Demand Ventilation in Commercial Kitchens
An Emerging Technology Case Study

Melink *Intelli-Hood® Controls*
Supermarket Application

FSTC Report 5011.06.13

Food Service Technology Center
September 2006

Prepared by:
Angelo Karas
Don Fisher

Fisher-Nickel, inc.
12949 Alcosta Blvd.
San Ramon, CA 94583
www.fishnick.com

Prepared for:
Pacific Gas & Electric Company
Customer Energy Efficiency Programs
PO Box 770000
San Francisco, California 94177

The information in this report is based on data generated at Pacific Gas and Electric Company's Food Service Technology Center.

Acknowledgments

California consumers are not obligated to purchase any full service or other service not funded by this program. This program is funded by California utility ratepayers under the auspices of the California Public Utilities Commission.

Los consumidores en California no estan obligados a comprar servicios completos o adicionales que no esten cubiertos bajo este programa. Este programa esta financiado por los usuarios de servicios públicos en California bajo la jurisdiccion de la Comision de Servicios Públicos de California.

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

Policy on the Use of Food Service Technology Center Test Results and Other Related Information

- Fisher-Nickel, inc. and the Food Service Technology Center (FSTC) do not endorse particular products or services from any specific manufacturer or service provider.
- The FSTC is *strongly* committed to testing food service equipment using the best available scientific techniques and instrumentation.
- The FSTC is neutral as to fuel and energy source. It does not, in any way, encourage or promote the use of any fuel or energy source nor does it endorse any of the equipment tested at the FSTC.
- FSTC test results are made available to the general public through technical research reports and publications and are protected under U.S. and international copyright laws.
- In the event that FSTC data are to be reported, quoted, or referred to in any way in publications, papers, brochures, advertising, or any other publicly available documents, the rules of copyright must be strictly followed, including written permission from Fisher-Nickel, inc. *in advance* and proper attribution to Fisher-Nickel, inc. and the Food Service Technology Center. In any such publication, sufficient text must be excerpted or quoted so as to give full and fair representation of findings as reported in the original documentation from FSTC.

Legal Notice

This report was prepared as a result of work sponsored by the California Public Utilities Commission (Commission). It does not necessarily represent the views of the Commission, its employees, or the State of California. The Commission, the State of California, its employees, contractors, and subcontractors make no warranty, express or implied, and assume no legal liability for the information in this report; nor does any party represent that the use of this information will not infringe upon privately owned rights. This report has not been approved or disapproved by the Commission nor has the Commission passed upon the accuracy or adequacy of the information in this report.

Disclaimer

Neither Fisher-Nickel, inc. nor the Food Service Technology Center nor any of its employees makes any warranty, expressed or implied, or assumes any legal liability of responsibility for the accuracy, completeness, or usefulness of any data, information, method, product or process discloses in this document, or represents that its use will not infringe any privately-owned rights, including but not limited to, patents, trademarks, or copyrights.

Reference to specific products or manufacturers is not an endorsement of that product or manufacturer by Fisher-Nickel, inc., the Food Service Technology Center or Pacific Gas & Electric Company (PG&E). Retention of this consulting firm by PG&E to develop this report does not constitute endorsement by PG&E for any work performed other than that specified in the scope of this project.

TABLE OF CONTENTS

Page

FIGURES

Page

TABLES

Page

Executive Summary

The objective of this case study was to evaluate the Melink *Intelli-Hood®Controls* demand ventilation control (DVC) package that was installed on the commercial kitchen ventilation (CKV) system in a supermarket in Northern California. Within the scope of the State-Wide Emerging Technologies Program and under the direction of PG&E, the study examined and compared the energy consumption and demand of the kitchen ventilation fans with and without the DVC system in operation.

The kitchen utilized three cooking lines with an exhaust hood over each: a rear deli line with a 9500 cfm hood, a front deli line with 5800 cfm hood and a Chinese cuisine line with two 4250 cfm side-by-side hoods, for a total exhaust ventilation rate of 23,800 cfm. Each cooking line also had a makeup air unit that supplied untempered outside air through ceiling diffusers.

The Melink *Intelli-Hood®Controls* system is designed to reduce fan energy consumption by slowing the exhaust and makeup air fans whenever full speed is not needed. It modulates the speed of motors with variable frequency drives (VFDs) based on input that it receives from two sources: (1) a temperature sensor(s) mounted in the exhaust duct and (2) an infrared (IR) beam that spans the length of the exhaust hood. An increase in the exhaust duct temperature or a disturbance in the IR beam signals the controller to increase the fan speed until the heat, smoke or steam is removed. As a function of the average fan speed and resultant airflow reduction, the energy required for makeup air heating and cooling is also reduced.

Implementation of this demand ventilation control strategy was shown to significantly reduce the energy consumption, electrical demand and cost associated with operating this supermarket CKV system. The average daily fan energy consumption was reduced by 74%—from 118 kWh/day without demand ventilation controls to 31 kWh/day with the controls. This represents an annual energy reduction of 31,370 kWh and cost savings of $3,770. The average fan power decreased from 8.5 kW to 2.3 kW for a 6.2 kW reduction, and the peak load reduction coincident with the statewide summertime peak demand hours of 12:00 noon to 6:00 pm decreased from 8.5 kW to 2.7 kW, a 70% demand reduction of 5.8 kW, which yielded a demand charge savings of $550 per year.

Figure ES-1 illustrates the combined exhaust fan power profile over the course of a typical operating day, with dashed lines indicating the average power with and without DVC. Figure ES-2 illustrates the total average daily fan energy consumption as well as the average reduction.

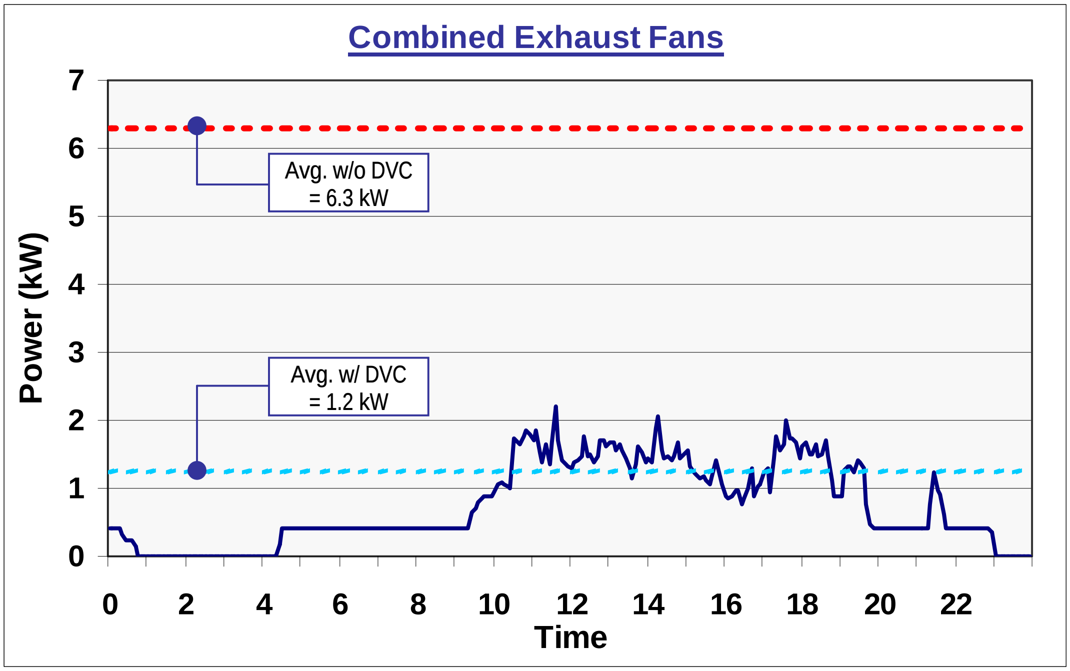

Figure ES-1. Combined Exhaust Fan Typical-Day Power Profile with DVC

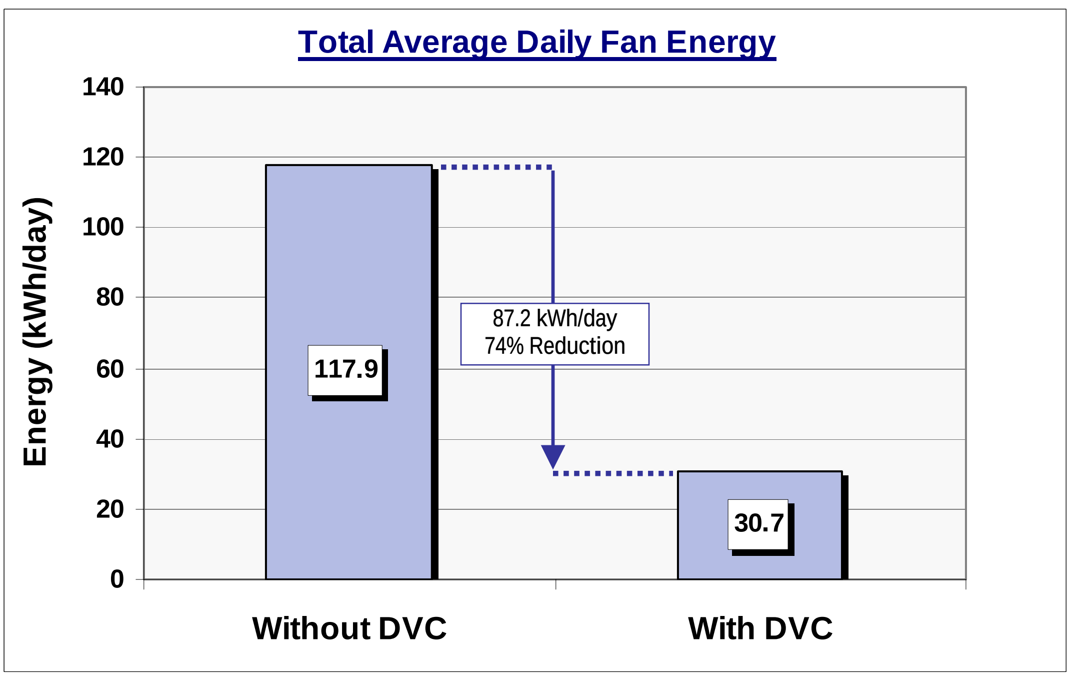

Figure ES-2. Total Average Daily Fan Energy Consumption with and without DVC

Additional cost savings were derived from the makeup air heating and cooling energy load reduction. The average exhaust (and associated makeup) airflow reduction was calculated to be approximately 40% (or 9,520 cfm), based on the measured average fan power reduction, using the applicable fan law. The calculated energy saved by subtracting this portion of makeup air was 3,800 therms/yr for heating and 9,900 kWh/yr for cooling, which yielded another $4,990/yr savings.

Combined total yearly operating cost savings derived from the fan energy reduction, demand reduction, and makeup air heating and cooling load reduction were $9,310. The installed cost of this Melink *Intelli-Hood®Controls* system for this application was approximately $18,000, which results in a payback period in the order of 1.9 years. Table ES-1 presents a summary of the demand ventilation control system energy and cost savings.

Table ES-1. Energy and Operating Cost Savings Summary

	Exhaust	Makeup Air	Total
Yearly Fan Energy without DVC (kWh)	32,920	9,510	42,430
Yearly Fan Energy with DVC (kWh)	6,300	4,755	11,060
Yearly Fan Energy Reduction (kWh)	26,620	4,755	31,370
Yearly Fan Energy Cost without DVC	$3,950	$1,140	$5,090
Yearly Fan Energy Cost with DVC	$750	$570	$1,320
Yearly Fan Energy Cost Savings	$3,200	$570	$3,770
Demand Reduction (kW)			5.8
Yearly Demand Charge Savings			$550
Yearly Heating Load Energy Reduction (therms)			3,800
Yearly Cooling Load Energy Reduction (kWh)			9,900
Yearly Heating and Cooling Energy Cost Savings			$4,990
Total Yearly Operating Cost Savings			$9,310
DVC System Installed Cost			$18,000
Pay Back Period			1.9 years

Calculated using $0.12/kWh, $8.00/kW monthly demand, $1.00/therm, operating 360 days per year (All values are rounded)

Introduction

Objective and Scope

The purpose of this field study was to measure the electrical energy and demand reduction realized from the installation of the Melink *Intelli-Hood*® *Controls* system—an emerging demand ventilation control (DVC) technology—at a supermarket kitchen in Northern California. The scope of the study included calculating the associated makeup air heating and cooling load reductions.

Within the State-Wide Emerging Technologies Program and under the direction of PG&E, the FSTC monitored energy consumption of the exhaust and makeup air fans with and without the demand ventilation in operation. The results of this case study can be used as another example that demonstrates the cost benefit of a commercial kitchen, demand ventilation control package.

Demand Ventilation Control (DVC) System Description

The Melink *Intelli-Hood*® *Controls* package (Figure 1) is a demand-ventilation-based energy management system for commercial kitchen exhaust hoods that minimizes fan energy use by reducing the exhaust and makeup air fan speed when little or no cooking is occurring. Furthermore, as a function of the fan speed and associated airflow reductions, makeup air heating and cooling energy is also reduced; in addition, the kitchen ambient noise level is significantly decreased.

The *Intelli-Hood*® system processor controls the speed of the exhaust and makeup air fans through variable frequency drives (VFDs) based on input signals it receives from two sensor sources: temperature probes placed in the exhaust duct collars, and optic sensors with an infrared (IR) beam that crosses the bottom of the exhaust hood. As a temperature probe senses a rise in temperature, the controller signals the fans to increase proportionally from a predetermined minimum speed to a controlled setpoint speed that is based on the temperature range programmed into the system; an appliance in either a cooking or a standby mode of operation can generate varying levels of temperature rise, and the fan speed is adjusted accordingly. The optic sensor IR beam can be broken by either smoke or steam produced by the cooking process; when this beam is sufficiently obstructed, the fans will go to 100 percent speed (or a preset maximum speed) until the smoke or smoke or steam is cleared.

Since the fans will operate at full speed only when required, the DVC system allows for ventilation rate safety factor for intermittent peak cooking load situations without sacrificing the reduced energy consumption of a lower average ventilation rate.

Introduction

Effective controller programming that is tailored for each equipment line and accompanying hood during system commissioning achieves optimized performance and savings. Each *Intelli-Hood*® processor can receive inputs from up to four separate hoods and then output control signals to VFDs for each hood's respective exhaust and supply fans. Cost-effectiveness increases proportionally with the ventilation system total airflow, applied fan power and operating time.

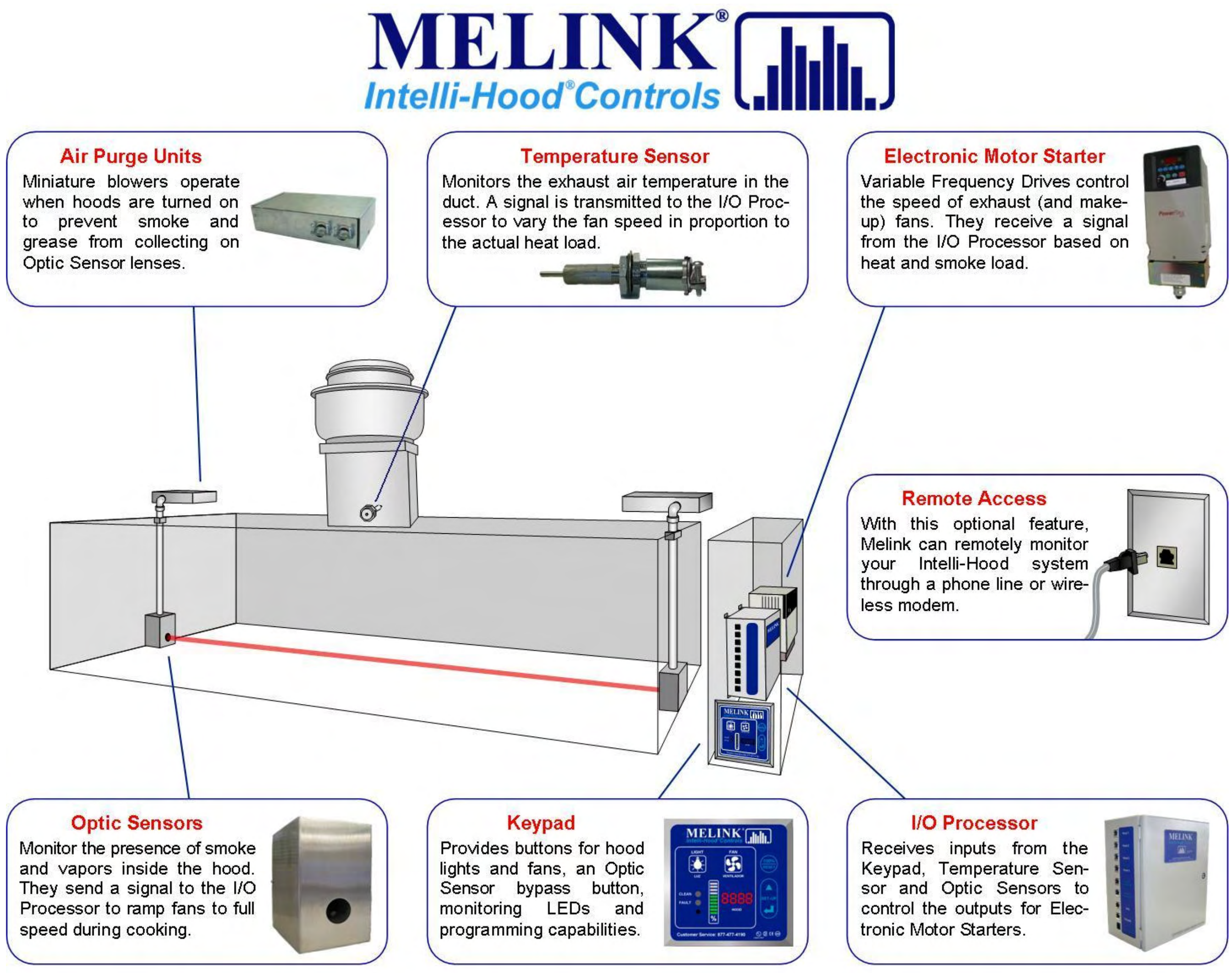

Figure 1. Melink Intelli-Hood® Controls System (Courtesy of Melink®)

Introduction

Site Description

This supermarket kitchen utilizes three cooking lines with wall-mounted canopy exhaust hoods: a rear deli cooking line with a 9500 CFM hood, a front deli cooking line with 5800 CFM hood and a Chinese cuisine cooking line with two 4250 CFM side-by-side hoods (designated Left Wok and Right Wok), for a total exhaust ventilation rate of 23,800 cfm. The kitchen also uses dedicated, un-tempered makeup air units, switched on via interlock with the exhaust fans, that supply outdoor air through ceiling diffusers. Figures 2 through 4 show each cooking line and hood configuration.

The kitchen ventilation system was originally equipped with manual fan control with individual wall switches at each hood. It was then retrofitted with a Melink *Intelli-Hood®Controls* demand ventilation control system, which was configured for fully automatic operation that would turn the fans on upon first detection of heat or smoke and then off at the end of the day after the equipment cooled.

Figure 2. Rear Deli Cooking Line

Figure 3. Front Deli Cooking Line

Figure 4. Chinese Cuisine Cooking Line

Procedure

Prior to the installation of the supermarket kitchen DVC system, full-speed exhaust and makeup air fan motor power values were measured and recorded with a Summit Technology PowerSight power analyzer. After the DVC system was installed and operating, data loggers were installed to record power and energy consumption – tracking the varying load profiles generated by the control system. Dent Instruments ElitePro data loggers, placed in the electrical service panel feeding each exhaust fan motor, recorded measurements at 5-minute intervals for a period of two weeks.

As part of the demand ventilation control strategy applied to this kitchen, by effectively lowering the average exhaust rates with the DVC system, the makeup air units were switched off, and the decreased requisite amount of makeup air was supplied by the supermarket main floor HVAC system air handler unit. Since the main air handler fan assumed the energy load of the makeup air fans, the associated makeup air fan energy reduction could not be directly measured and was therefore estimated.

Daily without-DVC fan energy consumption was calculated using the full-speed power readings multiplied by daily operating time. Due to inconsistent on-off time operating patterns while the exhaust fans were still manually controlled by the kitchen staff (before the DVC system installation), it was decided that the daily operating times that were recorded with the DVC system in operation would also be applied to the without-DVC exhaust fan energy consumption calculations, to allow for a more direct and normalized comparison of the equipment, independent of any variability in kitchen operating patterns. Yearly energy consumption was calculated using the average daily energy consumption values multiplied by 360 operating days per year.

Results and Discussion

Monitoring Results

Once the recorded data was collected and analyzed, power and energy consumption comparisons were made between the kitchen ventilation system with and without demand control. The exhaust fans running at full speed, while in manual control, operated at a continuous 6.3 kW total. With the demand controls in operation and the exhaust fan speeds varying in response to the cooking processes, the average exhaust fan power total decreased to 1.2 kW, for a 5.1 kW, 81% reduction.

The makeup air fan power reduction conservatively was estimated at 50% (compared to the 81% exhaust fan power reduction), and a 12-hour average daily operating time was used to calculate the combined makeup air fan energy savings. (It was not possible to directly measure the makeup air fan power reduction as the dedicated makeup up air units had been turned off as part of the DVC installation. Post DVC installation, all makeup air was supplied from the main building HVAC system.) Factoring the original makeup air fan power of 2.2 kW and the estimated 50% 1.1 kW power reduction, the combined total average fan power dropped from 8.5 kW down to 2.3 kW, for a 6.2 kW reduction. The combined-fan peak demand coincident with the statewide summertime peak hours of 12:00 noon to 6:00 pm decreased from 8.5 kW to 2.7 kW, yielding a demand reduction of 5.8 kW.

The average daily fan energy consumption was decreased from 91.5 kWh/d to 17.5 kWh/d for the exhaust fans and from 26.4 kWh/d to 13.2 kWh/d for the makeup air fans, yielding a 74% combined total fan energy savings of 87.2 kWh/d or 13,370 kWh/yr.

In addition to the fan energy savings gained from use of the DVC system, the reduction in exhaust and corresponding makeup airflow also resulted in less energy required to condition the supplied outdoor makeup air. Furthermore, in this application, where the reduced volume of supplied air now came through the main floor, it also greatly improved overall kitchen comfort, notably during cold mornings and hot afternoons, as the untempered makeup air that was originally supplied directly overhead or in close proximity of kitchen personnel was no longer being introduced into the kitchen.

Based on the measured average exhaust (and associated makeup) fan power reduction and using the applicable fan law, the average airflow reduction was calculated to be 40%, or 9,520 cfm. The heating and cooling load reduction derived from the deceased outdoor airflow was calculated by inputting the airflow and temperature values into the Outdoor Airload Calculator (OAC), a web-based tool developed by the FSTC (available at www.foodservicetechnologycenter.com), which generated a model of the annual heating and cooling load in kBtu based on ASHRAE weather data accessed by the calculator.

Results and Discussion

OAC input assumptions included heating the makeup air to 65ºF and cooling the makeup air to 76ºF while dehumidifying to 70% RH. The generated energy reduction values (shown in Appendix A) were 265,429 kBtu/yr for heating and 101,211 kBtu/yr for cooling. Applying a 70% heating efficiency and a cooling COP of 3.0, the estimated makeup air heating and cooling load reduction was calculated to be approximately 3800 therms/yr and 9,900 kWh/yr, respectively.

Table 1 lists the measured fan power values, operating times and energy consumption with and without the DVC system, the average daily energy reduction and percent reduction, and the yearly outdoor airload energy savings.

Table 1. Fan Power and Energy Consumption

	Rear Deli Exhaust	Front Deli Exhaust	Left Wok Exhaust	Right Wok Exhaust	Total Exhaust	Total Makeup Air	Combined Fan Total
Ventilation Rate (cfm)	9,600	5,800	4,250	4,250	23,800	---	---
Full-Speed Power without DVC (kW)	2.42	1.64	1.05	1.18	6.29	2.20	8.49
Average Power with DVC (kW)	0.41	0.40	0.21	0.22	1.23	1.10	2.33
Average Power Reduction (kW)	2.01	1.24	0.84	0.96	5.06	1.10	6.16
Average Daily Operating Time (hr)	17.8	11.5	13.2	13.3	---	12	---
Average Daily Energy without DVC (kWh)	43.1	18.8	13.9	15.7	91.5	26.4	117.9
Average Daily Energy with DVC (kWh)	7.21	4.61	2.79	2.88	17.5	13.2	30.7
Average Daily Energy Reduction (kWh)	35.9	14.2	11.1	12.8	74.0	13.2	87.2
Percent Energy Reduction (%)	83.3	75.5	79.9	81.6	80.9	50.0	74.0
Yearly Heating Load Energy Reduction (therms)							3,800
Yearly Cooling Load Energy Reduction (kWh)							9,900

Figure 5 illustrates the combined exhaust and makeup air fan total average daily energy consumption with and without the DVC system in operation and the reduction achieved with DVC. Figures 6 through 10 illustrate the typical-day power profile of the exhaust fans. They include dashed lines indicating the higher, full-speed fan power before DVC and also the reduced average fan power resulting from DVC. The typical-day profiles were chosen so that the daily energy consumption of each profiled day most closely matched the average daily energy consumption value.

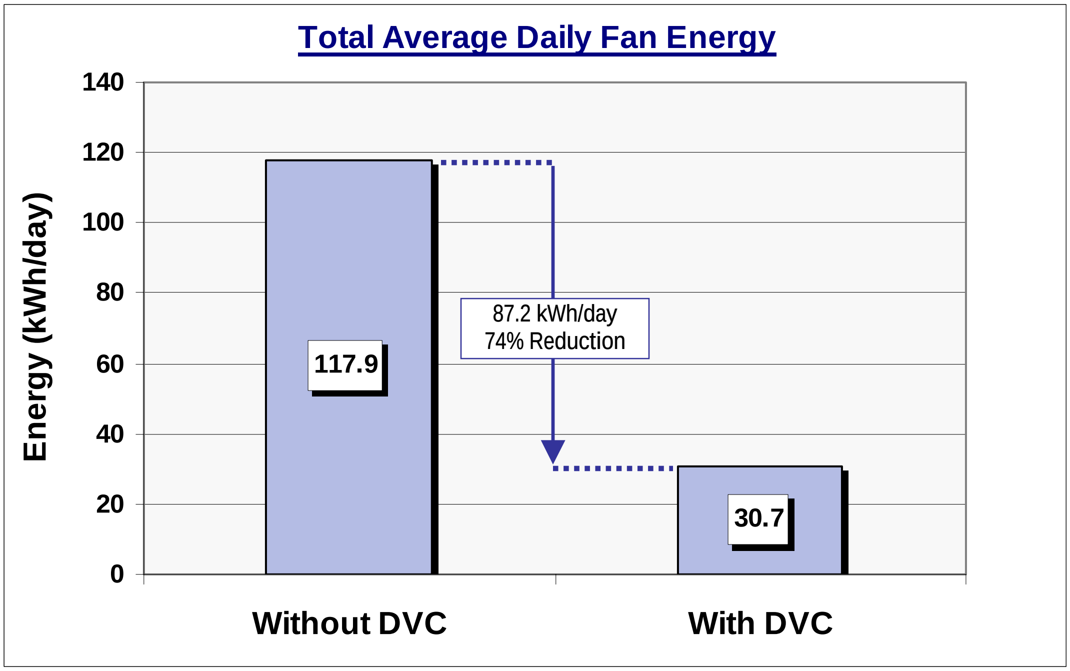

Figure 5. Total Average Daily Fan Energy Consumption with and without DVC

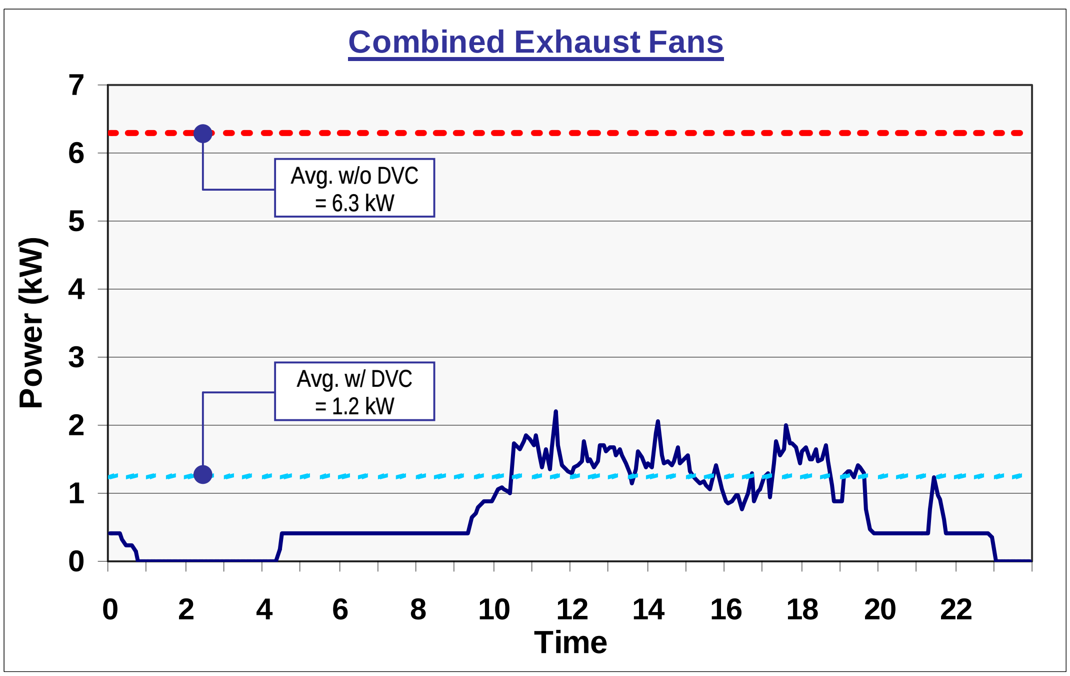

Figure 6. Combined Exhaust Fan Typical-Day Power Profile with DVC

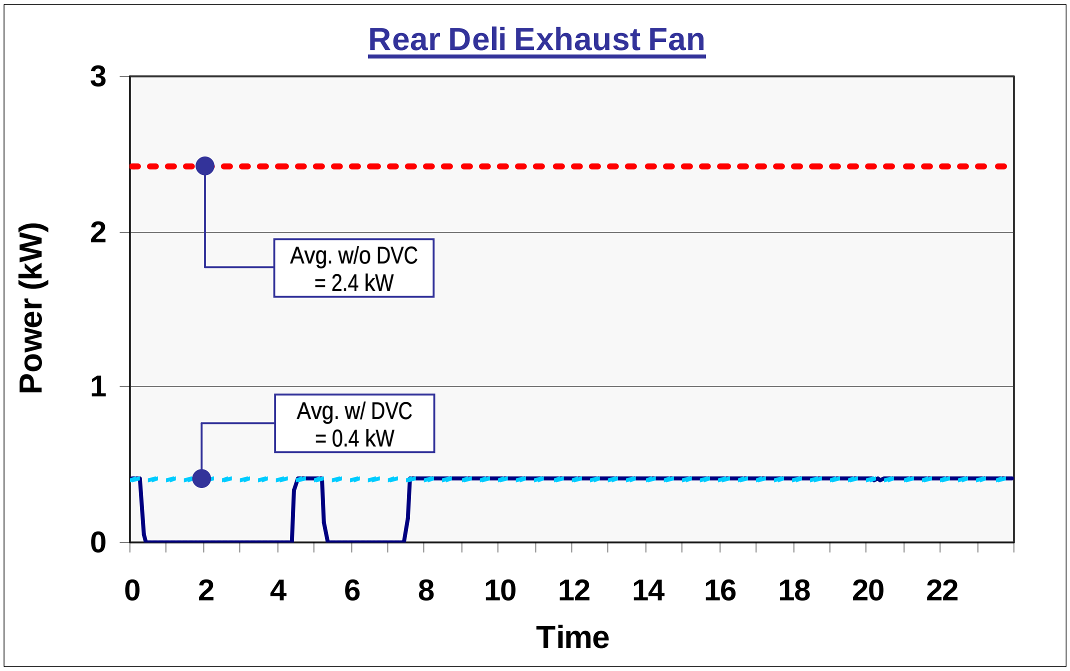

Figure 7. Rear Deli Hood Typical-Day Power Profile with DVC

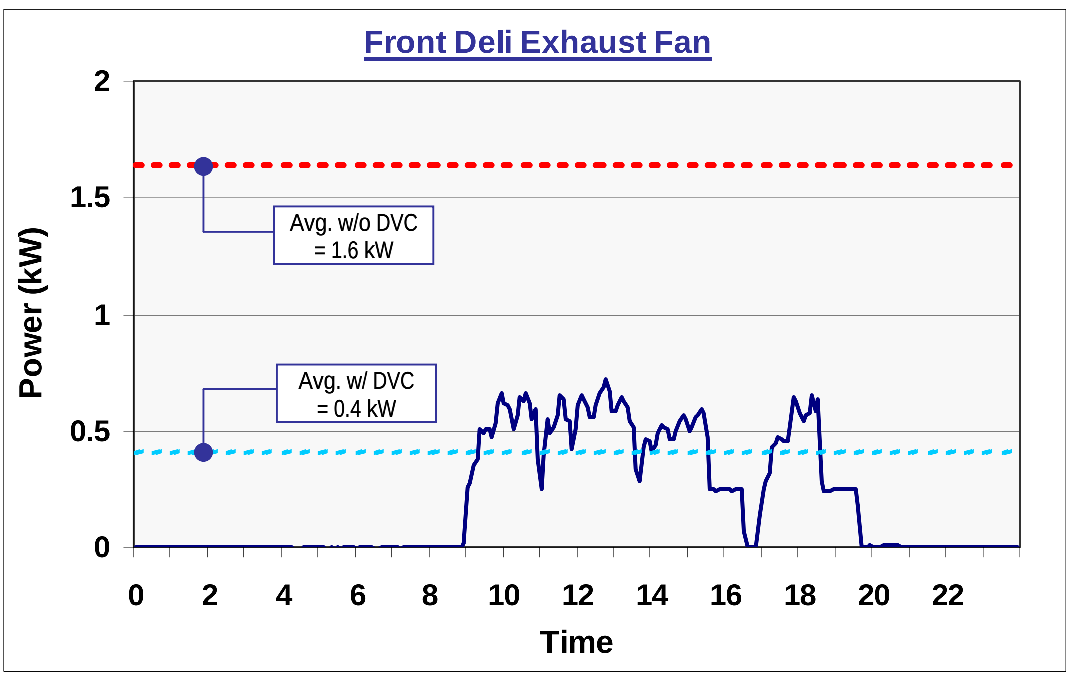

Figure 8. Front Deli Hood Typical-Day Power Profile with DVC

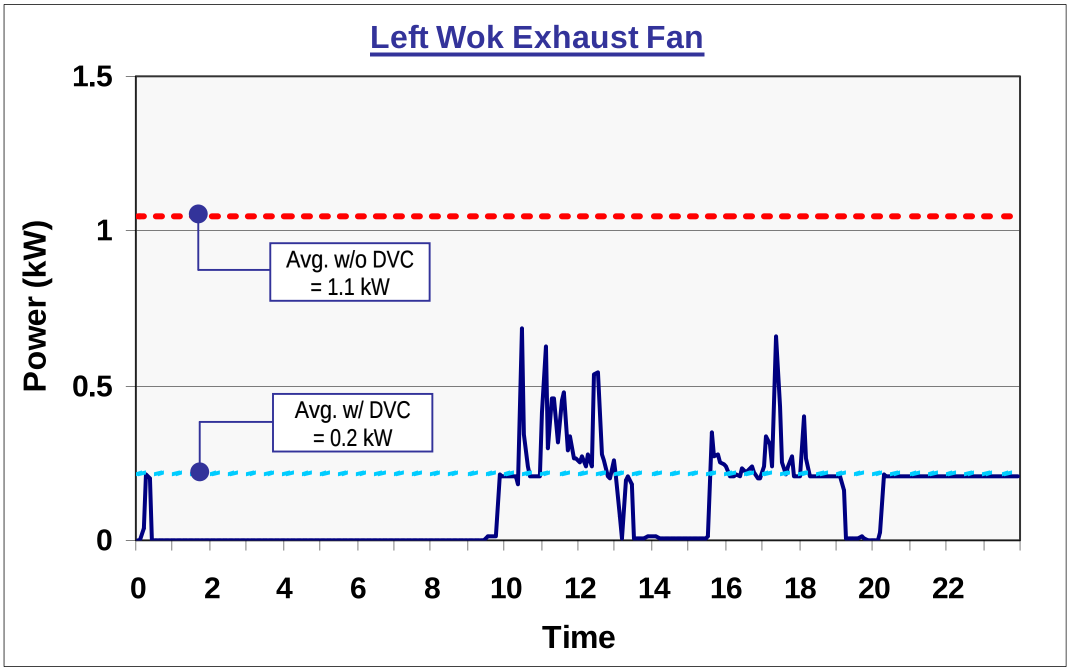

Figure 9. Left Wok Hood Typical-Day Power Profile with DVC

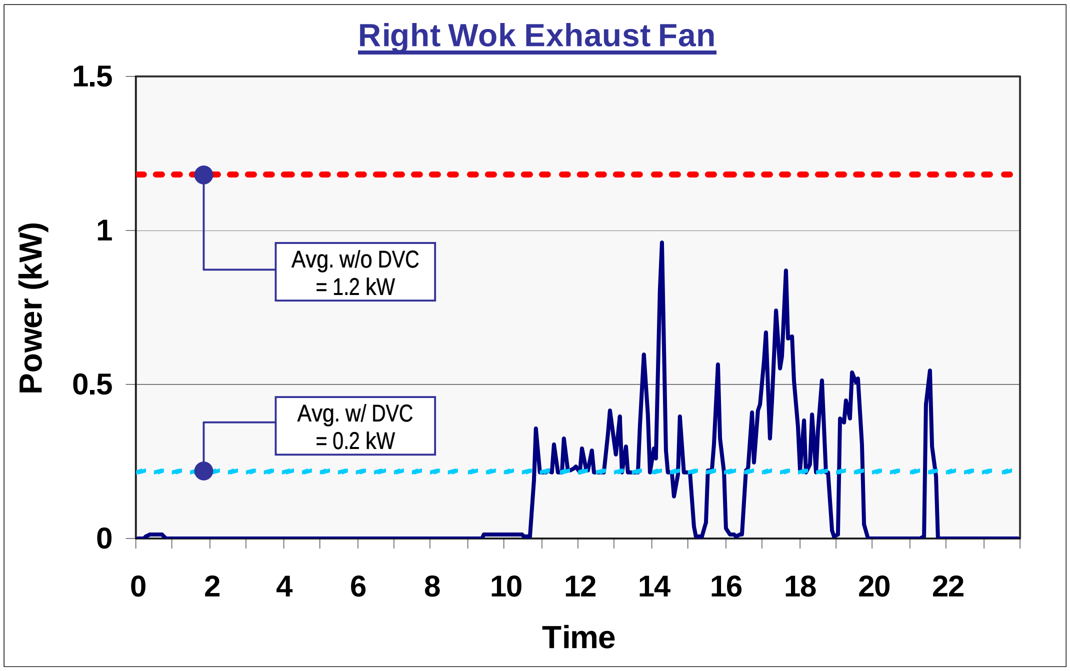

Figure 10. Right Wok Hood Typical-Day Power Profile with DVC

Results and Discussion

Energy Cost Savings and Payback

The 31,370 kWh per year total fan energy reduction yielded annual cost savings of $3,770, and the demand charge savings achieved from the 5.8 kW demand reduction were $550 per year. Additionally, the 9,520 cfm average ventilation rate reduction lowered the outdoor-air heating load by an estimated 3,800 therms per year and the cooling load by an estimated 9,900 kWh per year, for operating cost savings of $3,800 and $1,190, respectively. Combining the fan energy, demand charge and outdoor-air load cost savings together, the overall annual operating cost of this supermarket kitchen was reduced by $9,310 per year. The installed cost of the Melink *Intelli-Hood®Controls* system in this facility was approximately $19,000, which makes the calculated simple payback period for this DVC installation 1.9 years. Table 2 summarizes the overall energy savings, cost savings and the simple payback period achieved with the DVC system retrofit.

Table 2. Energy and Operating Cost Savings Summary

	Exhaust	Makeup Air	Total
Yearly Fan Energy without DVC (kWh)	32,920	9,510	42,430
Yearly Fan Energy with DVC (kWh)	6,300	4,755	11,060
Yearly Fan Energy Reduction (kWh)	26,620	4,755	31,370
Yearly Fan Energy Cost without DVC	$3,950	$1,140	$5,090
Yearly Fan Energy Cost with DVC	$750	$570	$1,320
Yearly Fan Energy Cost Savings	$3,200	$570	$3,770
Demand Reduction (kW)			5.8
Yearly Demand Charge Savings			$550
Yearly Heating Load Energy Reduction (therms)			3,800
Yearly Cooling Load Energy Reduction (kWh)			9,900
Yearly Heating and Cooling Energy Cost Savings			$4,990
Total Yearly Operating Cost Savings			$9,310
DVC System Installed Cost			$18,000
Pay Back Period			1.9 years

Calculated using $0.12/kWh, $8.00/kW monthly demand, $1.00/therm, operating 360 days per year (All values are rounded)

Conclusions and Recommendations

The savings resulting from this Melink *Intelli-Hood*®*Controls* system installation affirmed that demand ventilation control (DVC) can be a cost-effective solution to reducing the energy load and cost of operating exhaust ventilation systems in foodservice operations.

In addition to the fan operating cost and heating/cooling load energy cost savings, there were the added benefits of a significant reduction in the noise level generated in the kitchen by the exhaust ventilation system and more comfortable ambient temperatures due to the elimination of the unconditioned hot/cold outside makeup air. Although the positive benefit of a quieter and more comfortable kitchen is not as easily quantified, this is undoubtedly an overall improvement to the kitchen environment that could potentially lead to happier and more productive kitchen personnel.

With all these advantages in mind, the Food Service Technology Center supports the application of commercial kitchen demand ventilation control and initiatives by California utilities to encourage market transformation through targeted education and/or financial incentives for this emerging technology.

Appendix A: Outdoor Air Load Calculations

Result summary for Calculation Number: 1

Location:	SACRAMENTO, California
Elevation:	26 ft
Operating Hours:	8:00 o'clock until 20:00 o'clock
Hours of Operation:	12
Makeup Air Flow:	9520 cfm
Thermostat Setpoints:	Heating = 65 F, Cooling = 76 F

Dehumidification was set to limit the Relative Humidity to: 70 %
Based on a Space Temperature of: 76 F, with Reheating Option

Calculated Monthly loads:

Month	Heating Load	Cooling Load
January	66,541 kBtu	0 kBtu
February	38,518 kBtu	0 kBtu
March	38,226 kBtu	0 kBtu
April	17,149 kBtu	472 kBtu
May	2,402 kBtu	7,951 kBtu
June	440 kBtu	16,567 kBtu
July	0 kBtu	29,289 kBtu
August	433 kBtu	29,025 kBtu
September	25 kBtu	15,201 kBtu
October	2,772 kBtu	2,705 kBtu
November	32,266 kBtu	0 kBtu
December	66,656 kBtu	0 kBtu
Total_Year	265,429 kBtu	101,211 kBtu