Demand Control Ventilation for Commercial Kitchen Hoods

ET 07.10 Report

Prepared by:

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June 30, 2009

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Acknowledgements

Southern California Edison's Design & Engineering Services (D&ES) group is responsible for this project. It was developed as part of Southern California Edison's Emerging Technology program under internal project number ET 07.10. D&ES project manager Angelo Rivera conducted this technology evaluation with overall guidance and management from Paul Delaney. For more information on this project, contact *Angelo.Rivera*@sce.com.

Disclaimer

ABBREVIATIONS AND ACRONYMS

MUA	Make-Up Air
cfm	Cubic Feet Per Minute
DCV	Demand Control Ventilation
HVAC	Heating Ventilation and Air Conditioning
IR	Infrared
MDL	Micro Data Loggers
CT	Current Transducers
FLA	Full Load Amps
hp	Horse Power
SF	Supply Fan

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EXECUTIVE SUMMARY

Commercial kitchen hoods (hoods) are a significant component of energy consumption in restaurant and fast-food kitchens. They function to reduce fire hazards and exhaust cooking effluent to comply with air quality standards within a commercial kitchen. Exhaust hoods in these kitchens are normally tied to a make-up air (MUA) unit that balances building pressure during the kitchens operation. Generally, the hoods' exhaust requirements are sized to peak cooking usage of each appliance under the hood. Typical hoods have a simple "on" or "off" control strategy. When the hood is on, its exhaust and make up air fans are on at full speed or not at all. In reality food is not being cooked at all times therefore not needing the peak exhaust requirements. Due to the common control strategies employed in most commercial kitchens a significant amount of energy is wasted on venting unnecessary cubic feet per minute of air when appliances are not fully used. It is evident that there is an opportunity for energy efficient savings. The Melink Intelli-Hood demand control ventilation system (DCV) is an energy management system for commercial kitchen hoods. It optimizes energy efficiency by reducing the exhaust and make up air fan speed. This is accomplished by leveraging an infrared and temperature sensors to determine the minimum amount of exhaust air required to capture and contain effluent from the cookline.

The primary objective of this project is to verify field performance and demonstrate how the Melink Intelli-Hood demand control ventilation (DCV) system can reduce energy costs. The projects secondary objective is to evaluate the market sectors impacts on field performance and energy reduction on a DCV system. The different market sectors can have different hours of operation, appliances, and kitchen exhaust hood configurations. For this field evaluation two hotels and three quick-service restaurants were chosen. Also in this field evaluation only the exhaust and make up air fan motor energy savings were accounted for. Air conditioning savings, due to heat load reduction in the kitchen area, were not accounted for.

The Melink Intelli-Hood DCV system was shown to significantly reduce the energy consumption and electrical demand associated with operating a commercial kitchen exhaust hood. Table 1 lists the average kW draw, percentage reduction, daily operational values, daily energy consumption, annual energy consumption, annual savings, percentage energy usage reduction, and estimated annual operational cost for all hood data at each site. The savings results from the Melink Intelli-Hood DCV system installation can realize a 37-62% energy savings over current commercial kitchen hoods. The DCV system was most effective in the hotel market sector due to the amount of hoods, amount of HP servicing the hotel, and the hours of operations. Hotel kitchens are sized for peak food production - defined as the maximum food prepared at any given time in a hotel's kitchen. The hotel's kitchen sizing also means there are multiple hoods and higher amounts of HP needed to meet the maximum food demands. Since maximum food demands rarely happen, the hotel market sector has a high potential for savings. Most of the time there is limited kitchen use occurring in a given day, allowing a DCV system to save energy by running at minimal exhaust settings.

In the quick-service restaurant market sector there was a large percentage energy drop at each site, but a significantly lower energy savings. The lower energy savings were attributed to the lower hp motors, operational time, appliance usage, and amount of hoods. In addition to energy savings, with the installation of a DCV system, there was the added benefit of noise reduction from the kitchens' exhaust hood system.

This evaluation also showed that the performance of the DCV system was highly impacted by the different appliance types and their controls. The appliance types ranged from light-duty to extra heavy-duty. The opportunity for energy savings decreased as the appliances duty rating got closer to extra heavy-duty rated appliances. The higher the rating the higher the heat load and more effluent the appliance created during cooking. The opportunity for savings also decreased when the appliances controls created a constant heat load when either in use or not in use. Appliances that only produce heat when cooking gave a large opportunity for savings.

TABLE 1 OVERALL FIELD EVALUATION RESULTS

Overall Results For All Sites	Desert Springs Marriott	Westin Mission Hills	El Pollo Loco	Panda Express	Farmer Boys
Average demand without DCV system (kW)	27.9	12.1	4.7	5.2	2.9
Average demand with DCV system (kW)	10.7	5.2	2.9	2.0	1.4
Average kW reduction (%)	61.6%	57.0%	38.3%	61.5%	51.7%
Daily Operational Hours	24	24	15.36	13.1	15.83
Daily energy usage without DCV system (kWh/day)	670	291	72	67	44
Daily energy usage with DCV system (kWh/day)	257	125	45	26	23
Annual energy usage without DCV system (kWh/yr)	244,500	106,034	26,313	24,620	16,159
Annual energy usage with DCV system (kWh/yr)	93,681	45,595	16,442	9,559	8,276
Annual energy savings with DCV system (kWh/yr)	150,819	60,439	9,871	15,061	7,884
Percentage energy usage reduction (kWh/yr)	61.7%	57.0%	37.5%	61.2%	48.8%
Estimated annual operational savings (@$0.15 a kWh)	$22,623	$9,066	$1,481	$2,259	$1,183

INTRODUCTION

Commercial kitchen hoods are a significant component of energy consumption in commercial kitchens. They function to reduce fire hazards and exhaust cooking effluent to comply with air quality standards within a commercial kitchen. Exhaust hoods in commercial kitchens are normally tied to a make-up air (MUA) unit that balances building pressure during the kitchens operation. Generally, commercial kitchen hoods exhaust requirements are sized to peak cooking usage of each appliance under the hood. Typical commercial kitchen hoods have a simple “on” or “off” control strategy. When the hood is on, its exhaust and MUA fans are on at full speed or not at all. In reality food is not being cooked at all times therefore not needing the peak exhaust requirements. Due to the common controls strategies employed in most commercial kitchens a significant amount of energy was wasted on venting unnecessary cubic feet per minute of air (cfm) when appliances were not fully used. It was evident that there was an opportunity for change. A demand control ventilation system (DCV) is an energy management system for commercial kitchen hoods. It optimizes energy efficiency by reducing the exhaust and MUA fan speed. This is accomplished by leveraging sensors to determine the minimum amount of exhaust air required to capture and contain effluent from the cookline.

Derived from the SCE service territory database there are 37,212 restaurants, 5,553 hotels, 3,313 grocery stores, 9,105 schools/colleges, and 1,076 hospitals. Within the SCE service territory there is a total of 56,156 customers with the potential to use DCV systems. Within California it is estimated there are 124,040 restaurants, 18,510 hotels, 11,043 grocery stores, 30,553 schools and 3,243 hospitals. Within all of California it is estimated there is a total of 187,187 customers with the potential to use DCV systems. This was estimated by assuming SCE has 30%, PGE has 35%, SDGE has 20% and municipal utilities have 15% of Californians total customer utility service. For some market segments the applicability of the DCV technology might be as low as 50% and as high as 80%.

OBJECTIVE

The Primary objective of this project is to verify field performance and demonstrate how the Melink Intelli-Hood demand control ventilation (DCV) system can reduce energy costs. The project’s secondary objective is to evaluate the market sectors’ impact on field performance and energy reduction using a DCV system. The different market sectors can have different hours of operation, appliances, and kitchen exhaust hood configurations.

CONFIGURATIONS

Commercial kitchen exhaust hoods can come in many different configurations. These varying configurations can impact the hoods ability to capture and contain effluent, including odors, gases, heat, and oil. The better the system is designed, the lower the cfm needed to capture effluent and the lower the energy consumption of the kitchen exhaust hood. The hood style, construction features, and proximity of hood installation, give different capture areas, dictating the necessary exhaust cfm. The hood styles, in order from highest exhaust requirement to least, generally include; single-island canopy hood, wall-mounted canopy hood, double-island canopy hood, and back-shelf hood, as depicted in Figure 1.

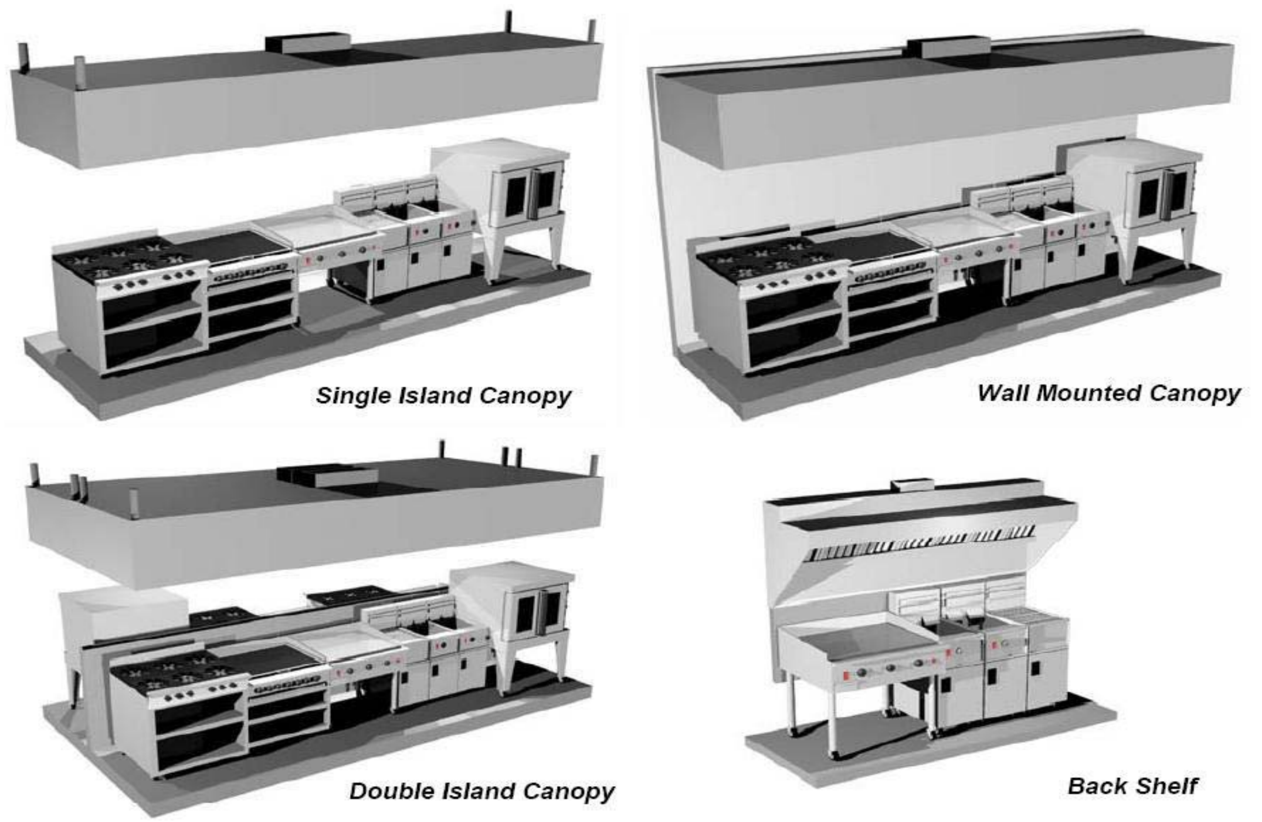

FIGURE 1 COMMERCIAL KITCHEN EXHAUST HOOD STYLES[1]

The appliances and the food being cooked under the hood can factor in the exhaust cfm requirements. Cooking appliances are categorized as light, medium, heavy, or extra heavy-duty, due to their strength of thermal plumes it can create. Thermal plume strength is also affected by the type of food being cooked on the appliance. The stronger the thermal plume the more exhaust cfm that is required.

Configuration of how MUA is introduced into the kitchen is also an important configuration. MUA balances the pressure of the kitchen when exhaust fans are in operation. As air is exhausted out of the hood, the air is replaced by an equal volume of air. Typically, a dedicated MUA unit is employed in a commercial kitchen. A dedicated MUA unit only makes up a percentage of the air exhausted. By not matching cfm exhausted air, the kitchen keeps a negative pressure. The remaining air volume, not replaced by the MUA unit, is taken from transfer air such as the dining area or a kitchens' air handlers system. A small negative pressure is desired to keep the kitchens odors from transferring into other areas the kitchen is connected to. If no MUA is introduced, kitchen pressure may become too negative and affect the capture and containment of effluent. When designing a dedicated MUA system for a commercial kitchen, how the air is introduced into the kitchen can factor into how much exhaust air to replace, and can affect the kitchen hoods ability to capture and contain affluent. A poorly designed MUA system with a high exhaust replacement cfm can make a kitchen hood perform poorly. Poorly designed MUA systems can hinder effluent or push effluent outside of the hoods containment area and into the kitchen space. MUA can be untreated (air taken from outside), or treated air (evaporative cooled or heated air). When MUA is introduced into the kitchen it has the ability to save Heating, Ventilation and Air Conditioning (HVAC) energy. This is accomplished by reducing the amount of conditioned air being exhausted. The most common configuration to introduce MUA into the kitchen is through integrated hood plenums. The different integrated hood plenums types in order of worst design to best are: short circuit, air curtain supply, front face supply, perforated perimeter supply, back wall supply, or any combination of integrated hood plenum types as depicted in Figure 2.

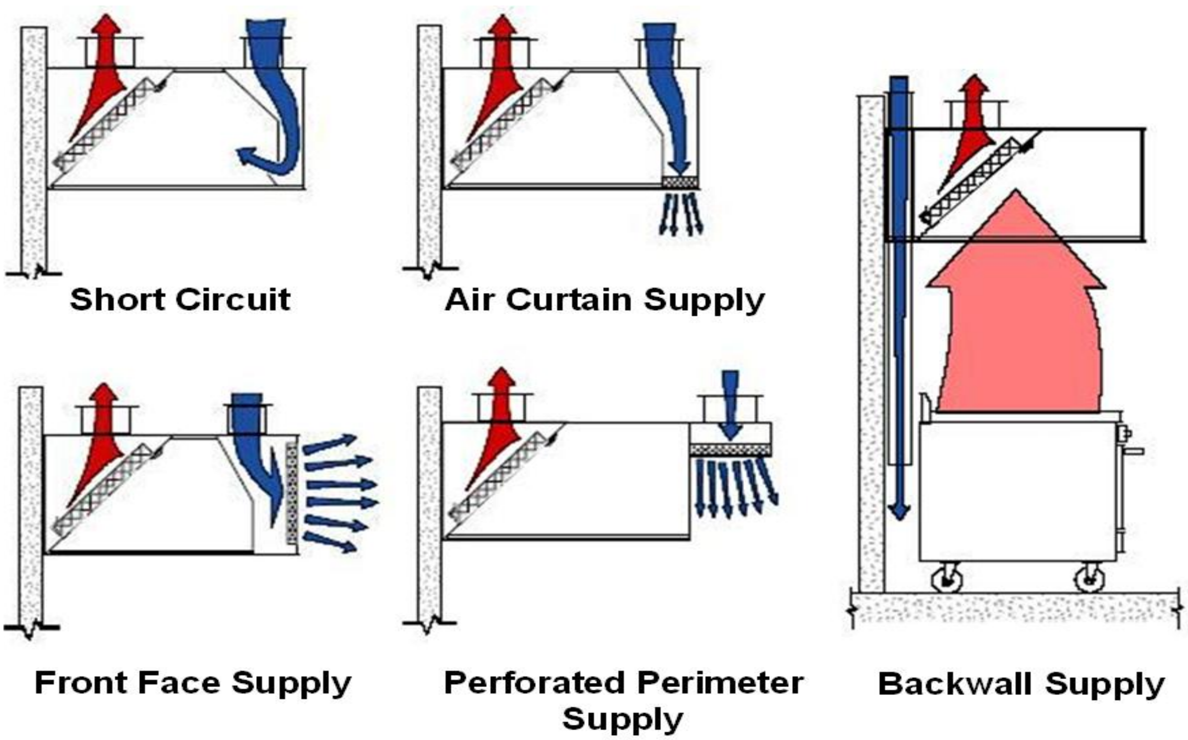

FIGURE 2 COMMERCIAL KITCHEN MUA CONFIGURATION TYPES[2]

BASELINE

For this field evaluation the baseline for each site was a commercial kitchen hood with the simple "on" or "off" control strategy. When the hood is "on" both exhaust and make-up air units are at full speed until turned off. The customers chosen for this field evaluation were either customer's who needed the DCV system retrofit to participate, or customers with an existing DCV system installed. At sites where the DCV system was a retrofit, electrical usage was logged. At sites where the DCV system was already installed, the keypad was used to override the DCV system before monitoring electrical usage. By overriding the DCV system, the simple “on” or “off” controls of the kitchen exhaust hood was restored to measure baseline data for the hood.

DEMAND CONTROL VENTILATION SYSTEM

The Melink Intelli-Hood DCV system was selected for this field evaluation because, at the time, it was the only commercially available DCV system. Although other manufacturers are in the process of developing their DCV systems, none were available at the time of this study. The Melink Intelli-Hood DCV system is an energy management system for commercial kitchen exhaust hoods. It can be installed in new construction or as a retrofit. The Intelli-Hood controls optimize energy efficiency by reducing the exhaust and MUA fan speed by leveraging sensors to determine the amount of exhaust air required to capture and contain effluent from the cookline. Since cooking does not occur at a constant, the kitchen exhaust and MUA fans vary their speed using a variable speed controller to meet the necessary minimum exhaust air requirements. This allows the exhaust system to run at the lowest possible speed to perform the required job. In addition, the noise level in the kitchen is reduced significantly as the system decreases the exhaust and MUA fan speed during low exhaust demand.

HARDWARE

The Melink Intelli-Hood system consists of 6 pieces of hardware as illustrated in Figure 3.

- **I/O Processor** receives inputs from the temperature sensor and optic sensor. With the inputs received from the sensors, the processor controls the output of the electronic motor starters. The processor also displays current operations of each hood and is able to be programmed by the keypad.
- **Temperature Sensor** monitors the exhaust air temperature in the exhaust duct. A temperature signal is transmitted to the I/O processor that uses the signal to vary the speed in proportion to actual heat load.
- **Optic Sensors** monitor the presence of smoke and vapors inside the hood. With the presence of smoke and/or vapors, a signal is sent to the I/O processor to ramp fans to full speed to remove it.
- **Air Purge Units** are miniature blowers that are equipped on both the optical transmitter and receiver to prevent grease from collecting on the optical sensor lenses when the kitchen hood exhaust system is operating.
- **Electric Motor Starter** is a variable frequency drive equipped on each exhaust and Make-up fan motor. The electric motor starter receives the signal from the I/O processor then adjusts the motor speed to meet each hood’s needs.
- **Keypad** allows users to turn on the system and displays current system fan levels. The keypad also gives the user programming capabilities for the system.

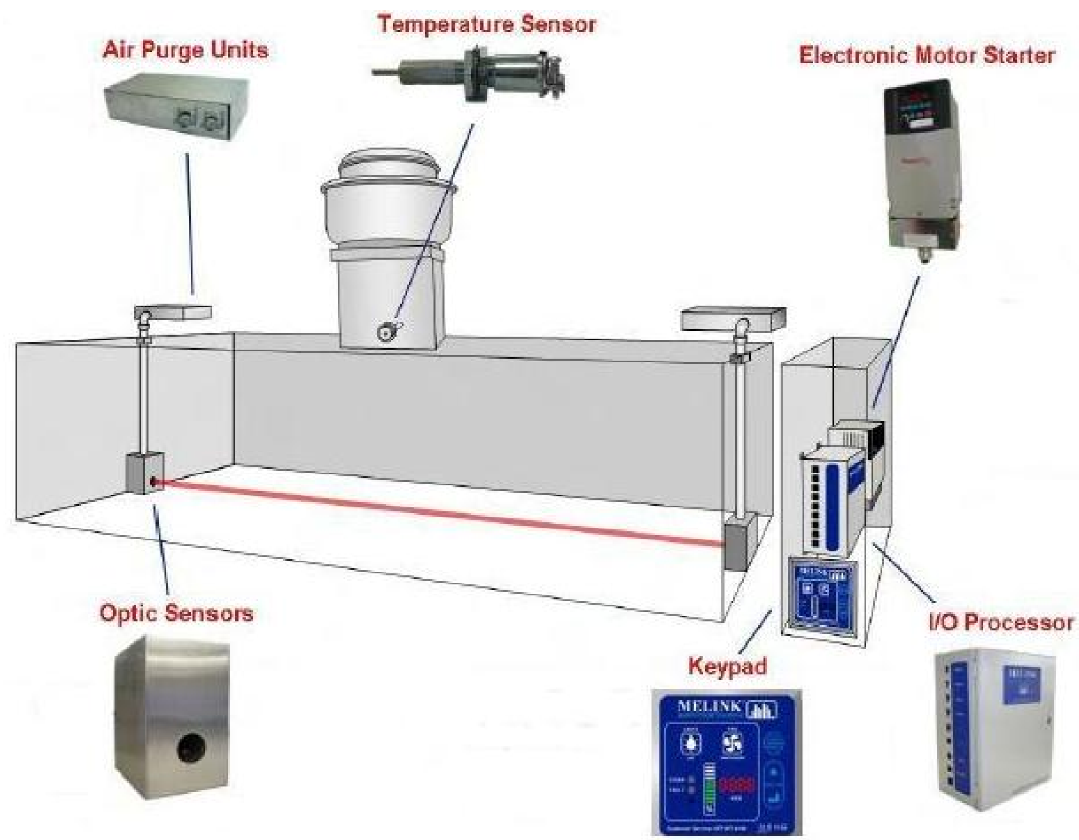

FIGURE 3 MELINK INTELLI-HOOD HARDWARE (COURTESY OF MELINK®)

CONTROLS

The Melink Intelli-Hood system I/O processor is the brain for the whole system. The I/O processor has the ability to control up to 4 exhaust fan motors and its corresponding MUA units. The I/O processor displays current system fan levels for each hood it controls on the keypad. The keypad is how different system parameters are configured, such as electric motor starter speed rate for corresponding temperature ranges and Infrared (IR) beam strength. The I/O processor receives exhaust duct temperature signals for each hood from temperature sensors. The different appliances under the hood produce heat load whether they are in use or on stand-by. The electric motor starter varies the exhaust fan and MUA motor depending on the temperature signal received and where it falls in the programmed temperature parameters as illustrated in Figure 4. The optical sensor consists of a receiver and transmitter. The optical sensor is mounted in the bottom center on each side of the hood. The transmitter transmits a red IR beam across the hood and when the receiver receives intensities of less than 95% of full input, a signal is sent to the I/O processor. Usually smoke or vapors from the cookline are the cause of the obstructions. When the signal is received the I/O processor runs the exhaust and MUA fans at full speed, regardless of the exhaust ducts temperature, to remove obstructions to the optical sensor as illustrated in Figure 4.

The Melink Intelli-Hood different parameters are tailored and programmed dependent on the configuration of the kitchen. Configurations such as hood length, hood type, hood design, how MUA is introduced, appliance exhaust requirements, and type of food being cooked play an important role on the different parameters. The parameters are programmed with kitchen configurations in mind during system commissioning to achieve optimized performance and energy savings.

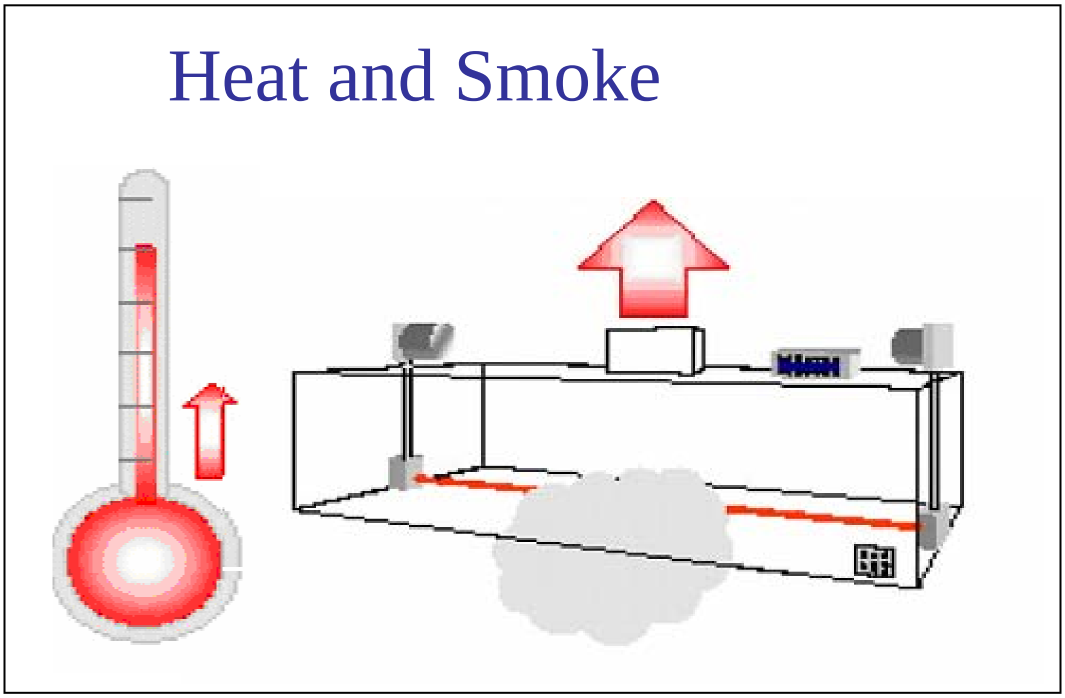

FIGURE 4 MELINK INTELLI-HOOD HEAT AND SMOKE DETECTION (COURTESY OF MELINK®)

APPROACH

To evaluate the field performance and demonstrate how the Melink Intelli-Hood DCV system can reduce energy costs, each customer's kitchen exhaust and MUA fan motor electrical usage was monitored. In this evaluation only the exhaust and MUA fan motor energy savings were measured. Since HVAC savings are weather dependent, cooling load reduction savings were not accounted for due to the complexity it would bring to this field evaluation. To determine potential energy savings realized by the Melink Intelli-Hood system at each site, three phases were completed.

- **Phase 1 - Baseline evaluation**: After the customer sites were chosen to participate in the field evaluation, the kitchen configuration was noted. The different exhaust and MUA fan motors were found and corresponding electrical service breakers were found. Fan motors name plate data was also recorded. A Micro Data logger was installed on each exhaust and MUA electrical breaker to monitor electrical usage of the corresponding fan motor. At sites where the DCV system was a retrofit, electrical usage was logged. At sites where the DCV system was already installed, the keypad was used to override the DCV system before monitoring electrical usage. By overriding the DCV system, the simple "on" or "off" controls of the kitchen exhaust hood were restored to measure baseline data for the hood. Since the motors ran constantly at full speed under the baseline controls of the kitchen hoods, the power draw from each fan motor was pretty much constant. Baseline data was recorded for about one week at each site and analyzed.
- **Phase 2 - System retrofit or adjustment:** After each kitchen exhaust hood electrical usage was baselined, phase two was initiated. At sites where the simple "on" or "off" controls strategy was employed, the DCV system hardware was installed and system parameters were programmed during commissioning. At sites where the DCV system was already installed, the keypad was used again to restore the DCV system controls.
- **Phase 3 - New system evaluation:** After installation or adjustment of the DCV system, the system was allowed to run for two weeks to ensure proper performance. The DCV system's electrical usage was monitored for about six weeks in the quick-service restaurants and twelve weeks in the hotels.

MONITORING EQUIPMENT

Micro Data Loggers, (MDL) Current Transducers, (CT) and wattnodes were also installed in the electrical breaker servicing each exhaust and MUA fan motor at all five sites as shown in Figure 5. The MDL logs power data coming from a wattnode. The wattnode generates pulses from voltage readings tapped into the circuit and amperage readings from CTs (generically, Power=voltage x amperage). Electrical service for each fan motor was either three phase 480v delta or three- phase 208v wye. When monitoring three phase 480v delta circuits, a WNA-3D-480P wattnode was used. When monitoring three phase 208v wye-wired circuits, a WNA-3Y-208P wattnode was used. The wattnode has an accuracy of 0.45% of reading + 0.05% of full scale through 25th harmonic. CTs used for each of the sites were either 5 or 20 amps. Maximum amperage draw of each fan motor dictated the CT size used for monitoring each motors electrical full load amps (FLA). The CTs has an accuracy of ±1% at 10% to 130% of rated current

Power data was measured in 15-second intervals and averaged into 5-minute data points logged by the MDL. A low sample interval was chosen to provide high accuracy and resolution for the readings. The compiled 5-minute data was downloaded monthly. A Fluke 43B power quality analyzer was used to verify data collected. Spot checks were also administered each time data was downloaded and the logger was reset.

FIGURE 5 MONITORING EQUIPMENT INSTALLATION

TEST SITE DESCRIPTIONS

The test sites chosen for this field evaluation include two hotel/resorts and three quick- service restaurants. These market segments were chosen specifically because there was a lack of energy savings information. The two hotels were also chosen due to their high potential for energy savings because of the number of commercial kitchen hoods and their corresponding horse power. The hotels have a large amount and variety of cooking appliances, kitchen operation hours, number of stories and diverse kitchen use. For these reasons both the Desert Springs Marriott and the Westin Mission Hills hotels were selected for this study. The quick-service market sector was another area of focus due to the large amount of customer foot traffic in addition to the lack of savings information on the market sector. The three quick-service restaurants selected all had different types of menus and corresponding appliances. The selected restaurants include an El Pollo Loco, Panda Express, and a Farmer Boys restaurant.

DESERT SPRINGS MARRIOTT

The Desert Springs Marriott hotel is located in Palm Desert, CA and serves 844 guest rooms. The hotel stands nine stories high with the kitchen located on the ground floor. The kitchen operates 24-hours a day, 365 days a year and serves breakfast, lunch, dinner, room service, and all of the hotels different catering needs. The kitchen consists of 6 wall-mounted canopy kitchen exhaust hoods. MUA is introduced into the kitchen by integrated short circuit supply registers within each hood. There is 21 hp of combined exhaust motor horse power to exhaust a total of 23,914 cfm. There is 11.5 hp combined MUA motor horse power to make-up 13,804 cfm. The MUA units replace 57% of exhaust flow from the kitchen. The air handler places 17,923 cfm of conditioned air into the kitchen space, of which 6,100 cfm of the air comes from outside. All exhaust and MUA fan motors run on 480v service. The Desert Springs Marriott was one of the customers where energy usage was baselined before the DCV system was retrofitted to their kitchen exhaust hoods. When the DCV retrofit system was installed, two systems were installed - System A and System B. The total cost of the retrofit for the new system including labor was about $28,000.

WESTIN MISSION HILLS

The Westin Mission Hills hotel is located in Rancho Mirage, CA and serves 472 guest rooms. It has a single-story kitchen that operates 18-hours a day, 365 days per year. Even though the kitchen only operates 18-hours a day, the kitchen hoods operate 24-hours a day providing high potential for demand controlled ventilation. The kitchen serves breakfast, lunch, dinner, room service, and all of the hotels catering needs. It consists of 3 wall-mounted canopy kitchen exhaust hoods. MUA is untreated and introduced into the kitchen by an integrated air curtain supply register, or by ceiling diffusers. There is 14 hp of combined exhaust motor horse power to exhaust a total of 21,594 cfm. There is 8 hp combined MUA motor horse power to make-up 14,920 cfm. The MUA units replace 69% of exhaust flow from the kitchen. The air handler places 12,000 cfm of conditioned air into the kitchen space. All exhaust and MUA fan motors run on 480v service. The Westin Mission Hills was one of the customers where energy usage was baselined before the DCV system was retrofitted into their kitchen exhaust hoods. The total cost of the retrofit for the new system including labor was about $22,000.

EL POLLO LOCO

El Pollo Loco is a quick-service chicken restaurant located in El Monte, CA. Store hours are Monday - Sunday 9:00a.m. to 12:00a.m., and is open 364 days out of the year. The kitchen is a single-story that serves flame-grilled chicken and other menu items. The kitchen consists of a wall-mounted canopy kitchen exhaust hood and a single-island canopy hood. MUA is evaporative cooled air and introduced into the kitchen by an integrated perforated perimeter supply register. There is 3 hp of combined exhaust motor horse power to exhaust a total of 7,760 cfm. There is 3 hp combined MUA motor horse power to make-up 5,330 cfm. The MUA units replace 69% of exhaust flow from the kitchen. The HVAC system places 5,000 cfm of conditioned air into the kitchen space. All exhaust and MUA fan motors run on 208v service. El Pollo Loco is one of the customers where energy usage was baselined before the DCV system was retrofitted into their kitchen exhaust hoods. The total cost of the retrofit for the new system including labor was about $15,500.

PANDA EXPRESS

Panda Express is a quick-service Chinese food restaurant located in Quartz Hill, CA. Store hours are Monday - Thursday 10:30a.m. to 9:30p.m, Friday - Saturday 10:30a.m. to 10:00p.m, and Sunday 11:00a.m. to 9:00p.m. The store is open 365 days out of the year. The kitchen is a single-story that serves a variety of Chinese food. The kitchen consists of two wall-mounted canopy kitchen exhaust hoods. MUA is evaporative cooled air and introduced into the kitchen by an integrated perforated perimeter supply register. There is 4 hp of combined exhaust motor horse power to exhaust a total of 6,000 cfm. There is 1 hp combined MUA motor horse power to make-up 4,800 cfm. The MUA units replace 80% of exhaust flow from the kitchen. The HVAC system places 5,000 cfm of conditioned air into the kitchen space. All exhaust and MUA fan motors run on 208v service. The Panda Express had the DCV system previously installed before this field evaluation. The total new construction cost for the new system including labor was about $8,000.

FARMER BOYS

Farmer Boys is a quick-service American restaurant located in Irwindale, CA. Store hours are Monday - Saturday 6:00a.m. to 10:00p.m, and Sunday 6:00a.m. to 9:00p.m and is open 364 days out of the year. The kitchen is a single-story that serves breakfast, lunch, and dinner entrees that can be ordered at anytime of the day. The kitchen consists of two wall-mounted canopy kitchen exhaust hoods and a single-island canopy hood. There is no dedicated MUA unit for the kitchen. Instead the HVAC system is introduced into the kitchen by an integrated perforated perimeter supply register. Since there was not a dedicated MUA unit, the air supply coming from the integrated perforated perimeter supply registers was not modulated when the DCV system was installed. There is 2.25 hp of combined exhaust motor horse power to exhaust a total of 6,500 cfm. The HVAC system places 2,606 cfm of conditioned air into the kitchen space. The rest of the MUA requirements are taken from the transfer air of the nearby dining area. All exhaust fan motors run on 208v service. Farmer Boys had the DCV system previously installed before this field evaluation. The total new construction cost for the new system including labor was about $9,000.

RESULTS AND DISCUSSION

After the data was recorded and analyzed, power and energy consumptions were compared between the kitchen ventilation system "with" and "without" a DCV system. Table 2 lists the average kW draw, percentage reduction, daily operational values, daily energy consumption, annual energy consumption, annual savings, percentage energy usage reduction, and estimated annual operational cost for all hood data at each site. Measured average kW for the baseline was pretty much a consistent number that fluctuated a little from the baseline. The measured average kW for new system case was only the average of the kW when the kitchen hood was on. The average kW for the two cases was used to calculate the average kW reduction using Equation 1.

$$\frac{(\text{Average kW w/o DCV} - \text{Average kW w DCV})}{\text{Average kW w/o DCV}} \times 100 = \text{Percentage Average kW reduction}$$

EQUATION 1 PERCENTAGE AVERAGE KW REDUCTION

Daily operations were 24-hours for the two hotels since they never turned off their hoods. For the three quick-service restaurants, the hours of operation for the kitchen exhaust hood system were estimated. These estimates were determined by using Equation 2. From the end use monitoring equipment data was downloaded. The data was a reading of demand draw averaged into a five-minute data point. Demand draw only occurred when the kitchen exhaust hood system was in operation. Since any demand draw meant the kitchens' exhaust hood system was in operation, the amount of data points with demand draw that were counted were the demand occurrences. When all the demand occurrences were summed they were multiplied by five minutes to give a sum of minutes of operation. The sum of minutes was then divided by the number of days the data came from to give the average daily operational hours.

$$\frac{\Sigma \text{ demand occurrences} \times \text{ 5:00 Minutes}}{\text{Operating Days}} = \text{Average Daily Operational Hours}$$

EQUATION 2 AVERAGE DAILY OPERATIONAL HOURS

The daily energy use was then calculated by multiplying the average kW times the operational hours to get daily energy consumption. The daily energy consumption was then multiplied by the number of days the restaurant was open for business to find annual energy consumption. The difference between the baseline and the new system provided the savings. The savings were divided by the baseline to get annual energy usage reduction. The savings were also multiplied by the rate of fifteen cents a kilowatt hour (kWh) to estimate the technologies' annual operational savings. This rate was derived from SCE's current rate structure, averaged for applicable commercial customers.

The percent reduction for all the sites ranged from 37% to 62% savings. This percentage was good, but did not translate into large energy savings or dollar savings unless the hours of operation and horse power were high. The range of savings was also greatly impacted by the appliances used and the corresponding food being cooked. If the appliance was rated a medium to heavy duty and had a constant heat load, the savings opportunity decreased significantly. For example, charbroilers have a constant heat load whether food is in the process of cooking or not. Appliances rated light to medium usually created heat load when cooking occurred, resulting in large savings opportunities.

TABLE 2 OVERALL FIELD EVALUATION RESULTS FOR ALL SITES

Overall Results For All Sites	Desert Springs Marriott	Westin Mission Hills	El Pollo Loco	Panda Express	Farmer Boys
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Percentage energy usage reduction (kWh/yr)	61.7%	57.0%	37.5%	61.2%	48.8%
Estimated annual operational savings (@$0.15 a kWh)	$22,623	$9,066	$1,481	$2,259	$1,183

DESERT SPRINGS MARRIOTT

The Desert Springs Marriott shows that hotels are a good application for a DCV system. Table 3 shows the results for all exhaust fans at the Desert Springs Marriott. The number of hoods, appliances usage, type of appliances, hours of operation, and horse power affected the DCV systems performance and its corresponding savings greatly. The number of kitchen hoods and their horse power attributed to the exhaust fan motor energy consumption of 115,078 kWh a year. After the DCV system was installed the energy consumption dropped by 69% to 50,757 kWh a year. The savings are 115,078 kWh a year. The reduction of 69% can be attributed to the appliances usage. Out of 6 hoods only one cookline was actually on 24 hours in a day, which was the room service cookline EF 164. The other five cooklines had appliances either turned off, or were put on a very low setting from10:00 p.m. to 4:00 a.m. the next day. Almost all EFs dropped to a very low state between those times. EF 159, 161, 162, and 163 all modulated very little throughout the day as shown in Appendix A, Figure 17 to Figure 20. Those EFs are all batch cooking cooklines with appliances that were either on or off. When the appliances were off there was no heat load to exhaust. When the appliances were on the savings were reduced and were dependent on the appliances duty rating. The appliances range from light duty to medium duty. The duty of the appliance combined with the limited activity provided for large savings seen at the site.

TABLE 3 DESERT SPRINGS MARRIOTT EXHAUST FAN RESULTS

Desert Springs Marriott Exhaust fan motors	EF 159	EF 160	EF 161	EF 162	EF 163	EF 164	Combined Data
Average demand without DCV system (kW)	1.5	6.4	1.9	1.7	2.0	5.5	18.9
Average demand with DCV system (kW)	0.1	3.8	0.4	0.4	0.3	0.9	5.8
Average kW reduction (%)	93.5%	41.1%	78.5%	75.9%	86.8%	84.3%	69.4%
Daily Operational Hours	24	24	24	24	24	24	24
Daily energy usage without DCV system (kWh/day)	36	153	45	41	47	133	454
Daily energy usage with DCV system (kWh/day)	2	90	10	10	6	21	139
Annual energy usage without DCV system (kWh/yr)	13,146	55,966	16,282	14,842	17,165	48,435	165,836
Annual energy usage with DCV system (kWh/yr)	855	32,961	3,501	3,570	2,266	7,604	50,757
Annual energy savings with DCV system (kWh/yr)	12,290	23,005	12,780	11,272	14,899	40,832	115,078
Percentage energy usage reduction (kWh/yr)	93.5%	41.1%	78.5%	75.9%	86.8%	84.3%	69.4%
Estimated annual operational savings (@$0.15 a kWh)	$1,844	$3,451	$1,917	$1,691	$2,235	$6,125	$17,262

Table 4 shows the results from the six MUA units. MUA is introduced to the kitchen through an integrated short circuit register inside the hood, which can create spillage of effluent from the kitchen exhaust hood. As a general rule of thumb, only 15% exhaust cfm should be made up by a short circuit style hoods. Any amount above 15% of the exhaust cfm starts to degrade the hoods ability to capture and contain effluent. The Desert Springs Marriott was exhausting 57%. Since the percentage was so high, the MUA units were turned off during the initial commissioning of the system. The customer noticed the building pressure was too negative and decided to turn two of the MUA units back on. The energy savings from turning off four of the MUA units was 45% or 35,741 kWh. For this study MUA energy savings were accounted for as part of the savings because the customers can see the impact on their energy usage and their corresponding bill. The total savings of the new system was 62% or 150,819 kWh. However, the EF energy savings, as the MUA savings could have been accomplished without a DCV system.

TABLE 4 DESERT SPRINGS MARRIOTT MUA RESULTS

Desert Springs Marriott MUA	MUA 10	MUA 11	MUA 6	MUA 7	MUA 8	MUA 9	Combined Data
Average demand without DCV system (kW)	1.0	1.0	0.8	2.1	2.8	1.3	9.0
Average demand with DCV system (kW)	0.0	0.0	0.0	2.1	2.8	0.0	4.9
Average kW reduction (%)	100.0%	100.0%	100.0%	0.0%	0.0%	100.0%	45.4%
Daily Operational Hours	24	24	24	24	24	24	24
Daily energy usage without DCV system (kWh/day)	25	24	19	51	67	31	216
Daily energy usage with DCV system (kWh/day)	0	0	0	51	67	0	118
Annual energy usage without DCV system (kWh/yr)	9,023	8,585	6,920	18,571	24,353	11,213	78,665
Annual energy usage with DCV system (kWh/yr)	0	0	0	18,571	24,353	0	42,924
Annual energy savings with DCV system (kWh/yr)	9,023	8,585	6,920	0	0	11,213	35,741
Percent energy usage reduction (kWh/yr)	100.0%	100.0%	100.0%	0.0%	0.0%	100.0%	45.4%
Estimated annual operational savings (@$0.15 a kWh)	$1,353	$1,288	$1,038	$0	$0	$1,682	$5,361

Figure 6 provides an example of a typical demand profile for exhaust fan EF 160. EF 160 is the kitchens main line, and handles a large amount of short order cooking. The black solid line represents the baseline case that consistently draws around 6.5 kW. This consistent demand draw is due to the fans simple “on” or “off” control strategy. The minor variation of the baseline is due to the loading and unloading of the exhaust fan as effluent is exhausted. The dashed redline represents the new system case (with DCV installed). As expected, the fan motor demand drops significantly from 10:00p.m. to 4:00 a.m. Between these hours, the short order food demands for the hotel are very low, so the kitchen staff turns off or runs the appliances at the lowest set point under the hood. With the appliances off or at low settings, there is little, if any, heat produced that needs exhausting. The DCV system was programmed to decrease fan speed as low as possible when the exhaust temperature dropped significantly. The dropped fan speed during this period of time translated into large demand reductions. Between 4:00a.m. to 7:00a.m. a rise in energy demand occurs as some appliances are turned on and at around 7:30 a.m. all appliances are fully functional and the energy demand fluctuates depending on the cooking taking place. This routine occurs about the same time everyday. However, to account for the variations in appliance shut offs; cooking demand during operational hours, and special-events catering, an average was taken from the 12 weeks of data. The average demand draw for EF 160 with the DCV system was 3.8 kW, which is represented by the dashed green line which gives a visual representation of energy usage drop from baseline to the new system case. Typical demand profile graphs for each of the five exhaust fans can be found in Appendix A, Figure 17 to Figure 21. The other exhaust fans followed the same pattern as EF 160. The only exhaust fan that didn't follow the general rule was EF 164. EF 164 was used for room service orders. The room service cookline has a 24-hour operation and has the opposite demand profile because the appliances are on the entire day, but the food demand varies from 7:00a.m. to 1:00a.m. the next day.

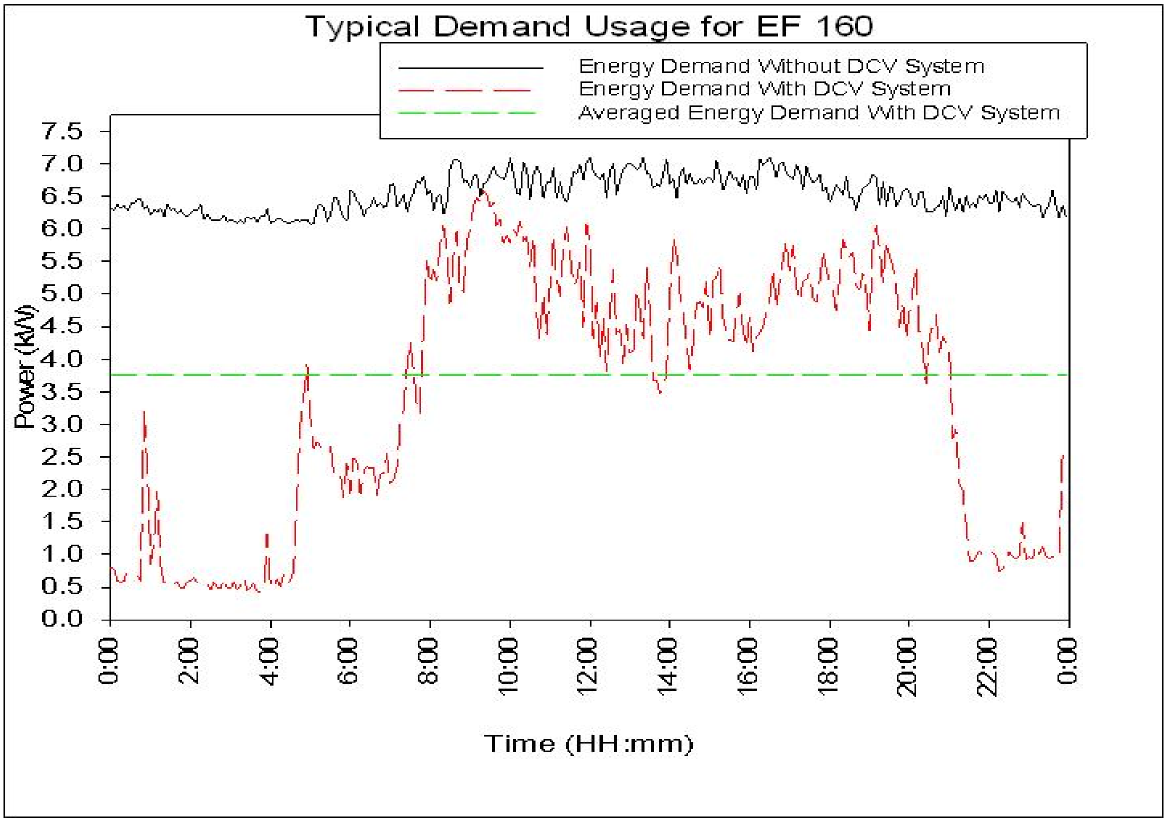

FIGURE 6 TYPICAL DEMAND USAGE FOR EF 160 AT DESERT SPRINGS MARRIOTT

WESTIN MISSION HILLS

The Westin Mission Hills is another hotel that demonstrates why hotels are a good application for a DCV system. Table 5 shows the results for all the EF and SF units for the Westin Mission Hills. The amount of exhaust fans, appliance usage, type of appliances, hours of operation, and horse power affected the DCV system performance and its corresponding savings greatly. The baseline energy consumption was 106,034 kWh a year. After the DCV system was installed the energy consumption dropped by 57% to 45,595 kWh a year. The savings are 60,439 kWh a year. The reduction is mainly due to the limited activity occurring in the two back-to-back 30-ft hoods. The hoods are mainly used for batch cooking. EF 7, 8, and 9 all service both hoods along with SF 2 and 3. Appliances under the hoods are mainly light to medium duty appliances. These appliances only create a heat load when the appliances are on. The only exceptions were the two griddles located under EF 8. The constant heat load from the appliances reduced the savings of just that particular exhaust fan. EF 10/MUA shows very little savings and modulation during operational hours due to the constant heat load from the griddle and charbroiler.

TABLE 5 WESTIN MISSION HILLS RESULTS

Westin Mission Hills	EF 10/ MUA	EF 7	EF 8	EF 9	SF 2	SF 3	Combined Data
Average demand without DCV system (kW)	3.8	1.9	2.2	2.2	0.6	1.3	12.1
Average demand with DCV system (kW)	3.0	0.3	1.0	0.6	0.1	0.1	5.2
Average kW reduction (%)	20.3%	83.2%	57.3%	71.4%	76.6%	90.9%	57.0%
Daily Operational Hours	24	24	24	24	24	24	24
Daily energy usage without DCV system (kWh/day)	92	46	54	52	14	32	291
Daily energy usage with DCV system (kWh/day)	73	8	23	15	3	3	125
Annual energy usage without DCV system (kWh/yr)	33,400	16,965	19,614	19,072	5,196	11,787	106,034
Annual energy usage with DCV system (kWh/yr)	6,785	14,117	11,237	13,612	3,979	10,710	60,439
Annual energy savings with DCV system (kWh/yr)	26,616	2,848	8,377	5,460	1,217	1,076	45,595
Percentage energy usage reduction (kWh/yr)	20.3%	83.2%	57.3%	71.4%	76.6%	90.9%	57.0%
Estimated annual operational savings (@$0.15 a kWh)	$1,017.70	$2,117.52	$1,685.51	$2,041.79	$596.81	$1,606.54	$9,065.87

Figure 7 gives an example of a typical demand profile for exhaust fan EF 8. EF 8 is the center EF motor serving the center 10-ft of the back-to-back 30-ft kitchen hood. The black solid line represents the baseline case. The baseline consistently draws around 2 kW. The consistent demand draw is due to the fans simple “on” or “off” control strategy. The EF actually varies a considerable amount. The variation is from 1.7 kW all the way up to 2.0 kW depending on the loading and unloading of the exhaust fan as effluent is exhausted. The dashed red line represents the new system case (with DCV installed). As expected, the fan motor demand drops significantly throughout the day. The exhaust setup is unique where the exhaust serves a batch cookline (hood 1 and 2). There also are no barriers between EF 7 and 9 exhaust registers. Since there are no barriers between the exhaust registers of the 30-ft kitchen hood, effluent not directly under could be exhausted by EF 8 as it runs at a higher speed most of the day. The appliances serviced by EF 8 are 2 griddles under hood 1; a kettle under, and a tilting skillet under hood 2. The griddles are on at all times, which create a consistent heat load. The consistent heat load keeps the fan at 0.8 kW. As items are cooked on the griddle, or batch cooking occurs on the kettles/tilting skillet, the fan modulates depending on exhausting needs. This routine, occurs about the same time everyday, but to account for the variations of appliance shut offs, cooking demand during operational hours, and special events catering, an average was taken from the 12 weeks of data. The average demand draw for EF 8 is 0.95 kW, which is represented by the dashed green line. The dashed green line gives a visual representation of energy usage drops from the baseline for the new system case. Typical demand profile graphs for each of the 4 exhaust fans and supply fans can be found in Appendix A, Figure 25 to Figure 27. The typical demand profile for the other exhaust fans servicing the 30-ft hoods have a considerably lower demand draw as the rated appliances are low-duty to medium-duty fans. The particular appliances serviced by EF 7 and 9 only create heat when cooking is taking place. The typical demand usage of the supply fans (SF) are also considerably lower since they modulate dependent on EF 7, 8, and 9 make up air requirements. Typical demand usage for EF10 / MUA modulation opportunity is a lot lower as the medium to heavy duty appliances place a high heat load on the DCV system.

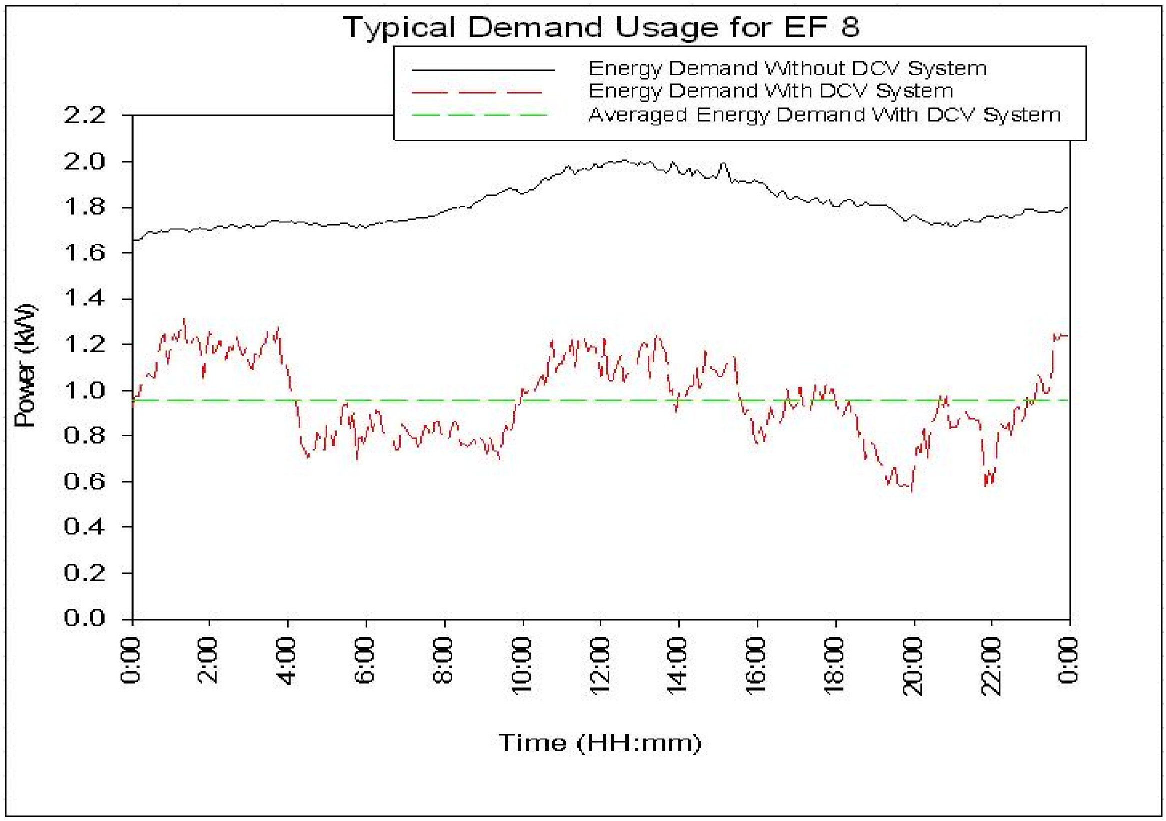

FIGURE 7 TYPICAL DEMAND USAGE FOR EF 8 AT THE WESTIN MISSION HILLS

EL POLLO LOCO

El Pollo Loco shows the impact a DCV system has on the quick service restaurant market segment. Table 6 shows the results for all the EF and MUA units for El Pollo Loco. The amount of exhaust fans, appliance usage, type of appliances, hours of operation, and horse power affects the DCV systems performance and savings greatly. The baseline energy consumption was 26,313 kWh a year. After the DCV system was installed the energy consumption dropped by 37% to 16,442 kWh a year. The savings are 9,871 kWh a year. The reduction was mainly due to the decreased kitchen exhaust demand during the first and last two hours of opening and closing. EF 1 and 2 serviced the two heavy duty charbroilers that chicken was cooked on. The charbroilers open flame and constant heat provided little opportunity for the DCV system to save energy. The bulk of the savings were in the morning and at night as the charbroilers were at a low setting in preparation for opening and closing. EF 2 serviced medium duty appliance combination ovens. The combination ovens only created a heat load when cooking occurred and were rated as medium duty appliances due to the exiting steam as the ovens' door opened. Since there was only one MUA unit, the MUA modulated dependent on all the EF current exhaust requirements, saving 43.5% of MUA energy usage. The savings for EF 1, 2, and 3 was 33% of the combined exhaust fans energy consumption. The exhaust fans servicing the charbroilers was the main reason for the lowered the savings.

TABLE 6 EL POLLO LOCO RESULTS

El Pollo Loco	EF 1,2,3	MUA 1	Combined Data
Average demand without DCV system (kW)	2.8	1.9	4.7
Average demand with DCV system (kW)	1.9	1.1	2.9
Average kW reduction (%)	33.4%	43.5%	37.5%
Daily Operational Hours	15.36	15.36	15.36
Daily energy usage without DCV system (kWh/day)	43	29	72
Daily energy usage with DCV system (kWh/day)	29	17	45
Annual energy usage without DCV system (kWh/yr)	15,676	10,637	26,313
Annual energy usage with DCV system (kWh/yr)	10,435	6,007	16,442
Annual energy savings with DCV system (kWh/yr)	5,241	4,630	9,871
Percent energy usage reduction (kWh/yr)	33.4%	43.5%	37.5%
Estimated annual operational savings (@$0.15 a kWh)	$786	$694	$1,481

At El Pollo Loco all the exhaust fans were connected on one circuit breaker. Figure 8 gives an example of typical demand usage for EF 1, 2, and 3. EF 1 and 2 are the exhaust fans servicing the two charbroilers used to cook chicken throughout the day. EF 3 services the different combination ovens. The black solid line represents the baseline case. The baseline consistently draws around 3 kW. The consistent demand draw is due to the fans simple "on" or "off" control strategy. The minor variation of the baseline is due to the loading and unloading of the exhaust fan as effluent is exhausted. The dashed red line represents the new system case (with DCV installed). When the workers arrive at the store around 7:00 a.m., the hoods are turned on and the chicken is pre-cooked in the combination ovens until 9:00 a.m. The demand jumps as the store begins to flame grill the chicken once the store opens at 9:00 a.m. The exhaust modulates very little while chicken is char broiled throughout the day. The modulation is very minimal due to the chicken and charbroiler's large amounts of effluent and heat. The large amount of heat is due to the charbroiler's open flames that operate on a high setting during chicken production. The major demand usage savings are really the two hours before the store opens and closes due to the charbroiler's not used, or being turned to the lowest setting. This routine, occurs about the same time everyday, but to account for the variations of chicken being cooked and their corresponding exhaust fan modulation, an average was taken from the 6 weeks of data. The average demand draw for EF 1, 2, and 3 with the DCV system is 2 kW, which is represented by the dashed green line. This green line gives a visual representation of energy usage drop from baseline for the new system case. The new system case average is only when the exhaust hood is actually on. The typical demand profile graph for MUA can be found in Appendix A, Figure 32. The MUA fans demand usage almost mirrors the EF demand usage since most of the MUA is supplying EF 1 and 2.

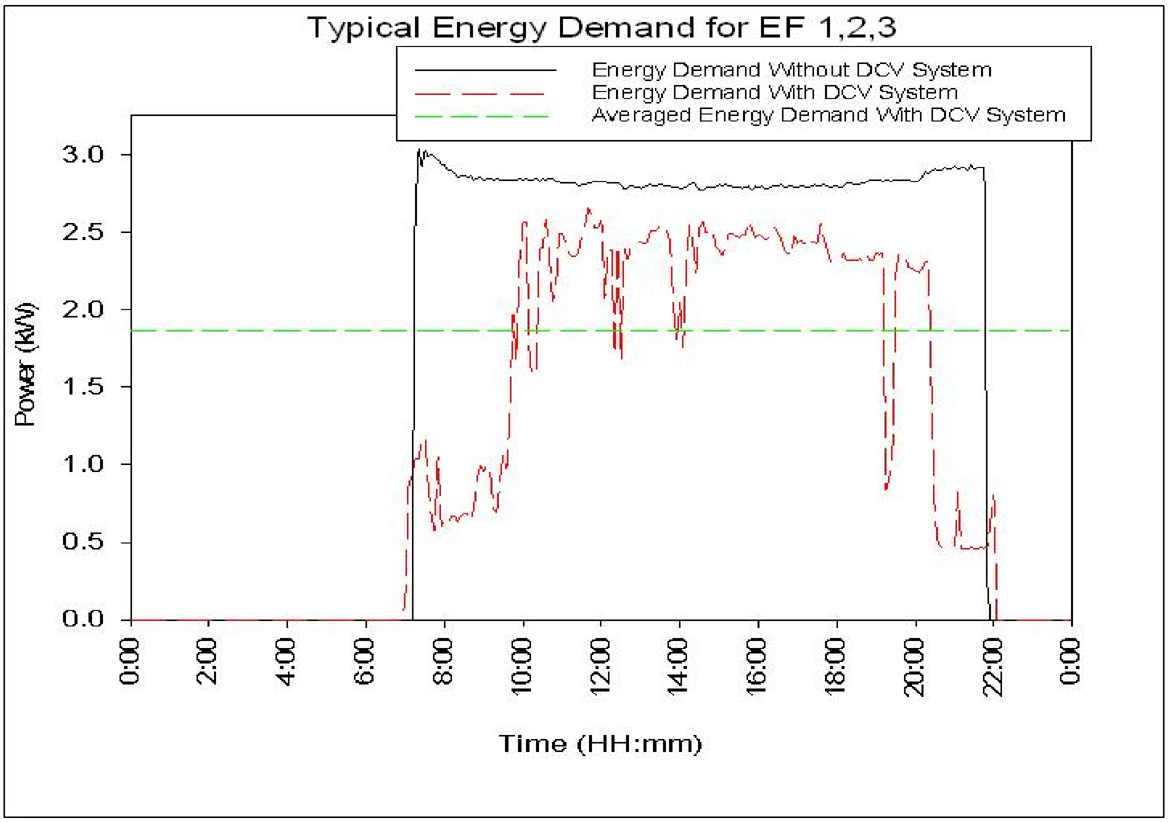

FIGURE 8 TYPICAL DEMAND USAGE FOR EF 1,2,3 AT EL POLLO LOCO

PANDA EXPRESS

Panda Express shows the impact a DCV system can have on the quick-service restaurant market segment. Table 7 shows the EF and MUA unit results. The amount of exhaust fans, appliance usage, type of appliances, hours of operation, and horse power affected the DCV system performance and its corresponding savings greatly. The baseline energy consumption is 24,620 kWh a year. After the DCV system was installed the energy consumption dropped by 61% to 9,559 kWh a year. The savings are 15,061 kWh a year. EF 1 and 2, and MUA service the three heavy-duty rated woks that cook the different menu items. The woks heat load occurs only when cooking. When cooking does occur, exhaust demand is high. The opportunity for modulation is very high in both of the kitchen exhaust hoods since cooking does not occur at all times. Most of the menu items were cooked on EF 1, resulting in 50% savings of the exhaust fans energy consumption. EF 2/ MUA savings are a little higher at 66% of the exhaust and MUA fans energy consumption. The combination of EF 2 cookline being the secondary wok used for cooking and a single MUA unit resulted in a little higher percentage of savings.

TABLE 7 PANDA EXPRESS RESULTS

Panda Express	EF 1	EF 2/MUA	Combined Data
Average demand without DCV system (kW)	1.5	3.6	5.1
Average demand with DCV system (kW)	0.8	1.2	2.0
Average kW reduction (%)	50.2%	65.8%	61.2%
Daily Operational Hours	13.10	13.10	13.10
Daily energy usage without DCV system (kWh/day)	20	47	67
Daily energy usage with DCV system (kWh/day)	10	16	26
Annual energy usage without DCV system (kWh/yr)	7,353	17,267	24,620
Annual energy usage with DCV system (kWh/yr)	3,660	5,898	9,559
Annual energy savings with DCV system (kWh/yr)	3,693	11,368	15,061
Percent energy usage reduction (kWh/yr)	50.2%	65.8%	61.2%
Estimated annual operational savings (@$0.15 a kWh)	$554	$1,705	$2,259

Figure 10 gives an example of typical demand usage for EF 1. Under the hood are 3 woks. The black solid line represents the baseline case. The baseline consistently draws around 1.6 kW. The consistent demand draw is due to the fans simple “on” or “off” control strategy. The minor variations of the baseline are due to the loading and unloading of the exhaust fan as effluent is exhausted. The dashed red line represents the new system case (with DCV installed). The new system demand usage has jagged modulations with a range of 0.6 to 1.4 kW daily at the Panda Express. The jagged modulation is due to the woks. The wok is a heavy-duty appliance that creates heavy heat. This type of appliance also does not produce a constant heat. Instead woks are only turned on when needed to refill the different entrees in the steam tables. So, as the food is cooked there is a quick demand for exhaust. When not needed, the appliance is turned off and the exhaust demand drops immediately. The different peaks are dependent on how many woks are used at a time. Towards the end of the night, between 8:00 p.m. to 10:00 p.m., the need to cook drops significantly and spot cooking occurs, as needed. The lowered cook demand drops the exhaust even more. The typical demand profile occurs about the same time everyday, but to account for the variations of fan modulation, an average was taken from the 6 weeks of data. The average demand draw for EF 1, with the DCV system, is 0.78 kW, which is represented by the dashed green line. This line gives a visual representation of energy usage drop from baseline for the new system case. The new system case average was only when the exhaust hood was actually turned on. Typical demand usage graphs for EF 2/MUA can be found in Appendix A, Figure 35. The EF2/MUA fans demand usage almost mirrored the EF 1 demand usage since the main appliances under the hood were woks and the MUA met both of the hoods MUA requirements.

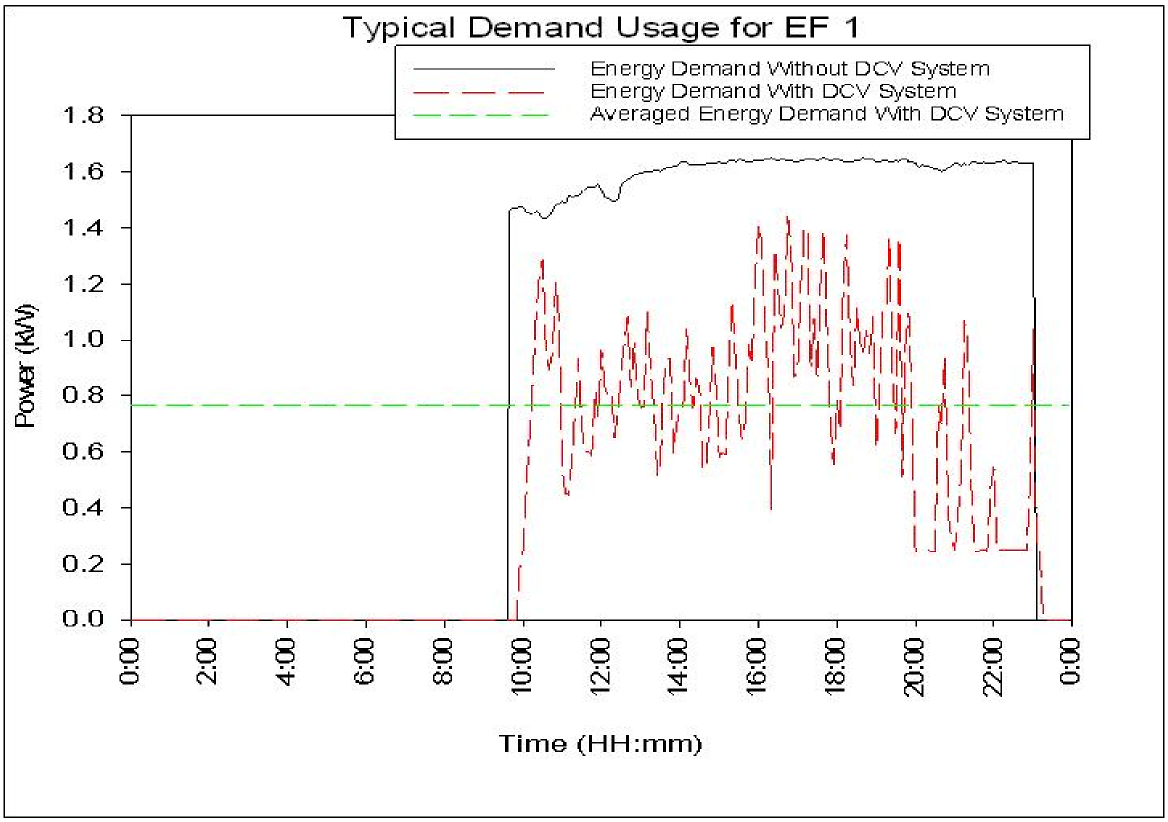

FIGURE 9 TYPICAL DEMAND USAGE FOR EF 1 AT PANDA EXPRESS

FARMER BOYS

Farmer Boys also shows the impact a DCV system can have on the quick-service restaurant market segment. Table 8 shows all the EF unit results for Farmer Boys. The amount of exhaust fans, appliance usage, type of appliances, hours of operation, and horse power greatly affected the DCV system and its corresponding savings . The baseline energy consumption was 16,159 kWh a year. After the DCV system was installed, the energy consumption dropped by 48.8% to 7,884 kWh a year. The savings are 8,276 kWh a year. EF 1 serviced four fryers rated as medium-duty appliances. The fryers produced a constant heat load throughout the day. As food was fried, effluent was exhausted. EF 1 modulated dependent on the fryers use throughout the day. The varying exhaust demand as fries are cooked, resulted in a 55.4% savings of exhaust fan energy consumption. EF 2 had an 82% savings, which was the largest savings due to its limited use. The cookline serviced by EF 2 is only used for very high kitchen demands. When the EF 3 cookline is unable to meet the kitchens cooking demands, the EF 2 cookline is used. EF 3 is the main cookline. The cookline has a heavy-duty rated charbroiler and a medium-duty rated griddle appliance under the hood. Both create constant heat during hours of operation. When business is slower the charbroilers are at the lowest setting. Modulation occurs during the slower times of the day. The main cookline is in operation consistently, which resulted in only a 20.7% savings for the exhaust hood.

TABLE 8 FARMER BOYS RESULTS

Farmer Boys	EF 1	EF 2	EF 3	Combined Data
Average demand without DCV system (kW)	1.0	0.7	1.1	2.8
Average demand with DCV system (kW)	0.4	0.1	0.9	1.4
Average kW reduction (%)	55.4%	82.0%	20.7%	48.8%
Daily Operational Hours	15.8	15.8	15.8	15.8
Daily energy usage without DCV system (kWh/day)	16	12	17	44
Daily energy usage with DCV system (kWh/day)	7	2	14	23
Annual energy usage without DCV system (kWh/yr)	5,658	4,205	6,296	16,159
Annual energy usage with DCV system (kWh/yr)	2,525	756	4,994	8,276
Annual energy savings with DCV system (kWh/yr)	3,133	3,449	1,302	7,884
Percent energy usage reduction (kWh/yr)	55.4%	82.0%	20.7%	48.8%
Estimated annual operational savings (@$0.15 a kWh)	$469	$517	$195	$1,183

Figure 10 gives an example of a typical demand profile for EF 3. The black solid line represents the baseline case and consistently draws around 1.1 kW. The consistent draw is due to the fans simple “on” or “off” control strategy. The minor variation of the baseline is due to the loading and unloading of the exhaust fan as effluent is exhausted. The dashed red line represents the new system case (with DCV installed). The new system demand does not modulate too much. The main demand savings are attributed to the charbroiler’s very low setting early in the morning and later at night when business is slow. The griddle keeps a constant temperature throughout the day when its settings are on high. The main line cooks constantly so the opportunity for savings is not as high. The typical demand profile, displayed below, occurs about the same time everyday for EF 3, but to account for the variations of fan modulation, an average was taken from the 6 weeks of data. The average demand draw for EF 3 with the DCV system is 0.85 kW, which is represented by the dashed green line. This green line gives a visual representation of energy usage drops from baseline for the new system case. The new system case average is only when the exhaust hood is actually on. Typical demand usage graphs for EF 1 and 2 can be found in Appendix E – Farmer Boys, Figure 39 to Figure 40. The EF 1 fan’s demand usage modulates about the same as fries are cooked throughout the day. EF 2 is at the lowest setting due to limited use.

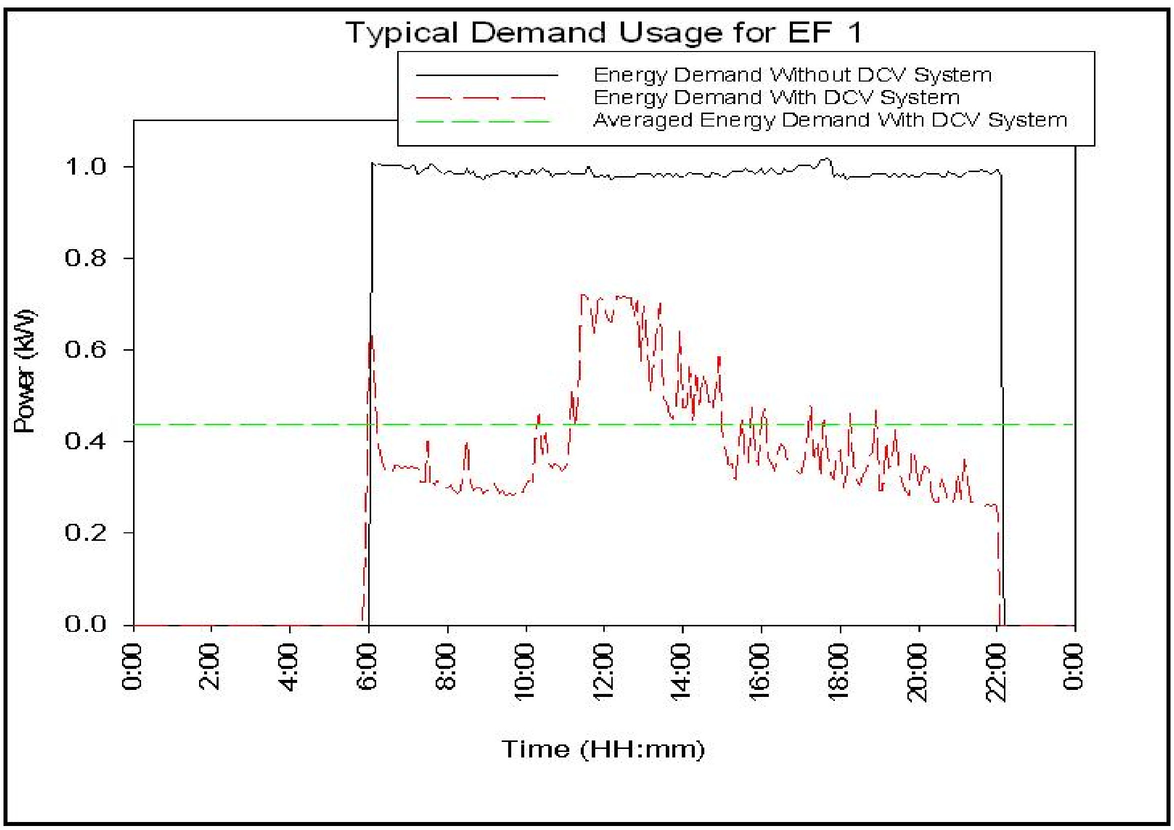

FIGURE 10 TYPICAL DEMAND USAGE FRO EF 1 AT FARMER BOYS

CONCLUSIONS

The Melink Intelli-Hood DCV system was shown to significantly reduce the energy consumption and electrical demand associated with operating a commercial kitchen exhaust hood. The savings results can realize a 37-62% energy savings over current commercial kitchen hoods energy usage. The DCV system was most effective in the hotel market sector due to the amount of hoods, amount of HP servicing the hotel, and the hours of operations. In hotels - kitchens are sized for peak food preparation which is defined as the maximum food preparation at any given time in a hotels' kitchen. The hotel kitchen sizing also means there are multiple hoods and higher amounts of HP needed to meet the kitchen's maximum food preparation. Since "maximum" food preparation rarely happens, the hotel market sector has a high potential for savings. Most of the time there is limited kitchen use occurring in a given day, allowing a DCV system to save energy by running at minimal exhaust settings. In the quick-service restaurant market sector there was a large percentage energy drop at each site, but a significantly lower energy savings. The lower energy savings were attributed to the lower hp motors, operational time, appliance usage, and the amount of hoods in the quick-service restaurant sector. In addition to energy savings, with the installation of a DCV system, there was the added benefit of noise reduction from the kitchens' exhaust hood system.

This evaluation also demonstrated that the performance of the DCV system was highly impacted by the different appliance types and their controls. Appliance types ranged from light duty to extra heavy duty. The opportunity for energy savings decreased as the appliances duty rating got closer to extra heavy duty rated appliances. The higher the rated duty, the higher heat load and more effluent the appliance created during cooking. The opportunity for savings also decreased when the appliances controls created a constant heat load when either in use or not in use. Appliances that only produce heat when cooking gave a large opportunity for savings.

RECOMMENDATIONS

In this field evaluation HVAC energy savings were not accounted for. The lowered kitchen air exhaust can impact HVAC load requirements as less conditioned air is exhausted in the kitchen space. A study should be initiated to evaluate the DCV systems' impact on HVAC systems. Since HVAC systems are weather-dependent, it is further recommended that simulation studies should be performed to evaluate DCV system impacts on HVAC systems.

APPENDIX A – DESERT SPRINGS MARRIOTT

KITCHEN HOOD DESCRIPTION

Hood 1 of system A is a 13-ft 6-in wall-mounted canopy hood. The exhaust fan motor is labeled as EF 159 and has a rated horse power of 2 hp. The MUA fan motor is labeled MUA 6 and has a rated horse power of 1 hp. The appliances under the hood from left to right as shown in Figure 11 include a deck oven, and a 4-burner range with oven. This cookline is known as the bakery and provides the majority of deserts and pastries.

FIGURE 11 DESERT SPRINGS MARRIOTT HOOD 1 SYSTEM A

Hood 2 of system A is a 12-ft wall-mounted canopy hood. The exhaust fan motor is labeled as EF 163 and has a rated horse power of 2 hp. The MUA fan motor is labeled MUA 10 and has a rated horse power of 1.5 hp. The appliances under the hood from left to right as shown in Figure 12 include two 6-burner ranges with ovens. This cookline is known as the cold prep line and is used for batch cooking and when extra cooking capacity is needed.

FIGURE 12 DESERT SPRINGS MARRIOTT HOOD 2 SYSTEM A

Hood 3 of system A is a 16-ft wall-mounted canopy hood. The exhaust fan motor is labeled as EF 164 and has a rated horse power of 3 hp. The MUA fan motor is labeled MUA 11 and has a rated horse power of 1.5 hp. The appliances under the hood from left to right as shown in Figure 13 include a 6-burner range with oven, a 5-ft Countertop Griddle on top of a 2-door refrigerator with a cheese melter mounted above, an under-fire charbroiler and two 14-in vat fryers. This cookline is known as the room service line and is used for room service food preparation.

FIGURE 13 DESERT SPRINGS MARRIOTT HOOD 3 SYSTEM A

Hood 1 of system B is a 26-ft wall-mounted canopy hood. The exhaust fan motor is labeled as EF 161 and has a rated horse power of 2 hp. The MUA fan motor is labeled MUA 8 and has a rated horse power of 3 hp. The appliances under the hood from left to right as shown in Figure 14 include a 5-pan pressure steamer, two brazing pans, , and two 40-gallon kettles. This cookline is known as the hot prep kettle line and is used for batch cooking.

FIGURE 14 DESERT SPRINGS MARRIOTT HOOD 1 SYSTEM B

Hood 2 of system B is a 13 ft wall mounted canopy hood. The exhaust fan motor is labeled as EF 162 and has a rated horse power of 2 hp. The MUA fan motor is labeled MUA 8 and has a rated horse power of 1.5 hp. The appliances under the hood from left to right as shown in Figure 15 includes two double-stacked combination ovens, and a rotisserie. This cookline is known as the hot prep oven line and is used for batch cooking.

FIGURE 15 DESERT SPRINGS MARRIOTT HOOD 2 SYSTEM B

Hood 3 of system B is a 28 ft wall mounted canopy hood. The exhaust fan motor is labeled as EF 160 and has a rated horse power of 10 hp. The MUA fan motor is labeled MUA 7 and has a rated horse power of 3 hp. The appliances under the hood from left to right as shown in Figure 16 include a refrigerated preparation table, a 6-burner range with oven, a 5-ft countertop griddle on top of a 2-door refrigerator with a cheese melter mounted above, a 3-ft charbroiler, a heat lamp, two 14-in vat fryers, two 6-burner ranges with ovens with a cheese melter mounted above. This cookline is the main kitchen line known as the Lakeview line and is used for short order cooking.

FIGURE 16 DESERT SPRINGS MARRIOTT HOOD 3 SYSTEM B

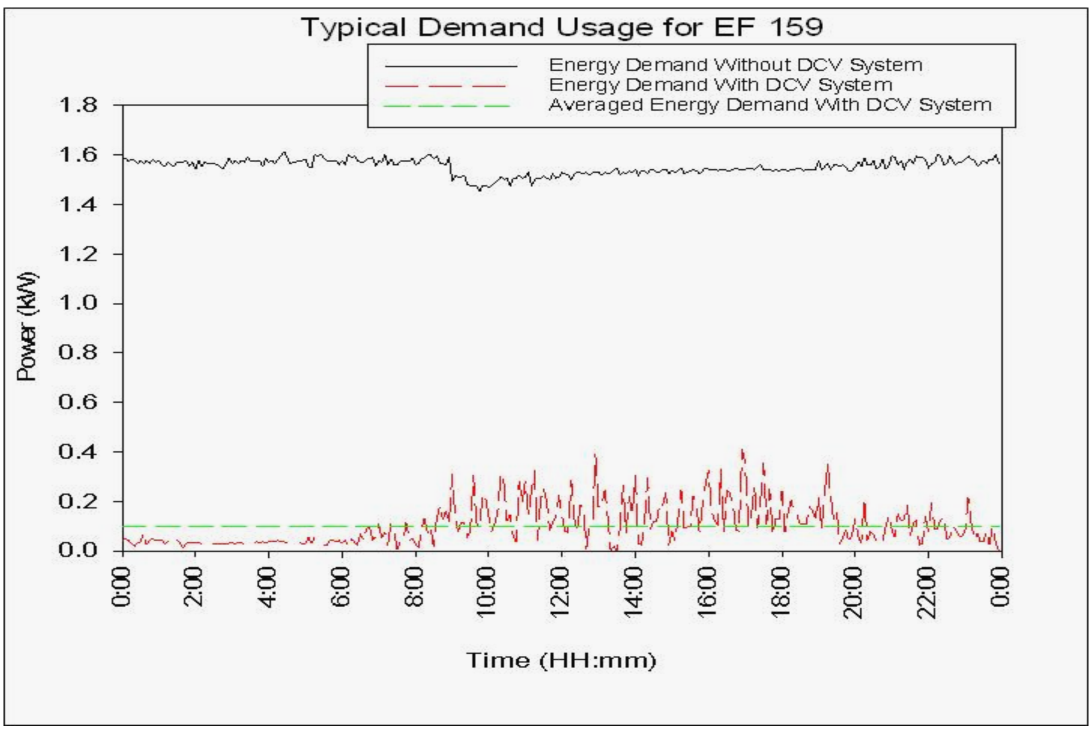

FIGURE 17 TYPICAL DEMAND USAGE FOR EF 159 AT DESERT SPRINGS MARRIOTT

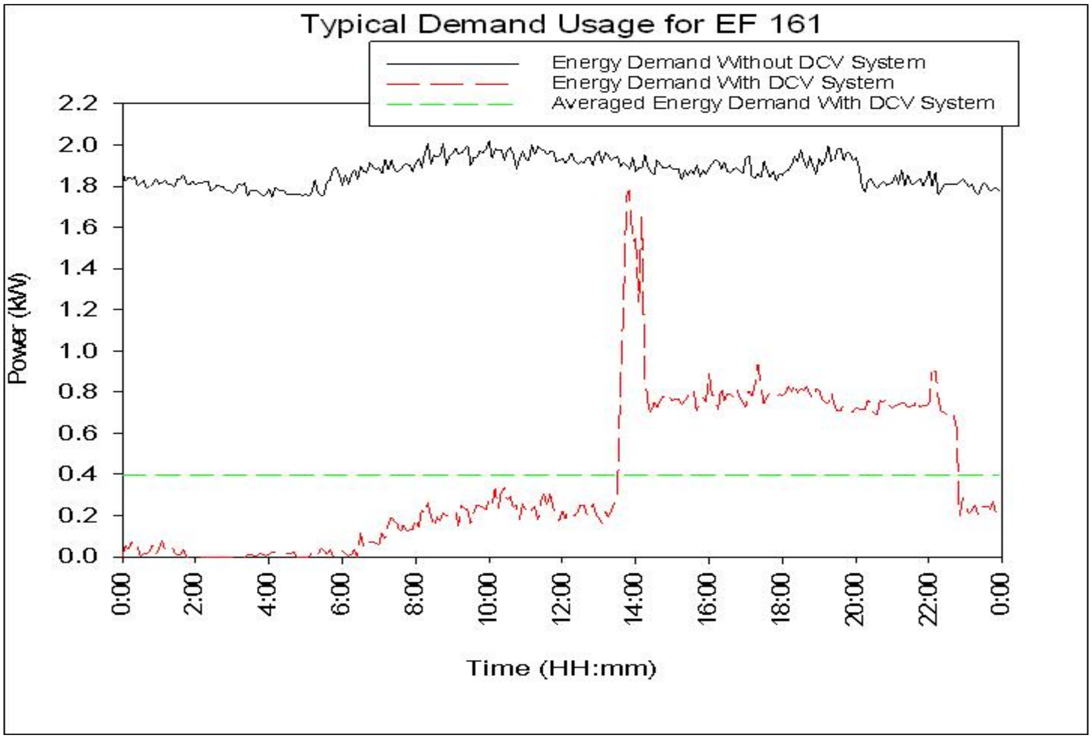

FIGURE 18 TYPICAL DEMAND USAGE FOR EF 161 AT DESERT SPRINGS MARRIOTT

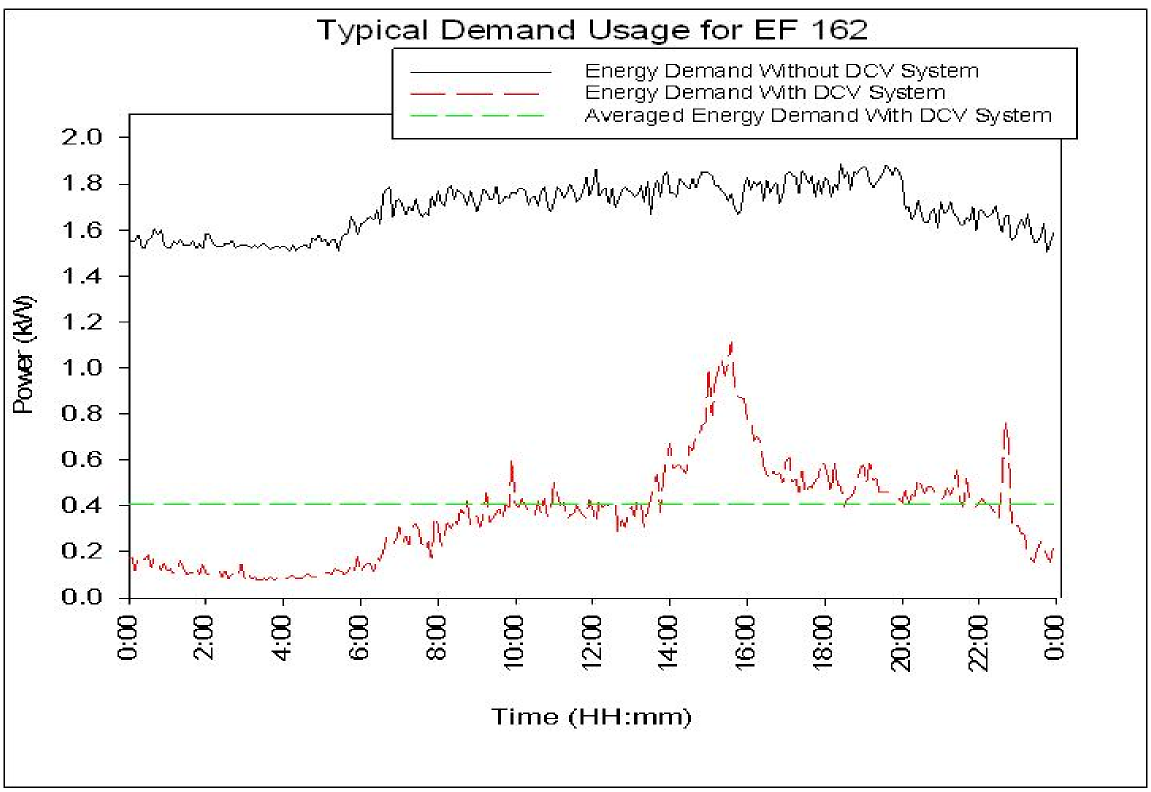

FIGURE 19 TYPICAL DEMAND USAGE FOR EF 162 AT DESERT SPRINGS MARRIOTT

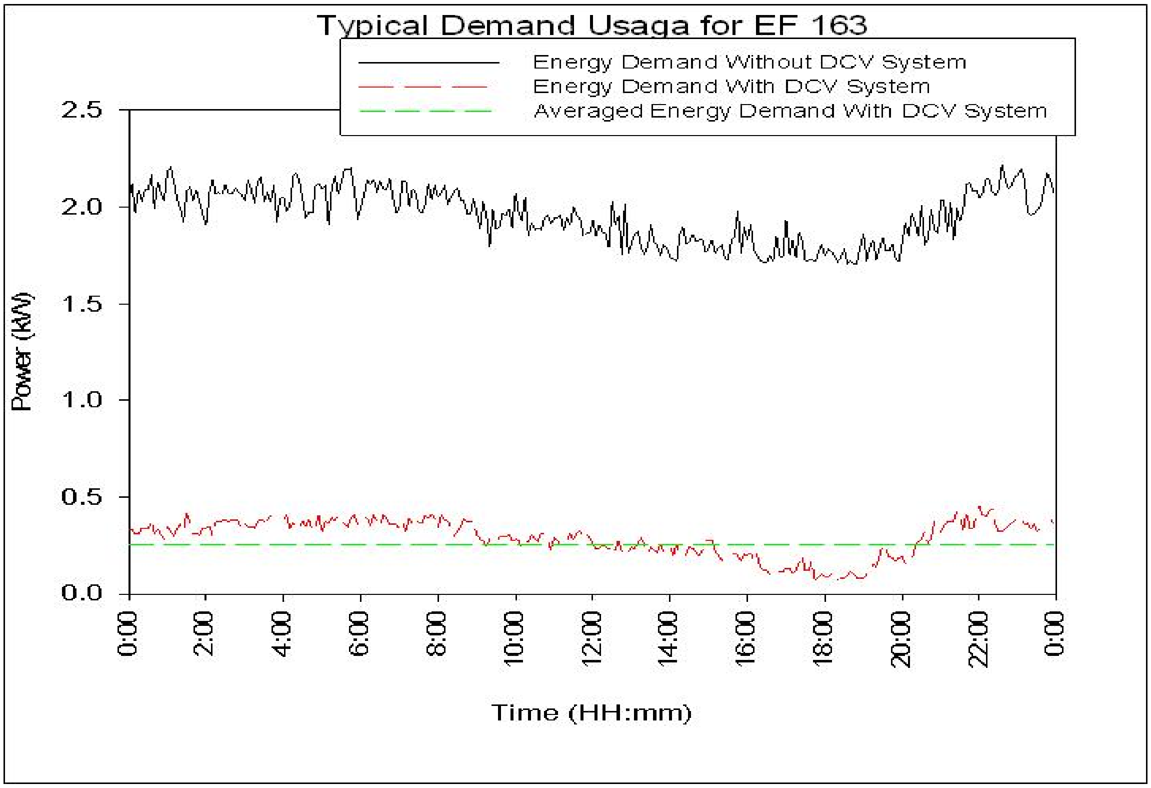

FIGURE 20 TYPICAL DEMAND USAGE FOR EF 163 AT DESERT SPRINGS MARRIOT

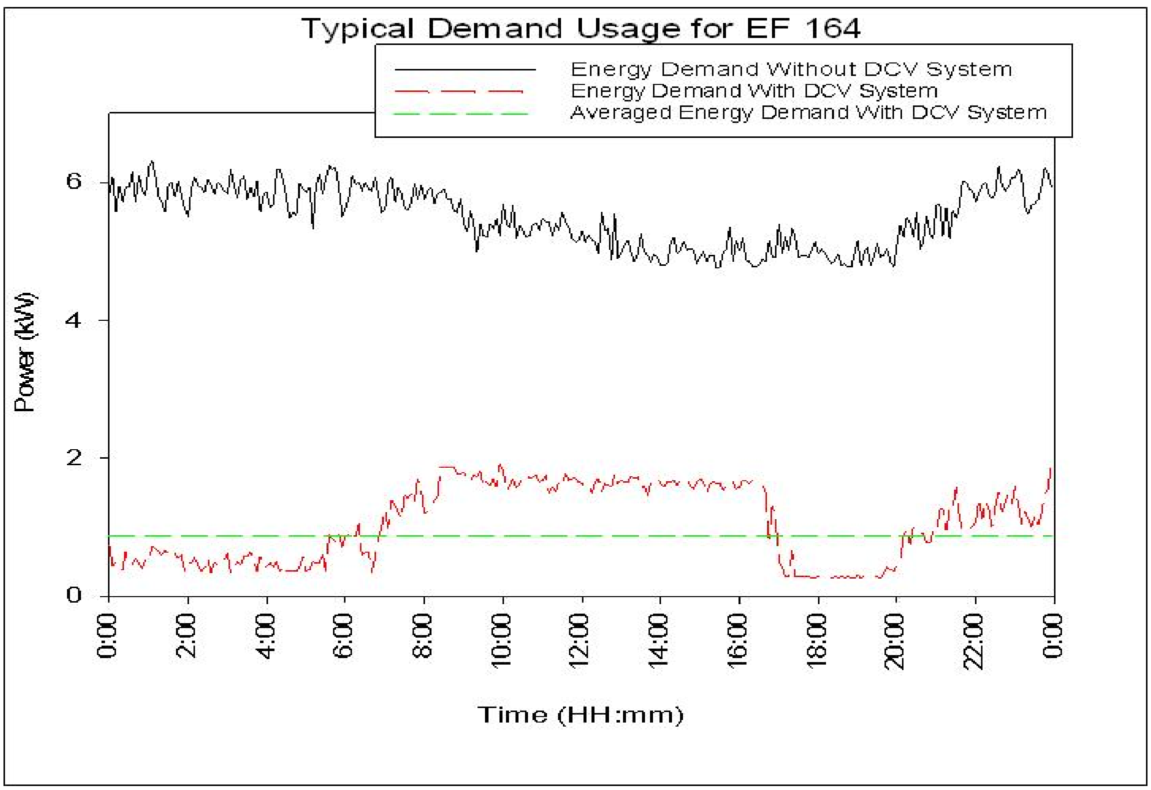

FIGURE 21 TYPICAL DEMAND USAGE FOR EF 164 AT DESERT SPRINGS MARRIOTT

APPENDIX B – WESTIN MISSION HILLS

KITCHEN HOOD DESCRIPTION

Hood 1 is a 30-ft wall-mounted canopy hood. Hood 1 has three exhaust fan motors meeting its exhausting requirements. The three exhaust fan motors service both hoods 1 and 2, which are back-to-back. There is one common exhaust duct for hoods 1 and 2 per exhaust motor. Exhaust motors service every ten feet of both hoods 1 and 2. The exhaust fan motors are labeled EF 7, EF 8, EF 9 and each have a rated horse power of 3 hp. This hood only has one MUA fan motor that is labeled SF 3 and has a rated horse power of 3 hp. The MUA was introduced into the kitchen through an integrated air curtain supply register in the front of the hood. The appliances under the hood from left to right as shown in Figure 22 include a 20-pan combination oven, double convection oven, two 18-in split vat fryers, a 4-ft griddle, 4-ft groove-sided griddle, two 4-burner countertop ranges, one with a cheese melter mounted above it. This cookline is the front line and is used for short order cooking.

FIGURE 22 WESTIN MISSION HILLS HOOD 1

Hood 2 is a 30-ft wall-mounted canopy hood. Hood 2 has three exhaust fan motors meeting its exhausting requirements. The three exhaust fan motors service both hoods 1 and 2, which are back-to-back. There is one common exhaust duct for hoods 1 and 2 per exhaust motor. Exhaust motors service every ten feet of both hoods 1 and 2. The exhaust fan motors are labeled EF 7, EF 8, and EF 9 and each have a rated horse power of 3 hp. This hood only has one MUA fan motor that is labeled SF 2 and has a rated horse power of 3 hp. The MUA was introduced into the kitchen through an integrated air curtain supply register in the front of the hood. The appliances under the hood from left to right as shown in Figure 23 include two 25-gallon tilting skillets, a 20-gallon kettle, a 45-gallon kettle, and a 35-gallon kettle. This cookline is the back line and is used for batch cooking.

FIGURE 23 WESTIN MISSION HILLS HOOD 2

Hood 3 is an 18-ft wall-mounted canopy hood. The exhaust fan motor is labeled EF 10 and has a rated horse power of 5 hp. The MUA fan motor is labeled MUA and has a rated horse power of 2 hp. The MUA was introduced into the kitchen through ceiling diffusers 3-ft away from the kitchen exhaust hood. Hood 3 is located just off of the main kitchen and is a part of the Bella Vista Restaurant. The appliances under the hood from left to right as shown in Figure 24 include a 6-burner range with oven, a 5-ft countertop griddle on top of a 4-door refrigerator, a 2-ft griddle on top of a 2-door refrigerator, a 3-ft under-fire charbroiler, and an 18-in split vat fryer. This cookline is known as the Bella Vista line and is used for short order cooking.

FIGURE 24 WESTIN MISSION HILLS HOOD 3

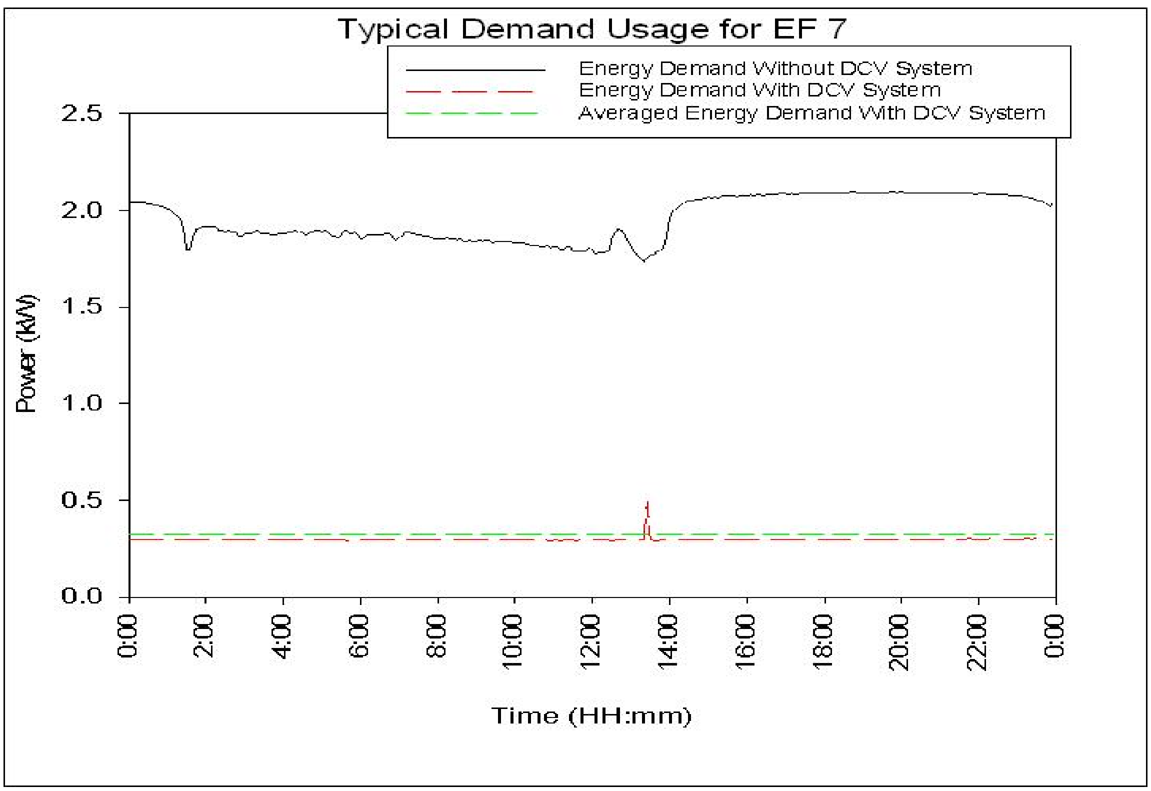

FIGURE 25 TYPICAL DEMAND USAGE FOR EF 7 AT WESTIN MISSION HILLS

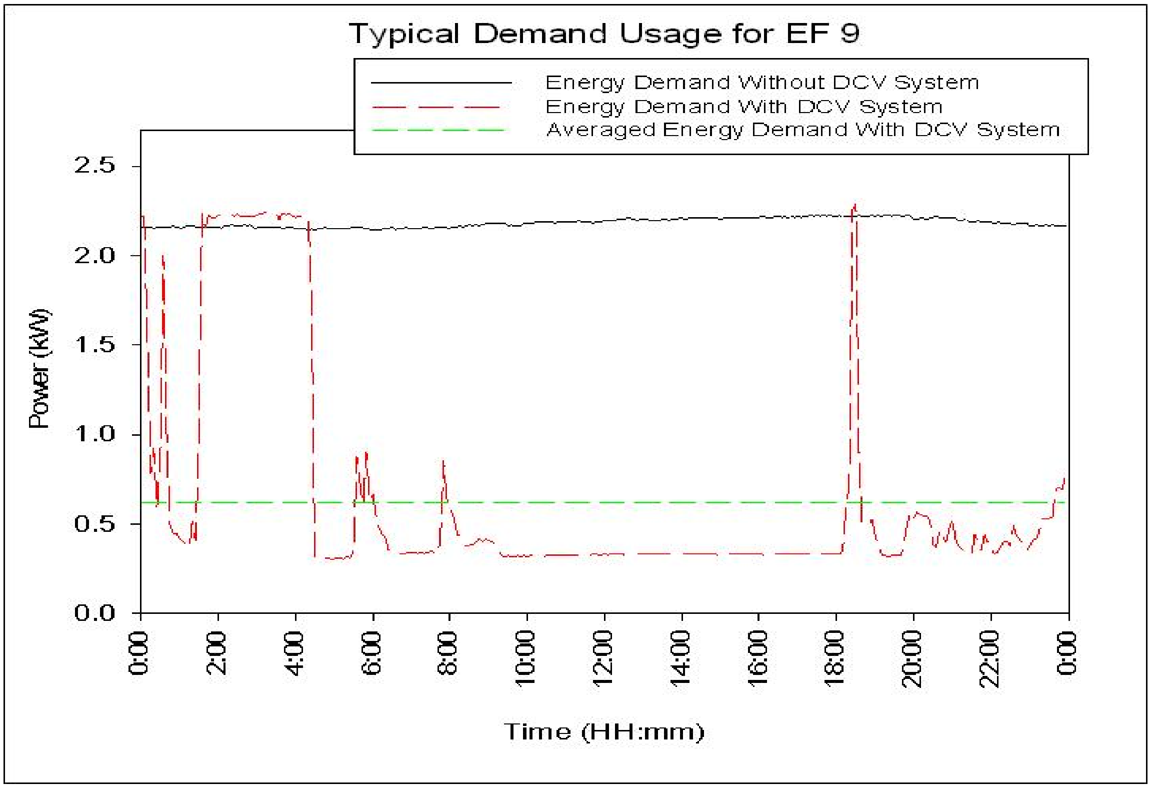

FIGURE 26 TYPICAL DEMAND USAGE FOR EF 9 AT WESTIN MISSION HILLS

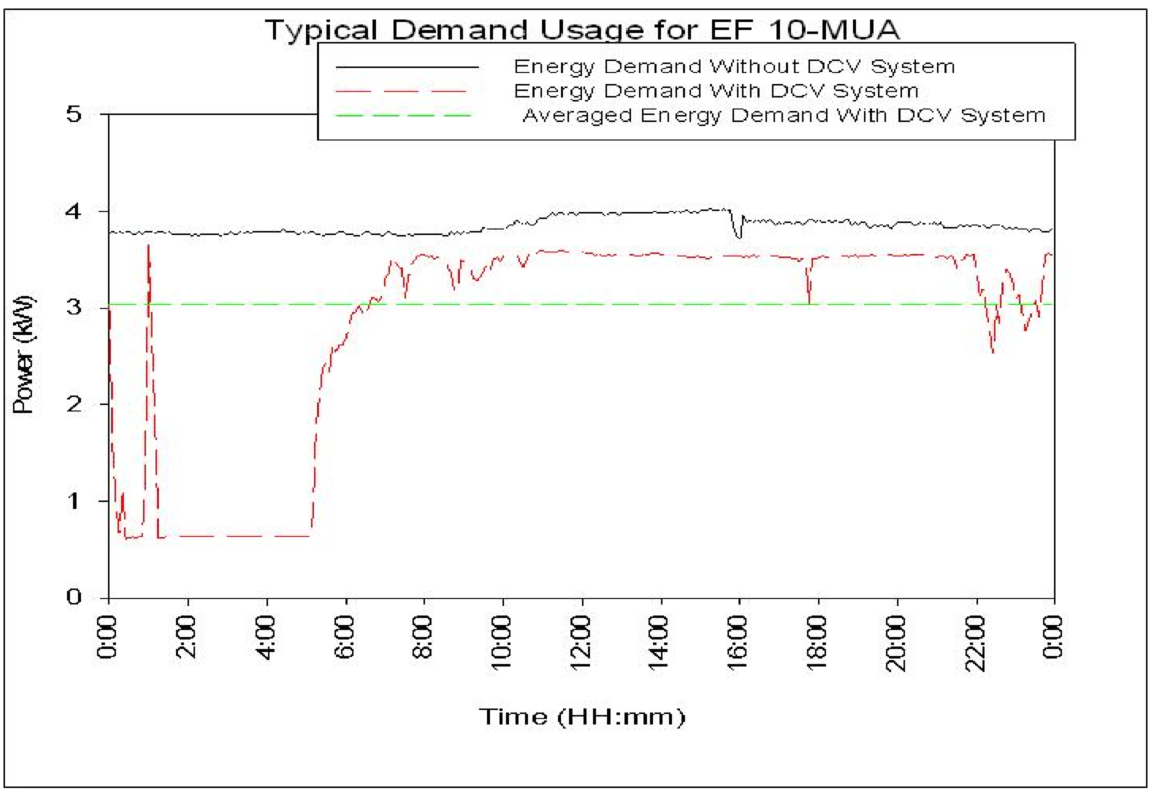

FIGURE 27 TYPICAL DEMAND USAGE FOR EF 10 / MUA AT WESTIN MISSION HILLS

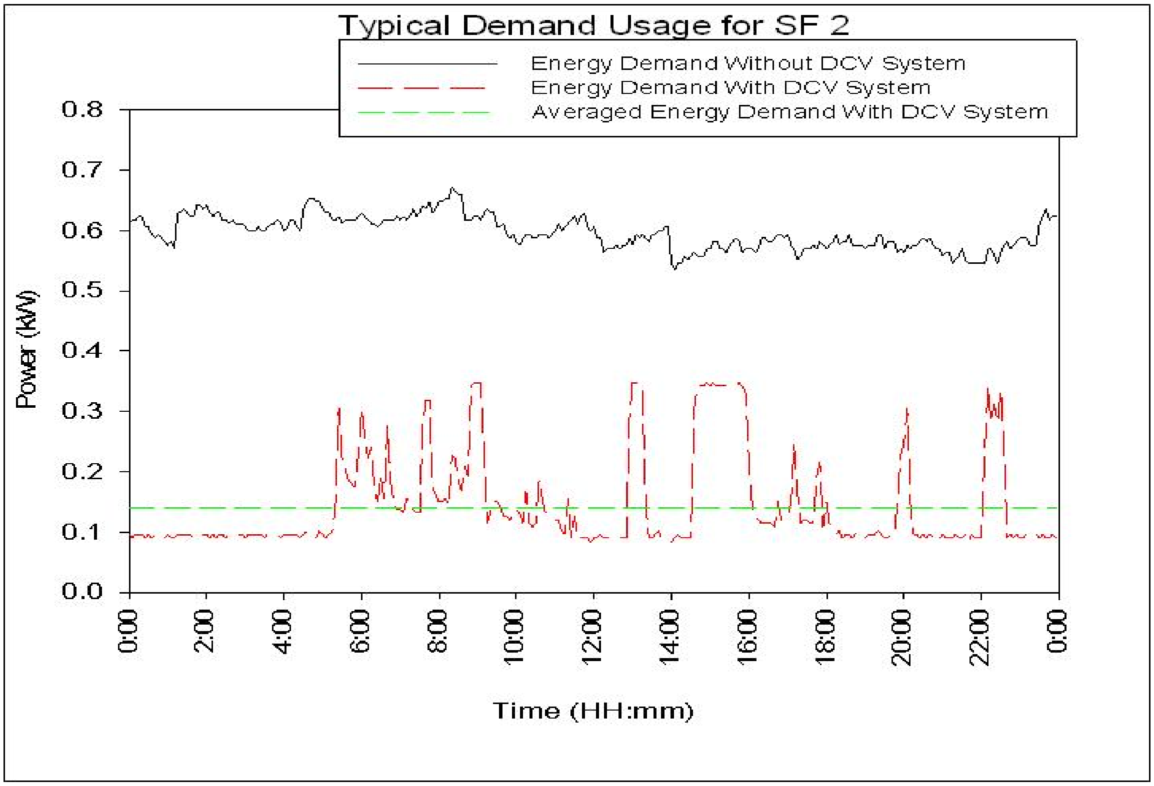

FIGURE 28 TYPICAL DEMAND USAGE FOR SF 2 AT WESTIN MISSION HILLS

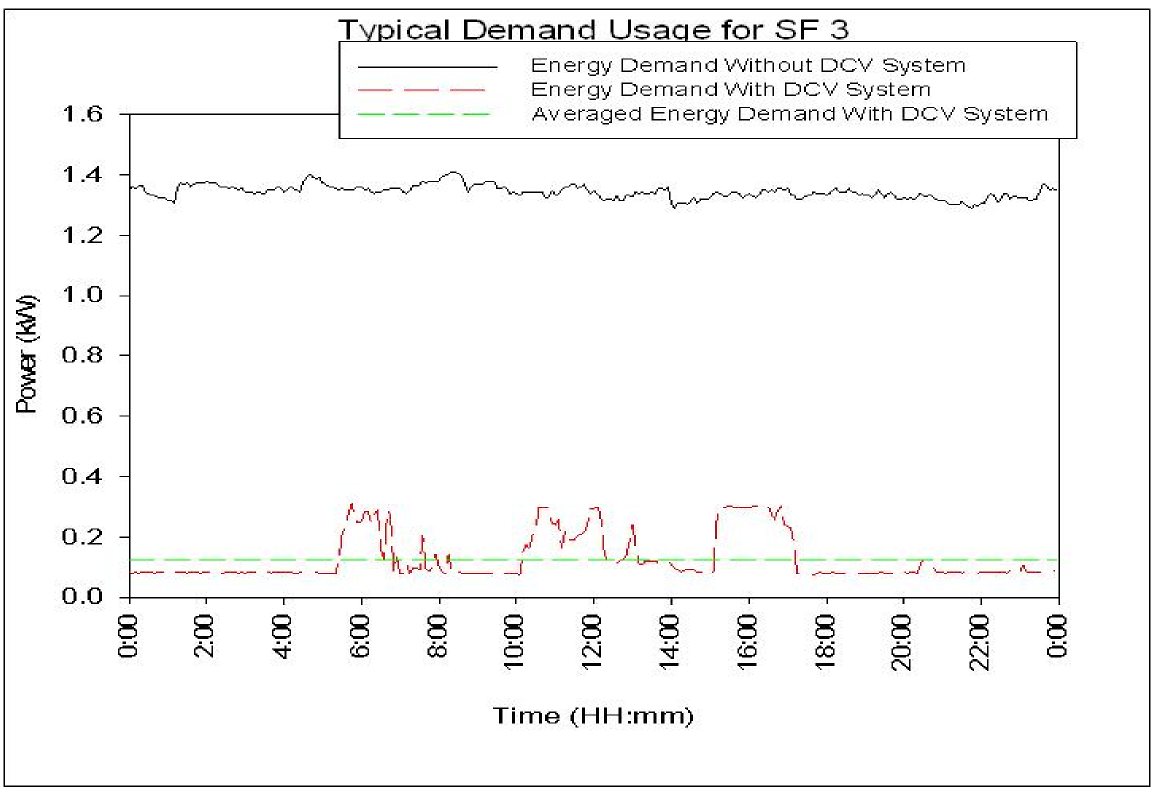

FIGURE 29 TYPICAL DEMAND USAGE FOR SF 3 AT WESTIN MISSION HILLS

APPENDIX C – EL POLLO LOCO

KITCHEN HOOD DESCRIPTION

Hood 1 is a 10-ft single-island canopy hood. The exhaust fan motors are labeled EF 1 and 2 which have a rated horse power of 1 hp each. The MUA fan motor is labeled MUA 1 and has a rated horse power of 3 hp. The MUA fan motor services all hoods in the kitchen. The appliances under the hood from left to right as shown in Figure 30 include two 4-ft charbroilers. This cookline is used for flame grilling the chicken.

FIGURE 30 EL POLLO LOCO HOOD 1

Hood 2 is a 10-ft wall-mounted canopy hood. The exhaust fan motor is labeled EF 2 and has a rated horse power of 1 hp. The MUA fan motor is labeled MUA 1 and has a rated horse power of 3 hp. The MUA fan motor services all hoods in the kitchen. The appliances under the hood from left to right as shown in Figure 31 include a 6-pan double-stack combination oven, a 10-pan combination oven, and a holding cabinet. This cookline is used for pre-cooking the chicken and batch cooking of other products.

FIGURE 31 EL POLLO LOCO HOOD 2

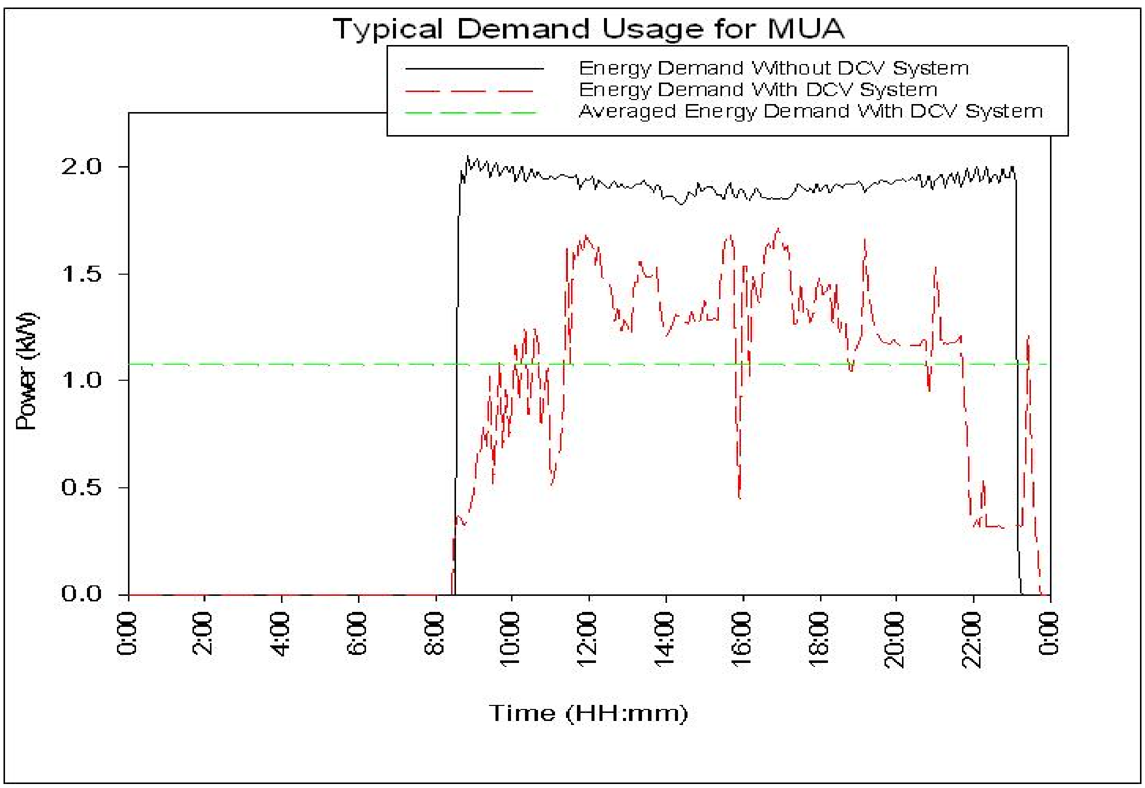

FIGURE 32 TYPICAL DEMAND USAGE FOR MUA AT EL POLLO LOCO

APPENDIX D – PANDA EXPRESS

KITCHEN HOOD DESCRIPTION

Hood 1 is an 8-ft wall-mounted canopy hood. The exhaust fan motor is labeled EF 1 and has a rated horse power of 2 hp. The MUA fan motor is labeled MUA 1 and has a rated horse power of 1 hp. The MUA fan motor services the two hoods in the kitchen. The appliances under the hood from left to right as shown in Figure 33 include a double-gas fired wok and a single-gas fired wok. This cookline is used for cooking menu items in batches.

FIGURE 33 PANDA EXPRESS HOOD 1

Hood 2 is an 8-ft wall-mounted canopy hood. The exhaust fan motor is labeled EF 2 and has a rated horse power of 2 hp. The MUA fan motor is labeled MUA 1 and has a rated horse power of 1 hp. The MUA fan motor services the two hoods in the kitchen. The appliances under the hood from left to right as shown in Figure 34 include an 18-in split vat fryer, a single-gas fired wok, and a gas-fired rice cooker. This cookline is used for cooking menu items in batches.

FIGURE 34 PANDA EXPRESS HOOD 2

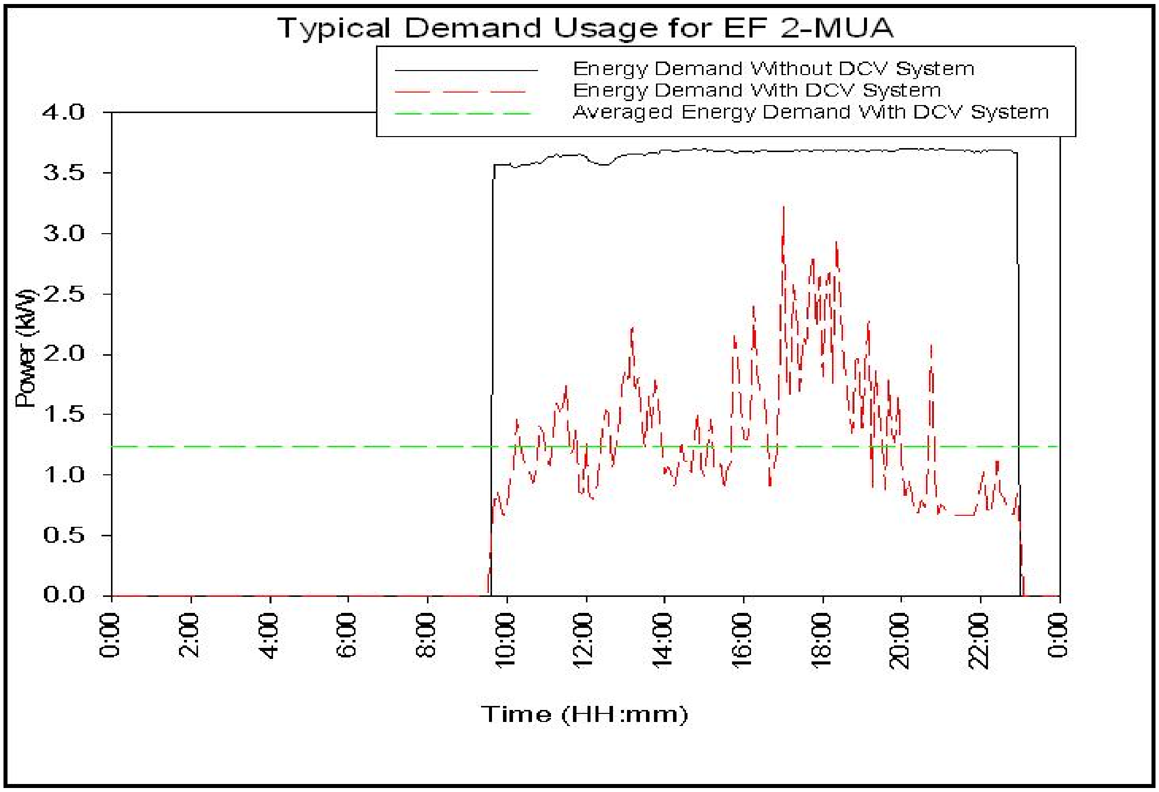

FIGURE 35 TYPICAL DEMAND USAGE FOR EF 2 / MUA AT PANDA EXPRESS

APPENDIX E – FARMER BOYS

KITCHEN HOOD DESCRIPTION

Hood 1 is a 6-ft single-island canopy hood. The exhaust fan motor is labeled EF 1 and has a rated horse power of 0.5 hp. The appliances under the hood from left to right as shown in Figure 36 include four 14-in fryers. This cookline is used for frying menu items in batches.

FIGURE 36 FARMER BOYS HOOD 1

Hood 2 is a 6-ft wall-mounted canopy hood. The exhaust fan motor is labeled EF 1 and has a rated horse power of 1 hp. The appliances under the hood from left to right as shown in Figure 37 include a 2-ft charbroiler on top of a 2-door refrigerator, a 3-ft countertop griddle on top of a 2-door refrigerator, and a hot food holding well. This cookline is rarely used and is on stand-by when there is an increased food demand.

FIGURE 37 FARMER BOYS HOOD 2

Hood 3 is a 6-ft wall-mounted canopy hood. The exhaust fan motor is labeled EF 1 and has a rated horse power of 1 hp. The appliances under the hood from left to right as shown in Figure 38 include a 2-burner countertop range on top of a 2-door refrigerator, a 3-ft countertop griddle on top of a 2-door refrigerator, and a 2-ft charbroiler on top of a 2-door refrigerator. This cookline is the main cookline used for all cook-to-order menu items.

FIGURE 38 FARMER BOYS HOOD 3

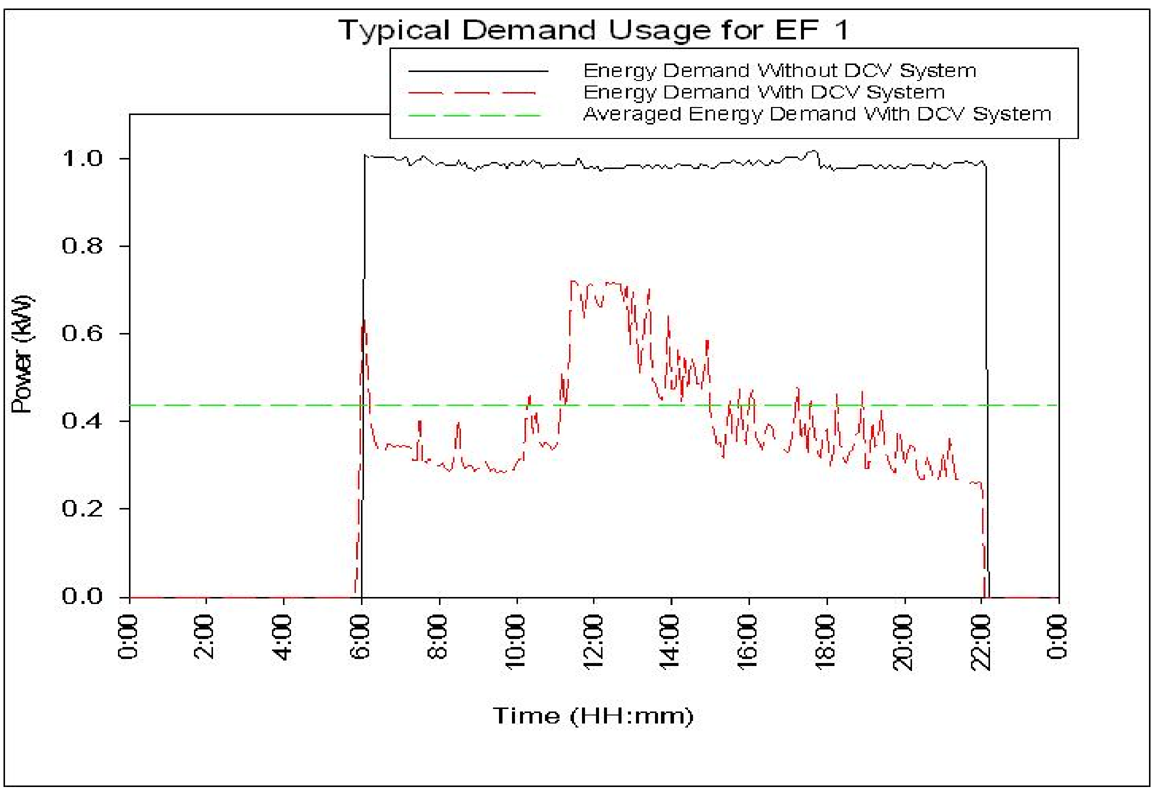

FIGURE 39 TYPICAL DEMAND USAGE FOR EF 1 AT FARMER BOYS

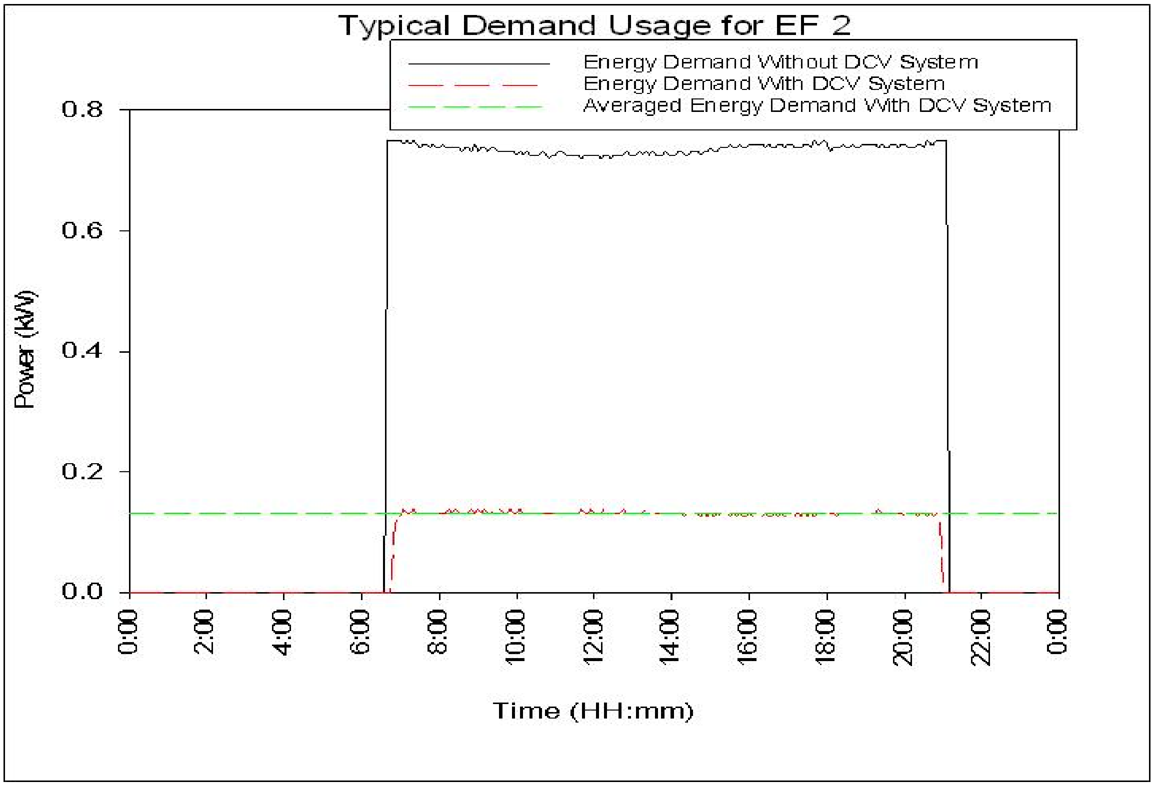

FIGURE 40 TYPICAL DEMAND USAGE FOR EF 2 AT FARMER BOYS

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1. Design Guide 1 Improving Commercial Kitchen Ventilation System Performance, Selecting and Sizing Exhaust Hoods. http://www.fishnick.com/equipment/ckv/designguides/

2. Design Guide 2 Improving Commercial Kitchen Ventilation System Performance, Optimizing Make Up Air. http://www.fishnick.com/equipment/ckv/designguides/