel uses a "heating only" MAU, which is appropriate considering the temperate coastal climate that San Francisco, CA experiences. In contrast, if the hotel were located in another city, such as Bakersfield, evaporative cooling would be desired to temper the air before it entered the kitchen.

As a result and benefit of having installed a demand ventilation control system, the MAU heating load was reduced in direct proportion to the reduction of airflow through the MAU. Estimating the corresponding energy savings required knowing the volume and temperature of the outdoor air entering the MAU as well as the temperature of the tempered air leaving the MAU. Inputting this data into the Outdoor Airload Calculator (OAC), a web-based tool developed by the FSTC (available at www.foodservicetechnologycenter.com), generated models of the annual heating load in kBtu based on ASHRAE weather data accessed by the calculator.

The outside air temperature was measured at the face of the air filters of the MAU located on the Hotel's rooftop. The tempered air was measured at a 4-way diffuser in the kitchen (Figure 22). The MAU airflow rate was calculated from the known average fan speed, in which the fan speed is proportional to the amount of air that a fan moves. The fan speed was determined based on the monitored energy use of the MAU fan under full- and part-speed conditions. The calculated average reduction in airflow through the MAU with the *Intelli-Hood Controls* fully functional was 5,750 cfm.

Figure 22. Temperature Loggers at the Filters in the MAU and at Kitchen's 4-way Diffuser

In Figure 23, the outdoor ambient temperature is plotted along with the temperature of the tempered air leaving the MAU at the 4-way diffuser. As the chart reveals, the MAU is continually heating the air entering the kitchen. The MAU duct thermostat set point was 70°F.

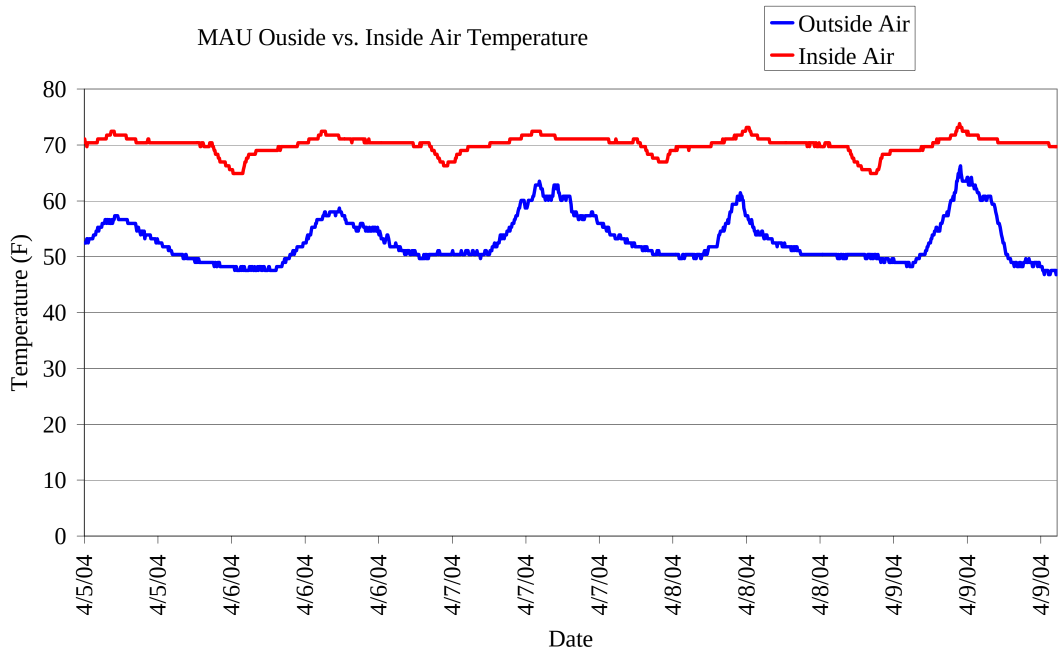

Figure 23. Outside and Inside Air Temperatures for the MAU

Using the Outdoor Airload Calculator and applying an efficiency of 70% for the gas-fired hydronic coil in the MAU, the energy saved by not heating 5,750 cfm of outdoor air to 70°F was estimated to be 11,826 therms. At $0.80 per therm, a cost saving of $9,460 was calculated. The results are listed in Table 5 and the heating load models generated by the Outdoor Airload Calculator are included in the Appendix.

Potential Additional Savings Through Reduced Makeup Air Temperature

In addition to the savings generated by reducing the volume of airflow at the MAU, the Mark Hopkins could save additional energy dollars by reducing the MAU's heating set point from 70°F to 68°F. This set point reduction could save the hotel an additional $2,900 a year.

Table 5. MAU Reduced Heating Savings

	Without Melink	Before Repair	After Repair
Average Air Flow (cfm)	19,500	16,200	13,750
Reduced Air Flow (cfm)	N/A	3,300	5,750
Annual Gas Saving (Therms)	N/A	6785	11,826
Annual Heating Savings at 70°F Set Point ($/yr)*	N/A	$5,425	$9,460
Potential Annual Savings with a 68°F Set Point ($/yr)*	N/A	N/A	$12,360

- Savings at $0.80 per therm.

Energy Cost Savings and Project Payback

The Melink *Intelli-Hood Controls* system as installed at the Intercontinental Mark Hopkins Hotel was a very good application for this demand ventilation technology. Contributing factors to the success of this installation included the large fan horsepower, scheduled cooking periods, and 24/7 operation. The fan energy alone for this kitchen would cost just under $16,000 a year without any ventilation control strategy. With the Melink *Intelli-Hood Controls*, the cost to operate the fans dropped to approximately $6,000 for an annual cost savings of almost $10,000 a year (see Figure 24).

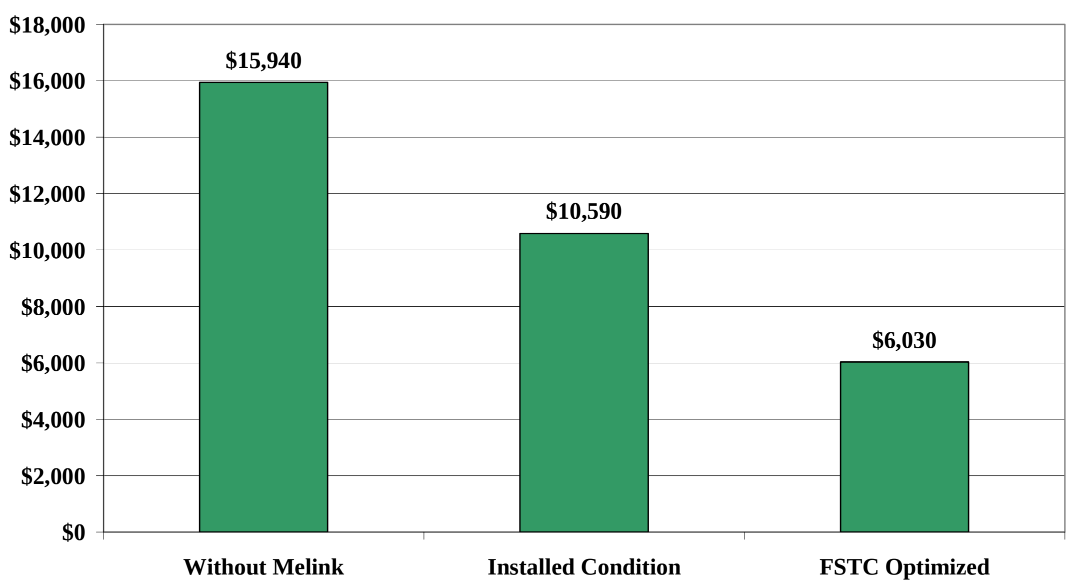

Figure 24. Annual Energy Cost for the Three Kitchen Fans

In addition to the fan energy savings there were $9,460 saved as a result of the reduced makeup air heating requirements.

Combining the fan energy savings with the reduced heating load, the Intercontinental Mark Hopkins Hotel was saving almost $20,000 annually. The installed cost of the Melink *Intell-Hood Controls* was approximately $15,000 making the payback period for this technology, at this installation, less than one year. Table 6 lists the overall energy and cost savings for this installation.

Table 6. Fan and MAU Savings

	Average kW	Average kWh/d	Annual Operational Cost
Fan Energy Without Melink *Intelli-Hood*	14.0	336	$15,940
Fan Energy With Melink *Intelli-Hood*	5.3	127	$6,030
Fan Energy Savings	8.7	209	$9,910
Calculated MAU Heating Savings	---	---	$9,460
Total Annual Savings	---	---	$19,370
Melink Intelli-Hood Cost			$15,000
Pay Back	---	---	< 1 year

* Savings at $0.80 per therm and $0.13 per kWh

Conclusions and Recommendations

The installation of the Melink *Intelli-Hood Controls* demand-ventilation system at the Intercontinental Mark Hopkins Hotel's kitchen in San Francisco, California was very cost effective. The reduced electrical demand of 8.7 kW, the annual fan energy savings of 76,285 kWh per year, and the 11,826 therms of natural gas saved, reduced the overall operating cost of this commercial kitchen by approximately $20,000 per year. The simple payback for this Melink *Intelli-Hood Controls* system was less than 1 year.

The reduced MAU heating was a significant portion of the overall savings, and the Mark Hopkins could gain additional savings by lowering the MAU temperature set point to 68°F. This small 2°F adjustment would save the hotel an additional $2,900 annually.

As with any exhaust hood modification, the commissioning of the demand ventilation system was very important to the success of the project. The FSTC team discovered that the Melink *Intelli-Hood* was programmed and fine tuned correctly during the initial installation. However, a faulty wiring harness, discovered during the monitoring phase of the project, effectively disabled one half of the control system. This partial system failure emphasizes the importance of commissioning, as well as the need for facility managers to periodically inspect energy management systems to ensure proper operation.

In addition to the cost savings returned by installing the Melink *Intelli-Hood Controls,* there was the added benefit of a significant reduction in the noise level generated by the exhaust ventilation system in the kitchen. Although the cost benefits of a quieter kitchen are harder to quantify, there is no doubt that this is an improvement to the kitchen environment that could potentially lead to happier and more productive kitchen personnel.

Kitchen exhaust ventilation systems in large hotels and institutional kitchens (such as hospitals and prisons) may represent one of the more cost-effective applications for demand ventilation control. It is recommended that California utilities encourage market transformation through targeted education and/or incentives for this emerging technology, particularly for the larger institutional-style kitchens.

Appendix A: Outdoor Air Load Calculations

Result summary for Calculation Number: 1
Location: SAN_FRANCISCO, California
Elevation: 16 ft
Operating Hours: 0:00 o'clock until 0:00 o'clock
Hours of Operation: 24
Makeup Air Flow: 19500 cfm
Thermostat Setpoints: Heating = 70 F, Cooling = 95 F

Dehumidification was set to limit the Relative Humidity to: No Dehumidification

Heating was locked out during: --
Cooling was locked out during: --

The Lockout of Heating or Cooling systems resulted in...
Insufficient Heating during: --
Insufficient Cooling during: --

The Heating Design Load is: 838.2 kBtu/h
The Cooling Design Load is: 0.0 kBtu/h

Calculated Monthly loads:

Month	Heating Load	Cooling Load
January :	369,898 kBtu	0 kBtu
February :	260,935 kBtu	0 kBtu
March :	303,878 kBtu	0 kBtu
April :	252,737 kBtu	0 kBtu
May :	214,945 kBtu	0 kBtu
June :	183,319 kBtu	0 kBtu
July :	156,006 kBtu	0 kBtu
August :	149,210 kBtu	0 kBtu
September :	135,246 kBtu	0 kBtu
October :	178,876 kBtu	0 kBtu
November :	248,176 kBtu	0 kBtu
December :	353,139 kBtu	0 kBtu
Total_Year :	2,806,363 kBtu	0 kBtu

Result summary for Calculation Number: 1
Location: SAN_FRANCISCO, California
Elevation: 16 ft
Operating Hours: 0:00 o'clock until 0:00 o'clock
Hours of Operation: 24
Makeup Air Flow: 3300 cfm
Thermostat Setpoints: Heating = 70 F, Cooling = 95 F

Dehumidification was set to limit the Relative Humidity to: No Dehumidification

Heating was locked out during: --
Cooling was locked out during: --

The Lockout of Heating or Cooling systems resulted in...
Insufficient Heating during: --
Insufficient Cooling during: --

The Heating Design Load is: 141.9 kBtu/h
The Cooling Design Load is: 0.0 kBtu/h

Calculated Monthly loads:

Month	Heating Load	Cooling Load
January :	62,598 kBtu	0 kBtu
February :	44,158 kBtu	0 kBtu
March :	51,425 kBtu	0 kBtu
April :	42,771 kBtu	0 kBtu
May :	36,375 kBtu	0 kBtu
June :	31,023 kBtu	0 kBtu
July :	26,401 kBtu	0 kBtu
August :	25,251 kBtu	0 kBtu
September :	22,888 kBtu	0 kBtu
October :	30,271 kBtu	0 kBtu
November :	41,999 kBtu	0 kBtu
December :	59,762 kBtu	0 kBtu
Total_Year :	474,923 kBtu	0 kBtu

Result summary for Calculation Number: 1
Location: SAN_FRANCISCO, California
Elevation: 16 ft
Operating Hours: 0:00 o'clock until 0:00 o'clock
Hours of Operation: 24
Makeup Air Flow: 5752 cfm
Thermostat Setpoints: Heating = 70 F, Cooling = 95 F

Dehumidification was set to limit the Relative Humidity to: No Dehumidification

Heating was locked out during: --
Cooling was locked out during: --

The Lockout of Heating or Cooling systems resulted in...
Insufficient Heating during: --
Insufficient Cooling during: --

The Heating Design Load is: 247.3 kBtu/h
The Cooling Design Load is: 0.0 kBtu/h

Calculated Monthly loads:

Month	Heating Load	Cooling Load
January :	109,110 kBtu	0 kBtu
February :	76,969 kBtu	0 kBtu
March :	89,636 kBtu	0 kBtu
April :	74,551 kBtu	0 kBtu
May :	63,403 kBtu	0 kBtu
June :	54,074 kBtu	0 kBtu
July :	46,018 kBtu	0 kBtu
August :	44,013 kBtu	0 kBtu
September :	39,894 kBtu	0 kBtu
October :	52,764 kBtu	0 kBtu
November :	73,206 kBtu	0 kBtu
December :	104,167 kBtu	0 kBtu
Total_Year :	827,805 kBtu	0 kBtu

Result summary for Calculation Number: 1
Location: SAN_FRANCISCO, California
Elevation: 16 ft
Operating Hours: 0:00 o'clock until 0:00 o'clock
Hours of Operation: 24
Makeup Air Flow: 13500 cfm
Thermostat Setpoints: Heating = 70 F, Cooling = 95 F

Dehumidification was set to limit the Relative Humidity to: No Dehumidification

Heating was locked out during: --
Cooling was locked out during: --

The Lockout of Heating or Cooling systems resulted in...
Insufficient Heating during: --
Insufficient Cooling during: --

The Heating Design Load is: 580.3 kBtu/h
The Cooling Design Load is: 0.0 kBtu/h

Calculated Monthly loads:

Month	Heating Load	Cooling Load
January :	256,083 kBtu	0 kBtu
February :	180,648 kBtu	0 kBtu
March :	210,377 kBtu	0 kBtu
April :	174,972 kBtu	0 kBtu
May :	148,808 kBtu	0 kBtu
June :	126,913 kBtu	0 kBtu
July :	108,004 kBtu	0 kBtu
August :	103,299 kBtu	0 kBtu
September :	93,632 kBtu	0 kBtu
October :	123,837 kBtu	0 kBtu
November :	171,814 kBtu	0 kBtu
December :	244,481 kBtu	0 kBtu
Total_Year :	1,942,867 kBtu	0 kBtu

Result summary for Calculation Number: 2
Location: SAN_FRANCISCO, California
Elevation: 16 ft
Operating Hours: 0:00 o'clock until 0:00 o'clock
Hours of Operation: 24
Makeup Air Flow: 13500 cfm
Thermostat Setpoints: Heating = 68 F, Cooling = 95 F

Dehumidification was set to limit the Relative Humidity to: No Dehumidification

Heating was locked out during: --
Cooling was locked out during: --

The Lockout of Heating or Cooling systems resulted in...
Insufficient Heating during: --
Insufficient Cooling during: --

The Heating Design Load is: 548.9 kBtu/h
The Cooling Design Load is: 0.0 kBtu/h

Calculated Monthly loads:

Month	Heating Load	Cooling Load
January :	233,308 kBtu	0 kBtu
February :	160,354 kBtu	0 kBtu
March :	187,767 kBtu	0 kBtu
April :	153,547 kBtu	0 kBtu
May :	127,256 kBtu	0 kBtu
June :	106,193 kBtu	0 kBtu
July :	87,643 kBtu	0 kBtu
August :	83,414 kBtu	0 kBtu
September :	74,876 kBtu	0 kBtu
October :	102,857 kBtu	0 kBtu
November :	150,029 kBtu	0 kBtu
December :	221,739 kBtu	0 kBtu
Total_Year :	1,688,983 kBtu	0 kBtu