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

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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%.

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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.

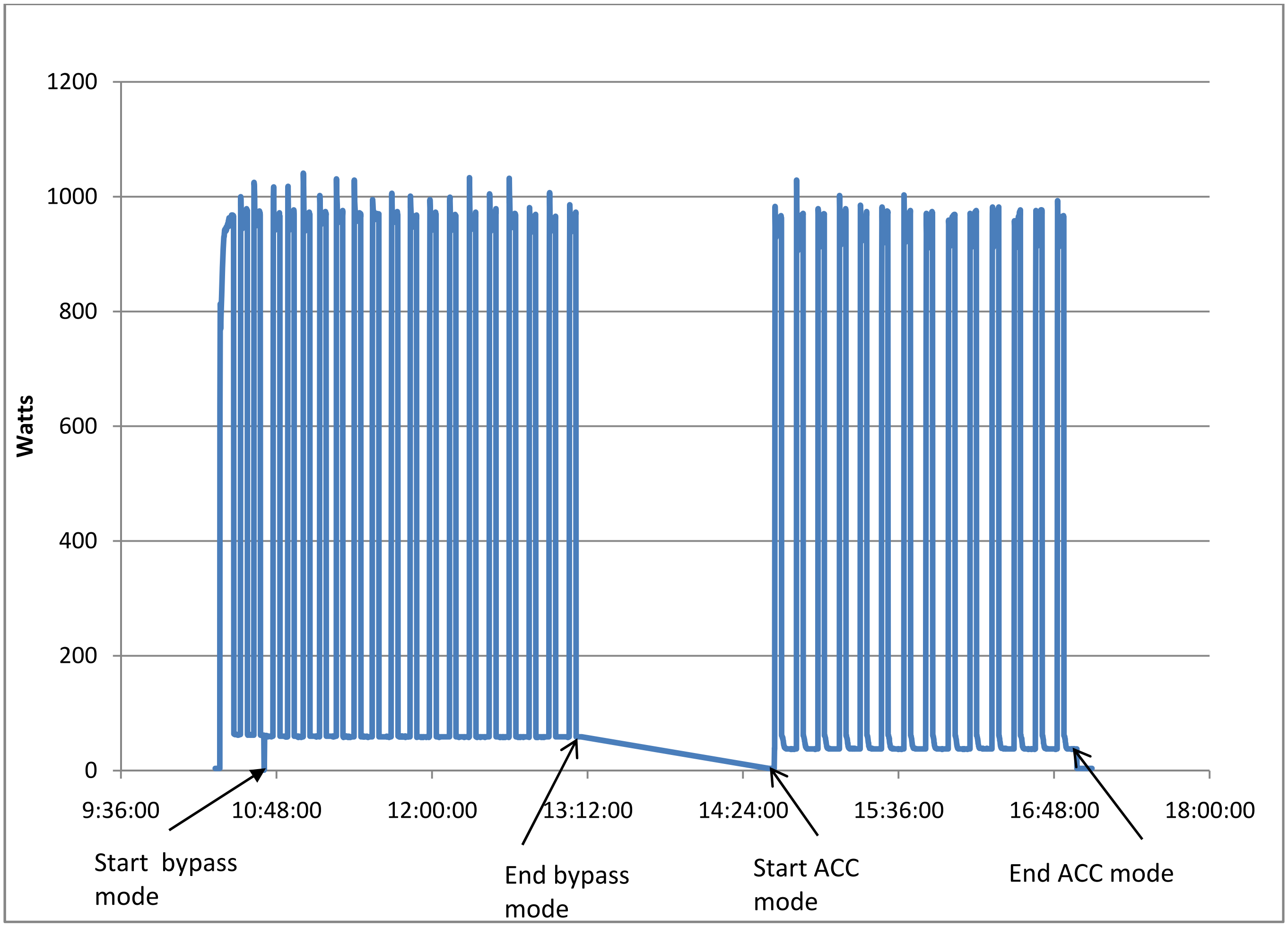

Figure 1: Watts versus time for cooling case (70 °F indoor, 85 °F outdoor)

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".

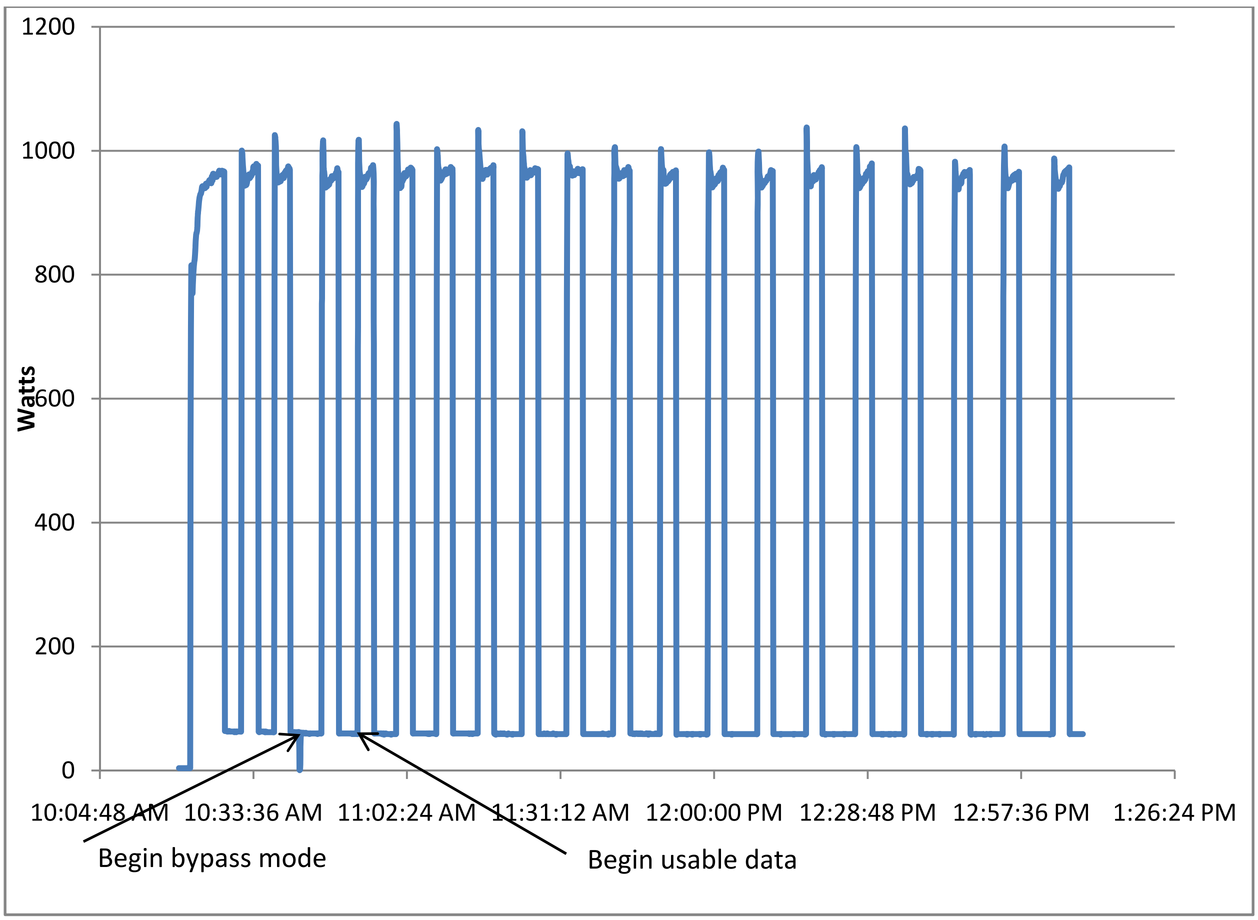

Figure 2: Watts versus time for operation in bypass mode (70 °F indoor, 85 °F outdoor)

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.

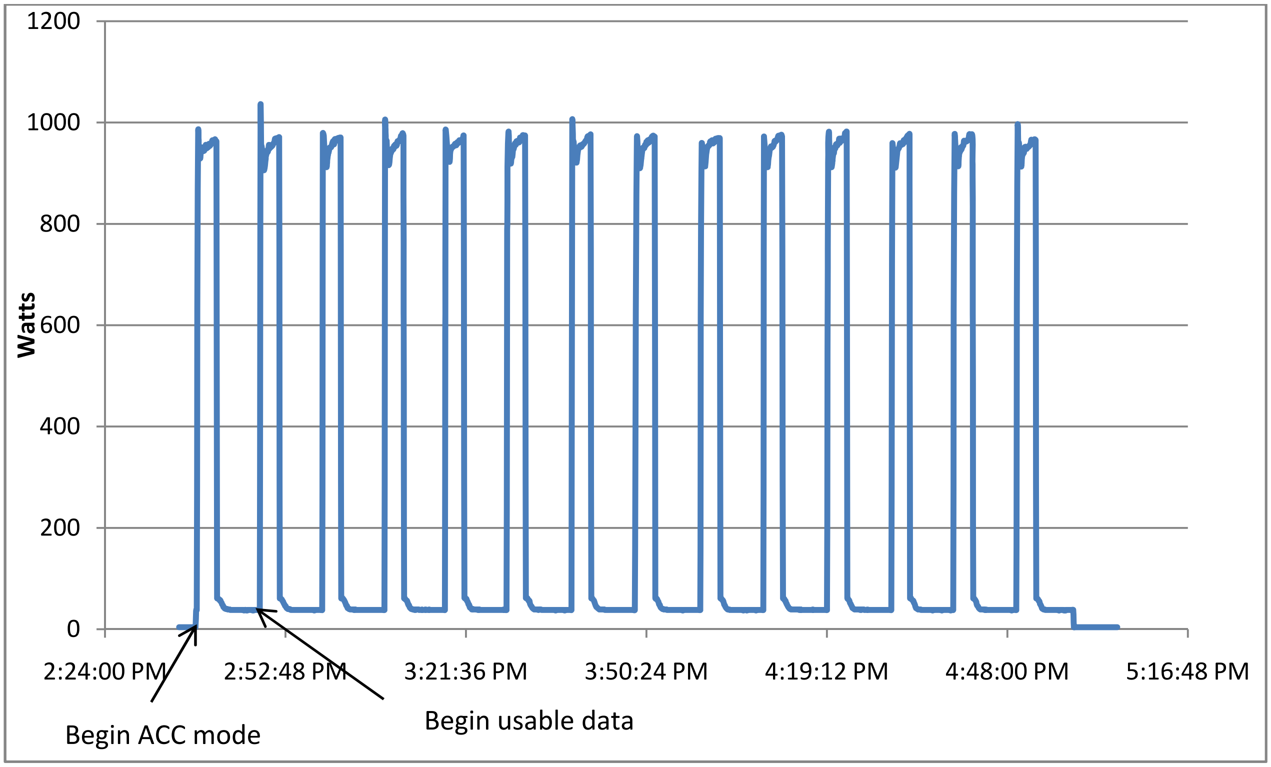

Figure 3: Watts versus time for operation in ACC mode (70 °F indoor, 85 °F outdoor)

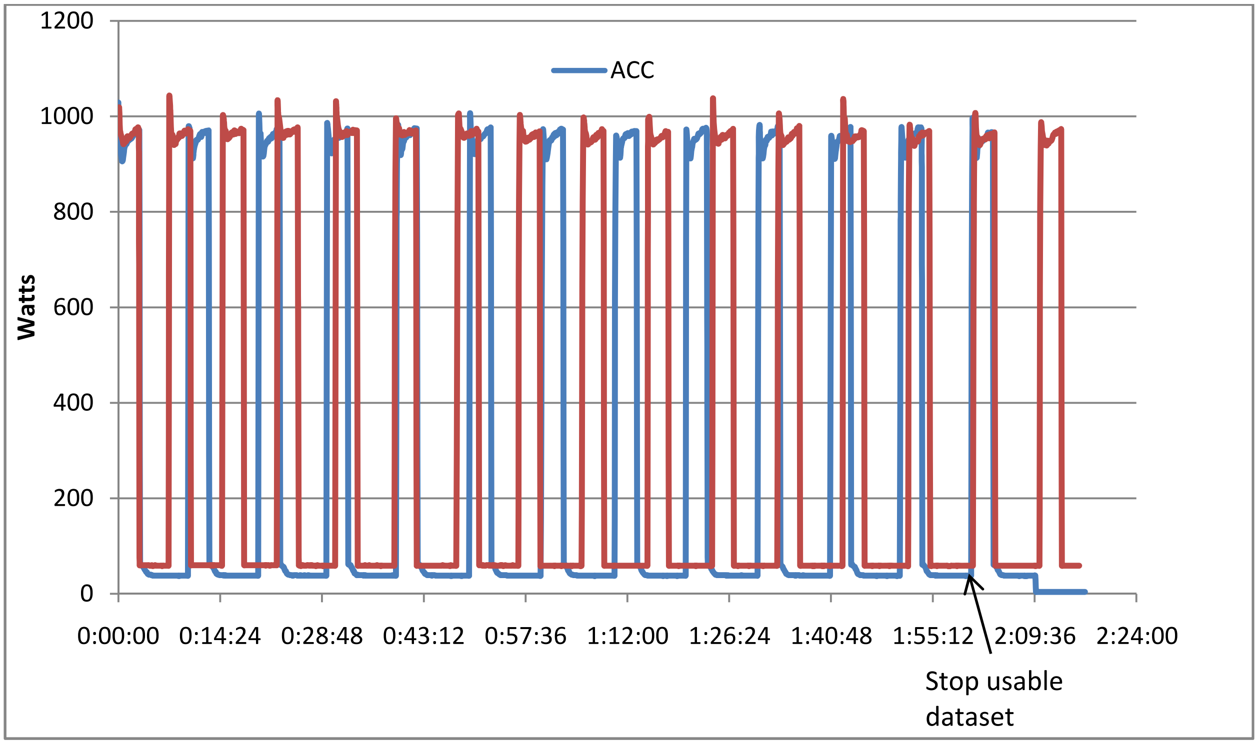

Figure 4: Overlapped plot of Watts versus time for both ACC and bypass modes (70 °F ID, 85 °F OD)

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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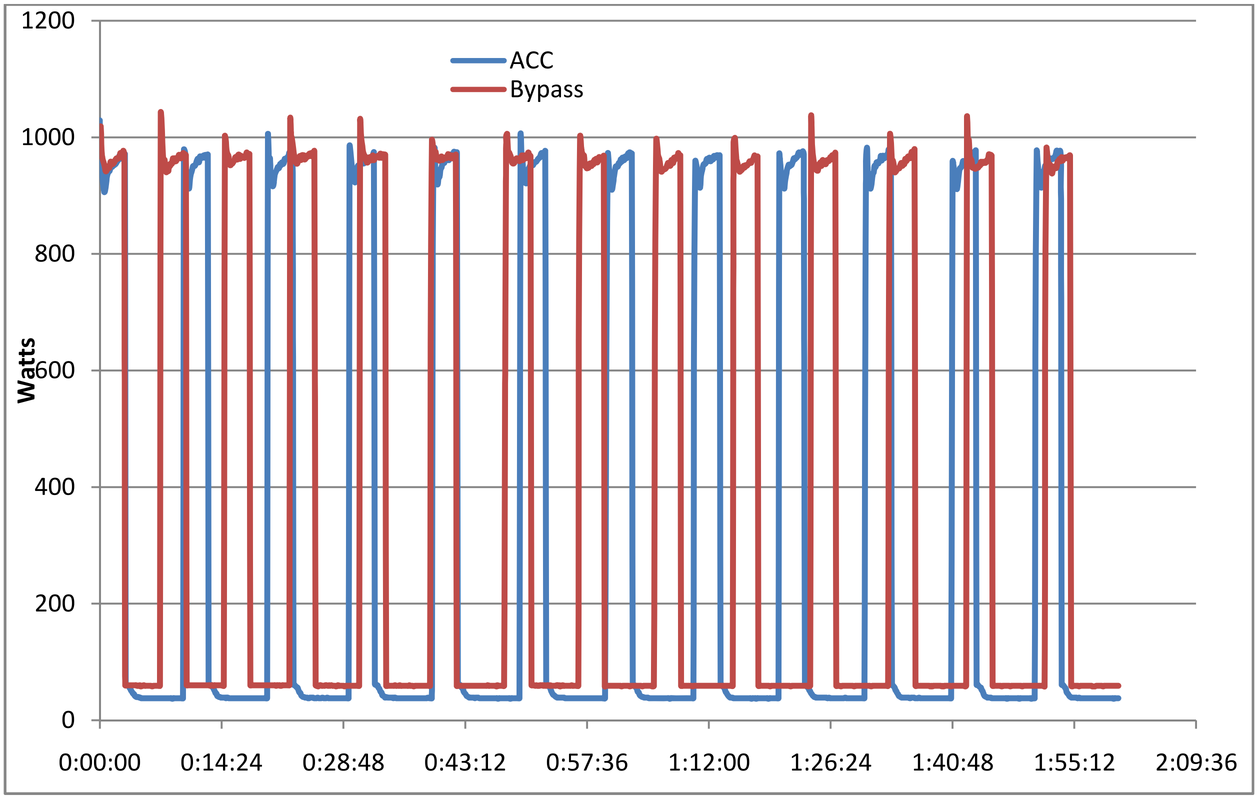

Figure 5: Overlapped plots of usable data envelopes (70 °F ID, 85 °F OD)

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.

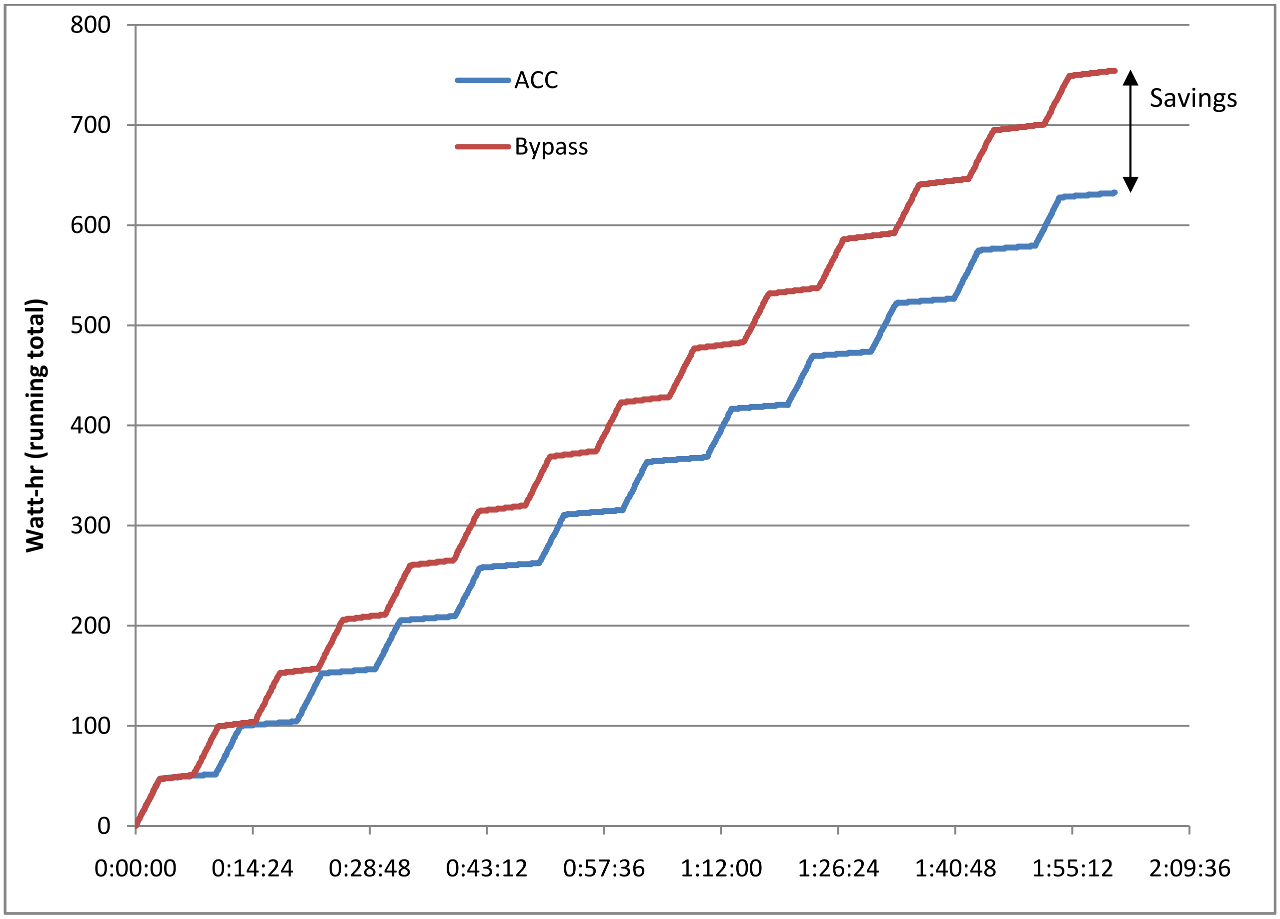

Figure 6: Plot of running Watt-hr consumption for ACC and bypass modes (70 °F ID, 85 °F OD)

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.

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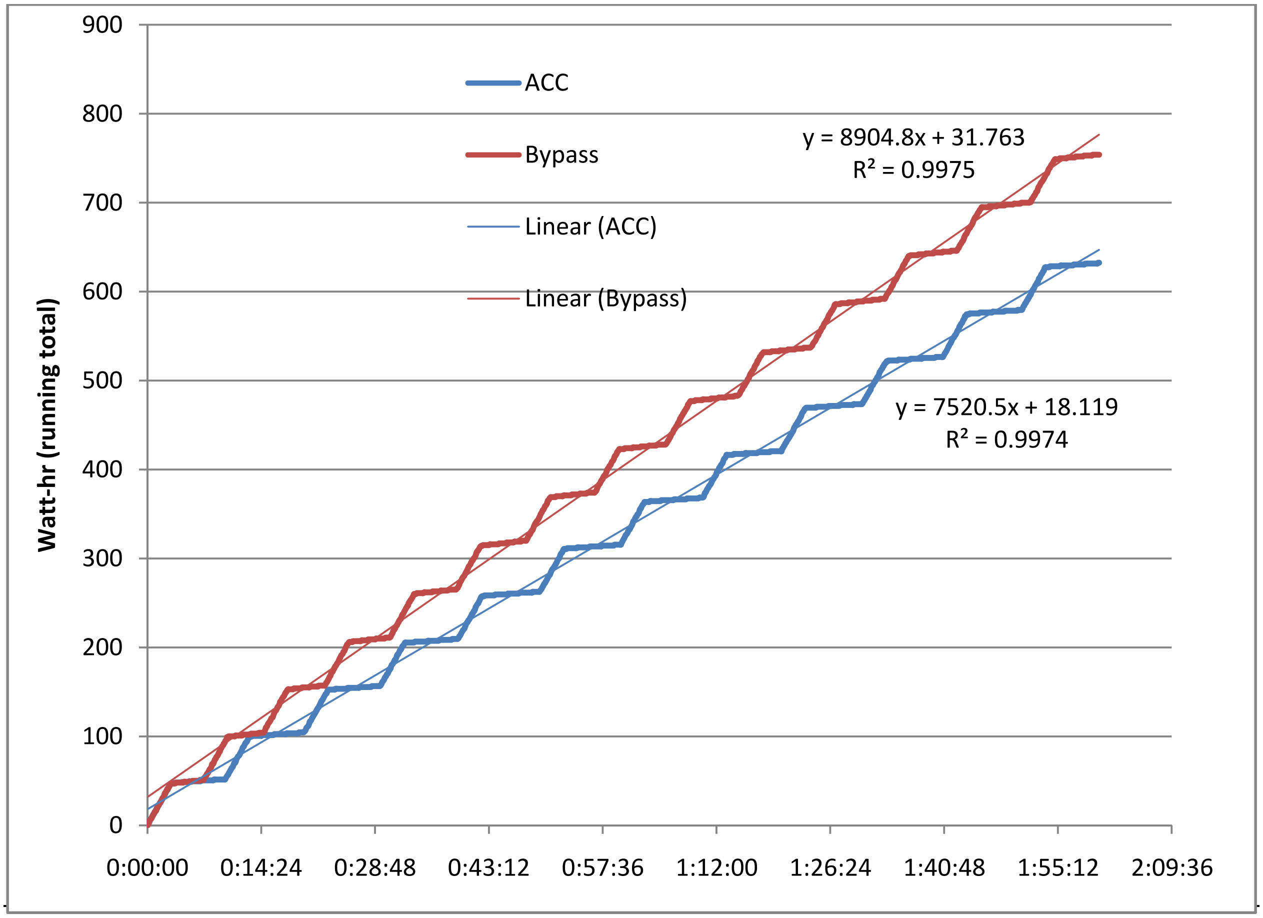

Figure 7: Linear curve fits applied to the data of Figure 6.

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.

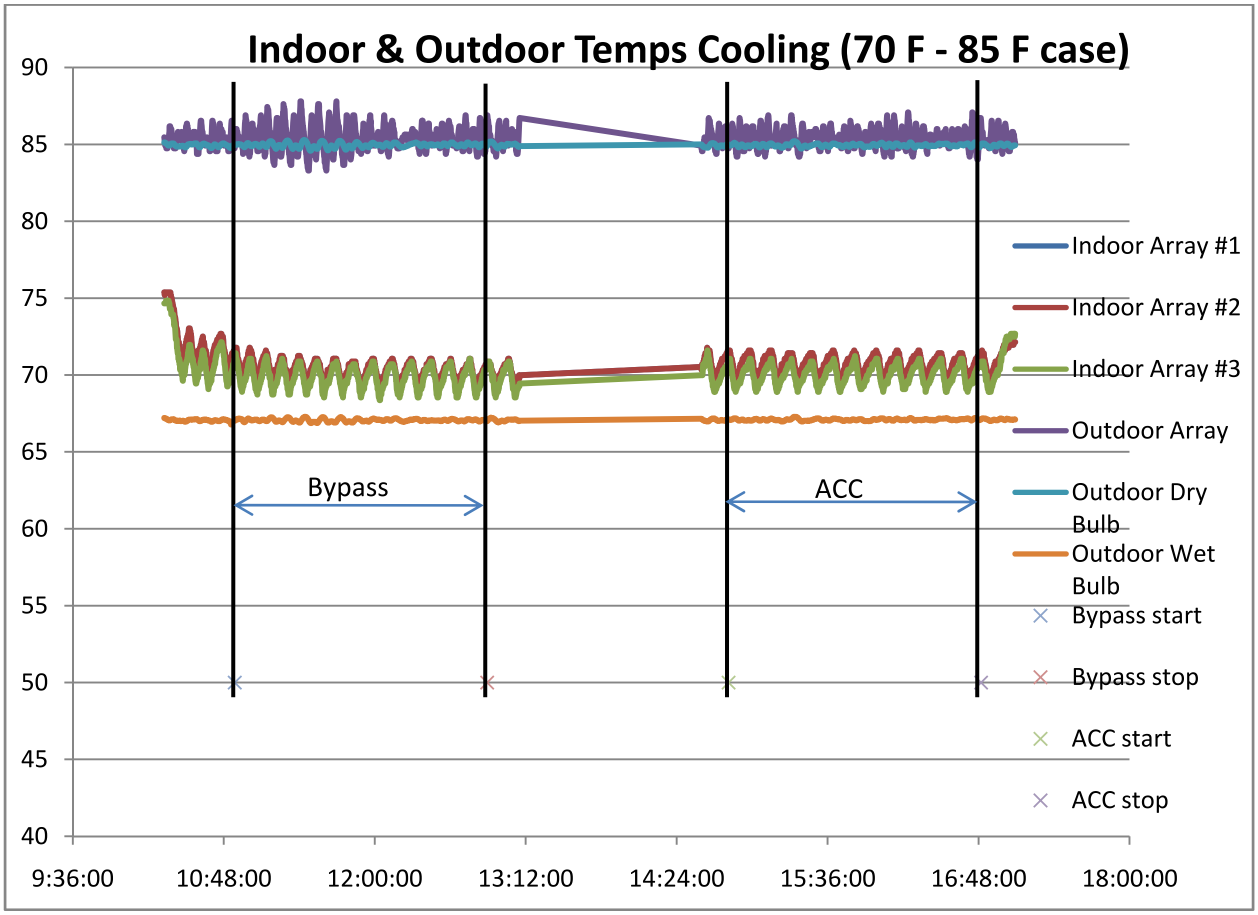

Figure 8: Temperature variations for the indoor and outdoor rooms during the test intervals

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.

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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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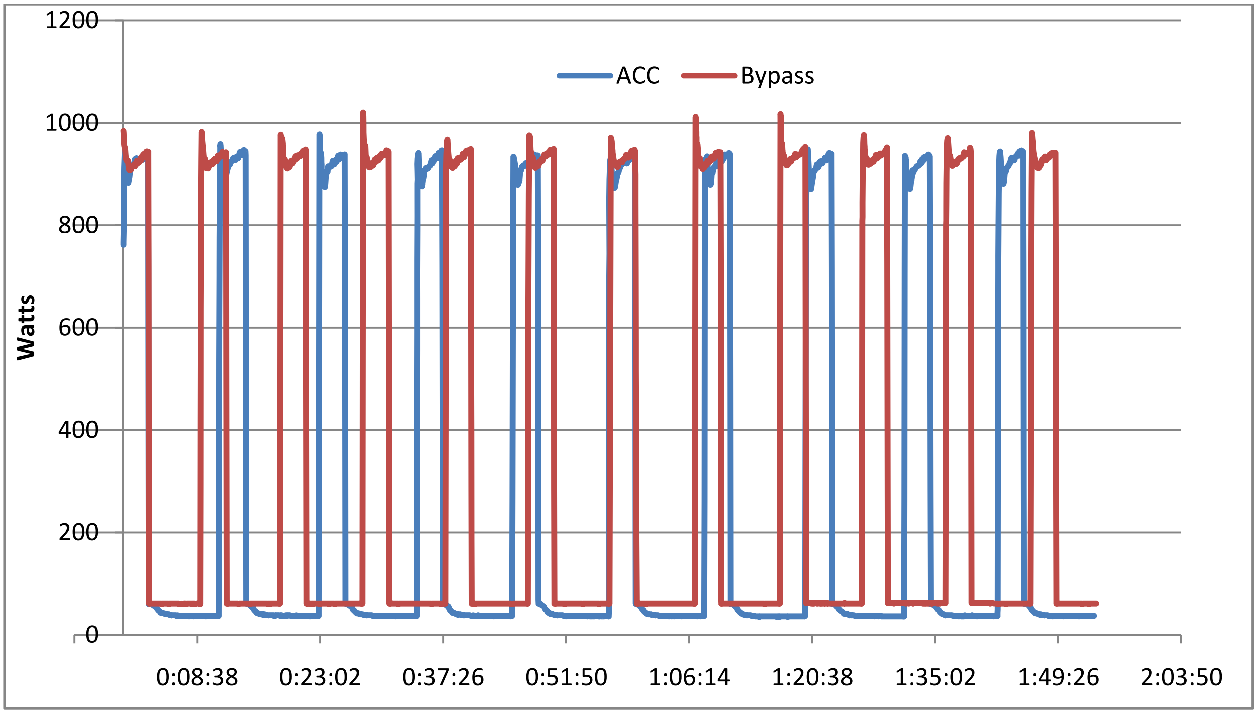

Figure 9: Comparison of power consumption in ACC and bypass modes (70 °F ID, 82 °F OD)

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%.

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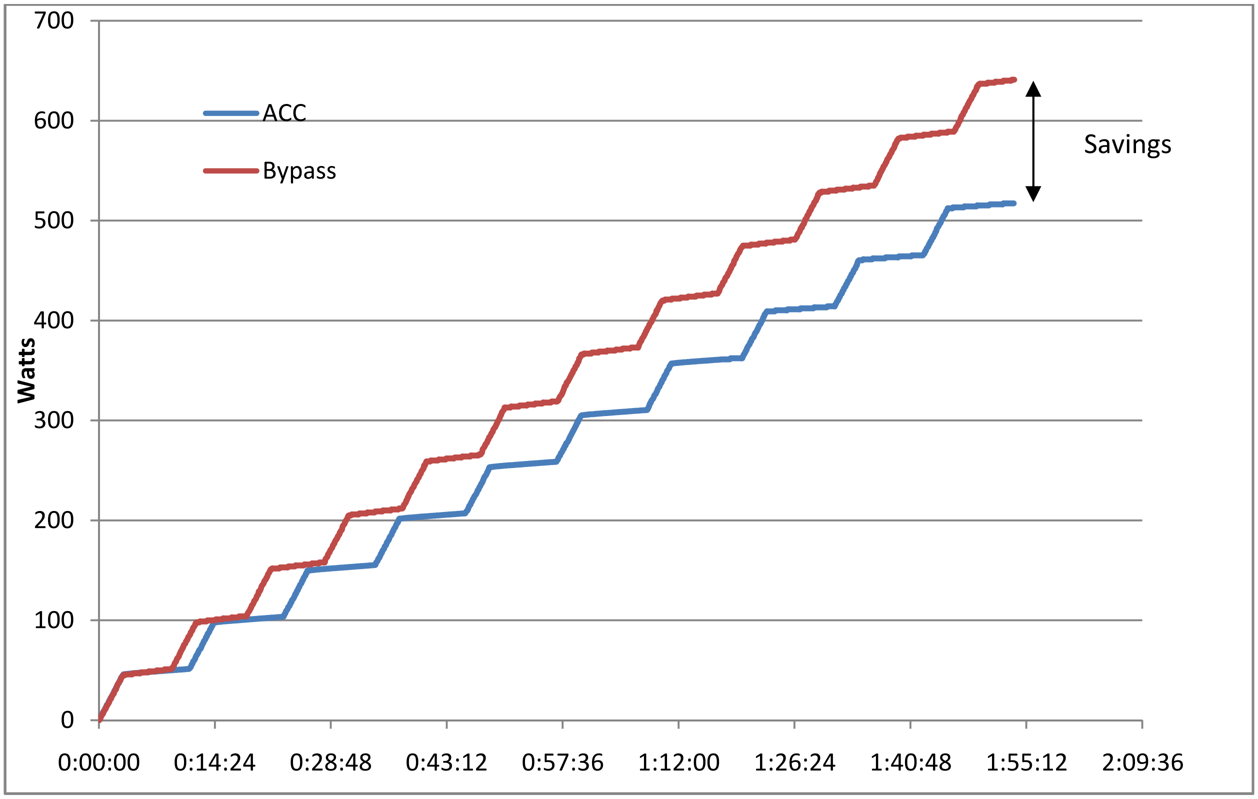

Figure 10: Running watt-hr consumption (70 °F ID, 82 °F OD)

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%.

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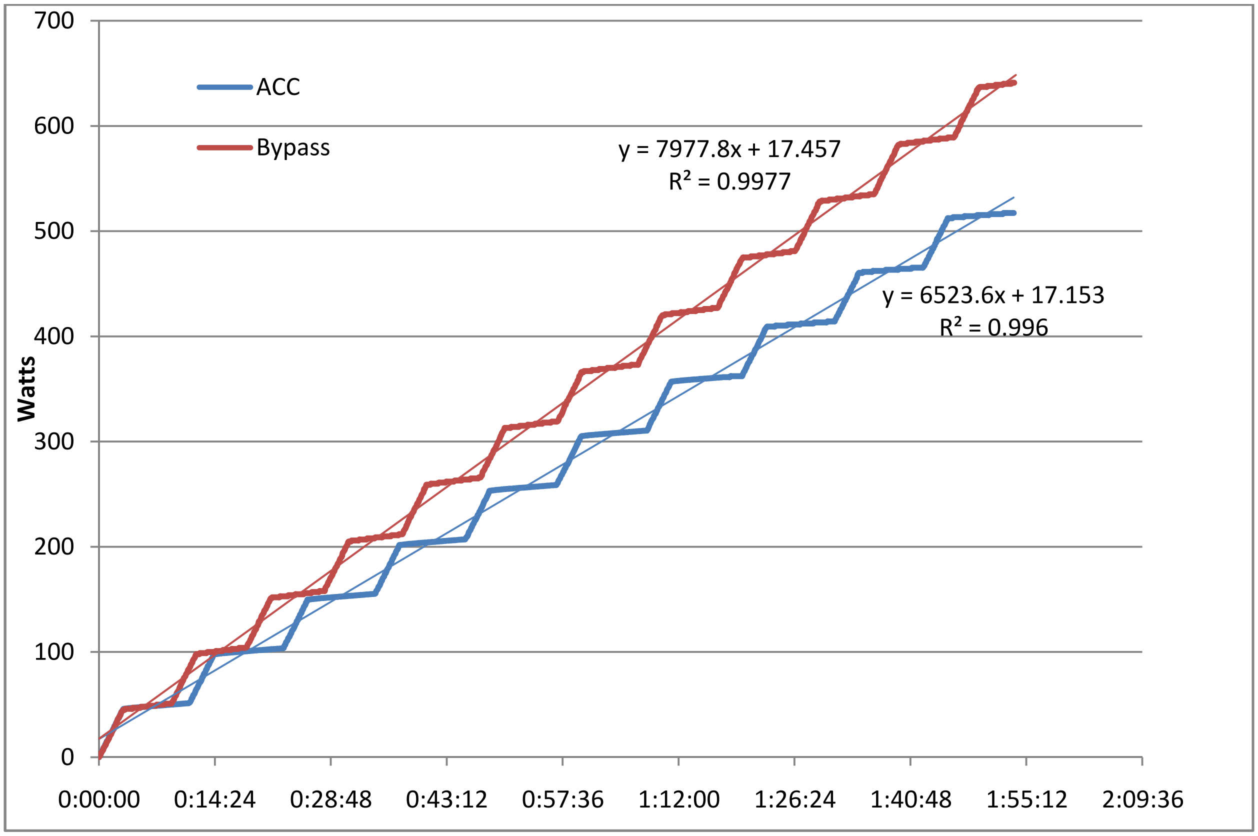

Figure 11: Linear curve fits applied to the data of Figure 10

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%.

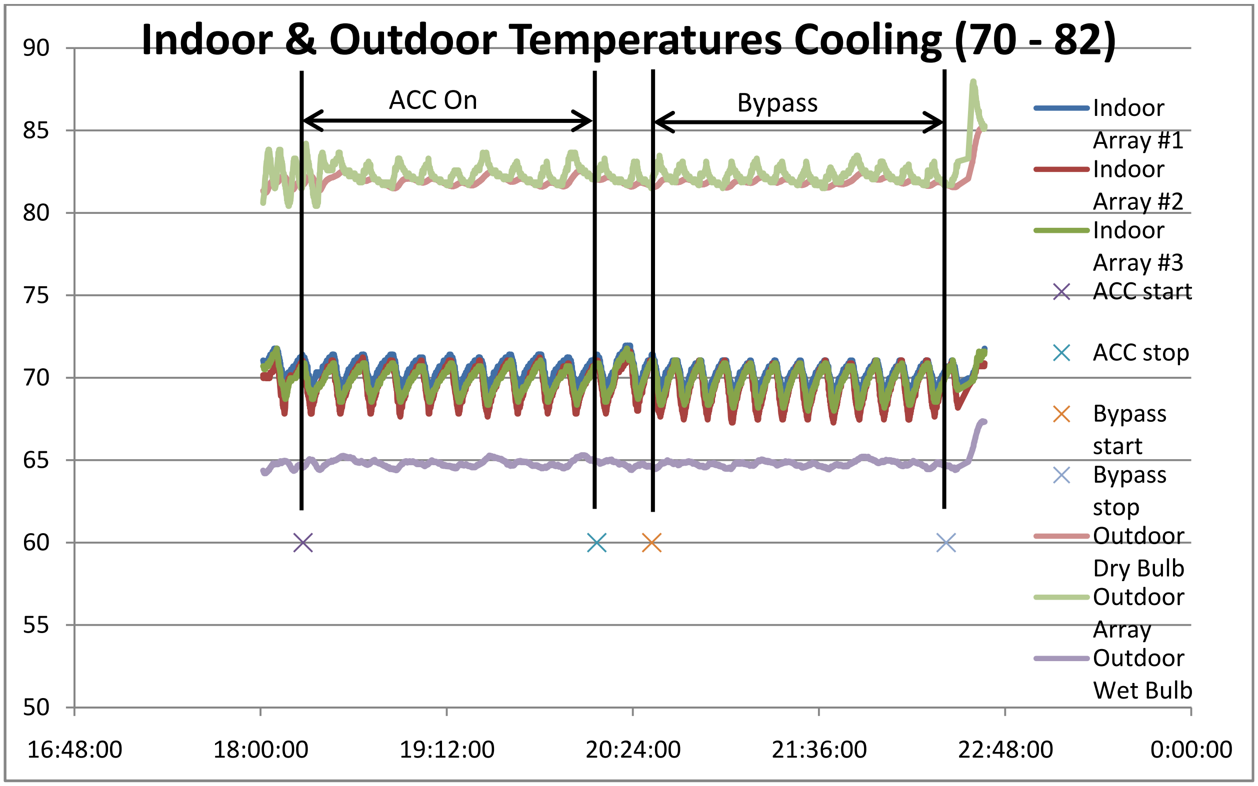

Figure 12: Temperature variations for the indoor and outdoor rooms (70 °F ID, 82 °F OD)

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)

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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.

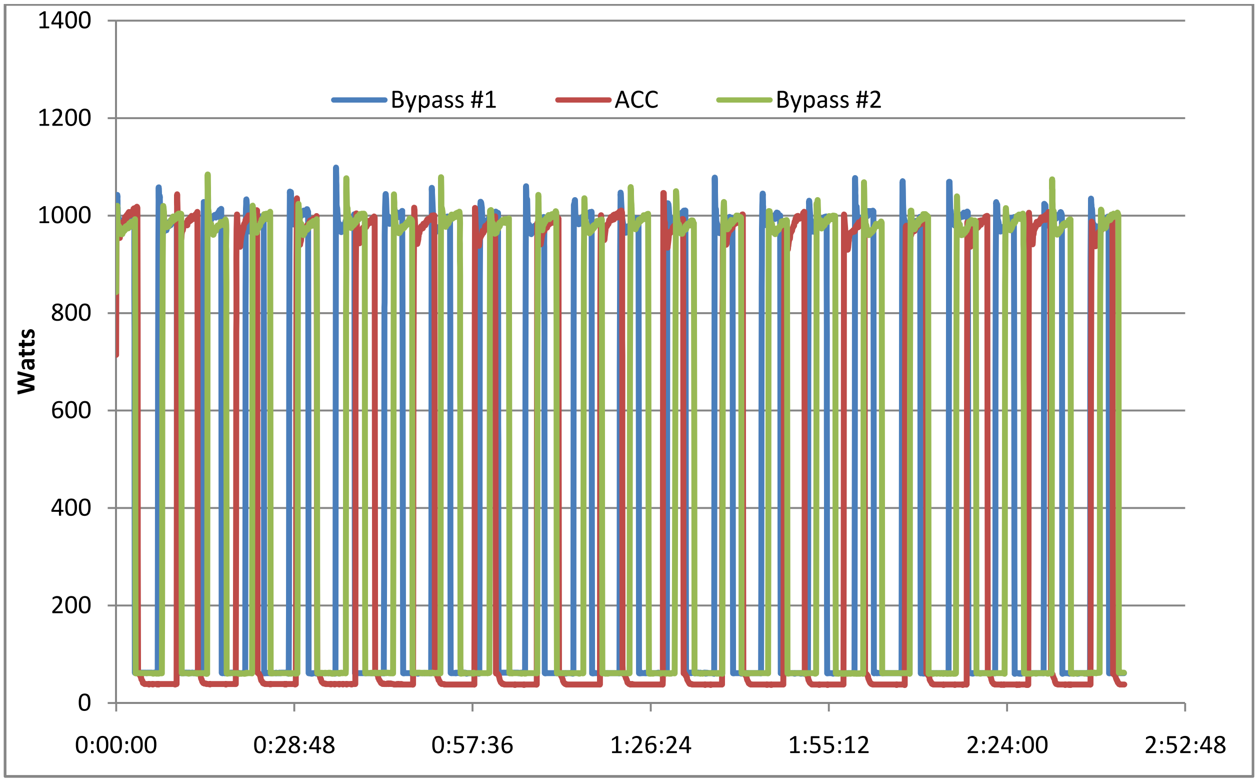

Figure 13: Comparison of power consumption in ACC and bypass modes (70 °F ID, 88 °F OD)

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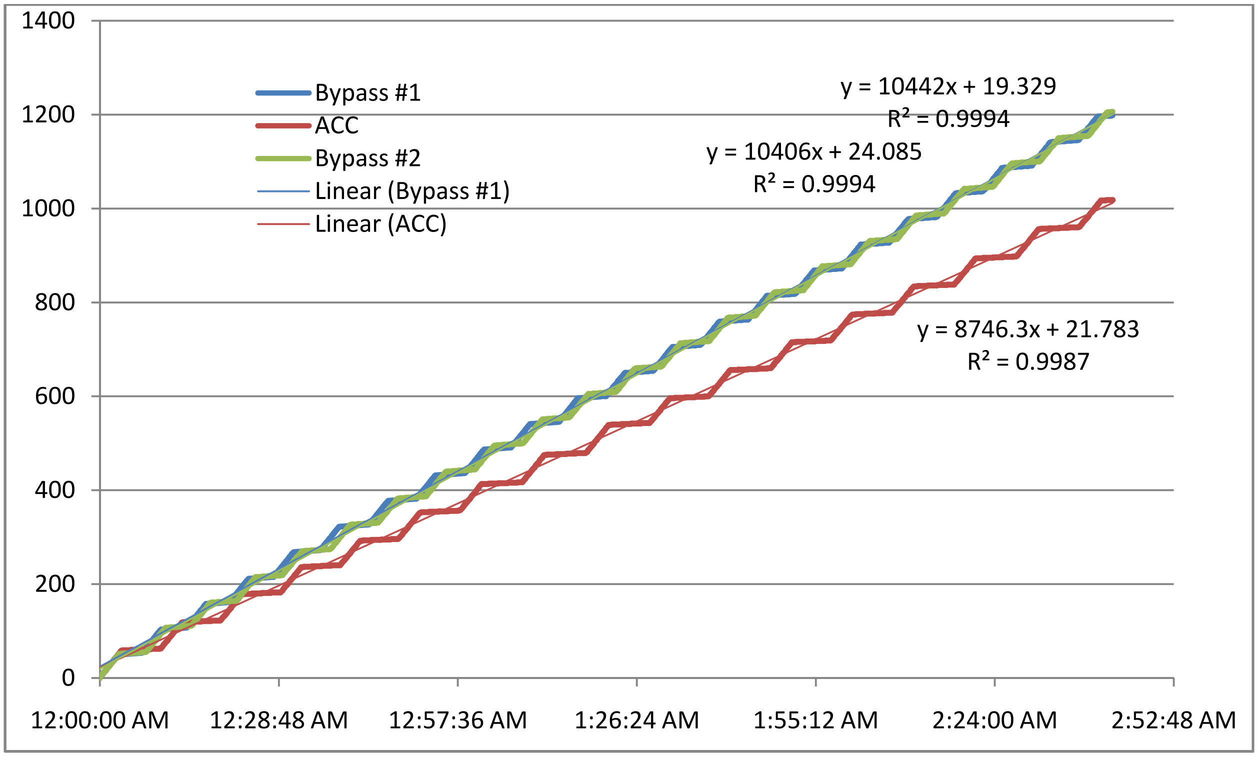

Figure 14: Watt-hr consumption comparison with trend lines (70 °F ID, 88 °F OD)

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.

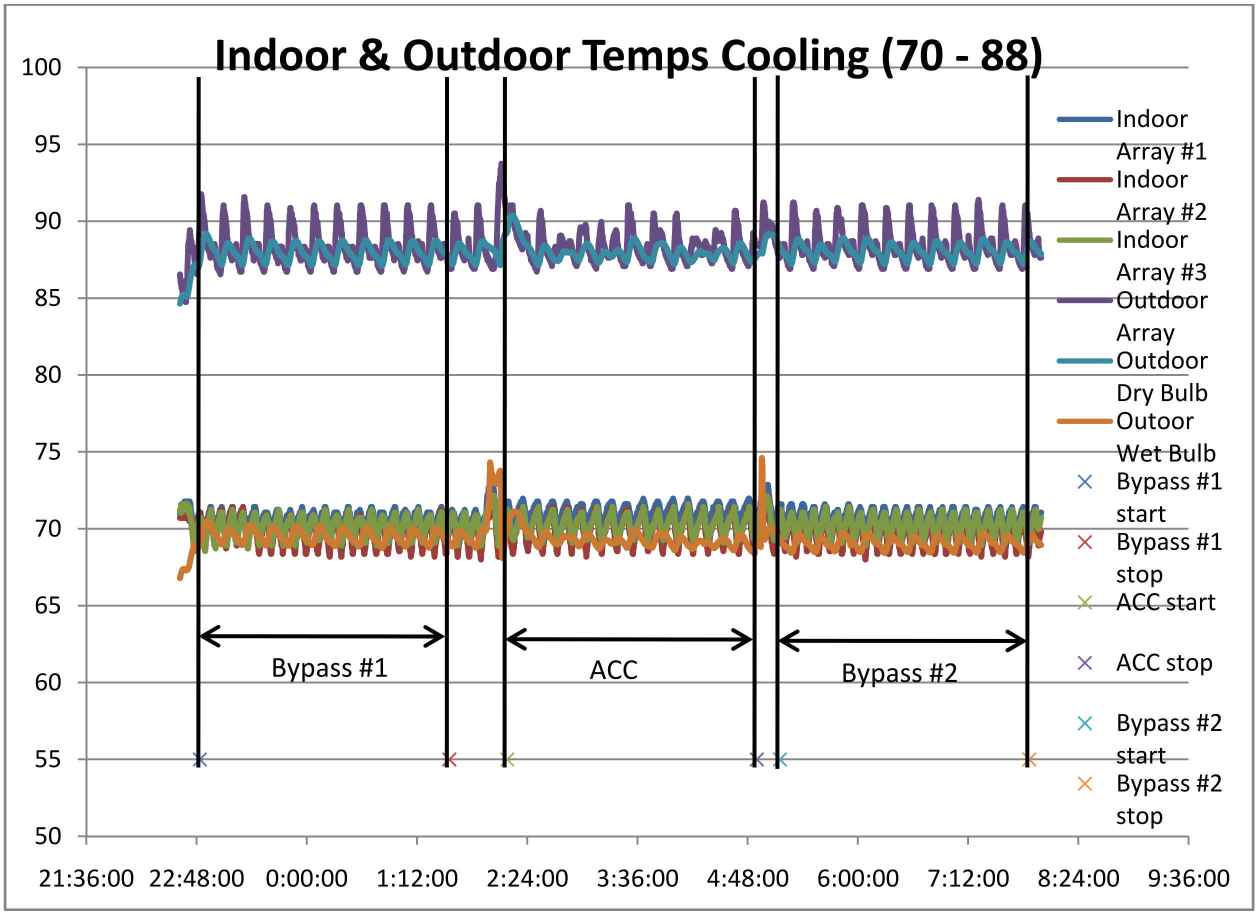

Figure 15: Temperature variations for the indoor and outdoor rooms (70 °F ID, 88 °F OD)

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.

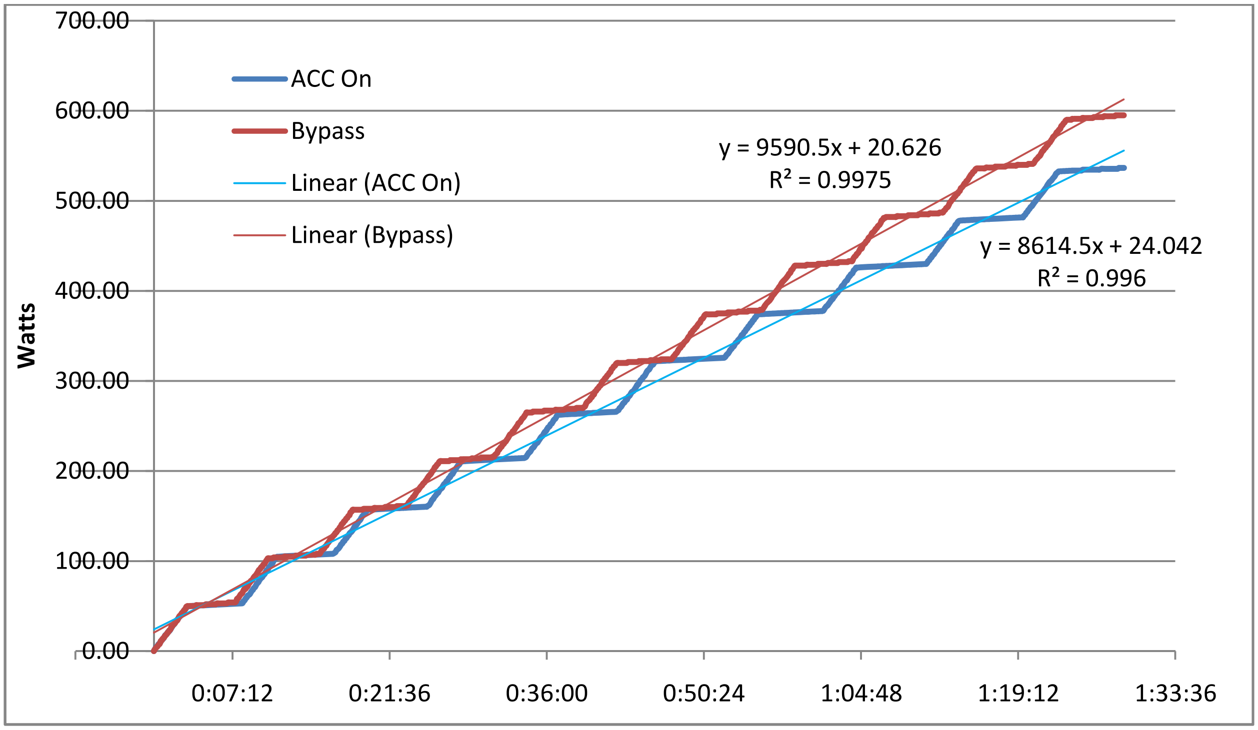

Figure 16: Watt-hr consumption comparison with trend lines (72 °F ID, 85 °F OD)

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%.

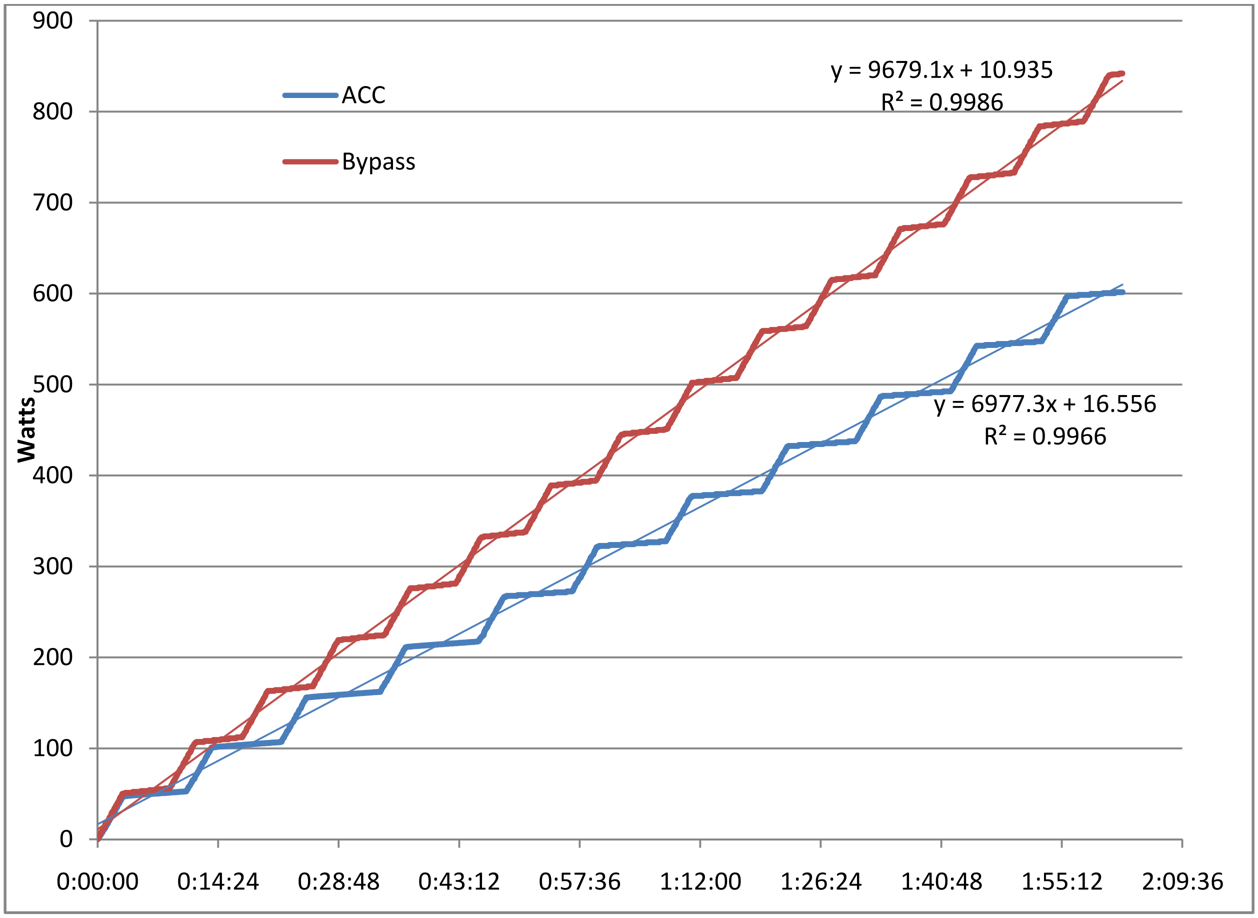

Figure 17: Watt-hr consumption comparison with trend lines (72 °F ID, 88 °F OD – higher RH)

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)

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 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.

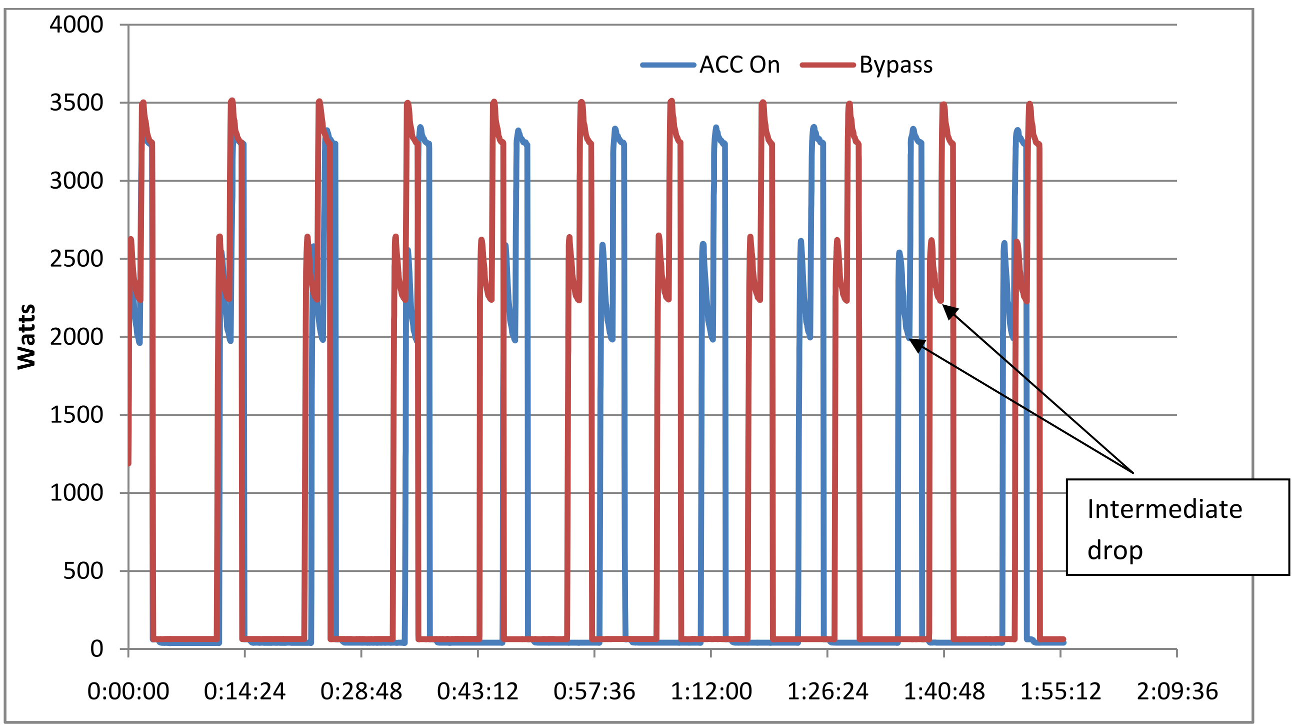

Figure 18: Comparison of Watt usage for bypass and ACC modes (74 °F ID, 45 °F OD)

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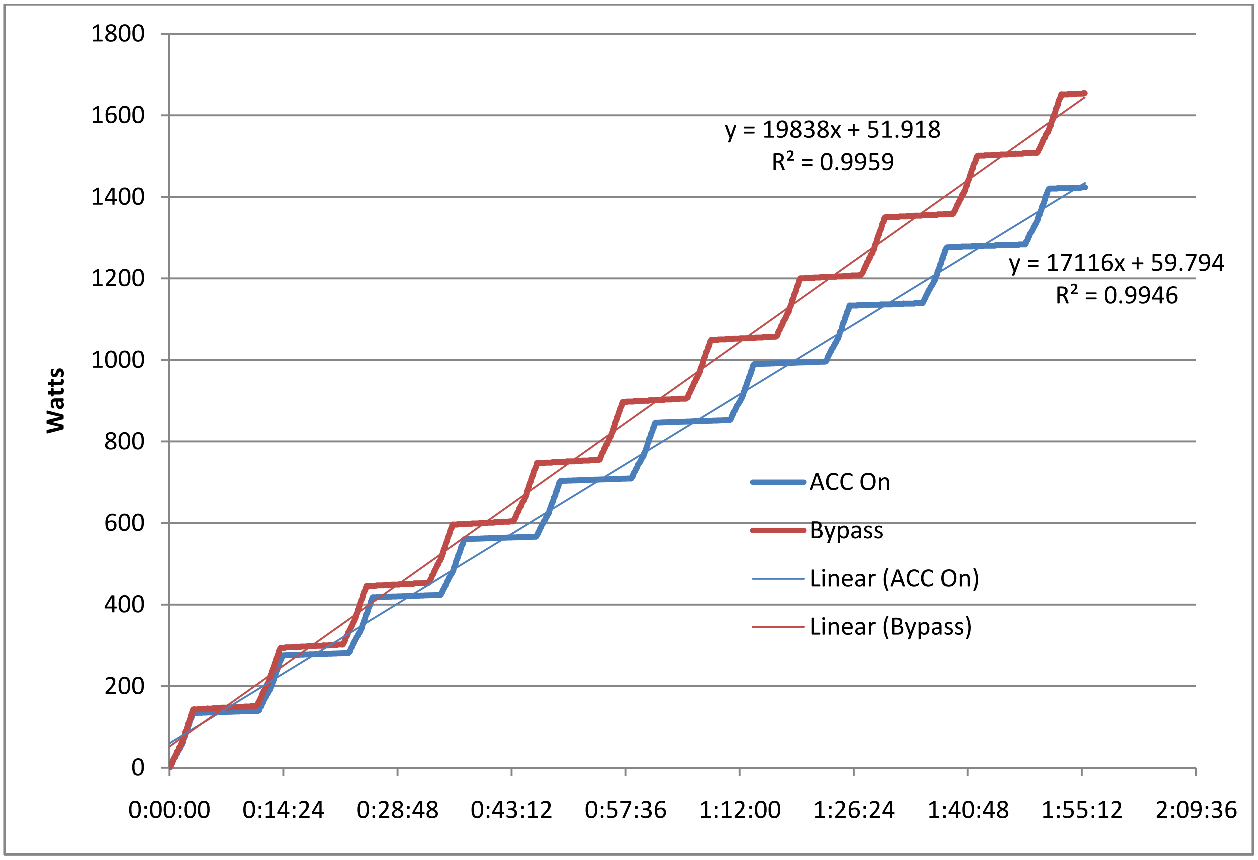

Figure 19: Watt-hr consumption comparison with trend lines (74 °F ID, 45 °F OD)

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.

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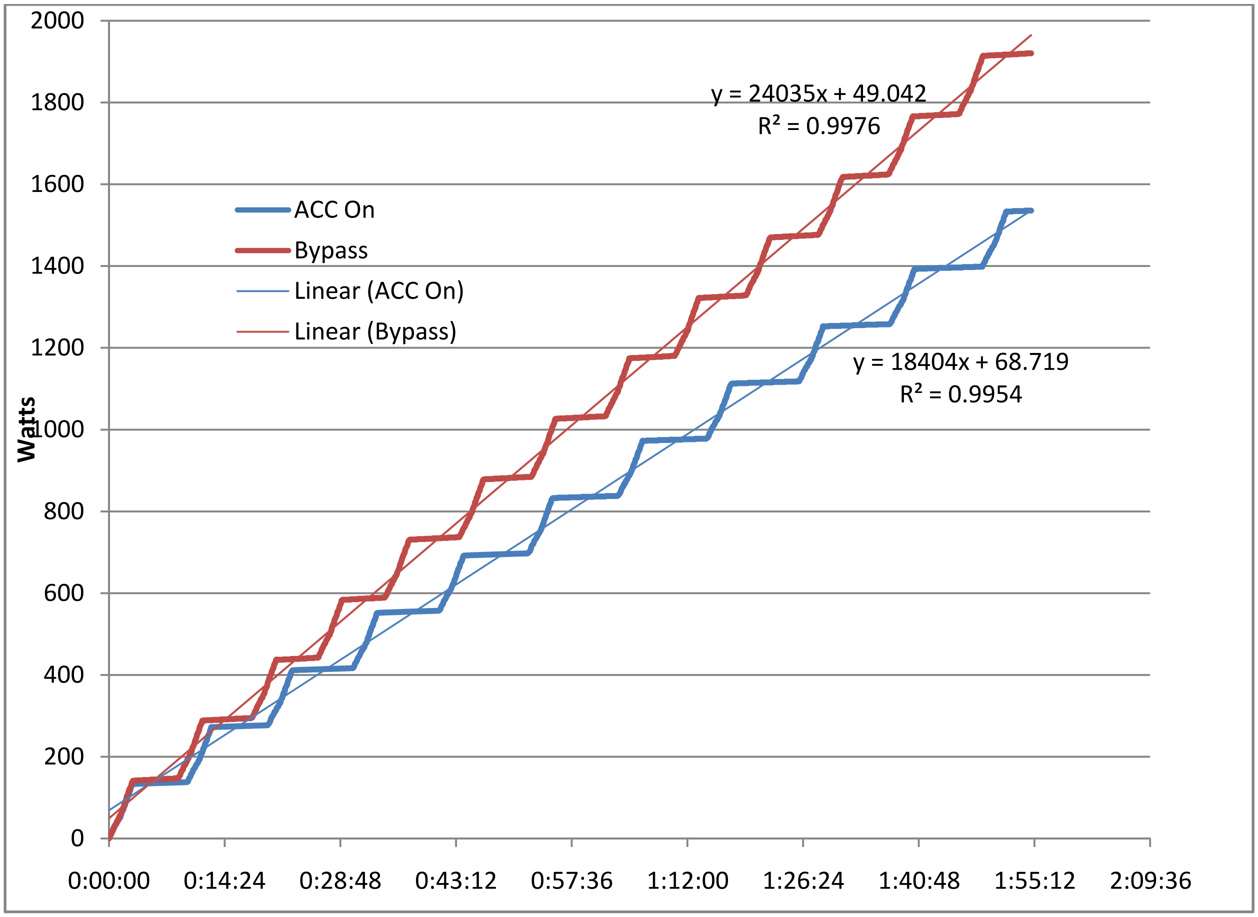

Figure 20: Watt-hr consumption comparison with trend lines (72 °F ID, 35 °F OD)

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.

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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.