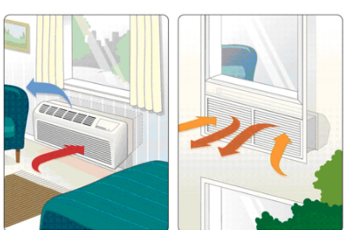
Aclectic
Adaptive Control Technologies

Adaptive Climate Control (ACC): Future of HVAC PTAC/PTHP Systems

VALIDATION TESTS



Brought to you by:

CUSTOM ELECTRONICS, INC. | Opto Generic Devices, Inc. | Halovation Innovation at Work

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SELECTED TEST RESULTS

1. ConEdison, Manhattan Plaza New York City
2. Environmental Test Laboratory, Ohio
3. EME Consulting Engineers (Third Party), Sponsored by NYSERDA, New York
4. State University of New York, Oneonta, NY
5. Tim Garrison (Third Party Testing)
6. McQuay Cooling Tests
7. Purdue University Tests (Phoenix)
8. ConEdison Tests by ERS

SELECTED TEST RESULTS

1. ConEdison, Manhattan Plaza New York City

Con Ed Study NYC Manhattan Plaza Energy Savings Work Sheet (kW & kWh Test) for:
OGD's ACC upgrade for 3000 NYC ptacs
Data Test March - > July 2014

		1 Ton Units	3/4 Ton Units	Total
		1,688	1,335	3,023
Hours	Summer	960	960	960
Hours	Winter	1200	1200	1200
Hours	Shoulder	240	240	240
Hours	Total	2400	2400	2400
kW	Base Summer	0.90	1.20	
kW	Base Shoulder	2.30	3.50	
kW	Base Winter	0.90	1.20	
Per Unit kWh	Base Summer	864	1152	
Per Unit kWh	Base Shoulder	2760	4200	
Per Unit kWh	Base Winter	216	288	
Total kW Pk Summer		1519.2	1602	3,121
Total kWh		1,458,432	1,537,920	2,996,352
Total kWh		4,658,880	5,607,000	10,265,880
Total kWh		364,608	384,480	749,088
Total Base kWh				**14,011,320**

Savings based on measurement: 50 watts per unit summer/shoulder.
Assumption: 100 watt decrease winter / shoulder
20% decrease in operating hours winter/ shoulder; 10% summer

Hours	Summer	864	864	
Hours	Winter	960	960	
Hours	Shoulder	192	192	
Hours	Total	2016	2016	
kW	Base Summer	0.85	1.15	
kW	Base Shoulder	2.20	3.40	
kW	Base Winter	0.80	1.10	
Per Unit kWh	Base Summer	734.4	993.6	
Per Unit kWh	Base Shoulder	2112	3264	
Per Unit kWh	Base Winter	153.6	211.2	
Total kW Pk Summer		1,434.80	1,535.25	2,970
Total kWh		1,239,667	1,326,456	2,566,123
Total kWh		3,565,056	4,357,440	7,922,496
Total kWh		259,277	281,952	541,229
Total Post kWh				**11,029,848**

Pk Summer kW Savings		151
Total Annual kWh Savings		2,981,472
Incentive:	DMP @ $1,250/kW	$ 188,938
	EPPS at 16 cents/kWh	$ 477,036
	Total Incentive	**$ 665,973**

SELECTED TEST RESULTS

2. Environmental Test Laboratory, Ohio

Environmental Test Laboratory
ETL Lab Testing

[Summary Results Only]

Data Analysis and Compare of:

OGD PTAC Upgrade versus

Standard PTAC Operation

ETL Ohio Lab Aug 2007

ETL Test of The : OGD V*hvac*
Adaptive Climate Controller (ACC)

The study was to determine how much retro-fitting a standard ptac with an OGD Adaptive Climate Controller (ACC) Impacted or Improved PTAC performance in:

- **Energy Use**
- **Demand Power Use**
- **Climate Impact**

The testing was done under controlled and monitored conditions in accord with ISO New England Measurement and Verification (M & V) Methods and other recognized test standards.

ETL Lab Test Analysis & Conclusions
ACC Performance & Energy Savings

- OGD's ACC does decrease peak power demand in nearly all cases (i.e., Lowers Kw Demand and Use)
- Greatest benefit is it saves total system energy, it increases operating energy efficiency and improves ptac performance.
- Climate data including temperature and humidity show marked improvement with ACC
- ACC upgrade not only meets but exceeds standard PTAC operations, plus M & V efficiency goals

Under same climate conditions all cases show:
ACC saves ≈ 30% to > 50%

ETL Comparison of Lab Controlled Matched Environmental Conditions of PTAC Operation:

:Bypass = Standard PTAC ops at set test conditions
:ACC = Same PTAC switched to ACC control, same test conditions

ETL Test Results Summary

Ptac Unit	Test Runs	Room Set Point	Bypass Watts	ACC Watts	Saved Watts	% Saved
#3 Carrier	Run #1	74º	725	335	**390**	**54%**
#4 Carrier	Run #1&2	70º	831	448	**383**	**46%**
#4 Carrier	Run #6	68º	884	628	**256**	**29%**
#2 LG	Run #1	70º	539	266	**273**	**51%**
#1 LG	Run #1	68º	604	347	**257**	**43%**
#1 LG	Run #10	72º	538	318	**220**	**41%**

Definitions

- **BYPASS =** Standard PTAC Manufacturing operation
- **ACC =** Operation of PTAC System under the control of the ACC

- **PTAC ON Cooling; Bypass =** Compressor on + Indoor fan on + Outdoor fan on
- **PTAC ON Cooling; ACC =** Compressor on + Indoor fan on ACC + Outdoor fan on
- **PTAC Non-Cooling; Bypass =** Compressor off + Indoor fan on + Outdoor fan off (LG)
- **PTAC Non-Cooling; Bypass =** Compressor off + Indoor fan on + Outdoor fan on (Carrier)
- **PTAC Non-Cooling; ACC =** Compressor off + Indoor fan on ACC + Outdoor fan off (LG)
- **PTAC Non-Cooling; ACC =** Compressor off + Indoor fan on ACC + Outdoor fan on ACC (Carrier)

- **Run Time** – The compressor duty cycle, the length of time the compressor ran
- **Demand *1 – Power (Watts)** – Is the amount of electric power required to operate a system
- **Energy *2 – (Watt-Hour)** – Is the amount of electric power required over time to operate the system
- **Total Hourly Power / Demand**
  – The total power consumed by the system during the test period (PTAC on + PTAC IDLE)
- **Total Hourly Energy**
  – The total energy consumed by the system during the test period (PTAC on = Cooling + Non-Cooling)

- ***1 Electrical Demand: (ISO-NE):**
  - "defined as installed measures (e.g., products, equipment, systems, services, practices and/or strategies) on end-use customer facilities that reduce the power needed,"
- ***2 Energy Efficiency (ISO-NE):**
  - "defined as installed measures (e.g., products, equipment, systems, services, practices and/or strategies) on end-use customer facilities that reduce the total amount of electrical energy needed,"

3. EME Consulting Engineers (Third Party), Sponsored by NYSERDA, New York

OPTO GENERIC DEVICES V-HVAC Inc.
PUMPKIN HOOK ROAD • PO BOX OGD • VAN HORNESVILLE • NY • 13475 • USA • 315-858-1002

Opto Generic Devices V-HVAC, Inc. technology was analyzed in a recent NYSERDA sponsored study. The results of that study are summarized in the following pages.

The savings data in the report are so encouraging, and the market for fractional horsepower motor upgrades is so significant similar to the findings of many other studies of our technology, that OGD V-HVACs line of products are eligible for NYSERDA incentives through four separate programs. These programs are NYSERDAs Program Opportunity Notices (PONs) # 855 Commercial and Industrial Performance Program, # 853 Smart Equipment Choices, # 835 Peak Load Reduction, and # 869 New Construction / Green Buildings Program.

We are very pleased with the results of this *Independent Study* and are excited about the impact our products will have on the HVAC and Energy Industries. Following is the information presented on the cover page of the Study and subsequent to that are excerpts from the study. In addition to these excerpts, we have prepared a tabular representation of the study results which provide savings and payback data for different sizes of motors and various project sizes.

Unit Ventilator VSD Energy Analysis

Prepared for

The Olde Draper Centre
7 Draper Avenue
Rotterdam. New York

Sponsored by

New York State Energy Research & Development Authority
17 Columbia Circle
Albany, New York 12203-6399

Prepared by

EME Group Consulting Engineers
135 Fifth Avenue
New York, New York 10010
212-529-5969

June 30, 2004

This project was conducted at the Olde Draper Centre facility in Rotterdam, New York. This building is the former Draper High School, portions dating back to the 1920s, with 130,000 square feet of space. Classroom Unit Ventilators with 20+ year old fan motors were selected for the study. The following facts were excerpted from the Report:

1. Executive Summary

The *intent of this project is to monitor the electric energy consumption of* steam unit ventilator *electric fan motors* retrofitted with thermostatically-controlled variable speed drives (VSDs).

EME used energy dataloggers to *monitor the combined* energy consumption of three unit ventilator fans for a period of one month while controls were alternated between standard line control and the VSD controls

2. Introduction

Three unit ventilator (UV) *fans in the building [classrooms] were retrofitted with VSDs manufactured by Opto Generic Devices, Inc*. Called the V-HVAC 120 Va c Adaptive Speed Al Controller, the VSD is *designed for economic control of fractional horsepower motors.*

Fan motors are standard efficiency and are generally *over twenty years old*.

3. Data Collection

The selected units had been fitted with new thermostatically controlled steam control valves and new fractional horsepower variable speed drives (VSDs) manufactured by Opto Generic Devices, Inc.

The VSD *[OGDs A1 Controller] is a small unit installed adjacent to the motor. A thermistor installed near the steam valve provides the temperature sensing by which the unit alters motor speed. A switch on the unit provides the option to control the motor by the VSD control or by the [units existing control system].*

After a week of baseline measurement [the bypass switch on the A1 Control Unit was switched to bypass mode no other modifications were made], test measurements were taken for one week, followed by another week of baseline and then another week of test measurements. Separately, heating degree days (HDD) were collected from the National Weather Service NOAA in order to normalize the data.

4. Energy Savings Analysis

Figure 1 shows the fan motor energy consumption for the period of study. Weeks one and three of the graph represent baseline data, when the fan motors were powered using [the units existing control system with no other modifications] . Weeks two and four represent testing with the VSD on the fan motors.

Tabulated and normalized for HDD, the total energy consumption for each week is:

Week	Total kWh	Total HDD	kWh/ HDD
1 (baseline)	80.8	183	.44
2 (test)	45.1	220	.21
3 (baseline)	81.1	259	.32
4 (test)	45.4	111	.41

Table 1. Baseline and control test data indicating kWh consumption and HDD.

Normalization to HDD is typically used with temperature-sensitive measurements to eliminate the temperature variable from the data

The logged data shows a decrease in daily consumption from the baseline to the test period of nearly 6 kWh, or 44% [reduction in kWh usage] . This reduction occurs in both testing periods and remains relatively constant over the course of each test period.

A small energy spike occurs that causes the kW value to rise approximately 0.1 kW nearly twice per hour for both cases. The rise is likely typical for the electrical system and is assumed not to affect this study. Aside from the semi-hourly spike, the average kW readings change little. For the base case, the average value without spiking is 0.463 kW, with a standard deviation of 0.005 kW. For the test case, the average value without spiking is 0.254 kW, with a standard deviation of 0.013 kW. *[This represents a 45% in kW demand].*

5. Conclusion

The VSD control reduces both energy consumption and demand of the motors. Recorded data indicate the control causes an immediate decrease in consumption, with little variation thereafter. As the control is based on temperature in the UV, changes in fan speed would be expected to coincide with changes in steam flow, as determined by the room thermostat. The variability of load conditions is evidenced by the change in heating degree days over the period of study of 35 HDD.

The above excerpts from EMEs NYSERDA sponsored report showed a 44% reduction in kWh usage and a 45% reduction in kW demand. Based on the information provided in the report, we have prepared the following extrapolations. Following the extrapolations are the conservative assumptions we used to prepare them.

The *Unit Ventilator VSD Energy Analysis* project that was performed at the Olde Draper Centre was performed on Unit Ventilators that utilized 1/8 hp motors. ASHRAE now recommends that all Unit Ventilators utilize 1/2 hp motors to insure adequate capacity to meet outside air requirements. With our line of products, whether the motor is 1/8 hp or 1/2hp or even 1-1/2hp, the same unit same cost controls any one of them.

The following page presents an Extrapolation of the Savings and Payback data that were presented in the above named report. Following is a list of the Conservative Assumptions made to prepare the Extrapolation.

In addition to extrapolating out the savings to different horsepowers, the installation costs are also extrapolated out, in that as the quantity of units installed increases the price per unit decreases (economy of scale). The report indicated a $450 installation cost which we believe to be a significantly high number. We have provided paybacks on several "typical" scenarios.

Motor	Annual	Installation Cost per Unit				Simple Payback (years)			
HP	Savings	< 10	10+	100+	1,000+	< 10	10+	100+	1,000+
1/8	$30	$450	$350	$250	$195	15.0	11.7	8.3	6.5
1/6	$40	$450	$350	$250	$195	11.3	8.8	6.3	4.9
	$60	$450	$350	$250	$195	7.5	5.8	4.2	3.3
1/3	$80	$450	$350	$250	$195	5.6	4.4	3.1	2.4
	$120	$450	$350	$250	$195	3.8	2.9	2.1	1.6
	$180	$450	$350	$250	$195	2.5	1.9	1.4	1.1
1	$240	$450	$350	$250	$195	1.9	1.5	1.0	0.8
1.5	$360	$450	$350	$250	$195	1.3	1.0	0.7	0.5

Data highlighted in Green are actual data from Analysis

Some Typical Project PayBacks: (based on above data)

A typical building with a mix of < 100 motors, 1/8 thru 1-1/2 hp: PayBack = 2.5 yrs.

If 1/8, 1/6, 1/4, 1/3 hp motors are eliminated from project: PayBack = 1.6 yrs.

If number of motors on project is > 1,000 and all hps: PayBack = 1.4 yrs.

Assumptions:

1. No kW demand savings are included in any payback calculations
2. No maintenance, replacement, or repair savings are included in any of the payback calculations
3. Savings assumed to be linear as horsepower increases from 1/8 to 1 hp but larger motors typically require more watts per horsepower and will likely generate higher levels of savings
4. We have accepted the $450 unit cost that was provided to EME by contractor but feel that cost is excessive
5. Since our product is the exactly the same for all motor sizes there will be no cost difference in terms of equipment or labor regardless of motor size
6. Price breaks dependent on number of total installed units have been provided starting at the $450 per unit cost but all costs and price breaks are very likely to be significantly less
7. The Analysis assumed 3,000 hours of operation annually which may be conservative if the Unit Ventilator performed in both the heating and cooling modes (as many do) and may be a conservative estimate for other types of equipment (which can also be upgraded with this technology)

SELECTED TEST RESULTS

4. State University of New York, Oneonta, NY

Energy Management Study

Using

A1 Motor Controllers

Conducted at:

The State University Campus at Oneonta
Ravine Parkway
Oneonta, NY 13820

By:

OGD Generic Devices, Inc.
174 Pumpkinhook Road
P.O. Box OGD
Van Hornesville, NY 13475

ENERGY SAVING TEST RESULTS FOR SUCO

Test Design Criteria:

The goal of this study was to identify the reduction of energy costs by employing the A1 temperature controlled motor speed control device produced by OGD, Inc on room univents. The study monitored the total electric energy consumption of two different univents located in two identical adjacent rooms. One univent was field retrofitted / upgraded in less than 40 minutes with the "Adaptive Speed" A1 unit installed. The second installed univent without (w/o) the A1 unit was set to its fixed medium-speed, the normal setting.
versus using its high speed setting giving it a lower total energy used by this unit w/o the A1.

Both units were equipped with power analyzer energy dataloggers to monitor the energy consumption of each unit real time and continuous. The study was to last for several weeks and actually ran about 5 weeks.

A number of factors govern pricing structure for electricity; we used 10.5 cents per KWH as the rate for our calculations. We also used only the 1/4hp fan motor savings with an average figure of $_____ per installed cost for the A1 speed controller, to calculate payback, etc.

Energy Savings Test Data:

1] On May 19, 2005 two energy-monitoring devices were installed in the Schumacher Building, in through-the-wall Herman Nelson univents. The univents contained (1) ¼ HP 115V 4.2 Amp 1027 RPM fan motor (GE M#KCP39LG=the prime electrical user), an electrical building monitor system and electric valve controls.

- **The 1st energy monitoring device was installed in room #202 along with the energy saving A1 device.**
- **The second energy monitoring device was installed in the next room #203, with no A1 installed.**

2] From May 29th thru June 28th of 2005 hourly readings were taken each day showing the energy consumption of each unit.

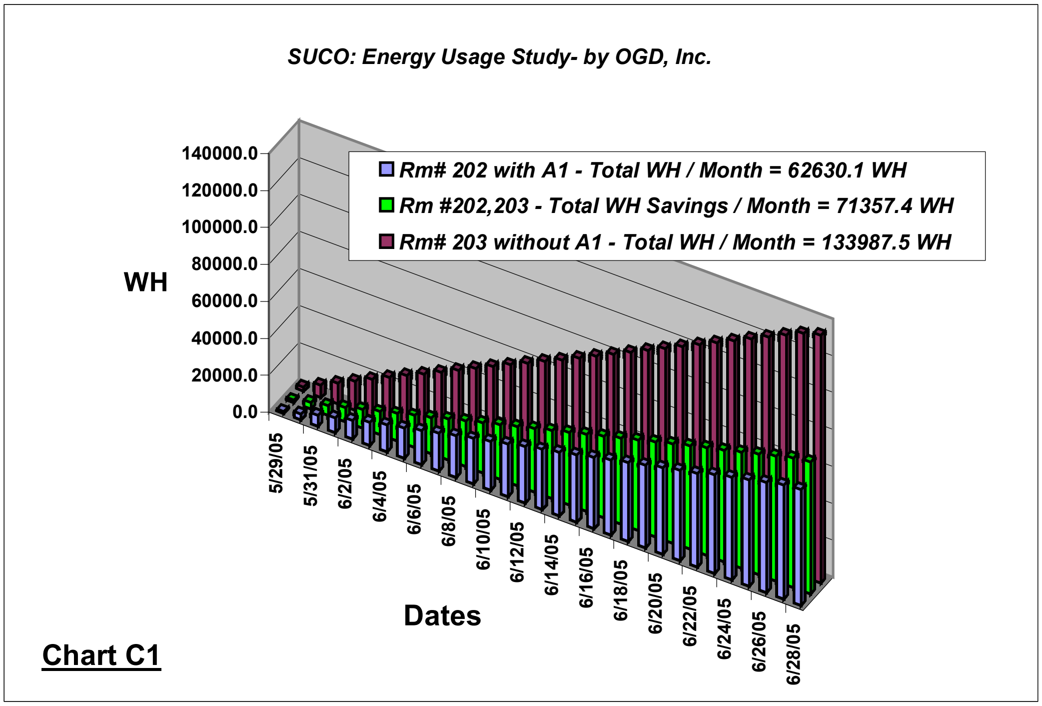
3] In late June 2005 this data was down loaded to an OGD field computer. The following are the results, Refer <u>Chart C-1</u> :

- **A total of 133,988 watt hours (wh) were used on the univent w/o the A1 installed. The A1 equipped univent used 71,357 less wh over the same time period.**

- **This equates to an average energy saving of over 50 % !**

- **For the installed <u>1/4 hp fan motor</u>, at the above electric rates, this equates to <u>a savings of $91.10 per unit per year.</u>**

The Chart below shows the energy usage with the A1 unit in blue (=63 kwh), W/o the A1 in purple (134 kwh) and the Net Energy Savings in green (=71 kwh)



Translating the above energy savings on the 1/4 hp fan motor into actual dollars saved is in the chart below and according to the following Equation:

71.35 KWH * 10.5 cents per KWH =$7.49 / 30 test days=$0.2496 per day. $0.2496 * 365 days / year <u>= savings of $91.10 per 1/4 hp unit* per year</u>

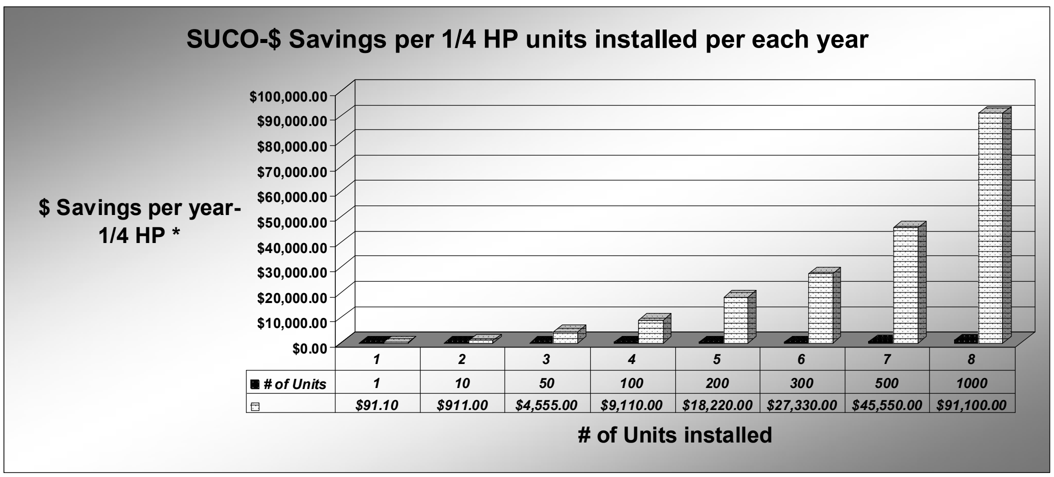
Savings for 1 /4 hp unit over one year

<u>* e.g. 1/2 hp = $182.20 per year</u>

The savings become considerable when the quantities of units already installed at SUCO are factored in. For instance if all 300 units in the Admin building are upgraded with the A1 controller the savings become at least $27,330.00 per year.

When considering a total installed cost of $______ (on quantity orders) a return on investment or payback of < ___ years is realized. This does not factor in increasing world energy costs, nor does it anticipate any motors larger than 1/4 hp… if these were included the payback would be even better!

Note the below chart showing savings based on multiple installs of only 1/4 hp* units.



Summation

It should be noted here that while the direct energy savings on the 1/4 hp fan motor from installing the A1 is considerable, its effect to an entire building would contribute other energy savings and improvements:

1. **First, added energy savings are generated due to the decreasing amount of (on line) time the main plant boiler or chiller unit is required to operate, along with associated pumps, steam & chiller valves, etc.**

2. **Then we have a smoothing out of the thermostat set-point temperature fluctuation, (See C-2& 3). From these charts you can see the ability for a thermostat to be set "higher for cooling" or "lower for heating" while maintaining the same or better comfort range.**

3. **Next, the improved longevity of the motors has a direct impact on reduced maintenance costs.**

4. **Simple, easy low cost field installation and systems upgrade. No motor change-outs, no sw reprogramming of your current BMS, no /low risk as a simple A1 bypass switch is included…. Less down time and quicker payback!**

5. **In other communication to you we have outlined other advantages to the A1 motor controller such as reduced noise levels, elimination of air stratification, draft reduction on personnel, etc.**

In the attached package you will also find the actual data pages that support the above charts and more. We will be happy to go over any of the findings and answer any questions you may have on this support data or our proposal sent to you to purchase a number of A1 units.

Roger, we appreciate the many efforts of your very professional staff in participating in this energy study. The support, insights and contributions by James Gage, Dave Gregory and of course you made this study so successful and valid.

Based on these findings and the many benefits that can accrue to the SUCO Campus we are confident you will find our proposal of merit. Thanks for letting us present to you the A1 unit as a most cost effective means of solving, reducing even eliminating what till now were ever increasing energy costs.

Sincerely,

Opto Generic Devices – OGD V/HVAC

SELECTED TEST RESULTS

5. Tim Garrison (Third Party Testing)

DRAFT

Test Analysis Report
Evaluation of an ACC Control System
Developed By Opto Generic Devices

Report Prepared: 1/25/09
Prepared by: Timothy J. Garrison, Ph.D.

DRAFT

1.0 Introduction

This report summarizes several tests and the associated results for a proprietary control technology developed by Opto Generic Devices and herein referred to as the ACC control unit. The ACC control unit was tested in several scenarios including: 1) control of a Packaged Terminal Air Conditioner (PTAC) unit operated in cooling mode; 2) control of a PTAC unit operated in heating mode; 3) control of a motor-driven blower unit at a line voltage of 267V; and, 4) operation a bank of heating elements at a high current load. The following sections describe the tests that were performed, the analysis of the data, and the results that were obtained. A summary of all findings is included in section 6.0 of this report.

2.0 PTAC Cooling Tests

2.1 Experimental Setup

The cooling tests were performed at ETL SEMKO – Intertek Testing Services located in Cortland, NY. Complete details on the test facility and the equipment can be found in the test report provided by Intertek; only a summary is given herein.

An LG brand PTAC unit was installed in the dividing wall between a two-room HVAC test facility. Conditions in one room, referred to as the outside room, were controlled, based on prescribed set points, by the Intertek climate control system. Conditions in the second room, referred to as the inside room, were controlled by the PTAC unit. An ACC control unit provided by Opto Generic Devices was connected to the PTAC unit. The ACC control unit was configured so that the PTAC could be operated under control of the unit or in bypass mode. In bypass mode the ACC control unit was bypassed, allowing the PTAC to run using the factory installed control system. It should be noted that operation in bypass mode was verified to have no impact on the PTAC. This was achieved by collecting test data with the ACC unit set to bypass mode and with the ACC control unit removed. The results were the same.

All testing and data recording were performed by personnel at Intertek. Data used in the analysis described herein were obtained directly from Intertek. The author of this report visited Intertek for two days, December 22 – 23, 2008 to review the facility, equipment, procedures, and to witness several tests.

2.2 Instrumentation & Data Collection

The following data were collected using calibrated measurement equipment provided by Intertek. The data were collected over time and written to a data file at approximately 5 second intervals. Details on the instrumentation, its operation and calibration are provided separately in the report produced by Intertek.

- Time and date

- The wet and dry bulb temperatures in the outside room (used to determine the relative humidity in the outside room).
- The temperature in the outside room as recorded by an array of thermocouple sensors
- The temperature of the interior room at 3 different locations. At each location an array of thermocouples were used to record the temperature.
- The voltage provided to the PTAC unit
- The current drawn by the PTAC unit
- The Watts drawn by the PTAC unit
- The Watt-hrs consumed by the PTAC unit, accumulated as a running total

2.3 Test Conditions

The LG PTAC unit was tested for various set points in the outside and inside rooms, as noted in Table 1 below. The set point temperatures were selected to be representative of typical temperatures experienced during operation of a PTAC for cooling. For each test condition, the PTAC unit was operated both with and without control by the ACC unit. Operation of the LG PTAC without the ACC unit is referred to as operation in "bypass" mode. Operation with the ACC unit is referred to as "ACC" mode.

Table 1 – Test conditions for the PTAC cooling experiments

Indoor Room Temp	Outdoor Room Temp	Outdoor Relative Humidity	Testing Order	Approx. Test time in each mode
70 °F	82 °F	40%	ACC then bypass	2 hrs
70 °F	85 °F	40%	Bypass then ACC	2 hrs
70 °F	88 °F	37%	Bypass then ACC then bypass	3 hrs
72 °F	85 °F	40%	ACC then bypass	2 hrs
72 °F	88 °F	72%	ACC then bypass	2 hrs

As noted in Table 1, in some tests the PTAC unit was run in ACC mode first and bypass mode second. For other tests, the order was reversed. In all but one case the PTAC unit was run for approximately 2 hours in each mode. For one test case (70 °F indoor, 88 °F outdoor) the unit was run in bypass mode first, then ACC mode, and then again in bypass mode. Also, for that case each mode was tested for approximately 3 hours. This allowed examination of the influence of the test duration and order.

It should be noted that originally Intertek was unable to set the relative humidity in the outside room above 40%. Such relative humidity values are low for typical summertime conditions in many regions of the country. Low relative humidity values also place a lower demand on the PTAC unit since there is less moisture to cool. However, for the last test condition the Intertek operators were able to change the outdoor room controls to achieve a substantially higher, and more realistic, humidity level of 72%.

2.4 Analysis procedures

In this section, the analysis procedures for one test case (70 °F indoor, 85 °F outdoor) are explained in detail. These same procedures were used to analyze each of the cases listed in shown in Table 1.

The first step in the analysis procedure was to plot the wattage data versus time. Figure 1 shows the plot of the wattage drawn by the PTAC unit versus time for the cooling test with an indoor temperature setting of 70 °F and an outdoor setting of 85 °F.

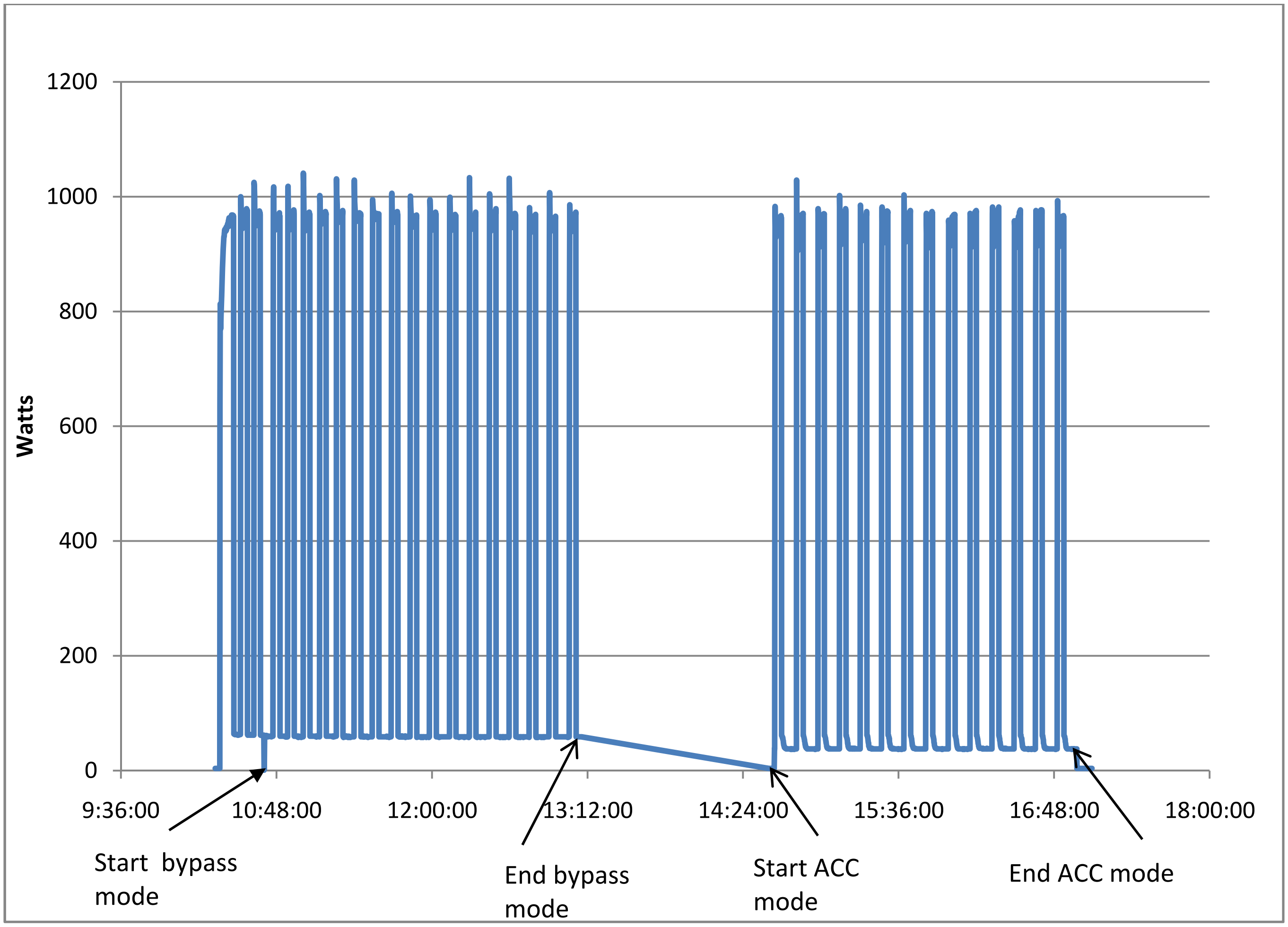


Figure 1: Watts versus time for cooling case (70 °F indoor, 85 °F outdoor)

Several things can be noted from this graph. The test began by allowing the unit to cycle several times to make sure everything was operating properly. The PTAC was then turned off to record a zero watt level, which was used as a reference mark to clearly note the start of the test data. This is indicated in Figure 1 as "Start of bypass mode". The unit was then operated in bypass mode for approximately 2 hours. The end of operation in bypass mode is indicated in Figure 1. The unit was then switched over to operate in ACC mode. Before starting the test in ACC mode, the PTAC unit was again shut off to establish a zero wattage reading, as indicated by the “Start ACC mode” marker on the figure. The PTAC unit was then run for approximately 2 hours using the ACC control mode.

The next step in the data analysis was to extract the data for each test mode. Figure 2 shows a plot of the watt demand versus time for the period when the PTAC was run in bypass mode. For all test cases, the first cycle of data was ignored. This must be done to account for the fact that the indoor room was not set to a common starting point before each test mode (bypass or ACC). Thus, the unit was run for one cycle, allowing the PTAC itself to establish the set point temperature within the interior room. The start of the usable analysis data begins at the point at which the PTAC power goes high (due to the start of a compressor cycle) following one complete PTAC cycle after the zero-watt marker. This point is marked in Figure 2 as “Begin usable data”.

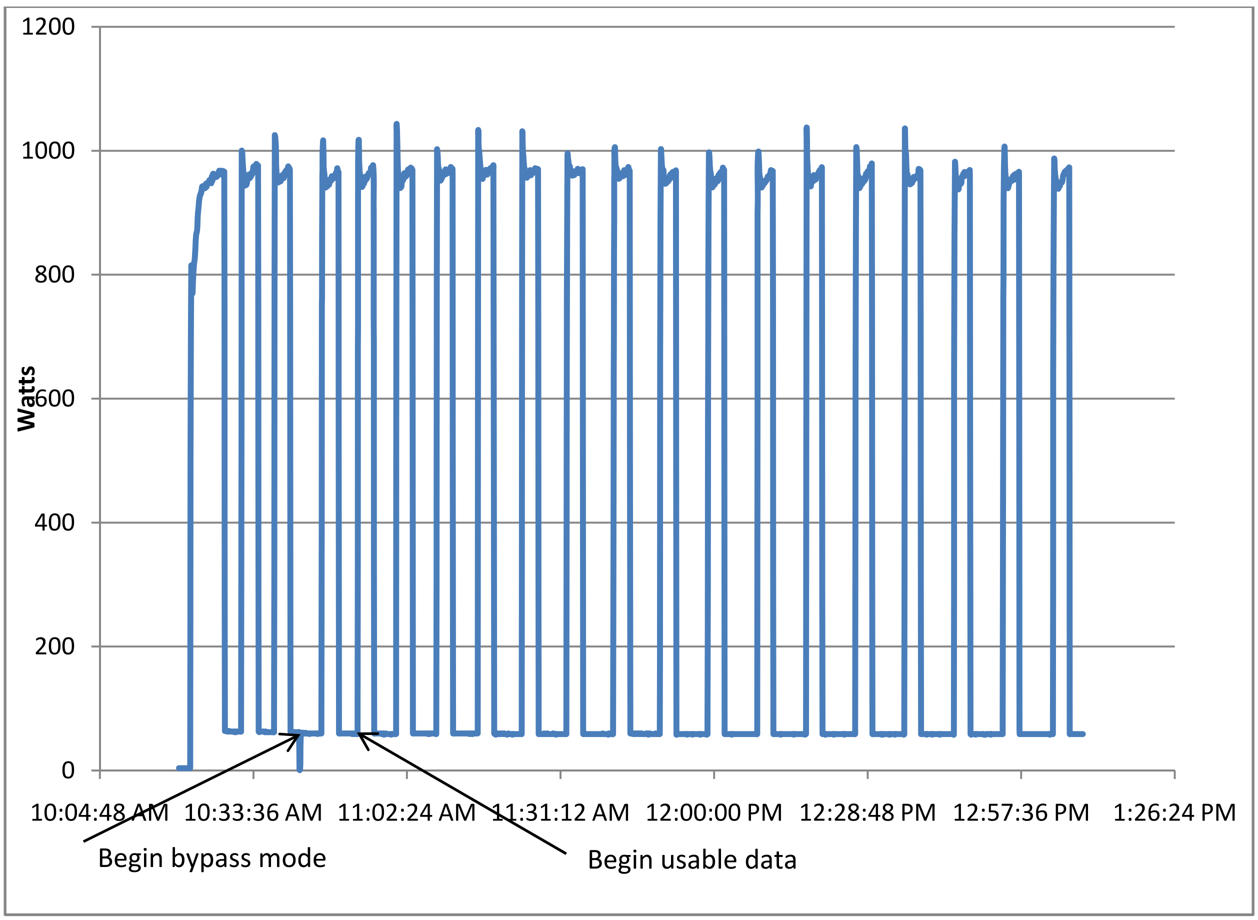


Figure 2: Watts versus time for operation in bypass mode (70 °F indoor, 85 °F outdoor)

A similar plot for operation in ACC mode is shown in Figure 3. As with the bypass case, the first cycle of data is not used to insure that the indoor room begins at the same starting conditions as in the bypass case. Both Figures 2 and 3 consist of cyclic periods where the wattage demand is low, due to operation of only the air circulation fan, and periods of high demand when both the fan and compressor unit are operational.

Once the start of the usable data envelope has been identified, the watt usage versus time for operation in both ACC and bypass modes were then plotted on the same axes for comparison purposes. To make this possible, the time is zeroed at the start of the usable data set (i.e. at the time indicated in Figures 2 and 3 and marked "Begin usable data"). Figure 4 shows the overlapped plot of watt usage versus time for both the bypass and ACC modes.

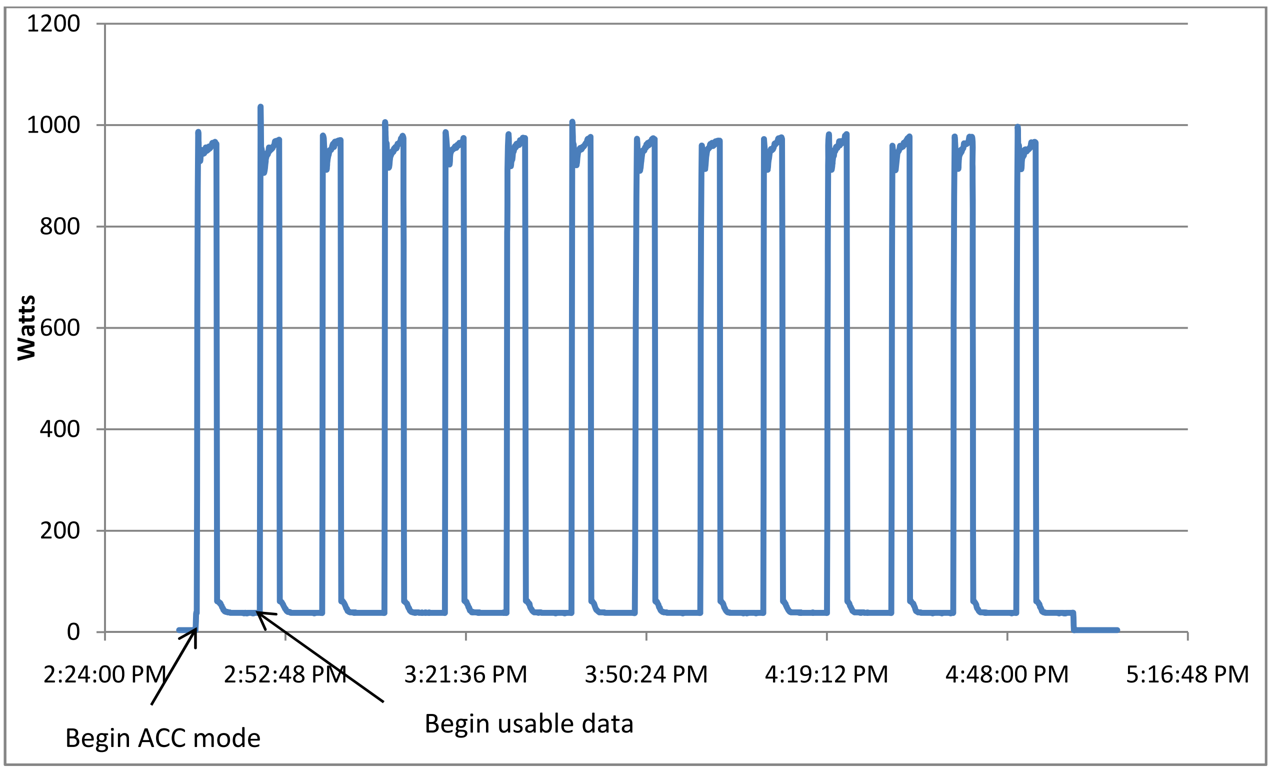


Figure 3: Watts versus time for operation in ACC mode (70 °F indoor, 85 °F outdoor)

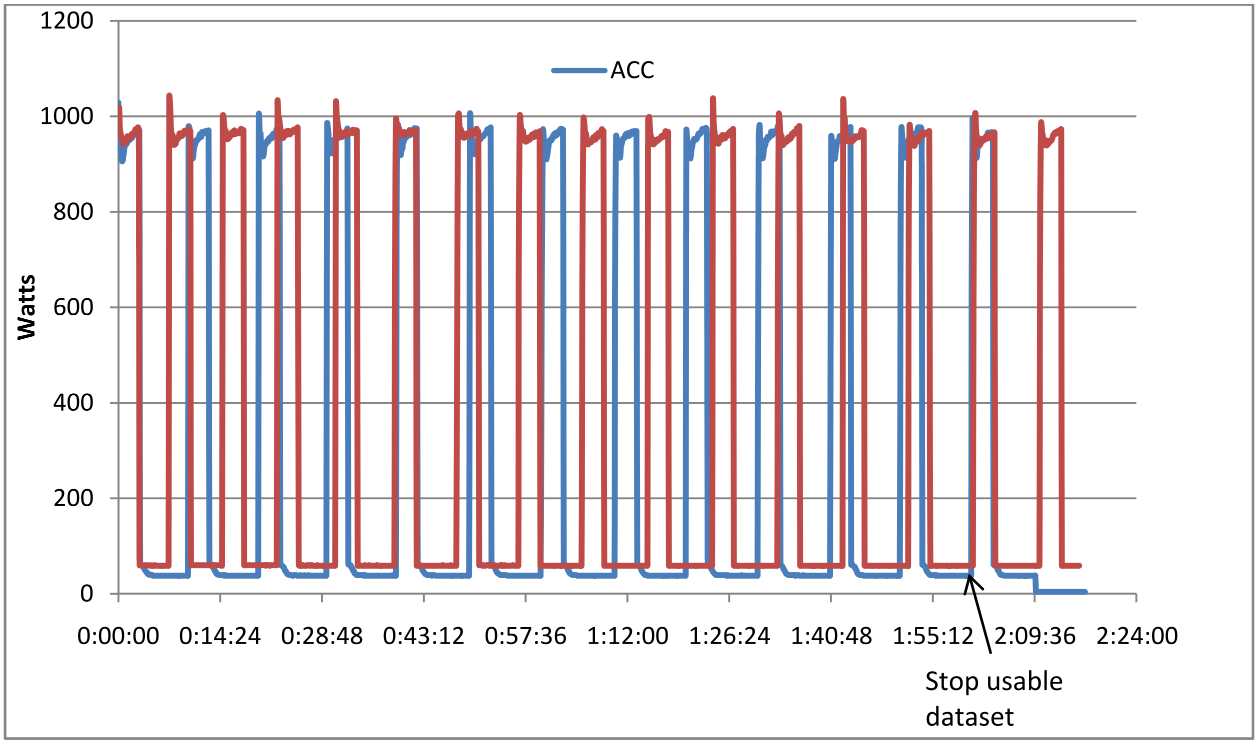


Figure 4: Overlapped plot of Watts versus time for both ACC and bypass modes (70 °F ID, 85 °F OD)

The next step in the analysis was to look for a suitable endpoint for the datasets. The goal was to end the datasets at a time for which the PTAC units were at analogous points in the operational cycle. As shown in Figure 4, for this case the end of the usable data envelop was selected at the indicated location. At this point both, in both the ACC and bypass modes, only the circulating fan is operating and the compressor is just about to turn on. This resulted in a usable data envelope of just over 2 hours.

For all of the cooling analysis cases listed in Table 1, the end of the usable data envelope was selected so that in both modes (ACC and bypass) only the circulating fan was operating, similar to the case shown in Figure 4.

Careful examination of the data showed that this method of selecting the start and end of the usable data envelopes was the proper way to fairly compare the operation between bypass and ACC modes.

Figure 5 shows a plot of the wattage draw versus time for the usable data envelopes in both ACC and bypass modes. These data envelopes were then used for the remainder of the analyses.

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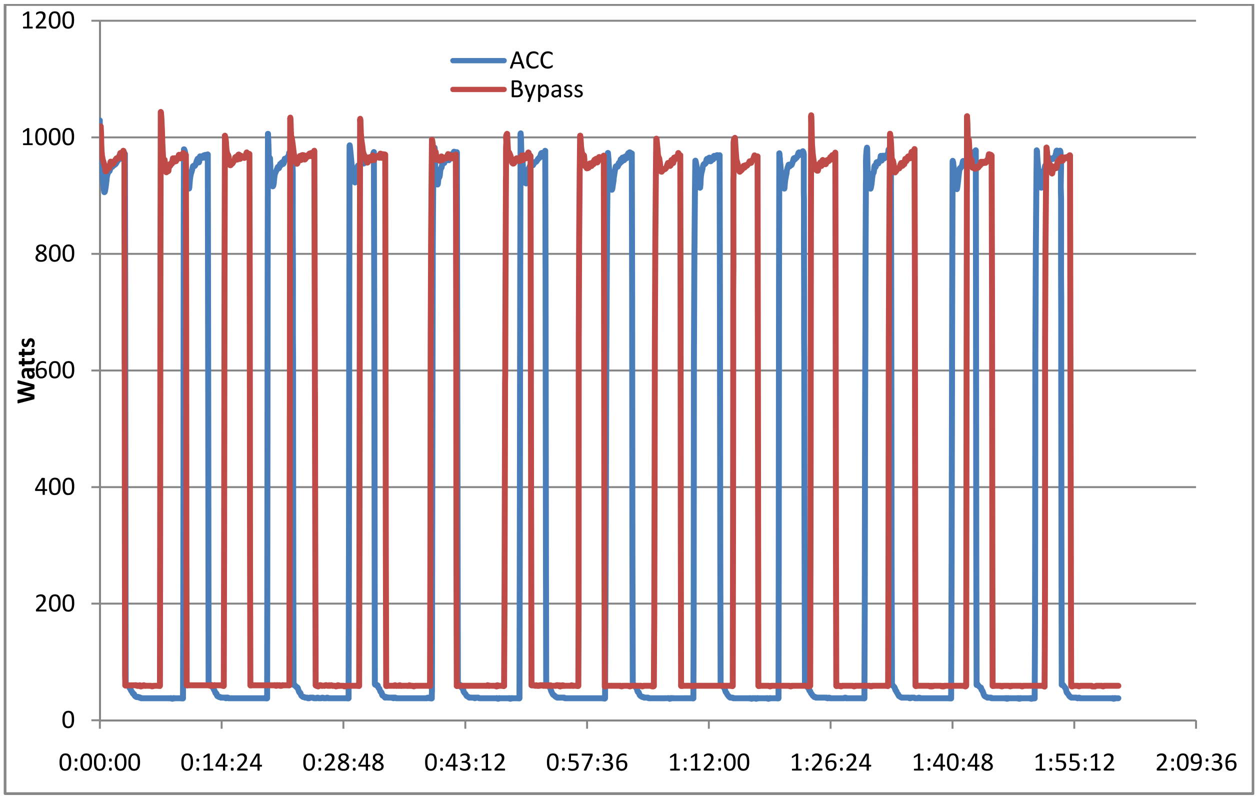

Figure 5: Overlapped plots of usable data envelopes (70 °F ID, 85 °F OD)

Once the usable data envelopes were identified the running watt-hours were plotted. The running watt-hour data were obtained directly from instrumentation used by Intertek and effectively represent the integrated running area under the plots shown in Figure 5. The corresponding plot is shown in Figure 6.

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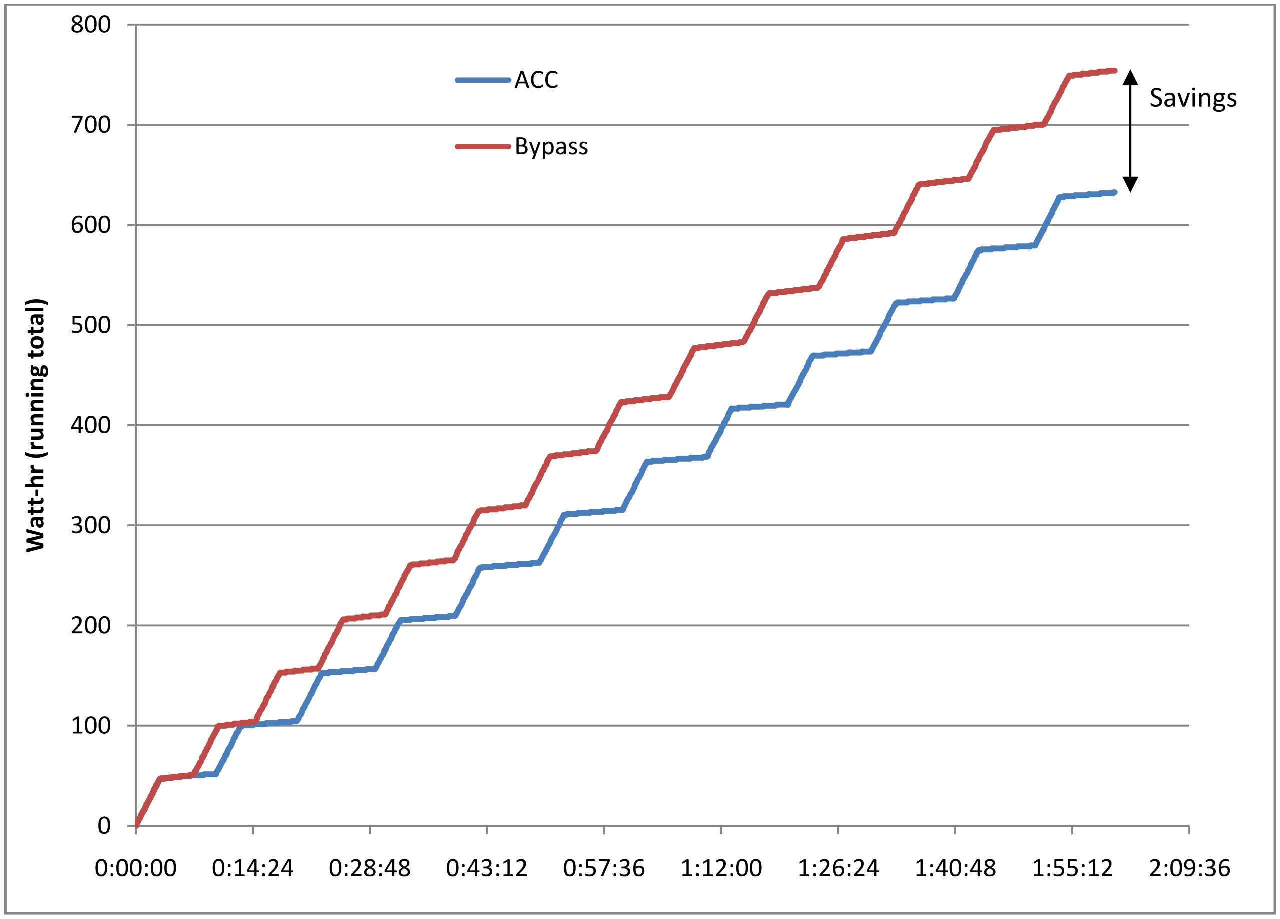

Figure 6: Plot of running Watt-hr consumption for ACC and bypass modes (70 °F ID, 85 °F OD)

Two comparative measures were applied to Figure 6 to determine the energy savings provided by using the ACC mode. The first was to determine the savings in Watt-hrs at the end of the usable envelope as indicated in Figure 6. For this particular case, after 2 hours and 25 seconds of operation in each mode, in ACC mode 632.5 Watt-hrs of energy were used by the PTAC unit while 754 Watt-hrs of energy were used in bypass mode. Thus, operation in ACC mode provides a savings of 121.5 Watt-hrs over the two hour period. This represents a savings of 16.1% when compared to the standard operation (i.e. bypass mode).

Examination of Figure 6 reveals that the running Watt-hr plots consist of portions of relatively low energy usage when only the circulating fan unit is running and periods of higher energy usage when both the fan and compressor units are operating. The general pattern repeats itself as the PTAC unit cycles. This suggests another way to interpret the data is to fit a basic curve to the data which captures the general rate of growth in Watt-hr usage. This is shown in Figure 7, for which a linear curve fit is used to capture the trend in the running Watt-hr usage.

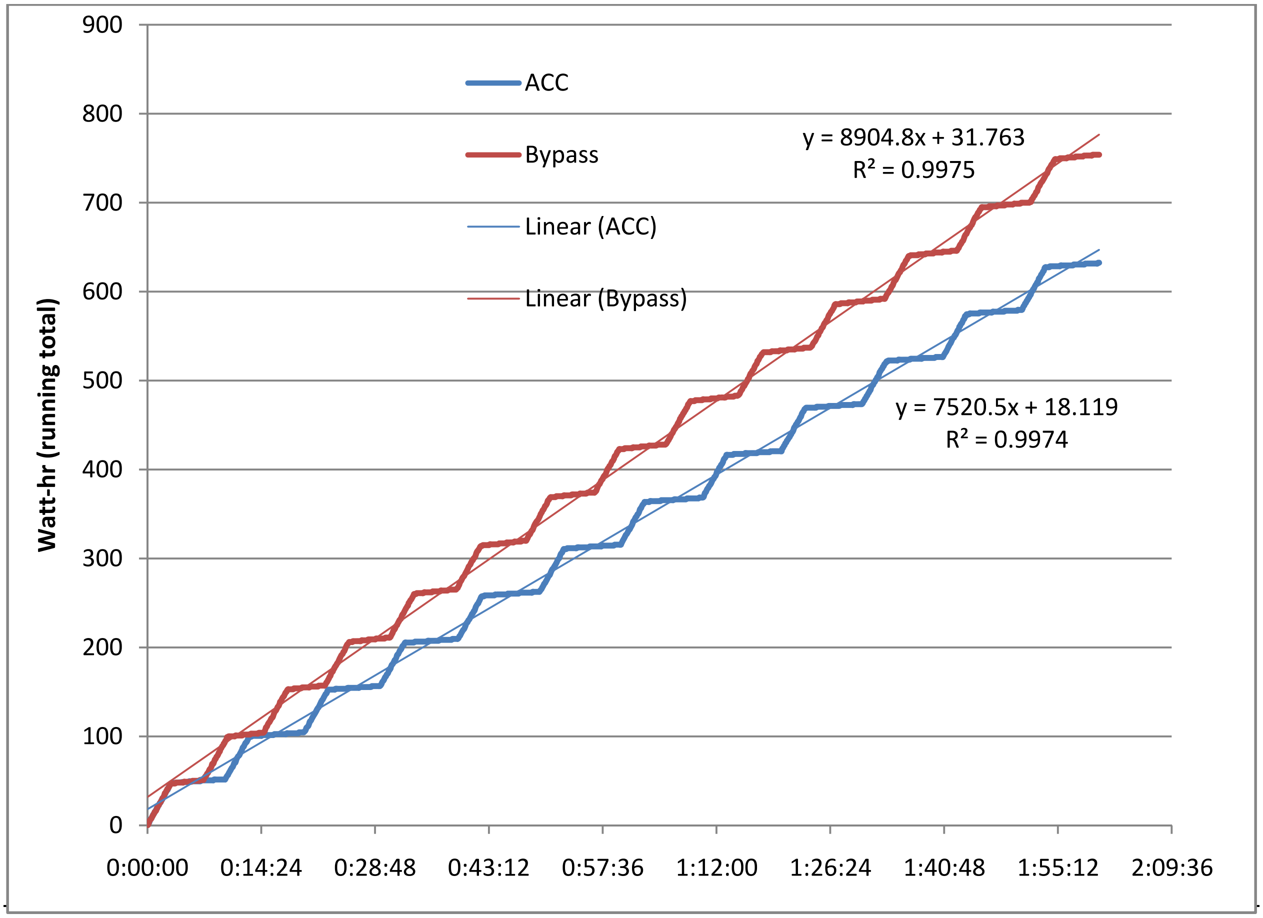

Figure 7: Linear curve fits applied to the data of Figure 6.

The slopes of the linear curve fits gives the net rate of growth in watt-hr usage versus time. Thus, these slopes represent another method to determine the savings provided using the ACC mode of control. For this case the savings would be (8904.8 – 7520.5)/8904.8 = 15.5%. This result is in close agreement with the value of 16.1% determined by using the first method. It is also useful to note that the R^2 value for both of the curve fits are very close to 1.0, indicating that the linear curve fits are good representations of the trend in the actual data.

In addition to the energy and power demand of the PTAC unit, the thermal conditioning of the indoor room was also examined from the data collected by Intertek. Figure 8 shows the temperature variations within both the indoor and outdoor rooms for the entire test period. For the indoor room, three temperature plots are shown, one for each of the thermocouple grids within the indoor room. For the outdoor room, the temperature of the thermocouple grid is shown along with the wet and dry bulb temperatures. These plots can be used to examine the spatial temperature variation within the indoor room (via comparison of the temperature values at the three locations) as well as the range of temporal temperature oscillations resulting from cycling of the PTAC unit. The outdoor data can be used to verify that the outdoor conditions were properly held and to calculate the relative humidity. For reference, the data envelopes used for analysis of the energy usage are marked on Figure 8.

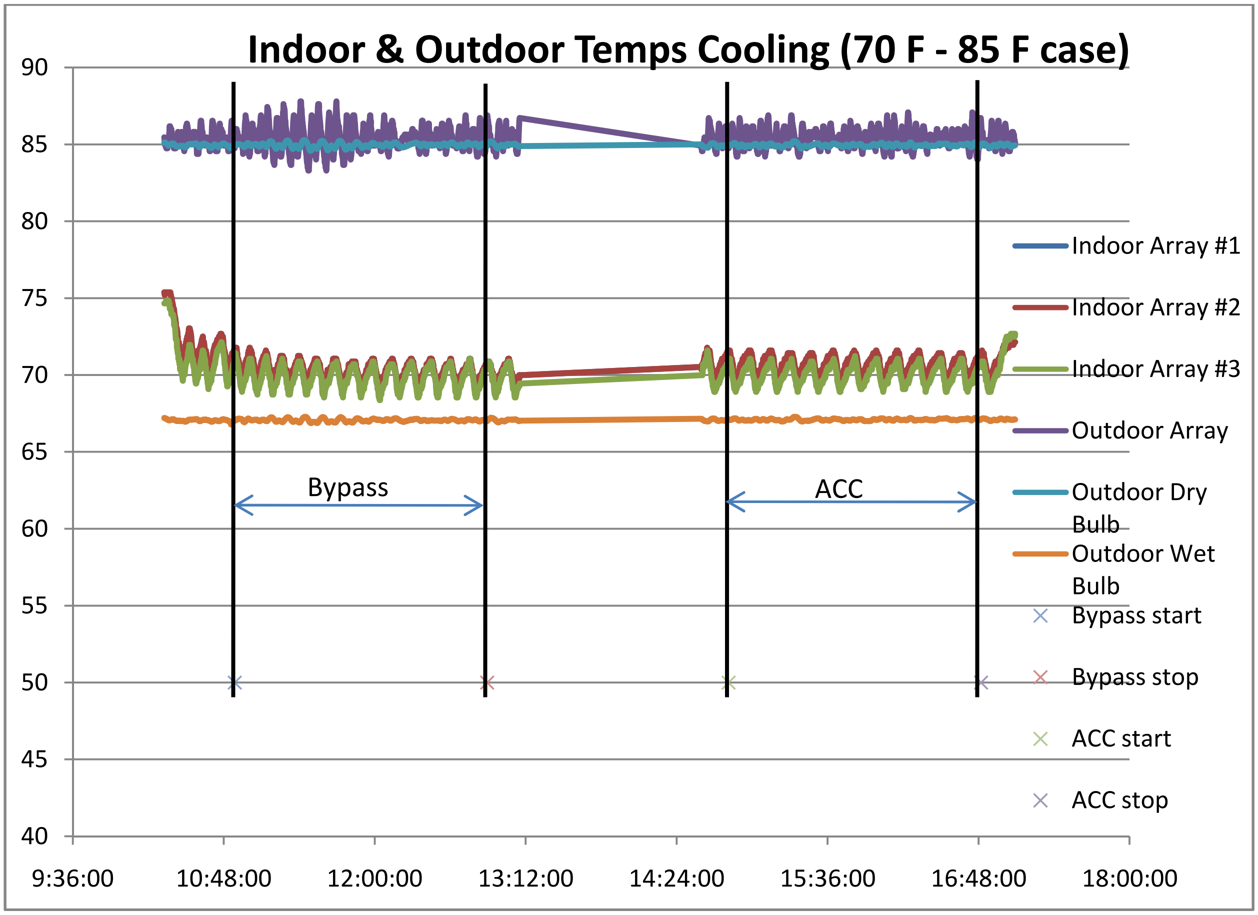

Figure 8: Temperature variations for the indoor and outdoor rooms during the test intervals

Examination of Figure 8 shows that the spatial temperature variations between the three indoor sampling locations is similar when the PTAC is operated in bypass and ACC modes. Also, the extent of the temporal temperature oscillations is similar when the PTAC is operated in both modes. In both cases the indoor room temperatures fluctuated by approximately ± 1.5 °F (i.e. the indoor room temperature fluctuated approximately between 68.5 °F and 71.5 °F for both cases when the PTAC was set to maintain an indoor temperature of 70 °F.

For the outdoor room the wet and dry bulb temperatures remained relatively constant at 67 °F and 85 °F, respectively. These values yield a relative humidity of 40% for the outdoor room.

2.5 Results

This section summarizes the results from all of the cooling tests conducted by Intertek.

2.5.1 PTAC Cooling test: indoor temperature set point = 70 °F, outdoor temperature set point = 85 °F.

The data and analysis for this case were presented in section 2.4 to demonstrate the analysis procedure. Examination of Figure 5 shows that the PTAC cycles more frequently when operating in bypass mode. In bypass mode the unit cycled on and off 14 times versus only 12 in ACC mode. This figure also shows that the power spikes corresponding to the start of cooling cyles are reduced by the ACC controller. Also, from this figure it can be seen that ACC controller results in lower power usage both when the compressor is on and when only the PTAC's circulating fan is operating. During the time when only the fan is running, the PTAC draws 38 Watts in ACC mode versus 59 Watts in bypass mode. This represents an energy savings of 36% when the circulating fan is running.

Figure 6 clearly shows that operation in ACC mode results in significant energy savings compared to bypass mode. Two different methods used to determine the savings yield similar results, with a calculated savings of 16% for this case.

Figure 8 shows that operation in ACC mode is capable of providing these savings without sacrifices in temperature stratification within the room and without increased temperature swings over time.

2.5.2 PTAC Cooling test: indoor temperature set point = 70 °F, outdoor temperature set point = 82 °F.

Following the procedure outlined in section 2.4, the raw data for this case was plotted, the first cycle of data in each mode was removed to eliminate variations in starting conditions and the end of the usable dataset was selected to maximize the length of the dataset while insuring that the cycles ended in fan-only operation. Figure 9 shows the usable data envelopes for both modes of operation.

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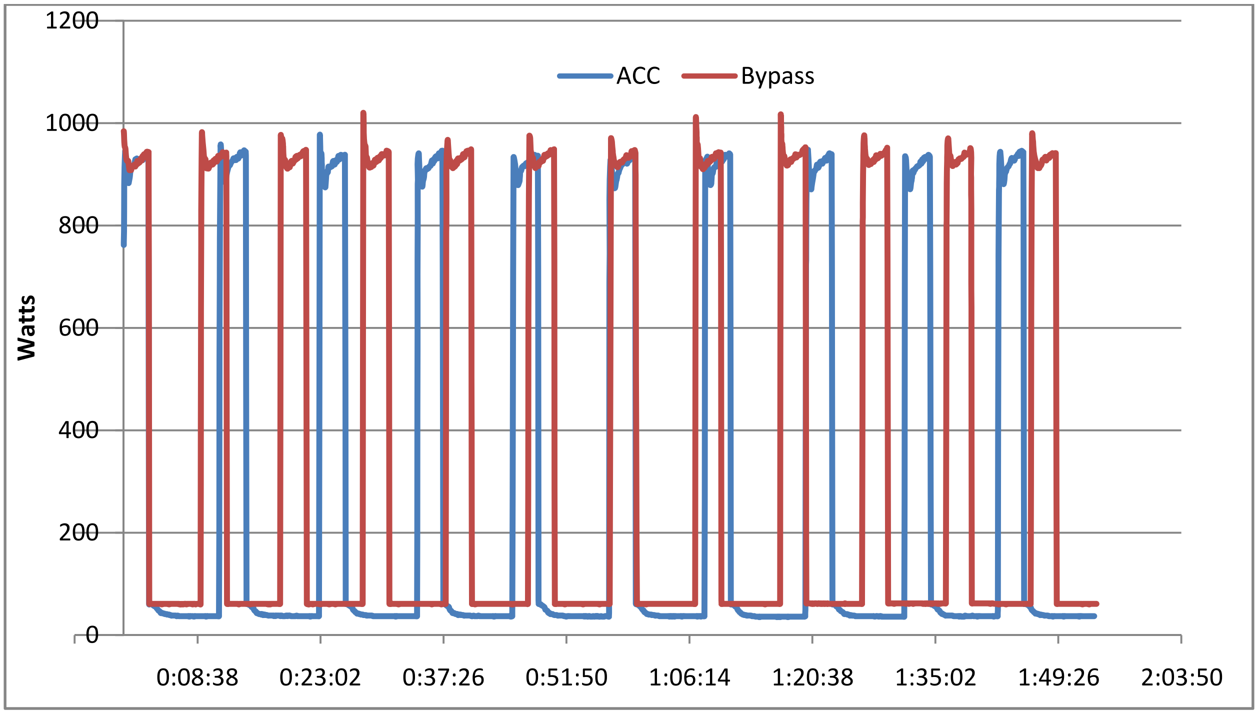

Figure 9: Comparison of power consumption in ACC and bypass modes (70 °F ID, 82 °F OD)

Examination of this figure again shows that the PTAC cycles more frequently in bypass mode. It also shows that operation in ACC mode reduces energy consumption by reducing power spikes at the start of cooling cycles and by reduced power consumption when the compressor is running as well as during the times when only the circulating fan is operating.

Figure 10 shows a plot of the watt-hour consumption over time for both modes. From this figure it is clear that operation in ACC mode provides appreciable savings in energy usage. After operation for approximately 1 hour and 54 minutes the PTAC consumed 641 Watt-hrs when operating in bypass mode and 517.2 Watt-hrs when operating in ACC mode. This represents a savings of 123.8 Watt-hrs during this time interval. Compared to the usage in bypass mode, operation in ACC mode provides an energy savings of 19.3%.

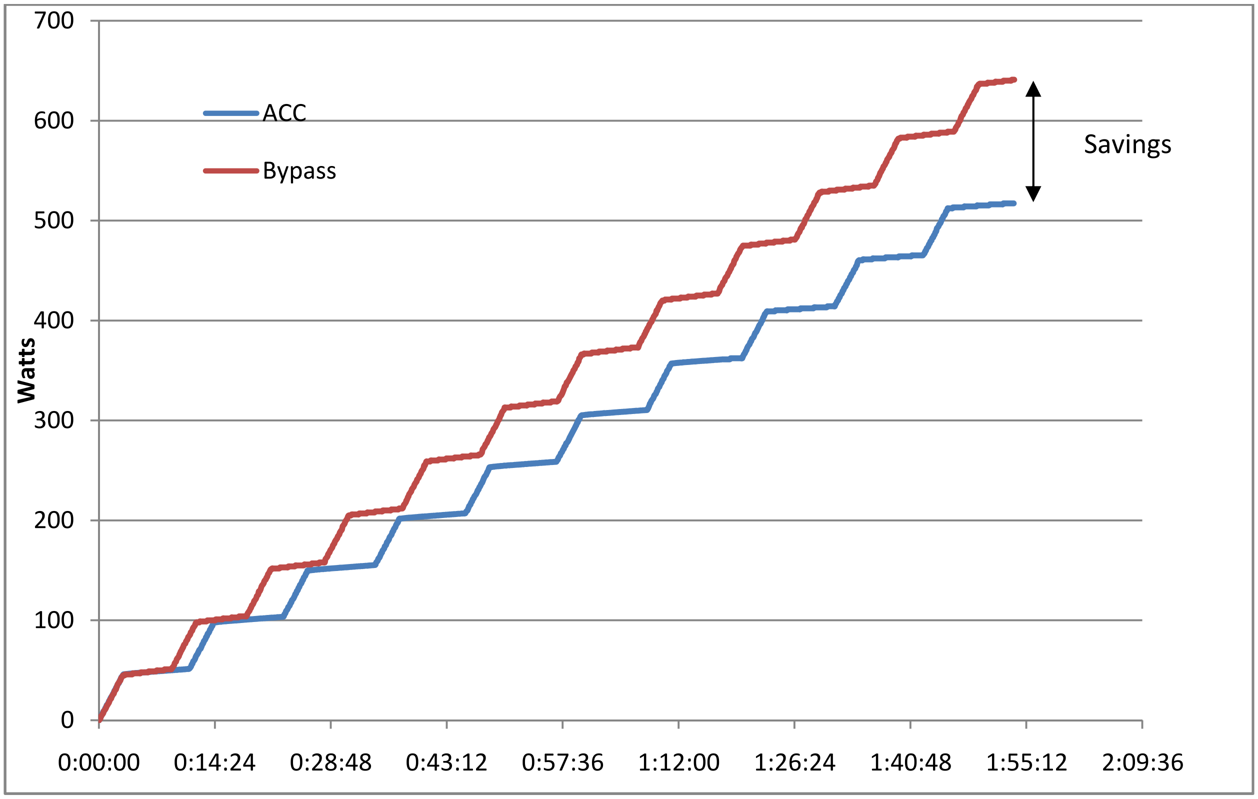

Figure 10: Running watt-hr consumption (70 °F ID, 82 °F OD)

Figure 11 shows the same data with the trending linear curves superimposed. Comparing the slopes of the trend lines gives an energy savings of 18.2% which is in reasonable agreement with the savings calculated from the total watt-hours consumed over the test interval. Averaging the results from the two methods gives an energy savings of 19%.

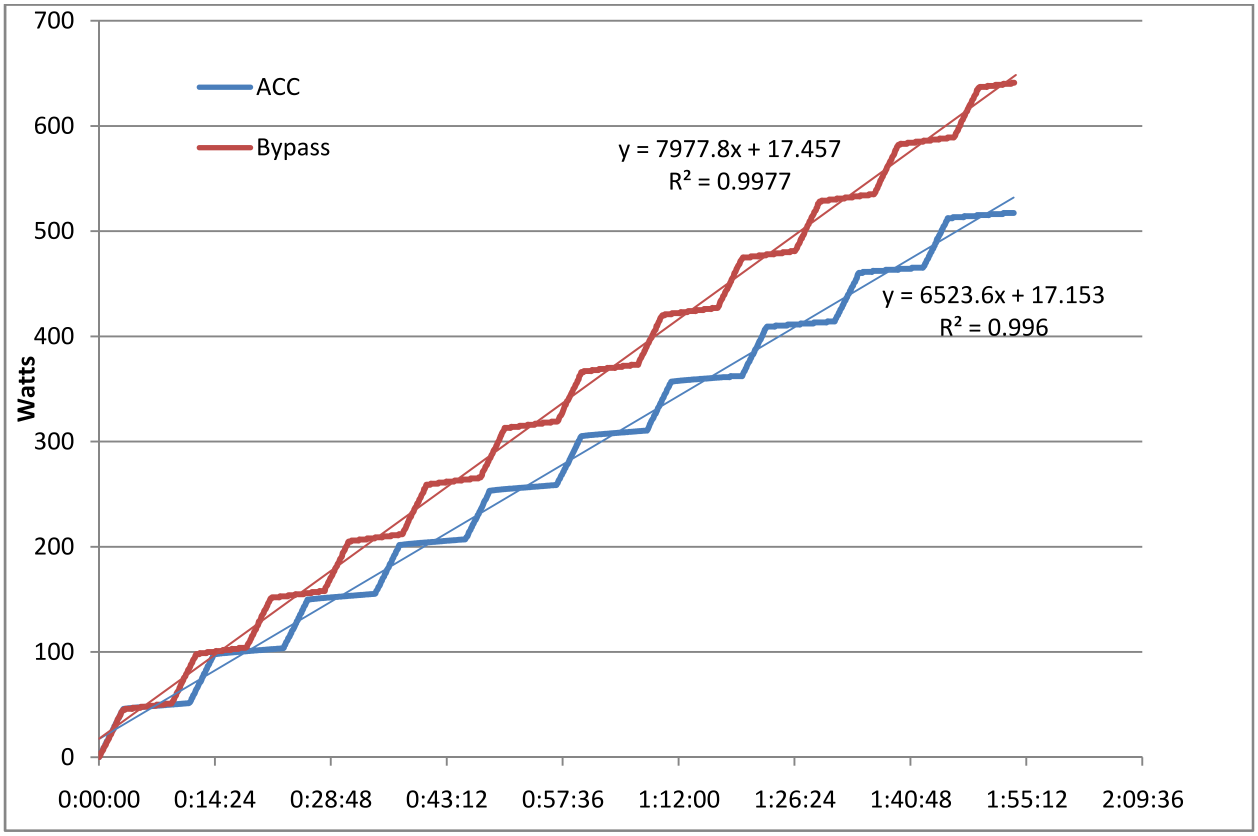

Figure 11: Linear curve fits applied to the data of Figure 10

Plots of the indoor and outdoor temperature variations are shown in Figure 12. Examination of Figure 12 shows that the spatial temperature variations between the three indoor sampling locations is similar when the PTAC is operated in bypass and ACC modes. Also, the extent of the temporal temperature oscillations is similar when the PTAC is operated in both modes. In both cases the indoor room temperatures fluctuated by approximately the same amount.

For the outdoor room the wet and dry bulb temperatures remained relatively constant at 65 °F and 82 °F, respectively. These values yield a relative humidity of 40%.

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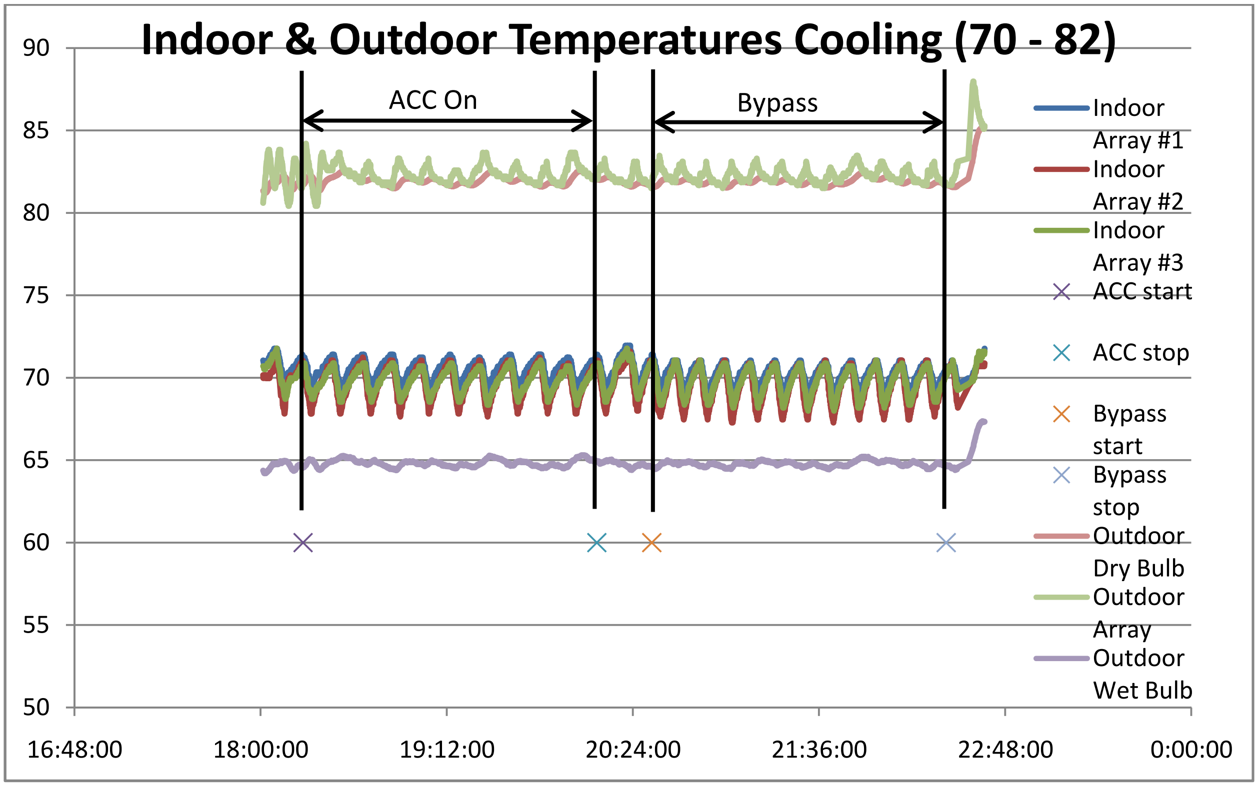

Figure 12: Temperature variations for the indoor and outdoor rooms (70 °F ID, 82 °F OD)

2.5.3 PTAC Cooling test: indoor temperature set point = 70 °F, outdoor temperature set point = 88 °F.

Analysis of this case followed the same procedures described previously. As noted earlier, there were two primary differences for this test case. First, the PTAC unit was tested in bypass mode, then ACC mode, and then again in bypass mode. Second, the data collection period was lengthened to approximately 3 hours in each mode.

Figure 13 shows usable datasets for all three of the tests (first bypass operation, ACC operation, second bypass operation). These datasets were developed using the methods discussed previously (discarding the first cycle, beginning the usable envelopes at the start of a compressor on cycle, and ending the envelopes when operating in fan-only operation). As noted in the previous cases, operation in bypass mode causes the PTAC to cycle more frequently and to use more energy when operating both the fan and compressor as well as when operating only the fan.

Figure 14 shows plots of the running watt-hour energy consumption for all three test modes. The usable data envelopes span a time interval of approximately 2 hours and 43 minutes. Several things can be noted from this graph. First, the cumulative Watt-hour curves for both of the bypass mode tests are nearly identical. Also, the linear trend lines have nearly the same slope for both tests in bypass mode. This shows that the order of test operation (bypass mode first then ACC mode or ACC first then bypass) does not influence the results. Second, this Figure shows that the energy consumed when operating in ACC mode is significantly less than operating in bypass mode.

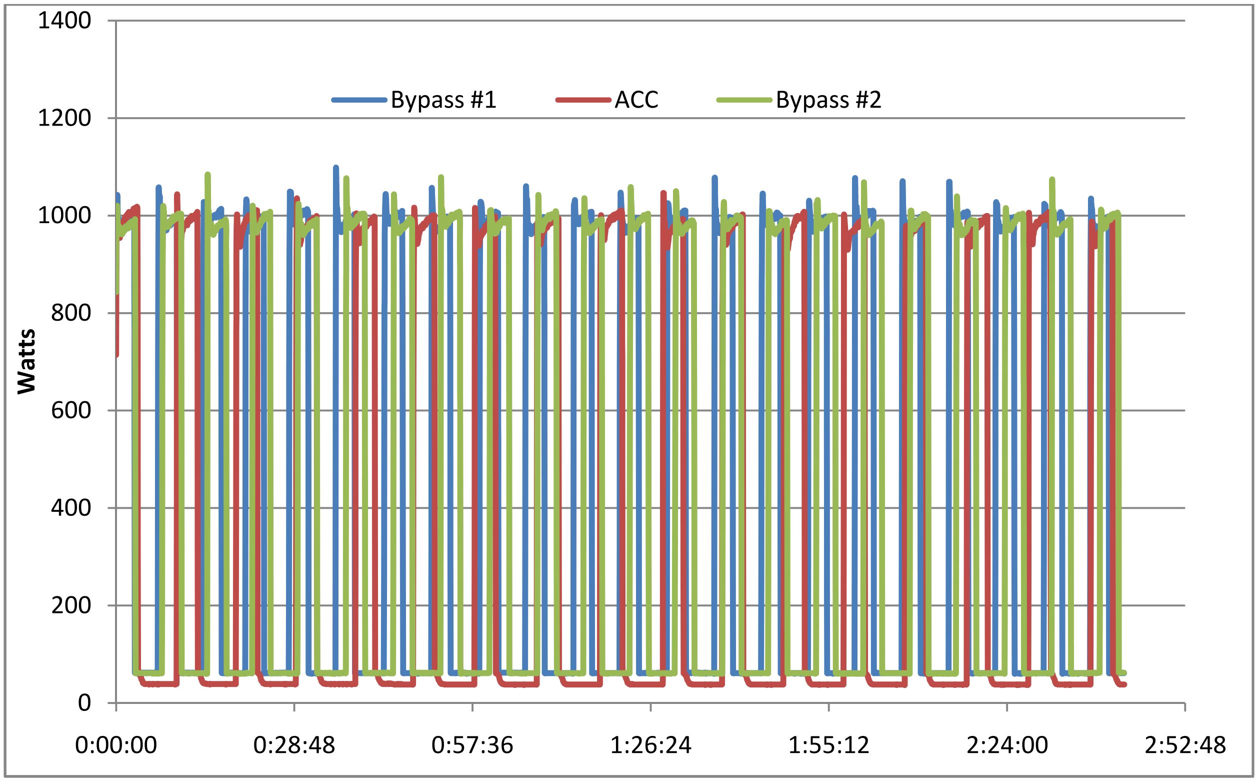

Figure 13: Comparison of power consumption in ACC and bypass modes (70 °F ID, 88 °F OD)

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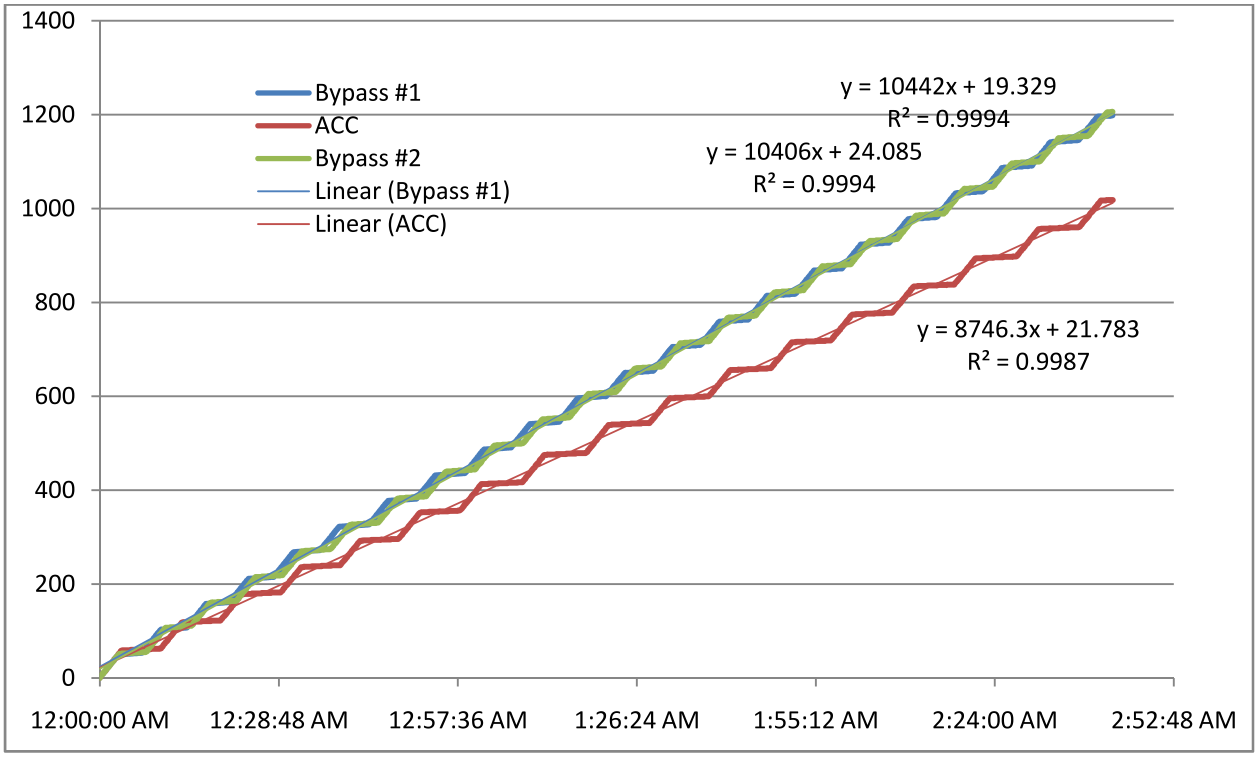

Figure 14: Watt-hr consumption comparison with trend lines (70 °F ID, 88 °F OD)

Comparing the Watt-hours consumed over the test interval and the slopes of the trend lines, operation in ACC mode provided an energy savings of 16% for this case.

The same data set shown in Figure 13 was re-analyzed using only the first 1 hour and 37 minutes of data. Analysis of the shorter data set yielded a calculated energy savings of 16%. This shows that the length of the dataset used does not influence the calculated energy savings provided the data set is long enough to get a reasonable correlation coefficient for the linear curve fit.

Figure 15 shows the variations in indoor and outdoor temperatures during this test. The figure also shows the outdoor wet and dry bulb temperatures. As seen in the previous cases, the spatial and temporal temperature variations are nearly identical for operation in ACC and bypass modes. This shows that the energy savings from operating in ACC control can be achieved without degraded climate control within the conditioned room.

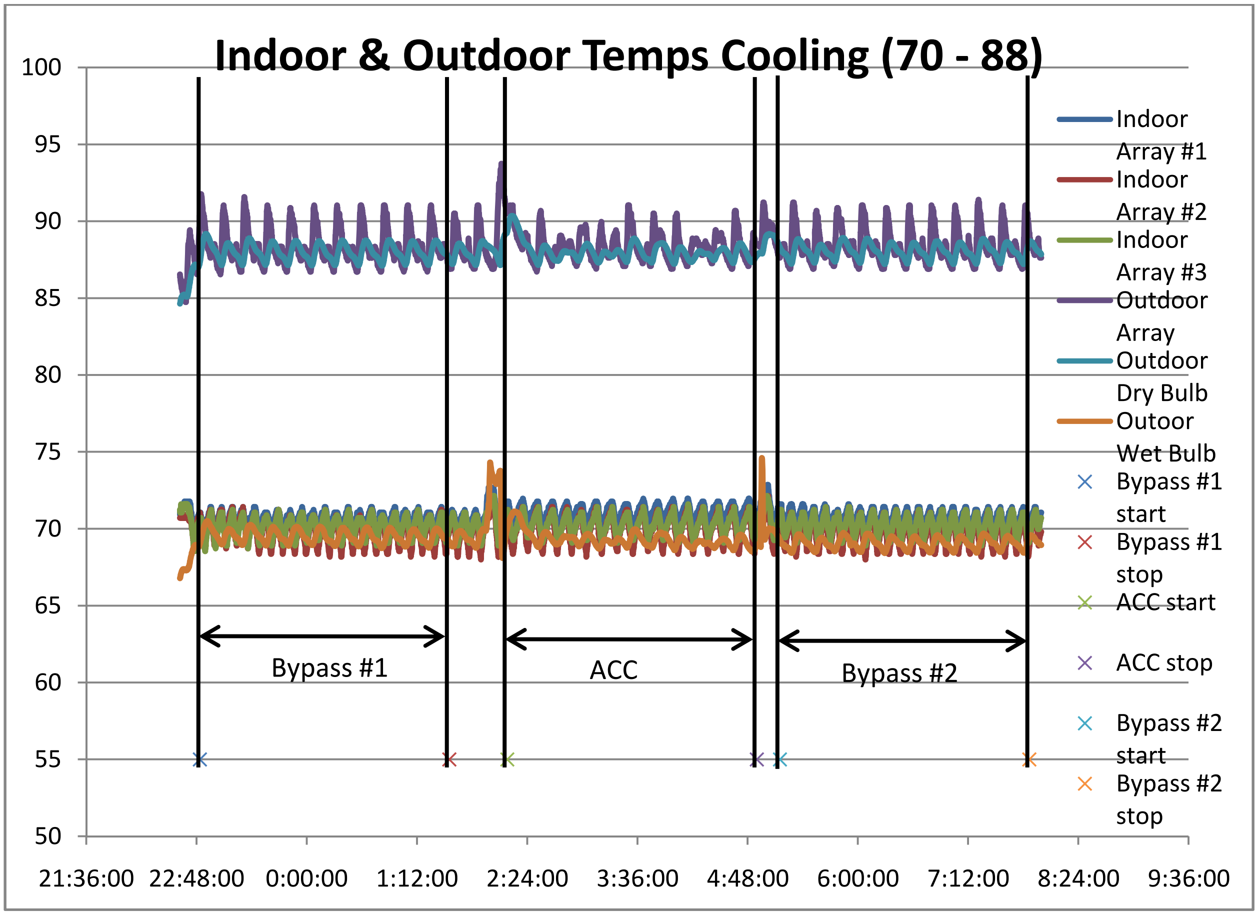

Figure 15: Temperature variations for the indoor and outdoor rooms (70 °F ID, 88 °F OD)

2.5.4 PTAC Cooling test: indoor temperature set point = 72 °F, outdoor temperature set point = 85 °F.

The same methods and analysis procedures described for the previous cooling cases were used to examine the data collected for this case. In the interests of brevity, details and figures from the intermediate analysis steps are not included. Figure 16 shows the net outcome of the analysis for this case.

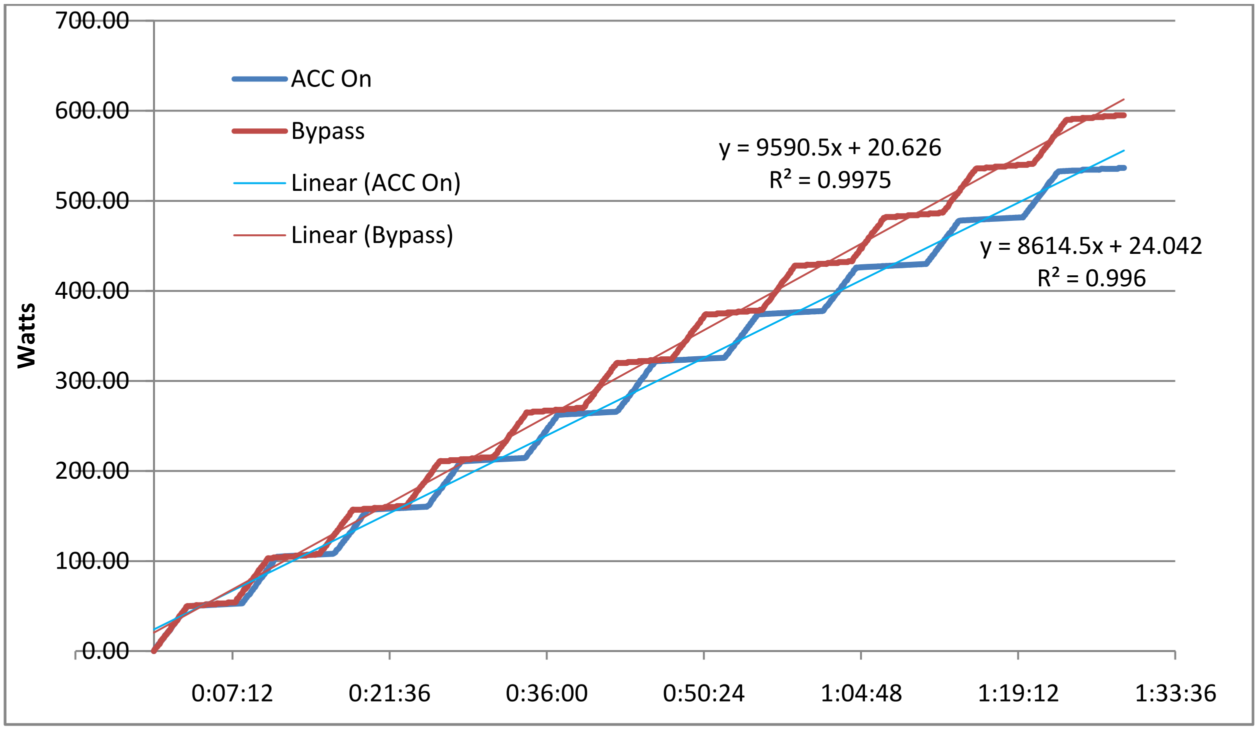

Figure 16: Watt-hr consumption comparison with trend lines (72 °F ID, 85 °F OD)

Analysis of this case shows an energy savings of 9% when comparing operation in ACC mode to bypass mode. A comparison of the temperatures within the indoor space showed similar spatial and temporal variations between operation in ACC and bypass modes. The relative humidity in the outdoor room was 40%.

2.5.5 PTAC Cooling test: indoor temperature set point = 72 °F, outdoor temperature set point = 88 °F.

This case was run with a considerably higher relative humidity in the outdoor room to make the thermal conditions more representative of summertime cooling conditions in humid climates.

As with the previous case, only the final results are presented here. Figure 17 shows a comparison of the Watt-hours consumed in both bypass and ACC modes along with the linear fits. This figure shows that the energy consumption is considerably less when the PTAC unit was operated in ACC mode. Analysis of Figure 17 shows that operation in ACC mode provided energy savings of 28%.

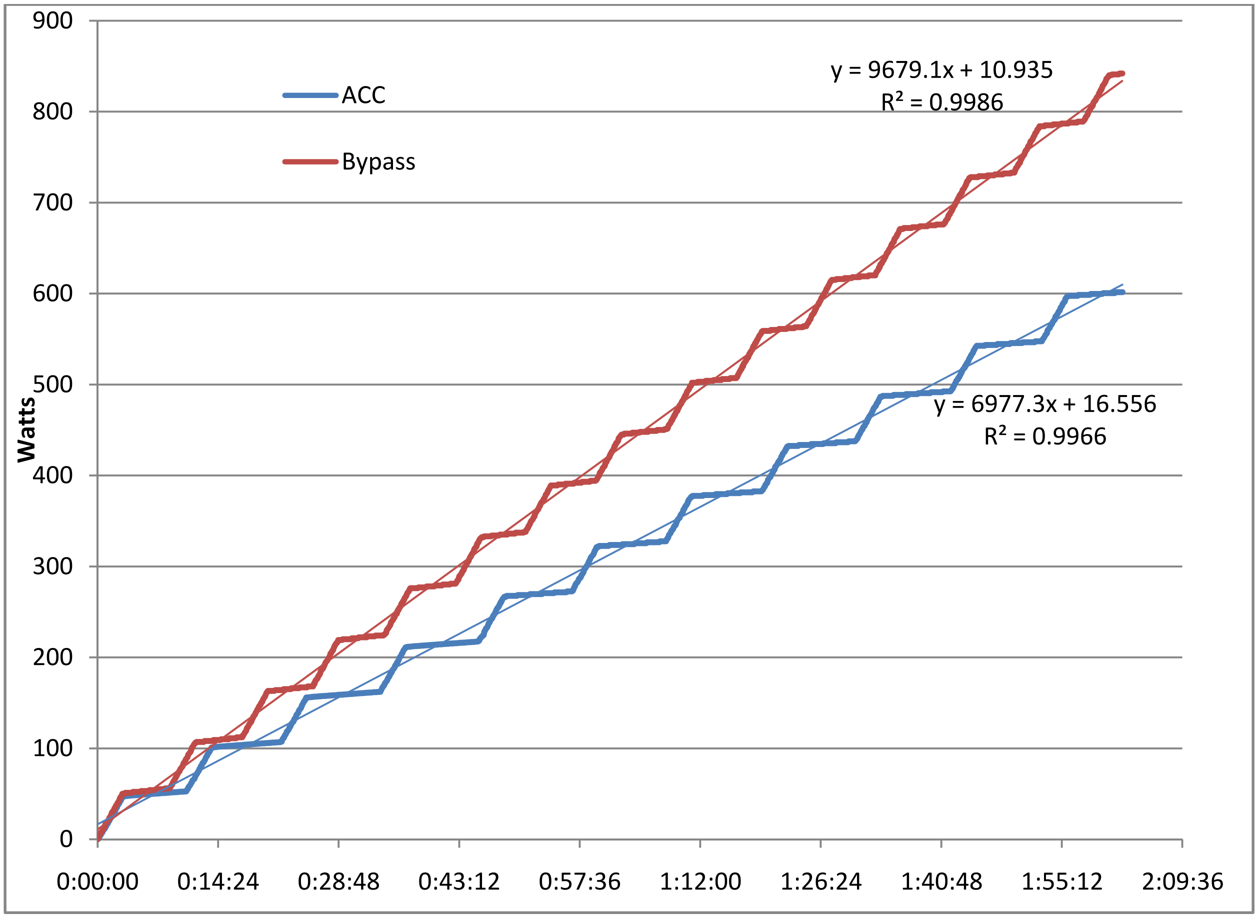

Figure 17: Watt-hr consumption comparison with trend lines (72 °F ID, 88 °F OD – higher RH)

2.6 Summary of Cooling Results

Table 2 below shows a comparison of the energy savings achieved using the ACC control system. Energy savings were obtained by the ACC controller in every case tested. All test cases represented reasonable temperature scenarios (indoor and outdoor temperatures). However, for most of the cases the relative humidity values in the outdoor space were low for typical summertime cooling conditions in humid climates. A lack of air moisture reduces the demand on the PTAC. For the one case at higher relative humidity (and more realistic conditions) the energy savings using the ACC control were significantly greater. This indicates that more substantial energy savings are possible using the ACC control when the conditions are more realistic (and more demanding) for the PTAC unit.

Table 2: Energy savings for cooling tests using the ACC control mode. (data for LG PTAC)

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Indoor Room Temp	Outdoor Room Temp	Outdoor Relative Humidity	Overall Energy Savings	Energy Savings – Circulating Fan only
70 °F	82 °F	40%	19 %	38 %
70 °F	85 °F	40%	16 %	36 %
70 °F	88 °F	37%	16 %	38 %
72 °F	85 °F	40%	9 %	39 %
72 °F	88 °F	72%	28 %	35 %

3.0 PTAC Heating Cases

3.1 Experimental Setup

The heating tests were performed at ETL SEMKO – Intertek Testing Services located in Cortland, NY. Complete details on the test facility and the equipment can be found in the test report provided by Intertek; only a summary is given herein. The test facility and configuration were identical to those used in the cooling tests. The only operational difference is that the outdoor room was maintained at low temperatures using the climate control system available at the test facility.

The tests were performed using the same LG brand PTAC unit used for the cooling test. As with the cooling tests, an ACC control unit provided by Opto Generic Devices was connected to the PTAC unit. The ACC control unit was configured so that the PTAC could be operated under control of the unit or in bypass mode. In bypass mode the ACC control unit was bypassed, allowing the PTAC to run using the factory installed control system. All testing and data recording were performed by personnel at Intertek. Data used in the analysis described herein were obtained directly from Intertek.

3.2 Instrumentation & Data Collection

The following data were collected using calibrated measurement equipment provided by Intertek. The data were collected over time and written to a data file at approximately 5 second intervals. The heating tests made use of the same measurement equipment and testing facilities as the cooling tests. Details on the instrumentation, its operation and calibration are provided separately in the report produced by Intertek.

- Time and date
- The wet and dry bulb temperatures in the outside room (used to determine the relative humidity in the outside room).
- The temperature in the outside room as recorded by an array of thermocouple sensors
- The temperature of the interior room at 3 different locations. At each location an array of thermocouples were used to record the temperature.
- The voltage provided to the PTAC unit
- The current drawn by the PTAC unit

- The Watts drawn by the PTAC unit
- The Watt-hrs consumed by the PTAC unit, accumulated as a running total

3.3 Test Conditions

The LG PTAC unit was tested for two different set points in the outside and inside rooms, as noted in Table 3 below. The set point temperatures were selected to be representative of typical temperatures experienced during operation of a PTAC. One condition represented a relatively light heating load, corresponding to an outside temperature of 45 °F, while the second case had a higher heating demand with an outdoor temperature of 35 °F.

Table 3 – Test conditions for the PTAC heating experiments

Indoor Room Temp	Outdoor Room Temp	Outdoor Relative Humidity	Testing Order	Approx. Test time in each mode
74 °F	45°F	48 %	ACC then bypass	2 hrs
72 °F	35 °F	60 %	ACC then bypass	2 hrs

3.4 Analysis procedures

The analysis procedures for the heating cases follow the exact same procedures as for the cooling cases. Please see section 2.4 for details on the analysis procedures.

3.5 Results

3.5.1 PTAC Heating test: indoor temperature set point = 74 °F, outdoor temperature set point = 45 °F.

Figure 18 shows a plot of the usable data envelopes for operation of the PTAC unit in both ACC and bypass modes for this heating case. Several things can be noted from this figure. First, the power consumption is significantly higher for the heating cases than for cooling. Peak wattages are above 3000 W as compared to around 1000 W for cooling cases. This can be attributed to the electrical heating elements used in the heating process. Second, as with the cooling cases, the PTAC unit cycles less frequently when operated in ACC mode. Third, the peak wattages are lower in ACC mode. The curve for bypass mode shows maximum wattages of approximately 3500 Watts whereas in ACC mode the peak values are around 3300 Watts. Also, during fan only operation, the Wattage draw is less in ACC mode. And finally, for heating mode the power cycles show an initial peak, then a drop in wattage followed by another increase. This is a result of having both a compressor and heating element which cyclically turn on at slightly different times. This intermediate drop in wattage is noted on Figure 18. It is

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clear that this drop is more pronounced for the case with ACC control. All of these factors contribute to lower power consumption in ACC control for heating cases.

Following the previously outlined analysis procedure, the Wattage plots shown in Figure 18 can be converted into energy usage plots. The results of that process are shown in Figure 19. This figure shows the energy consumption in Watt-hours for both ACC and bypass modes. The figure also shows the linear data fits.

These results show that operation in ACC mode provides an energy savings of 14% compared to operation in bypass mode. Examination of the plots of the spatial and temporal temperature variations within the indoor space shows that the ACC control mode is able to achieve the energy savings without degradation in control of the interior temperatures.

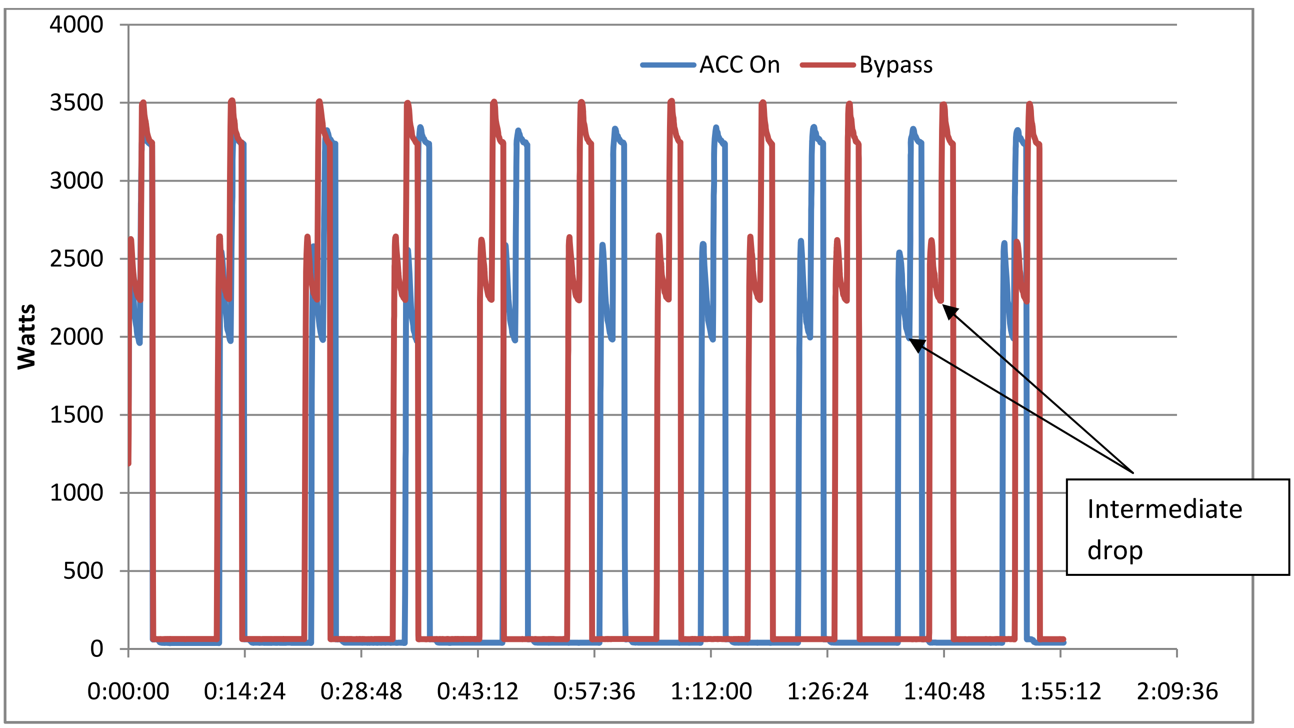


Figure 18: Comparison of Watt usage for bypass and ACC modes (74 °F ID, 45 °F OD)

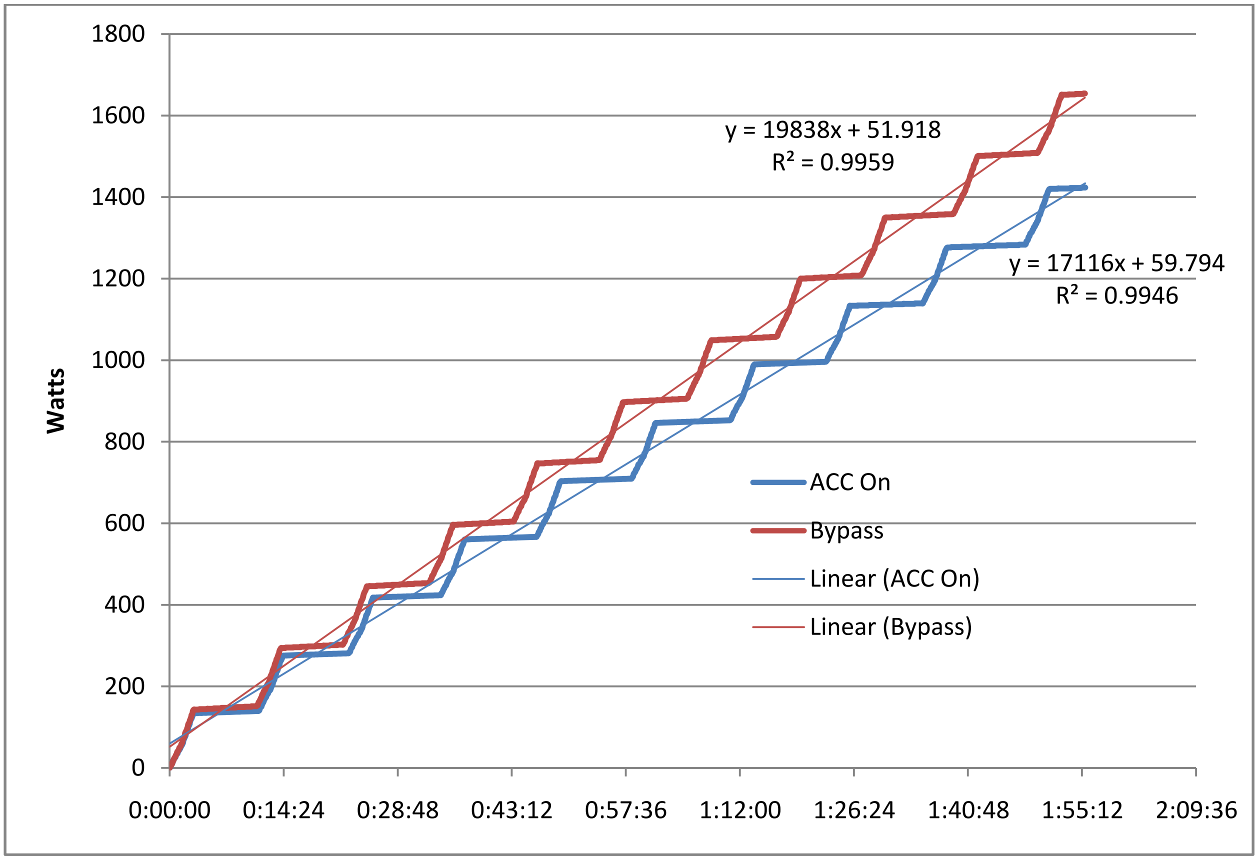


Figure 19: Watt-hr consumption comparison with trend lines (74 °F ID, 45 °F OD)

3.5.2 PTAC Heating test: indoor temperature set point = 72 °F, outdoor temperature set point = 35 °F.

Following the previously outlined analysis procedure results in the data shown in Figure 20 for the heating case with an indoor temperature of 72°F and an outdoor temperature of 35 °F. This figure shows the energy consumption (in Watt-hours) for operation in both ACC and bypass modes. The figure also shows the linear data fits. (Note that the wattage plot for this case shows the exact same behavior as that shown in Figure 18 with the same corresponding energy savings mechanisms resulting due to ACC control.)

These results show that operation in ACC mode provides an energy savings of 22% compared to operation in bypass mode. The results also show that as the heating demand increased (as compared to the previous heating case) the energy savings produced by the ACC control increased.

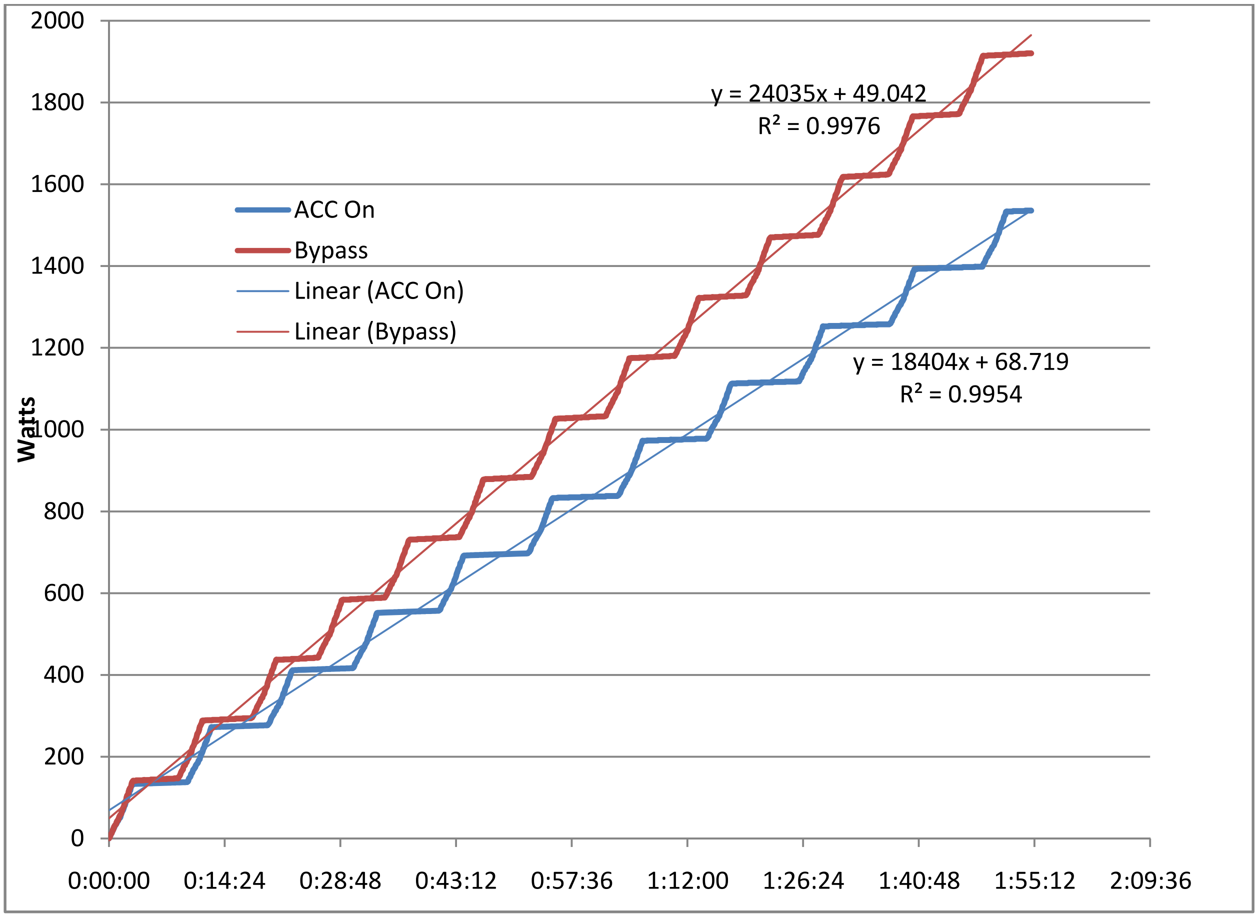


Figure 20: Watt-hr consumption comparison with trend lines (72 °F ID, 35 °F OD)

3.6 Summary of Heating Results

Table 4 below shows a comparison of the energy savings achieved using the ACC control system for operation of the PTAC in heating mode. Significant energy savings were obtained by the ACC controller in both case tested. Both test cases represented reasonable temperature scenarios (indoor and outdoor temperatures); one test represented a relatively minor heating load and the other a more demanding scenario. The savings produced by the ACC control were larger for the more demanding heating case.

Table 4: Energy savings for heating tests using the ACC control mode (data for LG PTAC)

Indoor Room Temp	Outdoor Room Temp	Overall Energy Savings	Energy Savings – Circulating Fan only
74 °F	45 °F	14 %	38 %
72 °F	35 °F	22 %	37 %

4.0 High Voltage Test

The goal of this test was to demonstrate if the ACC controller could successfully provide control at a higher line voltage. In this experiment the ACC controller was used to control an electric motor which was used to drive an air blower. The ACC controller was supplied with a voltage of 267 Volts. In bypass mode this power supply drove the motor at a rotational rate of 1109 rpm and the power and current drawn were 770W and 2.8 A, respectively. The motor and fan were also driven directly by the supply voltage (i.e. with the ACC control box was removed). The motor performance (wattage, current and rpm) was the same as when then the control unit was set to bypass. This test was done to verify that the ACC unit had no effect when operated in bypass mode.

After recording the motor performance specifications when operating in bypass mode, the unit was then switched from bypass to ACC control. Adjustment of the ACC controller showed that the control unit was able to vary the motor speed. The motor was slowed to a speed of 617 rpm. Lower speeds were not attempted due to bearing problems with the motor.

The last portion of this test was to verify that a thermistor input to the ACC unit could be used to control the motor speed. A thermistor was connected to the ACC unit and the thermistor was subjected to varying temperatures. Tests showed that raising the thermistor temperature increased the motor speed and decreasing the temperature decreased the speed.

Results of the high voltage tests showed that the OGD controller could successfully control the motor at a supply voltage of 267 V. No problems were noted with the operation of the motor/fan unit while under ACC control.

5.0 High Current Test

In this experiment the ACC control unit was used to control a cluster of space heaters. The supply voltage to the ACC unit was 208 V. Several potentiometer settings on the OGD controller (labeled low, mid and high in the table below) were tested to demonstrate that the unit could apply a broad range of control and savings in power usage. Measurements of current, voltage and power were recorded before (input) and after (control) the ACC control unit. Table 5 below summarizes the results from this test.

Table 5: Input and output measurements of the ACC controller under elevated current load

	Bypass mode	ACC Control		
		Setting 1 – low	Setting 2 - mid	Setting 3 - high
Input	21 Amps	20.5 Amps	17.1 Amps	8.1 Amps
	204 V	204 V	204 V	205 V
	4.25 kW	4.2 kW	3.48 kW	1.71 kW
Control	21 Amps	20.6 Amps	17.3 Amps	8.4 Amps
	203 V	198 V	166 V	79 V
	4.2 kW	4.06 kW	2.84 kW	0.64 kW

Comparing operation in bypass mode to operation under ACC control, use of the ACC controller was able to lower the power draw on the input and control by up to 60% and 85% respectively.

6.0 Overall Summary

The performance of a control system (ACC) developed by Opto Generic Devices was evaluated under several scenarios including: 1) control of a PTAC unit operating in cooling mode; 2) control of a PTAC unit operating in heating mode; 3) control of a motor/blower system at higher line voltage; and, 4) control of a bank of heaters with a high current draw.

For all of the PTAC heating and cooling tests examined (totaling 7 different operating scenarios), the ACC controller provided significant energy savings compared to native operation of the PTAC unit. Examination of the power usage plots from the PTAC unit shows that operation in ACC mode results in less frequent cycling of the PTAC unit, reduced power spiking and lower power consumption, both when the compressor (and heater) and fan are operating together and when only the circulating fan is operating alone. These factors result in sizeable reductions in energy consumption which can be clearly seen from plots of the cumulative Watt-hour consumption. Also, it was noted that these energy savings are achieved without sacrificing the temperature control in the indoor space. Table 2 summarizes the calculated savings for the cooling tests and Table 4 summarizes the savings for the heating tests.

Comparing the two heating cases, an increase in heating demand resulted in significantly larger energy savings. For operation in cooling mode, the test case at higher relative humidity (which also represents a higher demand and is much more realistic of a typical cooling scenario) showed substantially larger savings.

Testing of the ACC control unit at higher voltages (267 V) showed that the unit was cable of providing a broad range of control to an electrical motor used to drive a blower unit.

Testing of the ACC unit under an increased current load showed that the unit can operate properly and can provide a broad range of power control with the potential for very substantial power savings. No problems were noted in either the high voltage or high current test.

SELECTED TEST RESULTS

6. McQuay Cooling Tests

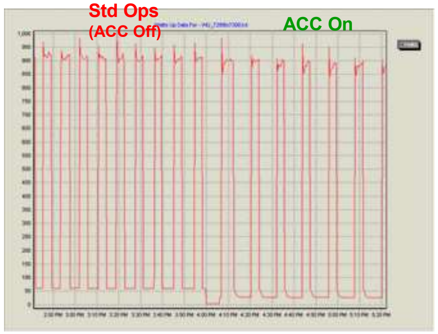
McQuay PTAC
Cooling Tests
For Power Consumption
And Climate Impact

PTAC Cooling McQuay Test #1

Average Savings

1. 29% reduction in compressor run time **(24 min TO 17 min)**
2. 23% reduction in number of compressor cycle times **(6.5 to 5)**
3. 14% increase in compressor off time **(36 min to 42 min)**
4. **33% overall power savings (From .39KWh to .26KWh)**
5. **Maintaining or improving the climate conditions**

McQuay PTAC Test #1 Set point 72º



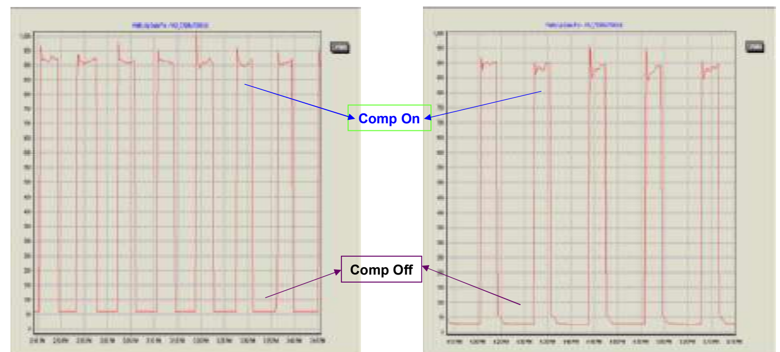
From the Watts Up graph, the following conclusions are evident:

1. The ACC reduces compressor run time
2. The ACC increases the compressor off time
3. The ACC reduces the number on cycles
4. The power consumption is much less with the ACC because of the above reasons

Std Ops vs. ACC

Std Ops
ACC OFF

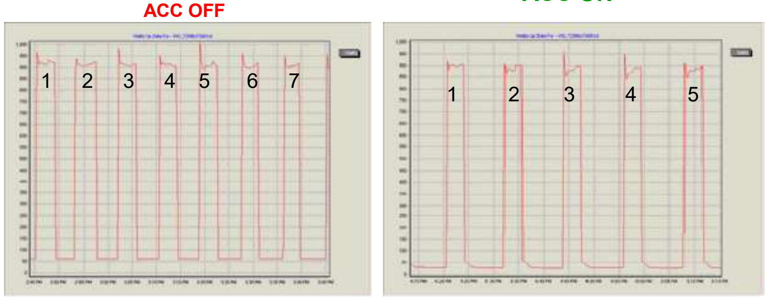
ACC



ACC vs. Std Ops

Compressor On

Std Ops **ACC OFF** | **ACC ON**



Cycle reduction Savings of 29% with ACC control versus standard operation

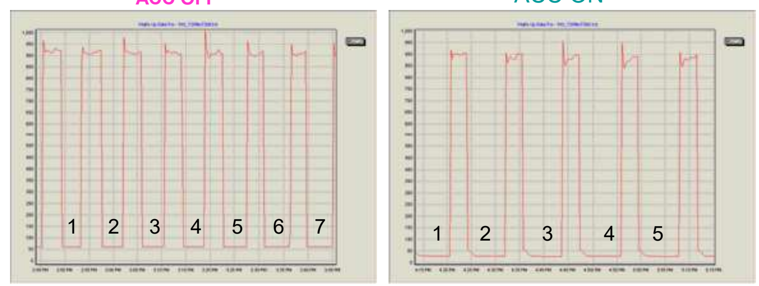
(5 ON Cycles with ACC; 2 more ON Cycles without ACC total 7 on cycles)

Also note the individual cycle-on times are shorter with the ACC.

ACC vs. Std Ops

Compressor Off

Std Ops **ACC OFF** | ACC ON



OFF Cycles & Times with ACC control versus standard operation

5 OFF Cycles @ 8.5 min With ACC Total = 42.5 min,

7 OFF Cycles @ 5 min With Out ACC Total = 35 min,

The Cycle Ratios = **28%** Plus the Off duration of 5 to 8.5 = **42%**

Std Ops vs. ACC : Test #1

Compressor ON

Std Ops (ACC OFF)

- In the span of an hour the compressor was on 7 times, with avg. on time of 3.5 min
- The total compressor run time in that hour was 24.75 min
- Therefore the compressor was **on for 41% of the time** in that hour

ACC ON

- In the span of an hour the compressor was on 5 times, with avg. on time of 3.6 min
- The total compressor run time in that hour was 18 min
- Therefore the compressor was **on for 30% of the time** in that hour

While Maintaining the same climate conditions.

Std Ops vs. ACC : Test #1

Compressor Off

Std Ops (ACC OFF)

- In the span of an hour the compressor was off 7 times, an avg. off time of 5.0 min
- The total compressor off time in that hour was 35 min
- Therefore the compressor was **off for 58.75% of the time** in that hour

ACC ON

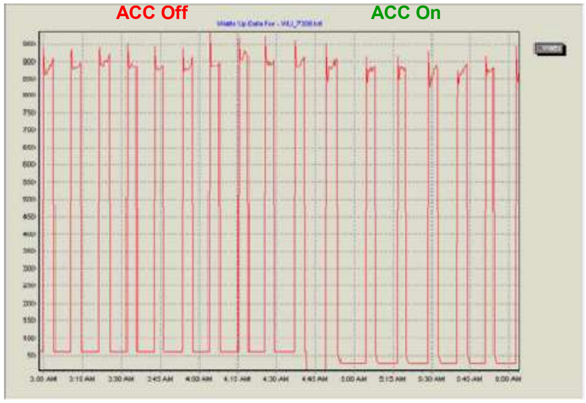
- In the span of an hour the compressor was off 5 times, an avg. off time of 8.5 min
- The total compressor off time in that hour was 42 min
- Therefore the compressor was **off for 70% of the time** in that hour

While Maintaining the same climate conditions.

SUMMARY Test #1

- 27% reduction in compressor run time **(24.75 min to18 min)**
- 28% reduction in number of compressor ON Cycles **(from 7 to 5)**
- 21% increase in total compressor OFF Time **(35 min to 42.5 min)**
- 2.2% reduction in compressor operating power **(896 W to 876 W)**
  Demand Reduction
- **<u>33% total power savings</u>** (.39 KWh to .26 KWh)

TEST #2 Set @ 74º

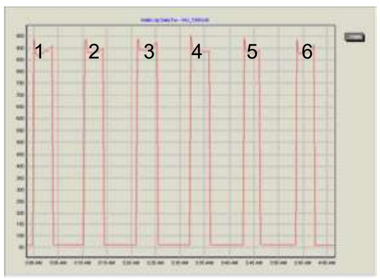


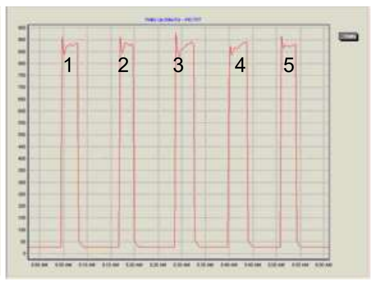
TEST #2 Set @ 74º

Std Ops
ACC OFF

Number of On Compressor Cycles

ACC ON





Cycle reduction Savings of 17% with ACC control versus standard operation

(5 ON Cycles with ACC; 1 more ON Cycles without ACC total 6 on cycles)

Std Ops vs. ACC Test #2

Run Time Calculations

Std Ops ACC OFF

- In the span of an hour the compressor was on 6 times, with a avg. on time of 3.83 min
- The total compressor run time in that hour was 23 min
- The compressor was on for 38% of the time in that hour
- The compressor was off 62% of the time in that hour

ACC

- In the span of an hour the compressor was on 5 times, with a avg. on time of 3.6 min
- The total compressor run time in that hour was 18 min
- The compressor was on for 30% of the time in that hour
- The compressor was off 70% of the time in that hour

SUMMARY Test #2

- 23% reduction in compressor run time **(23 min to 17.75 min)**
- 20% reduction in number of compressor cycles **(6 to 5)**
- 12% increase in total compressor off time **(37min to 42.25 min)**
- 2.1% reduction in compressor demand power
- **26% total power savings** **(.38KWh to .28KWh)**

Conclusions

- The OGD ACC performs very well when tested on the McQuay PTAC. With an **average power savings of 25% to 30+%.** The greater the Cycle demand on the compressor the more energy saved with the ACC. **In some instances as much as 50% savings were observed with!**
- The McQuay PTAC is not indicative or representative of an aftermarket retrofit, it is superior to and more energy efficient. Therefore one can expect a greater savings when the ACC is implemented on a typical aftermarket representative PTAC.
- Also Climate results for both tests with PTAC in Std Ops versus with the ACC show that **the ACC always maintains or improves the climate** conditions in the room occupied space.

7. Purdue University Tests (Phoenix)

Phoenix Device

Introduction

A preliminary study was done to find the kWh savings using the Phoenix device in a FCU in Third Street Tower lounge areas. The testing was done over several weeks to find the difference between a room and without the Phoenix device. An analysis was done looking at weekly values to make an estimate for the amount of energy that is estimated to be saved yearly. Table one shows the amount of money that is estimated to install the device and the yearly payback. These savings are found during cooling times in a well-insulated room. Third Street Tower is a fairly new building, high savings are estimated to be found in a higher or older buildings. The yearly estimated savings for the lounge area is $126 for a 1.5 HP device

Table 1 the expenses of installing one Phoenix Device

Expense	Cost
Phoenix Device	$300
Labor	$120
Total	$420
Payback	3.3 years

The labor costs are estimating that the job will take two people two hours to install. The cost used per hour was estimated to be $30. The majority of the time constraint when installing the device is finding where the FCU is located.

Constraints:

Throughout the project a list of limiting factors were found to hurt the feasibility of installing the Phoenix Devices in every fan coil unit. The preliminary study was unsuccessful at finding two equally sized room with DDC to monitor chilled water and steam savings.

1. Equally sized rooms
2. Single phase/120V
3. DDC controlled
4. Room near FCU to put Phoenix Device

Next Phase:

Finding a large area to renovate a building with Phoenix controllers and trend steam and chilled water savings. Four locations were found to have large amounts of FCU that are not on DDC. Lily does have some controls for FCU but the floor plans do not match SMAS. Finding two identical areas to track the most costly savings would help to further prove that this device is best fit for applications across campus. The steam and chilled water savings will help to improve the payback for the Phoenix Device but have been undetermined through the preliminary study.

Table 2 The number of FCU in each building and the estimated savings associated

Building	Location (floor)	# of FCU	Yearly Savings ($$)	Yearly Savings (kWh)
AGAD	2nd	12	$1,500	27,600
Lily	Basement, ground, main, 3rd	75	$9,500	172,000
PMU Hotel	Whole building	193	$24,403	443,691
WTHR	2nd, 3rd, 4th, ground	33	$4,200	75,900

Using the metering data an estimate was made on a weekly bases the average amount energy savings that could be trended. One difference between the building tested and the buildings represented below. These buildings are older compared to the one tested thus there are some energy saving methods that are not in place in older buildings, such as new windows.

Table 3 Comparing weekly energy saving to total metered consumption to find the percentage of savings

Building	Current Weekly Usage (kWh)	Estimated Savings (kWh)	% of Savings
AGAD	7,321	530	7%
Lily	109,969	3,316	3%
PMU Hotel	25,948	8,532	33%
WTHR	102,059	1,459	1%

The energy savings on a yearly scale save a substantial amount of savings but on a weekly scale represent a minor amount of electrical energy for the whole building. This is because FCU do not consume a large amount of the building's energy. Evaluating the steam and chilled water saving would be easier to see on a metered bases because FCU hold a larger energy share.

Conclusion

Installing the Phoenix Device in a building is the next step. The Phoenix Device is ideal for areas that have no building controls. This device is a cheaper solution than renovating an area with DDC. There is energy savings found even when omitting steam and chilled water. The electricity savings are low in comparison with a whole building and would be hard to find by simply trending metered data. Finding the steam and chilled water savings would help validate that installing this device on a campus scale would be financially feasible.

SELECTED TEST RESULTS

8. ConEdison Tests by ERS

www.aclectic.com | Tel: (518) 416-5624 | E-mail: Phaldar@aclectic.org

1430 Broadway, Suite 1609
New York, NY 10018
Phone: (212) 789-8182
Fax: (212) 658-9049
Web: www.ers-inc.com

MEMO

DATE: August 7, 2014

TO: Mike Ihesiaba, CECONY

FROM: Ryan Bossis and Satyen Moray, ERS

RE: DMP014/015 - M&V Plan

The Demand Management Program (DMP) projects DMP014/015 involve the installation of adaptive climate controllers (ACC) on existing PTAC units throughout a residential multi-family complex. The complex is divided into two towers connected on the lower floors. Each tower is assigned a separate DMP project number. The ACC varies the PTAC fan speed to match the load, thereby savings fan energy as well as properly sizing the airflow over the unit's coil.

Project Overview

The project was submitted with annual energy savings of 9.2 million kWh and peak demand savings of 531 kW between the two buildings. The initial energy savings estimate represented 39% of the baseline energy consumption and the peak demand savings represented 15% of the billed demand. The energy savings estimate is a very large fraction of the baseline consumption. The calculations and data supplied by the applicant did not provide significant confidence that these savings levels would be achieved. Therefore, ERS recommended a short metering test on one PTAC unit to determine the potential magnitude of the peak demand savings, before conducting the full sample of testing. Con Edison, the product vendor, installation contractor, and end customer agreed to this test.

Test Methodology

A vacant 2-bedroom apartment was selected for the testing to reduce disruptions to the tenants at this stage.. The controller unit was installed on the PTAC units in both bedrooms with a bypass switch option. Each unit was switched between bypass and ACC mode to understand how the controller worked and view the wattage differences of the units. Additionally, an overnight test was conducted in which the ACC in one room was left in bypass while the ACC in second room was kept active.. A Watts Up meter was used deployed on the two PTAC units to record wattage on a two second interval. Since the rooms were oriented in different directions (one to the East, one to the South), some uncertainty from solar loading was introduced during the daylight hours. However, during the overnight hours both rooms would experience similar weather conditions allowing for an "apples-to-apples" comparison.

Testing Results

The ACC controllers in both rooms had been installed prior to ERS visiting the site, and were set to ACC mode. A Watts Up meter with a real-time display had been installed by the installation contractor to view system power consumption. Both units had been set to maximum cool.

Starting with the East facing room with the ACC enabled, the PTAC unit's power consumption leveled off at approximately 940 W. With the controller set to bypass, consumption climbed to 950-970 W. With the controller turned back on, consumption fell to 945 W. Overall, this amounted to about a 20 W savings, or a 2% reduction.

For the South facing room, the power draw of the PTAC unit was 840-860 W with the ACC on. With the ACC set in bypass mode, the consumption of its PTAC unit increased to 880 W, indicating an average savings of 30 W or roughly a 3% reduction. ERS was also able to observe the discharge air temperature's effect on the fan speed. With the ACC controller on, the fan was slowed and discharge air temperature was 50°F. When the controller was switched to bypass, power draw increased as the fan speed increased, resulting in more air flow and increasing the discharge air temperature to 55°F.

These spot tests cannot be used to definitively quantify the project's savings due to variation in the orientation between the rooms, and no measured impact of cycling. However, they do show that the controller is capable of modulating the fan speed and this can result in reduced wattage draw.

Additionally, an overnight test was conducted to see how the units would perform over a prolonged period. This allowed data to be collected on the unit's cycling. Starting at 11 am on July 23, through 7 am on July 24, the South room was left in bypass mode while the East room was controlled by the ACC controller. The meters were set to record watts, volts, amps, and power factor at 2 second intervals, however the south room recorded only wattage. Additionally, the East room meter had an issue with the interval setpoint and recorded at approximately 2.25 second intervals. The data was rescaled to account for this impact.

Between the period of midnight to 7 am on July 24, the ACC controlled unit cycled on 17 times, while the uncontrolled unit cycled approximately 13.5 times. However, it is important to note there can be significant variability between the units. Although the temperature dials were set to approximately the same locations, the room with the controller was approximately 2°F cooler than the room without when the logger retrieval was conducted. It is not clear at this time if that is a result of the PTAC unit thermostats or the controller. In addition, the rooms were slightly different shapes and sizes, with different external loading. While these variables are not accounted for in a single test, they will be accounted for during the full M&V sample. In that test, multiple apartments will be tested, and a pre/post test will be conducted on each individual unit selected for testing, removing this source of variability.

ERS reviewed the fan and compressor energy use during several periods. The results are provided in Table 1. The analysis did not take into account variation in the ratio of fan to compressor runtime (changes in cycling) for the reasons mentioned above. This will be accounted for in the actual sampling. Overall, the unit with the ACC controller saw lower fan and compressor use, with the largest difference in wattage during the 2 - 6 pm period.

Table 1. Test Summary

Period	Component	ACC	Bypass	Savings	
		Watts		Watts	Percent
All	Fan	15	48	33	69.2%
	Compressor	882	919	36	3.9%
Day	Fan	15	48	33	68.1%
11 am - midnight	Compressor	903	941	38	4.0%
Night	Fan	14	47	33	70.5%
Midnight - 6 am	Compressor	828	841	13	1.6%
Peak	Fan	15	48	34	69.6%
2 - 6 pm	Compressor	917	982	66	6.7%

During the peak period savings were 34 W and 66 W for the fan and compressor respectively. Using an average metered duty cycle of 50% during the period, the weighted savings would be 50 W.

Potential Savings

Table 2 provides the potential savings of this measure, assuming 50 W savings per unit and 3,023 PTAC units.

Table 2. Potential Project Savings

Measure Name		Energy Savings (kWh/yr)	Peak Demand Savings (kW)
PTAC controller	DMP014	2,908,030	227
	DMP015	6,340,128	304
	Application total	9,248,158	531
	Desk review	N/A	N/A
	Spot testing	1,500,000	150

The values above assume that all apartments are occupied and that all PTAC units operate during the peak period. If fewer units are operating, then actual savings will only be a fraction of the projected savings. If the ACC controlled PTAC units continue to show increased cycling compared to the uncontrolled units, energy savings may not be achieved, resulting in a reduced incentive.

Energy savings were estimated using the 50 W average savings divided by the average energy use, yielding approximate a 10% savings. This was applied to 60% of the building's billed use for heating and cooling. Additional information regarding the buildings' energy breakdown is forthcoming from the facility.

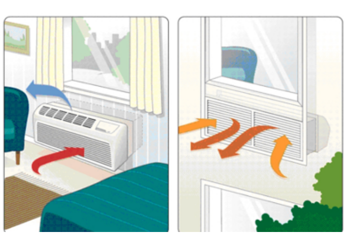
It was also noted that additional discussions with the vendor indicated that the savings submitted with the application were incorrectly entered with too high of a value. The total was meant to be approximately 6,000,000 kWh and 300 kW, similar to just the DMP015 portion.

As evidenced from the brief monitoring period, the ACC results in energy savings, however not at the level predicted by the vendor. The revised peak demand savings exceed the minimum threshold of 50 kW for the DMP. As a next step, we recommend deploying loggers on a statistically chosen sample of units to further develop the profiles associated with the ACC.

Adaptive Climate Control (ACC): Future of HVAC PTAC/PTHP

Aclectic

Adaptive Control Technologies



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