Experimental Evaluation of Abbotly Technologies Compressor Optimization Control Product "ESM System 4000" as applied to a 21-ton Roof Top Air Conditioner

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EXECUTIVE SUMMARY

A controlled Test Program of the Energy Saving Module System 4000 (ESM 4000) was undertaken by Oak Ridge National Laboratories, an arm of the US Department of Energy. The Test Program was designed to ascertain the effectiveness of the ESM 4000 in reducing the power consumption of air conditioning compressors, and to identify any effect this cost reduction technology may have on the conditioned space.

The ESM 4000 is specifically designed to reduce the electricity consumption and maximum demand of refrigeration/HVAC compressors by optimizing their performance within temperature control bounds set by the overall system controller. The ESM 4000 interfaces with existing air conditioning and refrigeration controls.

This report provides the results of the controlled laboratory Test Program for the ESM 4000. The ESM was installed on a 21-ton Lennox commercial roof top air-conditioning unit with four (4) scroll compressors. The Lennox HVAC unit selected to evaluate the ESM is the same model as units being installed in new Wal-Mart stores throughout North America. The rooftop unit was tested in baseline configuration (using the same NOVAR controller as used in Wal-Mart applications) and with the ESM 4000 compressor control. The cooling load imposed on the unit was the same for all tests. Outdoor temperature was controlled to simulate a representative summer day cycle for all tests. Tests were conducted in a two-room (indoor and outdoor) environmental chamber located at the Lennox R&D facility in Carrollton, TX under the supervision of Oak Ridge National Laboratories. The objectives of the Test Program were to:

1) Quantify the reduction in energy consumption of the HVAC unit attributable to the ESM 4000
2) Compare compressor cycle rates with and without the ESM 4000
3) Monitor indoor room temperature with and without the ESM 4000

Complete details and the analysis of the Test Program data are contained in this Report. In summary, the test results show the following impacts attributable to the installation of the ESM 4000 for high cooling load or demand – indoor room cooling load maintained at about 70% of the roof top unit's rated cooling capacity:

- **kWh Percentage Reduction with ESM 4000 on roof top unit:**
  Approximately 8% (corrected)
- **kWh Percentage Reduction with ESM 4000 on the compressors only:**
  Approximately 10% (corrected)
- **kW Peak Demand Percentage Reduction:**
  Approximately 1% (corrected)
- **Compressor Cycle Rates:**
  Baseline (NOVAR control only)
    Compressors 1&2 – .3 cycles/h (cph) and 104 minutes on per cycle
    Compressors 3&4 – 9.4 cph and 3.25 minutes on per cycle

With ESM 4000 controller active

All compressors – 3-4 cph and 12 minutes on per cycle on average (more equal utilization)

- **Indoor test room temperature:**

  Average room temperature was about 1.7 °F higher with the ESM 4000 "on" test period. **All kWh and kW reductions reported above are "as corrected" to equal indoor room temperature condition for both baseline and "ESM on" tests.**

NOTE: Comparison of compressor cycling rates over a full 24-h test period show ~6% reduction in cycling rate for compressors 1 & 2 and almost 40% reduction for compressors 3 & 4.

The limited size of the test chamber used in the Test Program presented a challenge to achieve stable room temperature control (with or without the ESM 4000). The fairly rapid temperature swings seen in both tests are not typical of "real world" installations where the roof top unit would be controlling a much larger volume of air with a slowly varying load, as in a large retail store. This author is not a controls expert but it seems reasonable to speculate that the wide temperature variations would confuse an intelligent control system that is designed to optimize roof top unit operation based on recent past demand history.

Further, in "real world" applications, each HVAC unit is matched to the specific heating and cooling demands of the space it is designed to serve. Under such circumstances the operating load on the HVAC unit should be a high fraction of its rated capacity during most of the cooling season. Therefore, it may reasonably be assumed that use of the ESM 4000 compressor controller would yield energy savings similar to those summarized above in such circumstances.

While not a stated objective of the Test Program, the reduction in energy consumed can be viewed as providing related benefits in at least two areas: First, the Environmental Benefits – The savings in electrical energy can be translated directly to a reduction in the emissions of power plant green house gases to the atmosphere; Second, it provides the Company with the opportunity to share in the rebate incentives being offered by a number of utilities to customers who achieve threshold levels of energy reduction.

In summary, for portions of the Test Program where the cooling load was a large percentage of the test roof top unit's capacity, the ESM 4000 significantly reduced electricity consumption and provided much more uniform utilization (less severe cycling rates) of the test AC's four compressors. A reasonable next step would be to conduct a field evaluation of the ESM 4000 in an actual building application. One way to conduct such a test would be to install the ESM 4000 on the ACs of a building and run for several weeks with the ESMs "on" one week and "off" the next while monitoring AC energy use along with indoor and outdoor air temperature and humidity conditions.

Summary

An experimental performance evaluation of the Energy Saving Module System 4000 (ESM 4000) as installed on a Lennox model LGA248H4B commercial roof top air-conditioner (RTU) having four scroll compressors of equal size and a total rated capacity of 21 tons cooling (74 kW) was undertaken. The RTU was tested with and without the ESM 4000 in the large two-room environmental chamber at the R&D facilities of Lennox Industries, Inc., located in Carrollton, Texas on April 21-24, 2005. The chamber upper room simulated outdoor ambient conditions during the test and the lower room served as the indoor conditioned space. RTU energy efficiency, compressor operational parameters, and indoor room air temperature control were studied. A 24-hour test protocol was developed to attempt to simulate "in field" performance of the RTU over representative daily temperature and room load cycles under controlled laboratory conditions. One baseline test (without ESM) was performed on April 21-22. Two tests were performed with the ESM 4000 installed, one on April 22-23 and a second on April 23-24.

Energy comparison of the baseline (ESM off) performance to ESM on performance over a 3.5-hour period where the indoor room cooling load was about 70% of the RTU rated capacity is shown in Table 1. Table 2 illustrates compressor and unit cycling rates and runtimes for each mode.

Table 1. Energy and efficiency comparison – high cooling load

Mode	Avg OD room temp	Avg ID room temp (± range)	Load, kWh	RTU total kWh	RTU peak kW	Compressor kWh
ESM off	93.9 °F	79.1 ± 5.6 °F	181.6	58.2	17.8	48.0
ESM on (1^{st} run)	93.9 °F	80.8 ± 8.9 °F	181.3	52.0	17.1	42.0
Diff	+0.0 °F	+1.7 °F	-0.2%	-10.7%	-3.9%	-12.5%

The total load for both tests was essentially equal. The total RTU power (compressors plus ID blower) during the ESM on run was almost 11% lower than that for the baseline case. Peak kW was almost 4% lower. However, the average ID room temperature was higher in the ESM mode (by 1.7 °F) and the variation was greater as well. If the average ID room temperature during the ESM off (baseline) tests had been equal to that during the ESM on test, estimated RTU efficiency during the baseline period would have been about 3.3% greater and its energy use would have been lower – about 56.5 kWh for RTU total, 17.3 kW for RTU peak, and 46.3 kWh for the compressors. ***On equal temperature basis, the RTU energy use with the ESM on was about 8% lower than for the baseline case and compressor energy use was reduced by about 10%.***

Table 2. 24-hour test comparison; cycle rates and runtime

	ESM off	ESM on (1st run)
Comp 1 cph	0.29	2.85
Comp 2 cph	0.29	2.57
Comp 3 cph	9.43	4.00
Comp 4 cph	9.43	4.29
Comp 1 min/cycle	207.52	16.04
Comp 2 min/cycle	207.52	17.74
Comp 3 min/cycle	3.29	5.37
Comp 4 min/cycle	3.24	10.41
RTU cph	0.29	0.86
RTU min/cycle	207.52	66.17

Cycling rates and run times per cycle were much more equally distributed among the four compressors in the ESM on case. ***This has positive implications for compressor reliability.***

A major factor affecting the applicability of the results to actual "in field" operation is the limitations imposed by the fixed and small ID room size of the test chamber relative to the capacity of the test RTU. The RTU blower was able to completely circulate all the ID room air in little more than 1 minute. In addition, the RTU's supply air discharge and return air intake in the test room were very close (approximately 10 feet) with some baffles in place to stop air traveling directly back into the return air ductwork. Heaters (three residential electric furnaces of varying capacity) were placed in the ID room to impose the cooling load on the RTU for the testing. These heaters were located directly under the return air duct, and thus the cool supply air from the RTU did not thoroughly mix with the heated space air before entering the RTU as would happen in a typical "real world" application. The rate of change in temperature was therefore a lot faster than would normally be the case.

An air conditioning system of the size of the test RTU installed in a large retail store might have perhaps 20 to 25 supply registers located in an area with the return air grill in a central position, depending on the installation. This allows for the supply air to be distributed throughout the conditioned space in the store, causing the air coming back into the return air duct of the unit to be true mixed air, and allow the air conditioner's temperature control system to stage up and down the compressors according to the return air or space temperature. The ESM 4000, if installed on the air conditioner, would act to monitor the system and make any changes to optimize the control of the compressors.

The net effect of the room size limitation (exacerbated by the placement of the heating units) resulted in higher room temperature swings than one would expect in a "real world" installation where the RTU would be controlling a much larger volume of air with a slowly varying load as in a large retail store. These factors made it more difficult for the RTU controls to achieve stable room temperature control (with or without the ESM) in these tests than in a real installation.

Acknowledgements

The contributions of Lennox Industries personnel in preparing the RTU test unit and test facilities to accomplish the testing discussed in the report are acknowledged. In particular the assistance of Arthur Longshore (lead testing technician) and Gene Havard (R&D engineer) are noted.

Introduction

Abbotly Technologies Pty Ltd makes a product called the Energy Saving Module System 4000, or ESM 4000. It is designed to interface with existing air-conditioning and refrigeration system controllers, and its purpose is to optimize compressor performance so as to reduce energy consumption and demand while maintaining the primary control set point (temperature, suction pressure, etc.) established by the system controller. For a detailed technical description of the ESM 4000 and an overview of its operation theory see references **[1]** and **[2]**. This report provides the results of a laboratory test of a 21-ton roof top air-conditioning unit (RTU) with and without an ESM 4000 during April 2005.

Test description and setup

Lennox Industries agreed to host this testing and to provide a test RTU unit. The test unit was a new model LGA248H4B commercial roof top air-conditioner having four scroll compressors of equal size and a total rated capacity of 21 tons cooling (74 kW). All the tests were performed in a large, two-room environmental chamber located at Lennox RDP facilities in Carrollton, TX. The chamber consisted of two rooms – an upper room to simulate outdoor (OD) conditions and a lower room for indoor (ID) conditions. Dimensions of the OD room were 29.7 ft wide x 25.9 ft long x 23.5 ft high for a total volume of about 18,000 ft^3. Dimensions of the ID room were 30.1 ft wide x 26 ft long x 11.5 ft high for a total volume of about 9,000 ft^3. The test RTU was installed in the OD room and ID room air was circulated through its evaporator coil to provide cooling to the lower room during the testing. OD room air was circulated through the condenser coil of the RTU. The set up mimics how the RTU would actually be installed on a commercial building roof. Lennox personnel set up the test unit RTU and verified that it achieved its nominal design capacity of approximately 21 tons at standard rating conditions of 95 °F OD temperature and 80 °F ID temperature and 50% ID relative humidity.

A 24-hour test protocol was developed to simulate “in field” performance of the RTU in a controlled laboratory environment. OD room temperature was controlled so as to vary in an approximately sinusoidal fashion between an upper limit of 95 °F (35 °C) and a lower limit of 75 °F (23.9 °C). Lennox personnel programmed the test chamber control system to automatically run the chamber through the desired profile over the 24-hour test period. Figure 1 shows the actual OD temperature profiles during both the baseline (ESM off) and the 2nd ESM on tests.

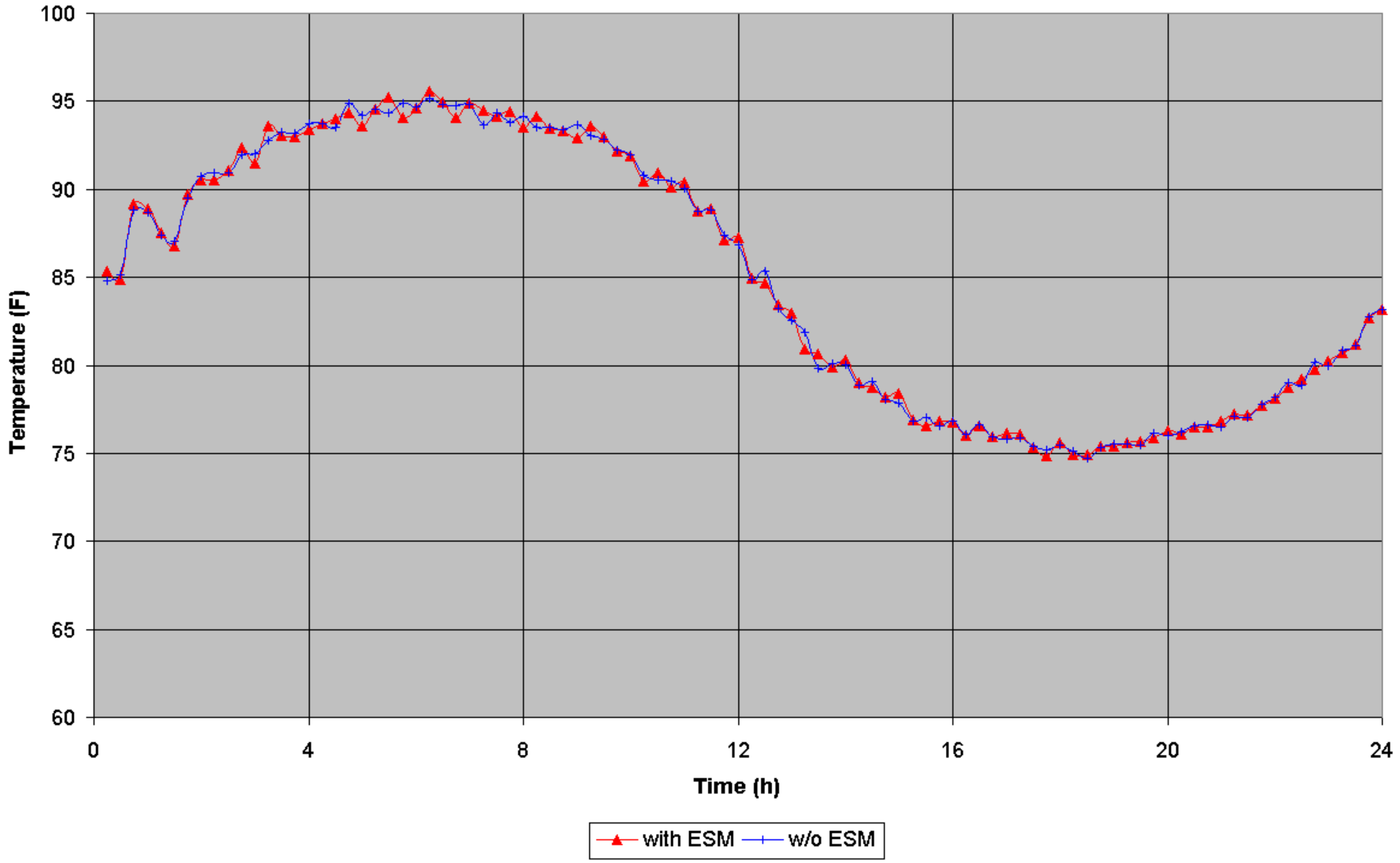

Figure 1. 15-minute average OD room temperature vs time (2nd ESM on test and baseline).

A load was imposed on the ID room using three electric furnaces. These furnaces were staged as shown in Table 3 to vary the ID room load as the OD room temperature varied during the testing.

Table 3. ID test room load staging for RTU testing

Stage	OD room temperature	Load (kW)
1	T < 80 °F	20.0
2	80 °F < T < 90 °F	45.0
3	T > 90 °F	57.5

Each furnace was controlled by a thermostat located in the OD room. A "safety thermostat" was located in the ID room to shut off all three heaters in the event of a failure of the RTU (so that the room would not dangerously overheat). In addition to the above variable load, the ID room was also subjected to a constant load from the RTU indoor blower and 576 Watts of lighting (18, 32W fluorescent lamps). Both the blower and lights operated on a 24/7 basis throughout each of the tests. After testing started it was observed that the stage 1 electric load was only 10 kW. Apparently only one-half of the resistance heat coils in that furnace were operational. Therefore, during the actual 24-hour tests the variable room loads were actually 10 kW lower than those listed in Table 1.

After the RTU was determined to be operating as designed, Abbotly personnel installed an ESM 4000 controller on the RTU (with a switch to enable bypassing the ESM).

Test control and data acquisition

Data measured during each test included the following:

- Compressor 1 power, W
- Compressor 2 power, W
- Compressor 3 power, W
- Compressor 4 power, W
- ID blower power, W
- RTU power (compressors plus blower), W
- ID room temperature (entering RTU evaporator)
- OD room temperature (entering RTU condenser)

The ID and OD temperatures were measured using thermocouple grids each having about 20-30 individual thermocouples. In this manner an average of the temperatures entering the evaporator and condenser were obtained.

Lennox's chamber data acquisition system logged all the data continuously throughout each 24-hour test. Data were aggregated into 15-minute periods by Lennox to facilitate precise determination of compressor cycling rates and runtimes. These 15-

minute data sets each contained 201 instantaneous logs of each data parameter (about 4-5 seconds between logs) and were provided to ORNL for analysis.

Three 24-hour tests were conducted as follows:

1. The OD room was stabilized at 85 °F and the ID room at 74 °F.
2. A 24-hour baseline test was then started. The RTU operated under control of a NOVAR onboard controller to maintain the ID room temperature. A temperature control at a set point of 74 °F was used. This controller is the one used in Lennox RTUs for WalMart applications. The baseline test started at about 8pm on 4/21/05.
3. After the baseline test was completed, the ESM 4000 was switched on and the OD and ID rooms stabilized at the starting temperatures.
4. Two 24-hour 'ESM on' tests were run. The first started at about 8:15 pm on 4/22/05 and the second at about 8:30 pm on 4/23/05.

Test results

Cycling rates and room temperature variations. Two ESM on tests were run as noted above. Midway through the first ESM on test, Abbotly personnel made an adjustment to the ESM 4000 set up in an attempt to better manage compressor cycling rates during the low cooling load portion (latter half) of the 24-hr test. No ESM adjustments were made during the second ESM on test. The ID room load profile for the baseline (ESM off) and the second ESM on test are illustrated in Figure 2. Due to the loss of one-half of the Stage 1 room heat input, these loads are about 2.5 kWh lower on average across the board than intended. The load varied as expected during the baseline test but there were significant abrupt variations during the first half of the ESM on test. During the ESM on test, the safety thermostat in the ID room shut off the heaters for periods of 2-5 minutes at several times. This thermostat was set at a relatively high cutout temperature (>110 °F), however it acted to shut off the heaters whenever the ID room temperature exceeded about 88-90 °F. Figures 3 and 4 illustrate average, maximum, and minimum ID room temperatures during baseline and ESM on tests, respectively. The ID room load minimums seen in figure 2 coincide with points of high maximum ID room temperature seen in Figure 4. Figure 5 illustrates how the ID room temperature varied over the full course of the baseline and second ESM on test. Figure 6 shows the ID room temperature variation for a 3.5 hour segment of the first ESM test. (During the first ESM on test the abrupt load variations did not occur.) Wide variations in these 15-minute average values are seen for both modes during the high load (first half) portions of all three tests.

The small size of the ID room (about 9000 ft^3) relative to the test RTU cooling capacity and the high room load and output most likely made it more difficult for the RTU controls (with and without ESM) to maintain a very stable room temperature. The RTU blower completely cycled the room volume through the evaporator in a little over one minute. Further, the RTU's supply air discharge and return air intake in the test room were very close (approximately 10 feet) with some baffles in place to force the cooled supply air from the RTU to circulate around the ID room before entering the return air ductwork. The three electric furnaces (placed in the ID room to impose the cooling load on the RTU for the testing) were located directly under the return air duct, and thus the cool supply air from the RTU did not thoroughly mix with the heated space air before entering the RTU as would happen in a typical “real world” application. The rate of change in temperature was therefore a lot faster than would normally be the case.

An air conditioning system of the size of the test RTU installed in a large retail store might have perhaps 20 to 25 supply registers located in an area with the return air grill in a central position, depending on the installation. This allows for the supply air to be distributed throughout the conditioned space in the store, causing the air coming back into the return air duct of the unit to be true mixed air, and allow the air conditioner’s temperature control system to stage up and down the compressors according to the return air or space temperature. The ESM 4000, if installed on the air conditioner, would act to monitor the system and make any changes to optimize the control of the compressors.

The net effect of the room size limitation (exacerbated by the placement of the heating units) resulted in higher room temperature swings than one would expect in a “real world” installation where the RTU would be controlling a much larger volume of air with a slowly varying load as in a large retail store. This author is not a controls expert but it seems reasonable to speculate that the wide temperature swings would confuse an intelligent control system that tries to optimize RTU operation based on recent past history. Having a larger ID test room volume and/or a smaller test RTU would have moderated the temperature change rate. Better placement of the test room heating units relative to the supply air outlet and return air intake would have helped this situation as well.

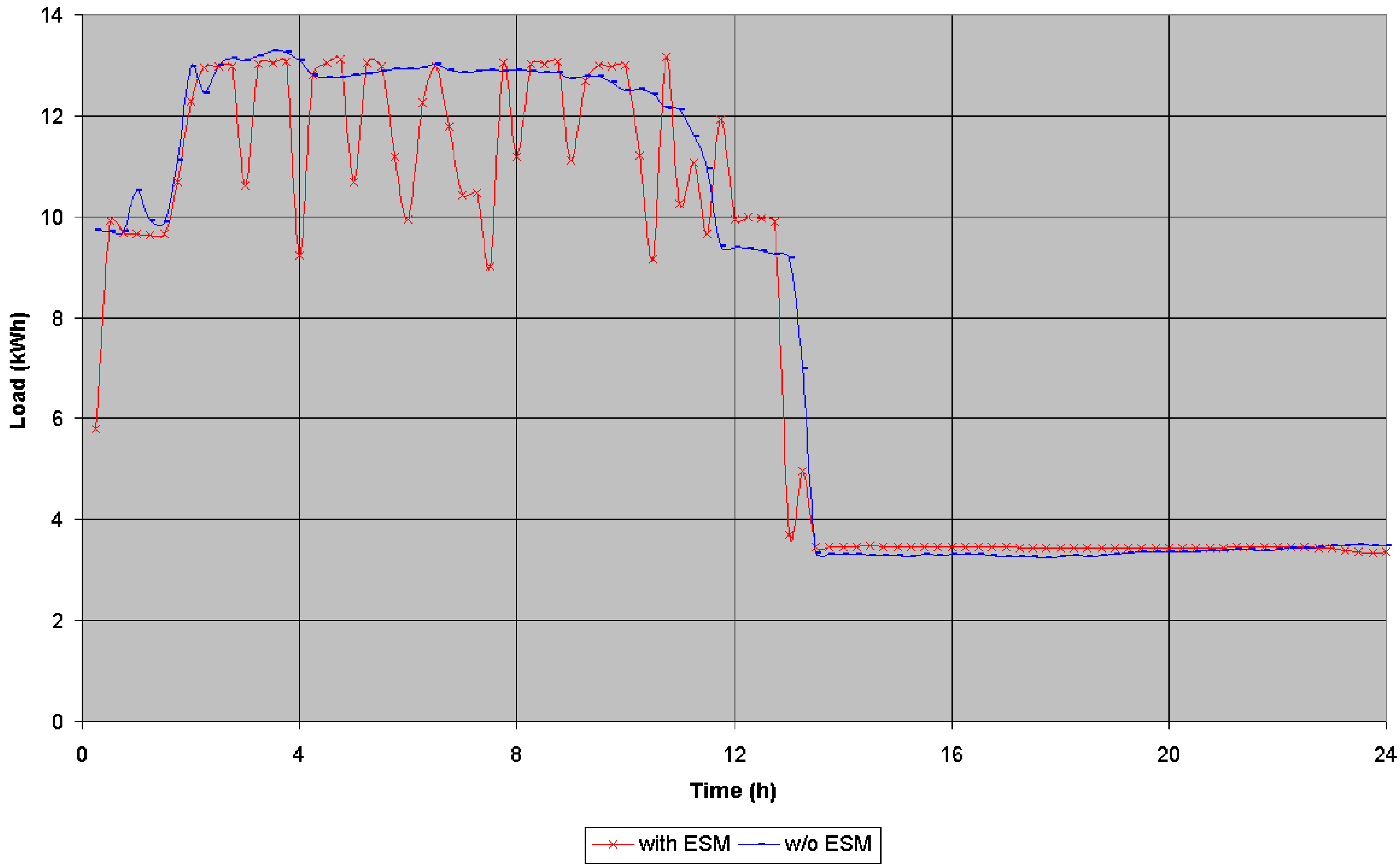

Figure 2. 15-minute average ID room load (kWh) vs time (2nd ESM on test and baseline).

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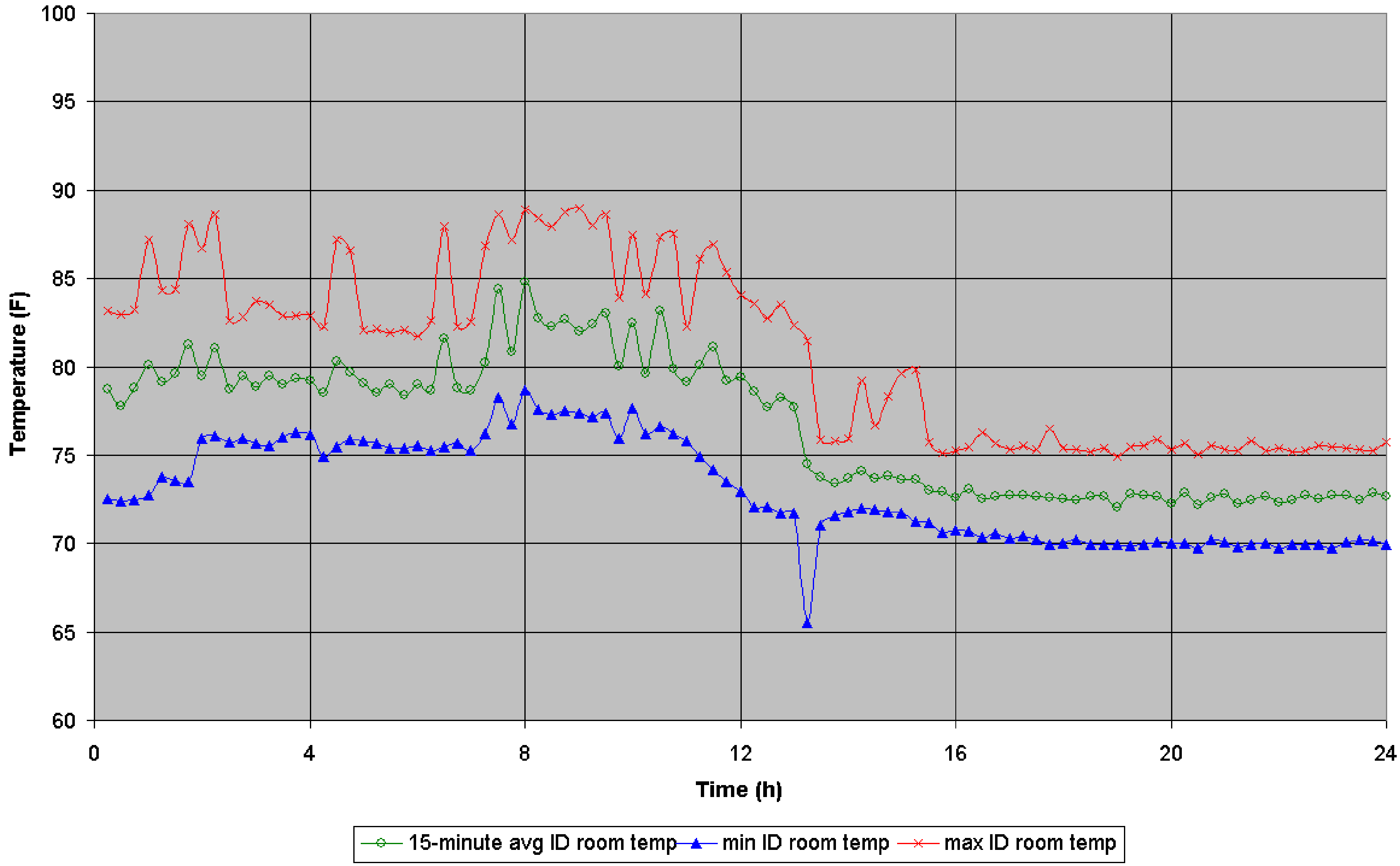

Figure 3. Average, minimum and maximum ID room temperatures for baseline test.

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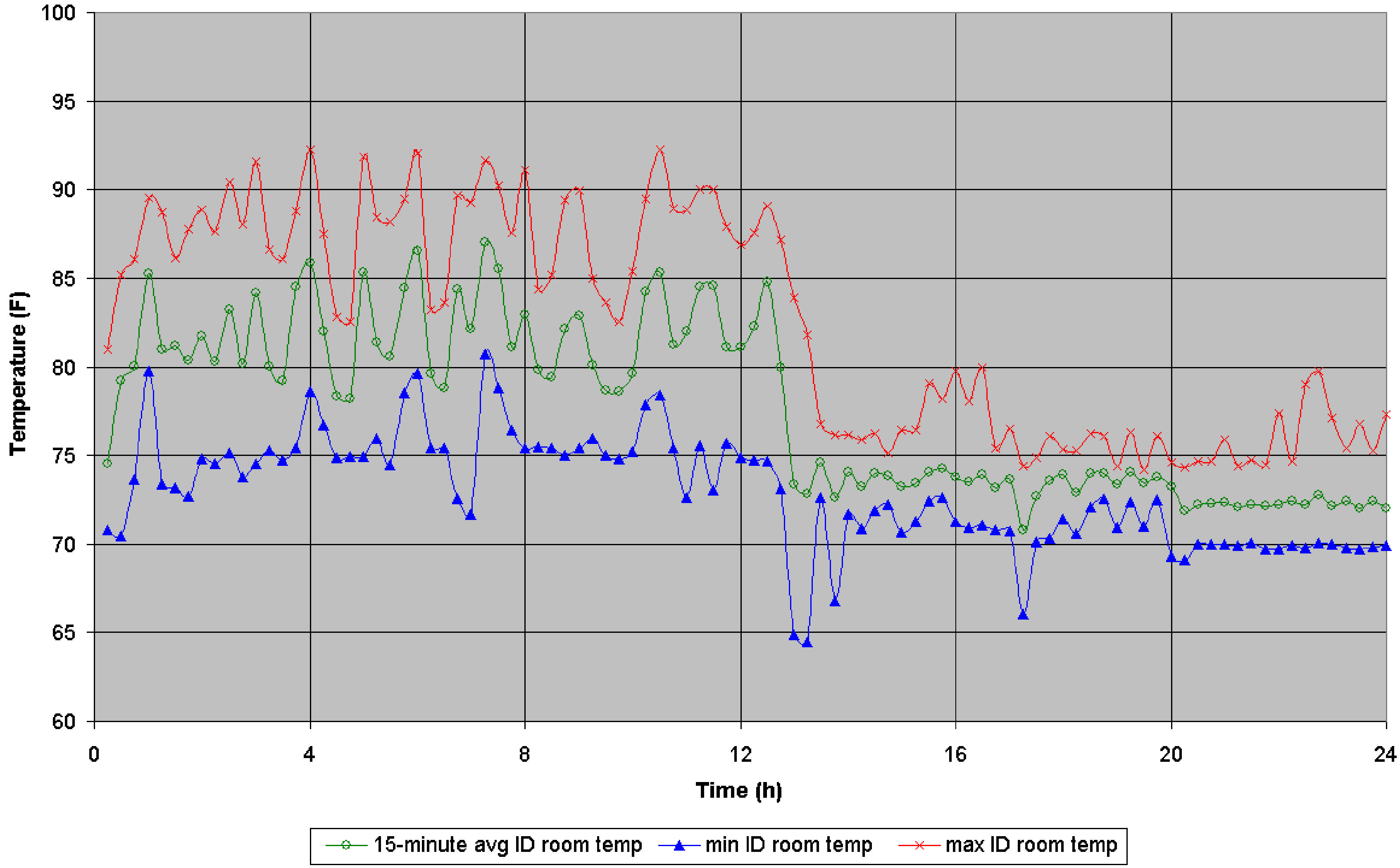

Figure 4. Average, minimum and maximum ID room temperatures for 2nd ESM on test.

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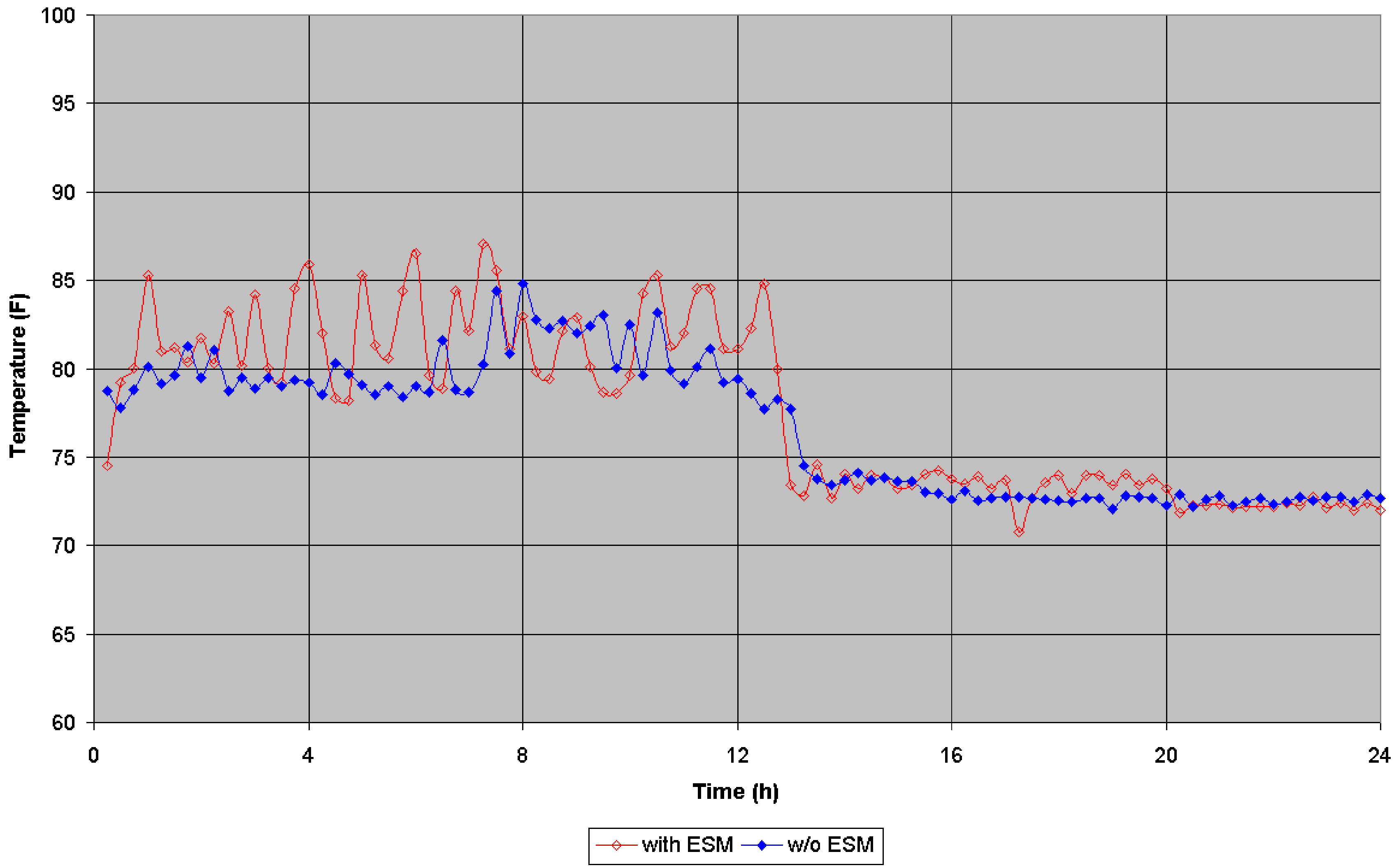

Figure 5. 15-minute average ID room temperatures vs time (2nd ESM on test and baseline).

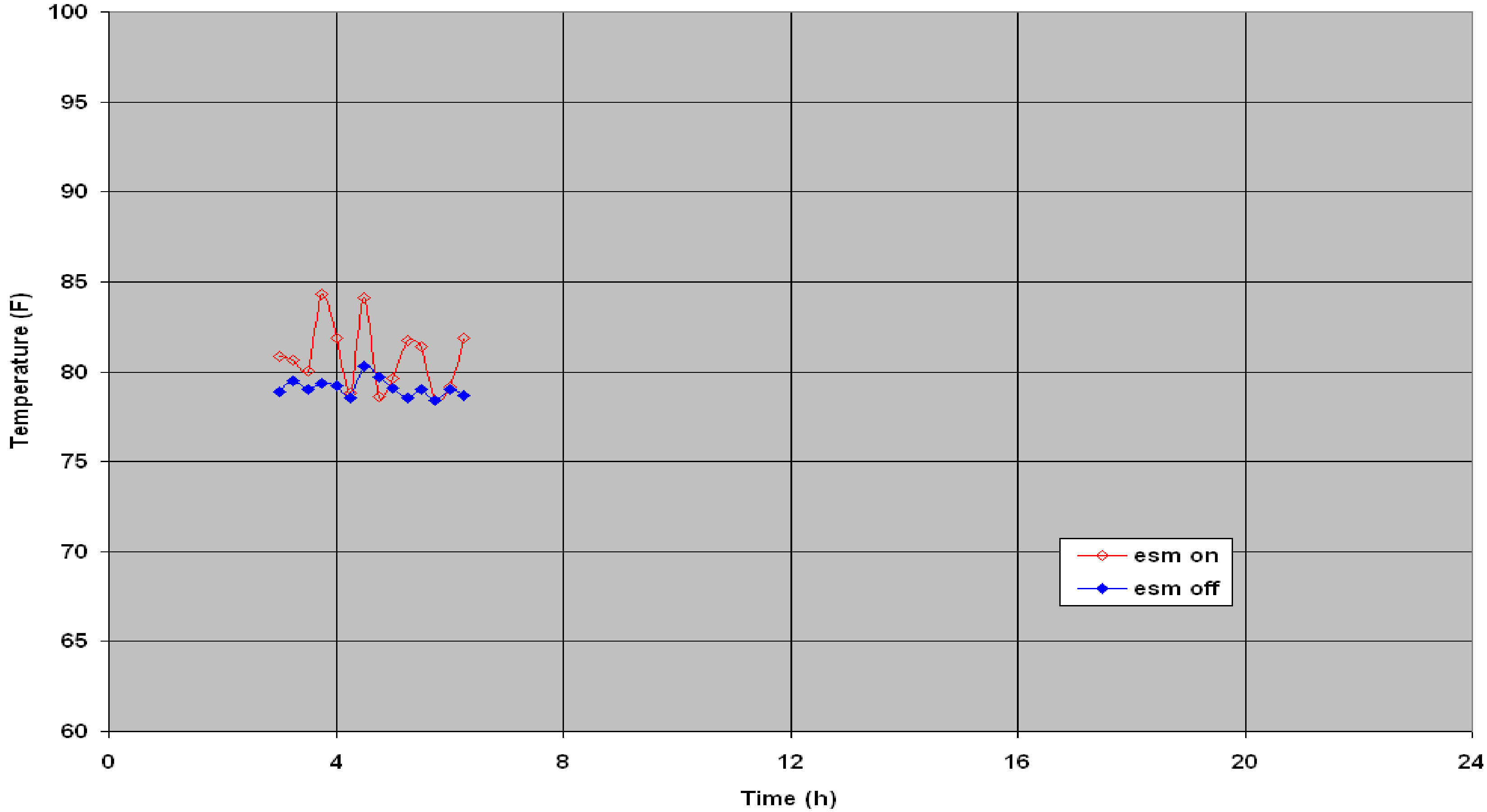

Figure 6. 15-minute average ID temperatures vs time (1st ESM on test and baseline).

RTU energy efficiency and compressor cycling comparison. Table 4 shows the overall RTU energy performance over the entire 24-hour test period for the baseline and 2nd ESM on tests. Table 5 illustrates compressor and unit cycling rates and runtimes for each mode.

Table 4. 24-hour test comparison; energy and efficiency

Mode	Avg OD room temp	Avg ID room temp (± range)	Load, kWh	RTU total kWh	RTU peak kW	Average COP	
						total	compressor-only
ESM off	85.0 °F	76.8 ± 2.0 °F	775.0	258.9	17.8	2.99	4.08
ESM on (2nd)	85.0 °F	77.6 ± 2.4 °F	737.9	238.4	17.4	3.09	4.35
Diff	+0.0 °F	+0.8 °F	-4.8%	-7.9%	-2.2%	+3.2%	+6.6%

The total load for the 2nd ESM on test was smaller (by about 5%) due to the periodic load drop offs described above. However, the total RTU power (compressors plus ID blower) was down by a larger percentage (about 8%). The net effect was a 3.3% higher overall COP for the ESM mode (6.6% higher compressor-only COP). The ID room temperature was slightly higher in the ESM mode (by 0.8 °F).

Table 5. 24-hour test comparison; cycle rates and runtime

	ESM off	ESM on (2nd)	Diff
Comp 1 cph	6.08	5.67	-6.7%
Comp 2 cph	6.08	5.75	-5.4%
Comp 3 cph	4.42	2.75	-37.8%
Comp 4 cph	4.42	2.67	-39.6%
Comp 1 min/cycle	6.74	6.22	-7.7%
Comp 2 min/cycle	6.73	6.71	-0.0%
Comp 3 min/cycle	3.29	4.96	+50.8%
Comp 4 min/cycle	3.27	4.88	+49.2%
RTU cph	6.08	4.79	-21.2%
RTU min/cycle	6.74	9.43	+40.5%

Compressor cycling rates (cycles/h or cph) for all compressors were reduced by the ESM (by almost 40% for compressors 3 and 4). Runtime per cycle stayed about the same for compressors 1 and 2 but increased by about 50% for 3 and 4. Runtimes for compressors 3 and 4 in the baseline case were nearly equal to the minimum time imposed by the NOVAR controller (3 min/cycle).

Energy comparison of the baseline (ESM off) performance to ESM on performance over a 3.5-hour period where the indoor room cooling load was about 70% of the RTU rated capacity is shown in Table 6. Table 7 illustrates compressor and unit cycling rates and runtimes for each mode.

Table 6. Energy and efficiency comparison – high cooling load

Mode	Avg OD room temp	Avg ID room temp (± range)	Load, kWh	RTU total kWh	RTU peak kW	Compressor kWh
ESM off	93.9 °F	79.1 ± 5.6 °F	181.6	58.2	17.8	48.0
ESM on (1st run)	93.9 °F	80.8 ± 8.9 °F	181.3	52.0	17.1	42.0
Diff	+0.0 °F	+1.7 °F	-0.2%	-10.7%	-3.9%	-12.5%

The total load for both tests was essentially equal. The total RTU power (compressors plus ID blower) during the ESM on run was almost 11% lower than that for the baseline case. Peak kW was almost 4% lower. However, the average ID room temperature was higher in the ESM mode (by 1.7 °F) and the variation was greater as well. If the average ID room temperature during the ESM off (baseline) test had been equal to that during the ESM on test, the estimated RTU efficiency would have been about 3.3% greater and its energy use would have been lower – about 56.5 kWh for RTU total, 17.3 kW for RTU peak, and 46.3 kWh for the compressors. On equal temperature basis, the RTU energy use when operating under ESM compressor control was about 8% lower than in the baseline case and compressor energy use was reduced by about 10%.

Table 7. 24-hour test comparison; cycle rates and runtime

	ESM off	ESM on (1st run)	Diff
Comp 1 cph	0.29	2.85	882.8%
Comp 2 cph	0.29	2.57	786.2%
Comp 3 cph	9.43	4.00	-57.6%
Comp 4 cph	9.43	4.29	-54.5%
Comp 1 min/cycle	207.52	16.04	-92.3%
Comp 2 min/cycle	207.52	17.74	-91.5%
Comp 3 min/cycle	3.29	5.37	63.2%
Comp 4 min/cycle	3.24	10.41	221.3%
RTU cph	0.29	0.86	-21.2%
RTU min/cycle	207.52	66.17	-68.1%

Cycling rates and run times per cycle were much more equally distributed among the four compressors in the ESM on case.

Figures 7 and 8, below illustrate the compressor cycling patterns and indoor room temperature variations during this 3.5-hour sample period during the first ESM on and baseline runs, respectively. The very rapid cycling rate for compressors 3 and 4 when operating without the ESM 4000 controller can clearly be seen in Figure 8. Note that cycling rate for these two compressors is much less severe when under ESM control - also noted in Table 7 above.

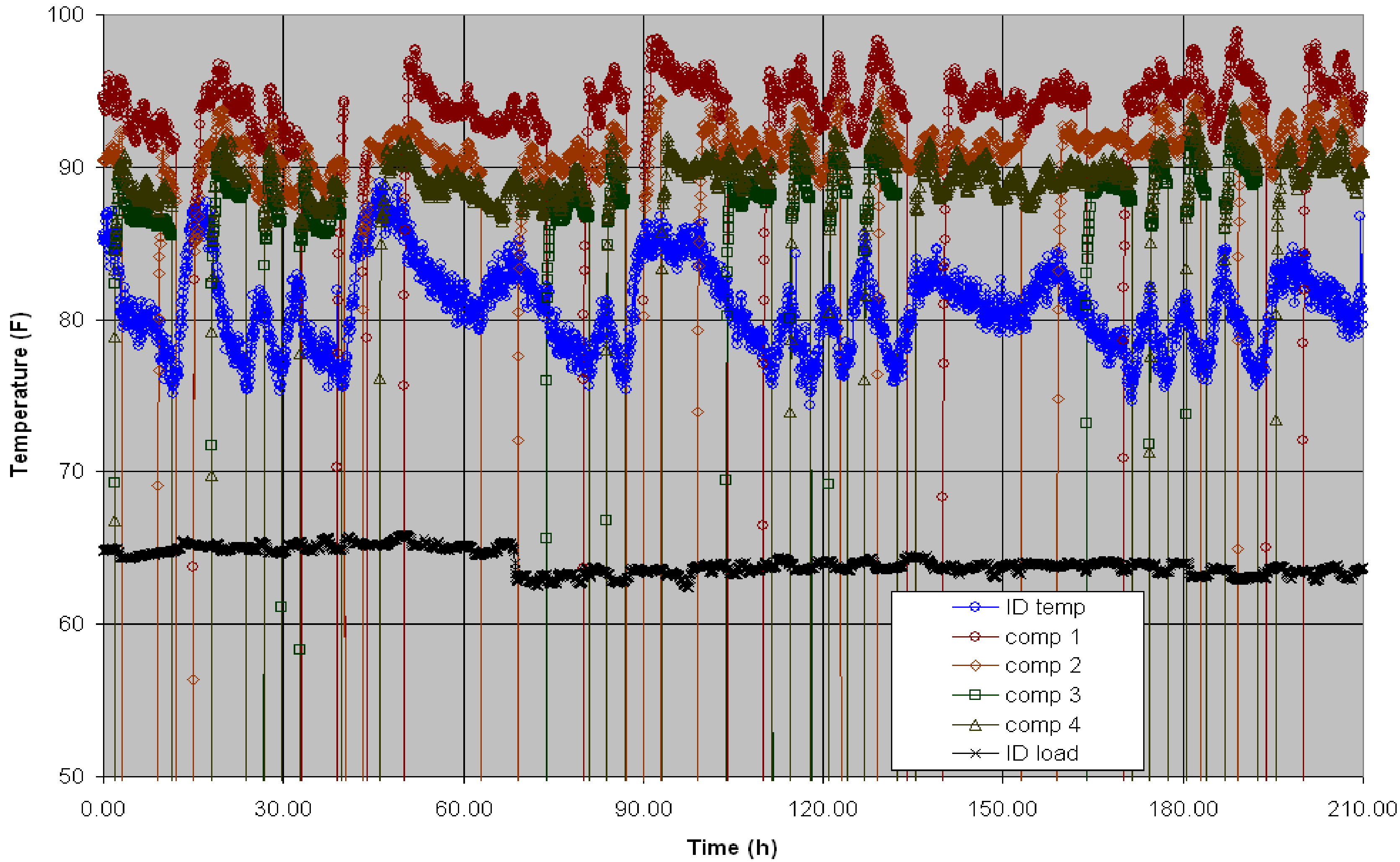

Figure 7. ID temperature & compressor cycling patterns during high load period from 2.75-6.25 hrs into 24-hour test – ESM on run #1 (NOTE: room load about 52 kW, or 15 tons)

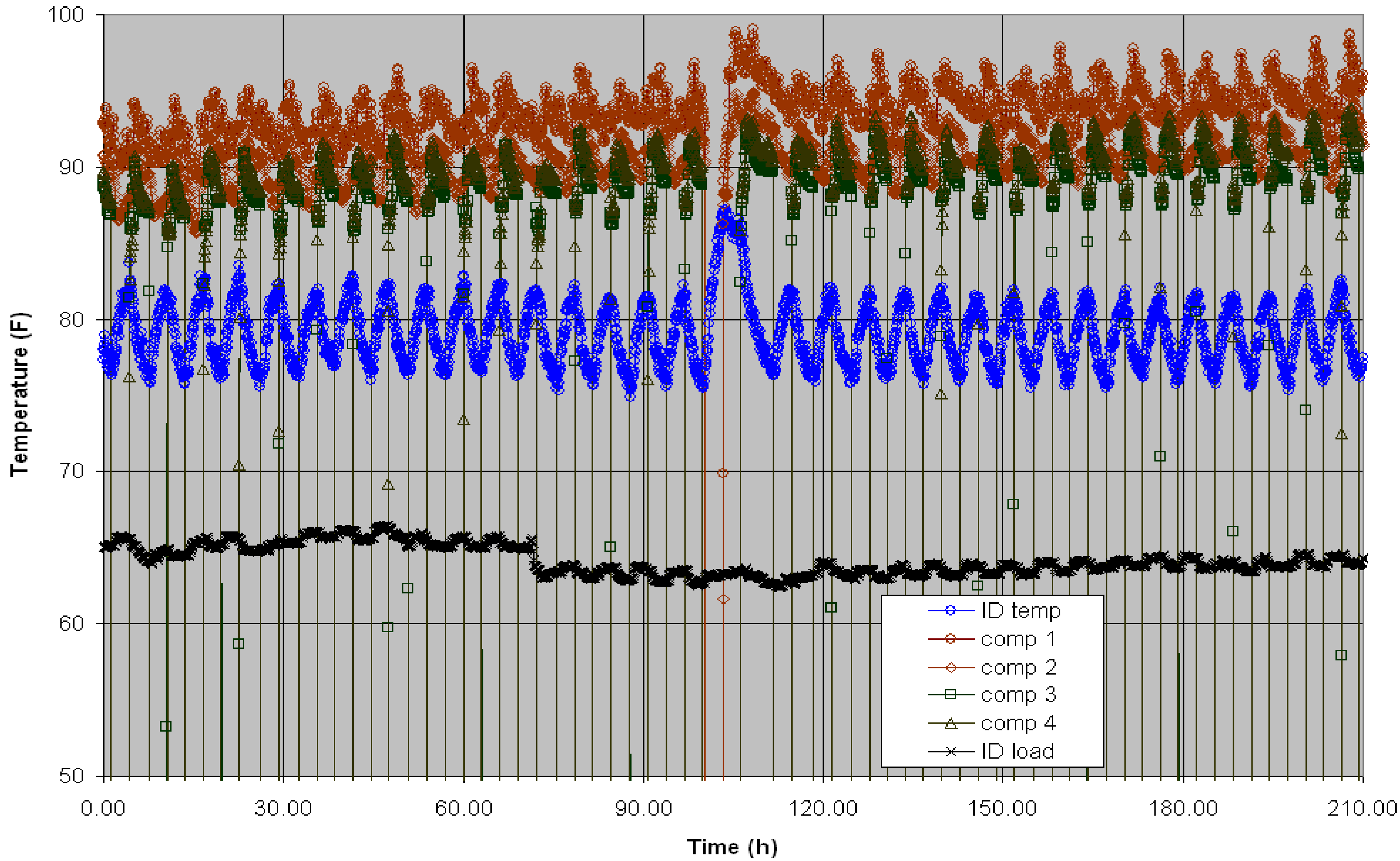

Figure 8. ID temperature & compressor cycling patterns during high load period from 2.75-6.25 hrs into 24-hour test – ESM off (NOTE: room load about 52 kW, or 15 tons)

Table 8 shows the overall RTU energy performance over the last half of the baseline and 2nd ESM on 24-hour tests. Table 9 illustrates compressor and unit cycling rates and runtimes for each mode during this same period. In this portion of the test the ID room cooling load was quite low – only about 18% of RTU rated cooling capacity.

Table 8. Low ID room load comparison; energy and efficiency

Mode	Avg OD room temp	Avg OD room temp	Load, kWh	RTU total kWh	RTU peak kW	Average COP	
						total	compressor-only
ESM off	77.5 °F	72.8 ± 2.7 °F	144.1	68.6	7.6	2.10	3.81
ESM on	77.5 °F	73.0 ± 2.8 °F	147.9	71.3	8.3	2.08	3.67
Diff	-0.0 °F	+0.2 °F	+2.3%	+3.9%	+9.2%	-1%	-3.7%

For the low load part of the test, the overall performance with and without the ESM was essentially the same. The ID room temperatures in each mode were also approximately equal. During this part of the tests the room load (about 13.5 kW or 3.8 tons) was less than the capacity of one of the RTU compressors. Under these conditions, both the baseline NOVAR control and the ESM on control modes tended to operate the unit at about the same cycling rates and close to the NOVAR-mandated 3 minute minimum run time per cycle as indicated in Table 9. The ESM control nevertheless did reduce the cycling rate and increase cycle runtimes somewhat.

Table 9. Low ID room load comparison; cycle rates and runtime

	ESM off	ESM on	Diff
Comp 1 cph	9.5	7.5	-21.0%
Comp 2 cph	9.5	7.9	-16.8%
Comp 3 cph	0	0.3	-
Comp 4 cph	0	0.2	-
Comp 1 min/cycle	3.05	3.7	+21.3%
Comp 2 min/cycle	3.05	3.96	+29.8%
Comp 3 min/cycle	0	1.99	-
Comp 4 min/cycle	0	3.20	-
RTU cph	9.5	7.3	-23.2%
RTU min/cycle	3.05	5.05	+65.6%

References

1. Abbotly Technologies 2003. ESM System 4000 (Series 3) Application Handbook – Rev 4 VS400.
2. Abbotly Technologies 2003. Energy Saving Module System 4000 Technical Overview.