Evaluation of a Kitchen Ventilation Demand Control System Installed in a Swiss Chalet, Alliston, Ontario

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BACKGROUND

The energy intensity and utility costs associated with operating a commercial kitchen ventilation (CKV) system are recognized within the HVAC design community and food service industry. However, the commercial kitchen exhaust system and its associated makeup air system continue to be designed and operated as single speed ventilation systems, without the ability to respond to variations in cooking equipment usage in a working kitchen.

A more recent innovative and attractive energy saving strategy is the application of demand ventilation control (variable speed fan control) to kitchen exhaust systems. Demand control capitalizes on the fact that cooking appliances spend many hours in an idle or ready-to-cook mode that does not need the same ventilation rate as a cooking condition. The application of two-speed or variable speed fans can achieve reductions in exhaust (and makeup) airflow when appliances are not being used to capacity (or have been turned off). NFPA 96 (Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations) was amended in 2001 to permit a minimum exhaust duct velocity of 500 fpm (changed from 1500 fpm). This code change will facilitate retrofitting demand ventilation controls in existing kitchens.

OBJECTIVE

The objective of this Enbridge customer case study was to evaluate the technical and economic benefits of installing the Aerco VariSpeed, a commercially available, demand-ventilation (variable speed) control package, on the kitchen ventilation system at a Swiss Chalet restaurant in Alliston, Ontario. The overall goal is to promote energy-efficient design strategies for commercial kitchen ventilation (CKV) systems while the underlying benefit for Enbridge is effective demand side management (DSM) of the gas load associated with heating makeup air (MUA) in commercial kitchens.

AERCO VARISPEED *CONTROLS*

The Aerco *VariSpeed*™ *Controls* package is a demand-ventilation-based energy management system for commercial kitchen exhaust hoods (Figure 1). The *VariSpeed* controls the speed of the exhaust fans and MUA fan through variable frequency drives (VFDs) and the Aerco AutoAirBalance system. The controller receives input from temperature probes placed in the exhaust duct collars. As a temperature probe senses a rise in temperature, the controller signals VFDs on the exhaust fans to ramp up proportionally from a predetermined minimum speed to a predetermined maximum speed. A pressure differential sensor (between the kitchen and the outside of the restaurant) signals the controller to increase or decrease the makeup air by modulating the intake dampers on the rooftop unit. The VariSpeed processor can also control a two-speed makeup air unit or simply turn off a single-speed makeup air unit when there is an adequate supply of makeup air through the rooftop units. In this case, the makeup air unit was turned off when the exhaust rate dropped to its “idle” condition.

Figure 1. *VariSpeed Controls* (Courtesy of Aerco Industries).

DESCRIPTION OF EXHAUST VENTILATION SYSTEM

The exhaust ventilation system in the Swiss Chalet kitchen comprised seven hoods with a total exhaust airflow of 11,000 cfm. A dedicated, direct-fired makeup air (MUA) unit supplied replacement to the kitchen space through several 4-way ceiling diffusers. Variable frequency drives (VFDs) were installed on the exhaust fan motors for Hood 1 and Hood 2. Temperature sensors were installed in the exhaust duct collars for these two hoods selected for control by the VariSpeed system. An AutoAirBalance system was also installed, which would signal the controller to modulate dampers on the rooftop HVAC units and/or shut off the makeup air unit.

Table 1. Exhaust Hood Airflow (in CFM).

Hood 1	Hood 2	Hood 3	Hood 4	Hood 5	Hood 6	Hood 7	Tot Exh
3605	2459	1000	838	915	1014	1137	10968

Exhaust Hood 1:

A wall-canopy style hood (12 ft wide by 40 inch deep) installed over a short-order appliance line. Exhaust airflow was measured at 3605 cfm (300 cfm/ft).

Figure 1. Exhaust Hood 1.

Exhaust Hood 2:

A wall-canopy style hood (12 ft wide by 40 inch deep) installed over gas-fired rotisserie ovens. Exhaust airflow was measured at 2459 cfm (205 cfm/ft).

Figure 2. Exhaust Hood 2.

Figure 3. Rooftop perspective (showing 7 exhaust fans & MUA unit).

HOOD TUNE UP

The relative large exhaust ventilation rate (11,000 cfm) and associated makeup air requirement for this restaurant kitchen was due the multiplicity of cooking equipment positioned independently throughout the back of the house. When a large number of smaller hoods are used instead of one or two larger hoods over a consolidated cookline, the exhaust ventilation requirement will be higher due to the relative increase in hood perimeter. Five of the seven hoods were less than 5 feet in length, with airflows in the 1000 cfm per hood range. In simple terms, the face velocity of the replacement air decreases as the hood perimeter dimension increases with respect to the hood length dimension. End panels permit a reduced exhaust rate in most cases, as all of the replacement air is drawn across the front of the equipment, which improves containment of the effluent plume generated by the hot equipment. They are a relatively inexpensive way to improve hood performance and reduce the total exhaust rate. Another benefit of end panels is to mitigate the negative effect that cross drafts can have on hood performance. It is recognize that partial end or side panels can provide almost the same benefit as full panels.

So, to maximize individual hood performance and potentially allow the variable speed control to maximize the reduction in exhaust flow, each hood was retrofit with partial end panels. This was accomplished by confirming the suitability of such enclosures by positioning a cardboard mockup of the proposed stainless steel panels. Once “blessed” by the operations manager, Aerco fabricated and installed permanent side skirts (as illustrated in Figures 5 - 10)

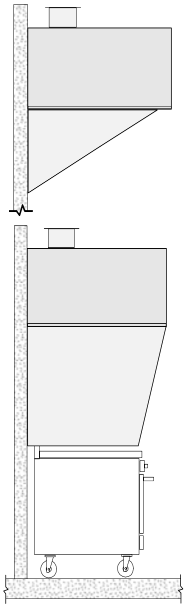

Figure 4. Illustration of partial and full end panels.

Figure 5. Hood 1 – cardboard mock-up of partial end panels.

Figure 6. Stainless steel panels installed.

Figure 7. Hood 2 – cardboard mock-up of partial end panels.

Figure 8. Hood 2 – stainless panels installed.

Figure 9. Fryer hood with open ends (and poor performance).

Figure 10. Fryer hood with end panels and complete capture.

FIELD MEASUREMENTS AND CALCULATIONS

The full-speed current draw of the two primary exhaust fans was measured in the field and the power calculated using measured voltage and an assumed power factor of 0.8. Part load measurements were also made and used to calculate the power at the average operating speed for each fan based on average speeds recorded during the monitoring phase of the project (Figures 11 & 12) Makeup air fan power was estimated at 0.4 kW per 1000 cfm, for total of 3.2 kW for the 8000 cfm makeup air unit. The calculated reduction in fan power (Table 1) totaled 3.2 kW or 56% of the fan loads being modulated. This power reduction translates to an annual energy saving of 21000 kWh. Applying an effective electricity rate of $0.08 per kWh, the calculated cost saving in fan energy was $1680 per year.

Table 2. Fan Power Reduction.

			Reduction:
EF-1 (Hood 1)	1.27 kW @ 100%	0.38 kW @ 62%	0.89 kW
EF-2 (Hood 2)	1.21 kW @ 100%	0.18 kW @ 47%	1.03 kW
Total exhaust fan	2.48 kW	2.13 kW	1.91 kW
MUA fan (est.)	3.20 kW @ 100%	40% run-time reduction:	1.28 kW
Total fan power reduction:			3.2 kW

The average reduction in airflow was calculated for each fan based on the linear relationship between the fan speed and the airflow. The reduction in airflow is shown in Table 2. Note that the airflow for Hood 6 and Hood 7 were reduced permanently by 20% as a by-product of the hood tune-up. Overall, the average exhaust airflow was reduced by 28%. However, the average airflow reduction for the two hoods being modulated in response to exhaust temperature was 44%.

Table 3. Airflow Reduction.

			Reduction:
Hood 1	3605 cfm @ 100%	2235 cfm @ 62%	1370 cfm
Hood 2	2459 cfm @ 100%	1156 cfm @ 47%	1303 cfm
Hood 6	1014 cfm @ 100%	811 cfm @ 80%	203 cfm
Hood 7	1137 cfm @ 100%	910 cfm @ 80%	227 cfm
Total Average Exhaust Reduction:			3103 cfm

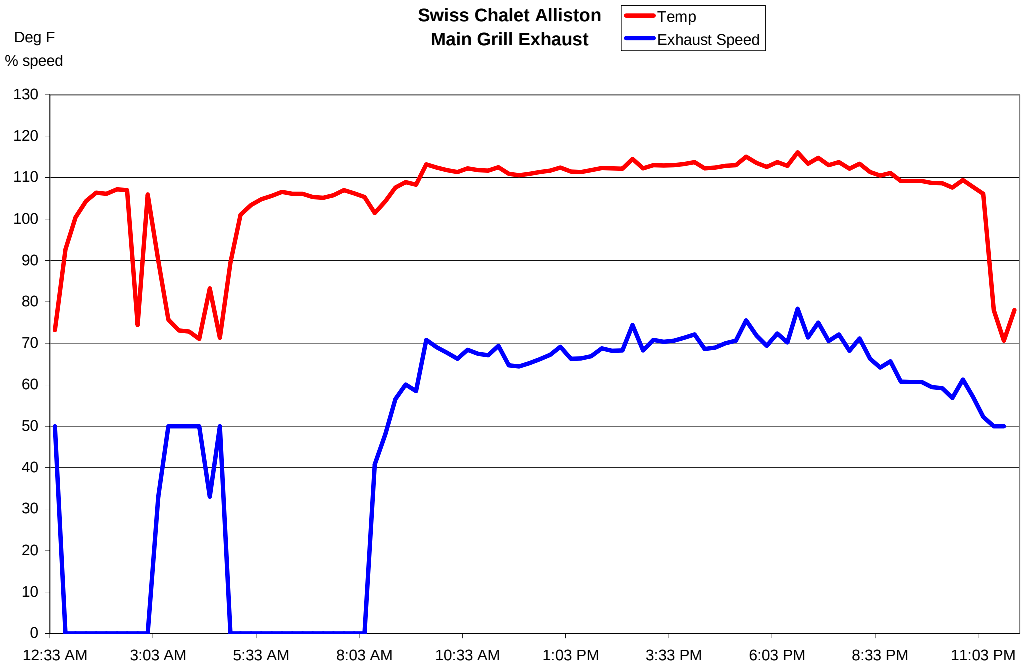

Figure 11. Hood 1 – fan speed and duct temperature.

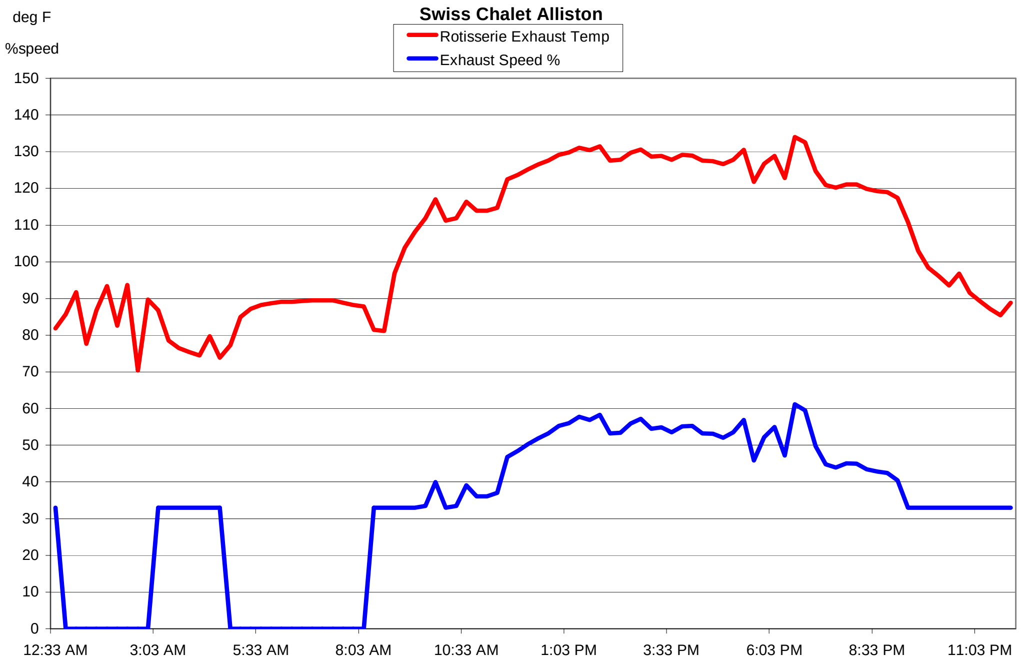

Figure 12. Hood 2 – fan speed and duct temperature.

REDUCTION IN MAKEUP AIR HEATING LOAD

The reduction in makeup air heating load was assumed to be proportional to the reduction in exhaust and makeup airflow. To be conservative, the reduction in exhaust flow of 2230 cfm (versus the reduction in MUA of 2400 cfm) was used to calculate the reduction in heating load using the Outdoor Airload Calculator.[1] This software applies ASHRAE equations for heating and cooling of moist air to each of the 2190 weather data bins. Based on "operating hours" input, the software determines the time that the makeup air system is operating per weather data bin. It reports monthly heating & cooling energy use and peak 4-hour bin load for a year. The output for the Boston Pizza calculation is shown in Table 3, where (the reduction of) 2230 cfm of outdoor air showed an annual heating load (reduction) of 375,229 kBtu.

Table 4. Outdoor Airload Calculator.

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Result summary for Swiss Chalet
Location:            Toronto, Ontario
Elevation:           568 ft
Operating Hours:     8:00 o'clock until 2:00 o'clock
Hours of Operation:  18
Makeup Air Flow:     3100 cfm
Thermostat Setpoints: Heating = 68 F, Cooling = 72 F

The Heating Design Load is: 258.8 kBtu/h
The Cooling Design Load is: 56.4 kBtu/h

Calculated Monthly loads:
Month                    Heating Load      Cooling Load
January                    92,605 kBtu            0 kBtu
February                   83,262 kBtu            0 kBtu
March                      71,608 kBtu            0 kBtu
April                      45,557 kBtu           95 kBtu
May                        23,881 kBtu          154 kBtu
June                        9,167 kBtu        2,882 kBtu
July                        3,413 kBtu        5,275 kBtu
August                      4,274 kBtu        3,472 kBtu
September                  15,344 kBtu        1,087 kBtu
October                    37,589 kBtu           44 kBtu
November                   55,341 kBtu            0 kBtu
December                   79,578 kBtu            0 kBtu
Total_Year                521,619 kBtu       13,009 kBtu
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Assuming 95% heating efficiency for the direct-fired makeup air furnace, and applying a representative gas cost of $0.33/m^3 ($0.90/therm), a $4940 per year heating load saving was calculated. This dollar saving translates to approximately $1.60 per cfm, which is in line with rule-of-thumb estimates for climate zones like Toronto.

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[1] The Outdoor Airload Calculator, OAC, was developed by Pacific Gas and Electric Company and is freeware available for download through the Food Service Technology Center website (http://www.fishnick.com/tools/oalc/).

RETURN ON INVESTMENT

The cost of the Aerco-installed demand ventilation control system for this Swiss Chalet was $22,000. With fan energy savings of almost $1700 and makeup air heating savings of $4900, the total energy cost saving was $6600 per year. This would return the investment in a little over 3 years (i.e., simple payback = 3.3 years). Subsequent to this demonstration project, Aerco Industries introduced a dedicated kitchen hood system (not expandable as a comprehensive energy management system) at cost of approximately $10,000. In this application, the payback would be reduced to 1.5 years.

CONCLUSION AND RECOMMENDATION

The demand ventilation control reduced the restaurant’s total exhaust airflow (and calculated cost) by 28%, with an associated reduction in fan power (and calculated cost) of 40%. Based on the projected payback, Swiss Chalet should consider this technology within its specifications for new facilities. It is important to recognize, that the hood tune-up (i.e., addition of partial end panels) was an integral part of the project, maximizing the benefit of the demand ventilation control system. For new facility design, this can be accomplished by prudent specification of the hoods and their installation.

In today’s world of automated HVAC control, the commercial kitchen ventilation (CKV) system is still operating in the dark ages—*you turn it on, you turn it off, and in between it operates at full speed!* It is estimated that there are 50 million cfm being exhausted by single-speed systems from restaurants and institutional kitchens in Enbridge service territory alone. The potential for demand-side management of gas load through widespread application of demand ventilation control in commercial kitchens is significant.

This retrofit case study demonstrated an average reduction in exhaust and makeup airflow of approximately 3100 cfm. The associated makeup air heating load reduction was equivalent to 15,000 m^3 of natural gas consumption, reflecting an annual heating-load-reduction index approaching 5 m^3 per cfm (of reduced airflow).