Analysis of Energy Recovery Ventilators
Florida Power and Light Company

Final Report

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Executive Summary

This report describes the study of an energy recovery ventilator (ERV) installed at a 25,000 sq ft. two-story office building located in Daytona Beach, Florida. The aim of the study was to evaluate the effectiveness of a membrane type heat recovery device manufactured by Dais Analytic, Inc. of Odessa, Florida on commercial office buildings requiring continuous ventilation. The use of the ERV significantly reduced the building's total energy consumption (kWh) and the peak demand (kW). An hourly simulation model was also developed that predicts the ERV related savings for every hour (8760 hours) of the year. This model was duly verified using actual field data recorded during two consecutive cooling seasons and one winter heating season.

The energy recovery ventilator (ERV) is a device which pre-conditions the outside air with the building exhaust air. This pre-conditioning significantly reduces the load on the cooling system of the building, thereby, producing significant savings pertaining to heating, ventilation and air conditioning (HVAC) energy consumption for the building. These savings are particularly large for geographic locations with prolonged, humid summers, like Florida.

Florida Power & Light Company funded this research to evaluate the potential of energy savings (kWh) and peak demand savings (kW) associated with the use of the ERV. A polymer membrane-type ERV was used for this study. The membrane type ERV provided total energy transfer, exchanging both sensible and latent heat between the incoming outdoor air and exhaust air. While the total energy savings correspond to the energy saved annually, the demand savings refers to the average kW reduction achieved from 4-5 PM during the summer peak month and from 7-8 AM during the winter peak month.

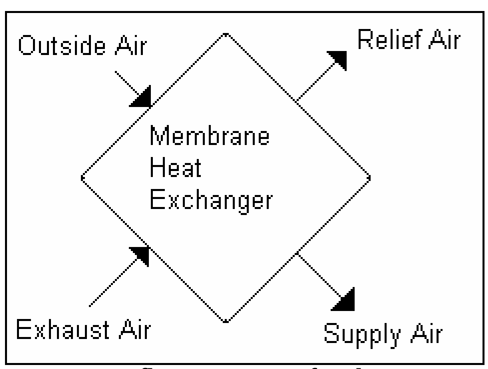

Figure 1. Airflow Diagram for the ERV Unit

The thermal efficiency is calculated (using enthalpy, assuming equal exhaust and supply air flow) as follows:

$$\eta = \frac{h_{outside\_air} - h_{supply\_air}}{h_{outside\_air} - h_{exhaust\_air}}$$

The savings due to the ERV can be easily interpreted from the figure-1. The cross-flow in the ERV results in heat exchange between the incoming stream (outside air) and exhaust stream (return air from conditioned space). The difference between the supply air condition coming out of the ERV and the incoming air condition entering the ERV is the actual saving achieved. For the hourly simulation model and the manual ERV analysis, a 70% thermal efficiency was assumed. This assumption was validated during field data collection. However, this number (along with several other input parameters in the model) was maintained as a variable to allow for simulation of any kind of heat recovery device.

The first model used for this work was the Carrier's HAP v.4.10b software. With the use of actual data collected at the site, the computer model was validated. The actual demand profile for the building was compared to the modeled data for the month of September. The modeled data agreed very well (within 7%) with the actual data. However, the HAP model had inherent shortcomings in evaluating heating month calculations. The heating scheme for the computer model does not shut down the chillers when the outdoor air temperature drops below the balance point as the actual building operation dictated. Therefore, a spreadsheet-based hourly simulation model (HSM) was developed which calculates both demand (kW) savings and energy (kWh) savings for 8760 hours of the year.

The spreadsheet simulation model tabulates the dry and wet bulb temperature data for every hour of the year and applies psychrometric calculations to obtain other thermo-physical property data such as enthalpy which is used to calculate the amount of energy recovery. With specific assumptions about the ERV unit and its operation, the monthly reductions in building electrical demand and consumption were calculated for the entire year. The HSM model can calculate annual energy savings with and without electric resistance heating and/or automatic bypass controls for maximum customer bill savings during very mild weather conditions. The results of the model were compared to the data collected at the site for verification. This model was then run for five Florida cities namely, Miami, Tampa, Orlando, Jacksonville and Tallahassee.

The primary objective of using the ERV was to reduce the building power demand (kW) during the 3:00 PM to 6:00 PM interval, the period of maximum electrical demand in summer for the utility. To confirm the potential of the device, repeated experiments were conducted during peak summer months. To achieve this, the office building under study was equipped with a web-based Tritium monitoring system which collects a vast array of information on the building system controls. Sensors were installed at the ERV (and other subsystems) which measured and recorded the air properties at four locations (see figure-1). Other valuable data like building kW consumption, chiller load, air handler unit (AHU) details, and air flow rates were available on a real-time basis to researchers at the University of Florida where the HSM model was developed.

Turning the ERV on and off while observing the online data resulted in almost immediate impact on the building kW demand. The HVAC kW showed a sudden rise as the ERV was by-passed (exhaust air released to the atmosphere and not being passed through the ERV).

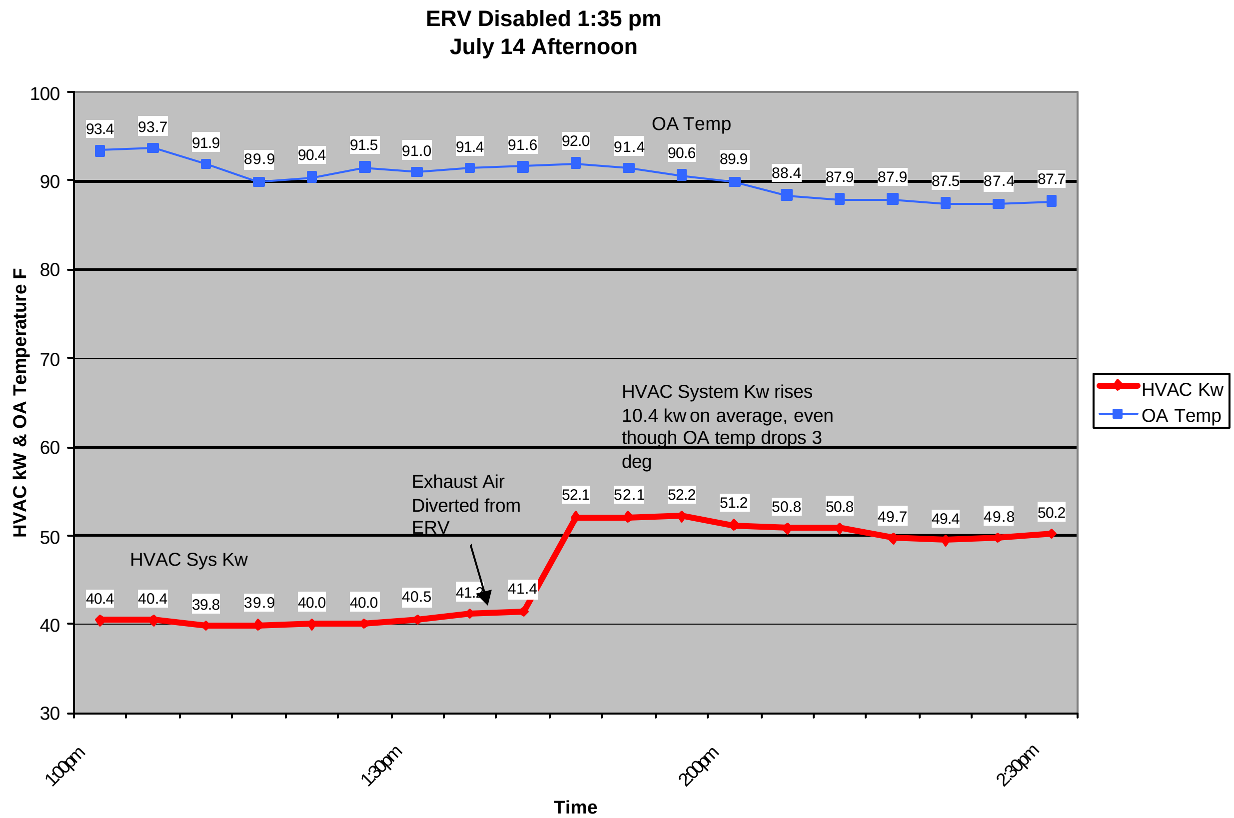

Figure 2. HVAC Rise as Exhaust Air is Diverted Away from ERV.

It should be noted that the Carrier HAP weather library did not include Daytona Beach as one of the stations. Subsequent runs indicated that Orlando weather data provided a fairly true correlation with the actual data collected. Therefore, Orlando results were used in the comparisons with actual data observed for Daytona Beach. The actual savings recorded (figure-2 for example) were confirmed by the hourly simulation model, which was then duplicated for five Florida cities.

The model also provides a simple payback period analysis and the annual dollar savings for each geographic area. In addition to accounting for automatic bypass controls, a provision to choose either a heat strip or gas furnace for heating months to calculate associated savings is also included in the model. Unlike electrical resistance heating, there would be no winter kW demand savings with a gas furnace. The FPL territory estimate was evaluated using the appropriate weighting factors provided by FPL. Table-1 below provides an example of the annual energy savings pertaining to each weather station and a weighted territory estimate of kWh, kW and dollar savings when using electric heating during the winter months without bypass during mild weather.

		Miami	Orlando	Tampa	Jacksonville	Tallahassee
Annual Energy Savings(kWh)	Cooling	13265	10132	9702	7814	7810
	Heating	888	2357	3013	7599	10042
	Total	14152	12488	12715	15413	17852
Accumulated Billing Demand Reductions (kW)		136	158	187	219	243
	$/kWh	0.0428				
	$/kW	8.16				
Annual Dollar Savings (kWh x $0.0428 + kW x $8.16)		$1,715	$1,827	$2,068	$2,448	$2,744
Weights Applied		50%	25%	15%	10%	0%

Total FPL Territory Estimate (Applying Above Weights)	**KWh**	**13647**
	KW	**157**
	$	**1869**

Table 1: Modeled Customer Savings; Weighted FPL-Territory Savings Estimate with an ERV System (Electric Heating, Without Automatic Bypass Mode)

		Miami (kW)	Orlando (kW)	Tampa (kW)	Jacksonville (kW)	Tallahassee (kW)
April	**Summer Months (Peak 4-5 PM)**	6.6	6.0	6.0	4.7	3.5
May		9.1	7.9	6.0	7.1	8.9
June		9.1	7.9	9.6	9.2	10.9
July		9.5	9.4	8.9	9.2	10.1
August		9.8	10.0	10.9	10.4	10.1
September		10.6	8.4	9.0	8.5	8.3
October		8.0	8.7	8.3	5.8	5.1
November	**Winter Months (Peak 7-8 AM)**	0	0.0	22.6	32.6	37.5
December		29.3	30.8	23.7	34.0	40.4
January		23.3	27.6	33.0	39.9	46.1
February		20.8	23.4	31.3	34.0	33.6
March		0.0	18.4	17.7	23.9	28.1

Table 2: Monthly Summer and Winter Peak Demand Reductions for FPL Territory.

		Peak Demand Reduction, summer (4-5 pm)	Peak Demand Reduction with Resistance Heating, winter (7-8 am)	Peak Demand Reduction without Resistance Heating, winter (7-8 am)	Energy Savings with automatic bypass, with resistance heating	Energy Savings with automatic bypass, without resistance heating	Energy Savings without automatic bypass, with resistance heating	Energy Savings without automatic bypass, without resistance heating
					annual	annual	Annual	annual
Weather Data	FPL Weight	(kW)	(kW)	(kW)	(kWh)	(kWh)	(kWh)	(kWh)
Miami	0.5	9.8	28.6	0	14,153	13,265	11,480	10,592
Orlando	0.25	9.1	30.5	0	12,489	10,132	7,529	5,172
Tampa	0.15	10.2	33.0	0	12,715	9,702	7,497	4,484
Jacksonville	0.1	10.4	39.9	0	15,413	7,814	8,918	1,319
Tallahassee	0							
Weighted Estimate		**9.75**	**30.84**	**0**	**13647**	**11402**	**9639**	**7394**
		(kW)	**(kW)**	**(kW)**	**(kWh)**	**(kWh)**	**(kWh)**	**(kWh)**

Table 3: Modeled Utility Savings; FPL Energy Recovery Ventilator R&D Results Summary

The HSM provides the option of performing the energy savings estimate with or without the automatic bypass and electric heating option. Thus, there are four scenarios for each weather station. The FPL territory estimate for each of the four scenarios has been tabulated above in Table-3.

The membrane-type ERV has definitely illustrated both in the field and by computer modeling that it saves a substantial amount of energy and reduces electrical demand in the Florida climate. In FPL territory, it is estimated a membrane-type ERV can reduce summer peak HVAC demand by 16%, winter peak demand by 26%, and annual energy consumption by 11% (assuming resistance heat and automatic bypass for this example of maximum savings). The FPL HSM model can estimate the savings for other ERV types based on their heat transfer effectiveness rating. The hourly-simulation model provides an excellent tool for engineers to use for analyzing the HVAC system capacity reduction and the total dollar savings through use of an ERV.