TESTS OF ADSIL COATING

Test B - Long Term Test

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Prepared for:
Bob Suggs

Florida Power & Light Company
9250 W. Flagler Street
Miami, Florida 33174

Principal Investigator
Dr. Charles J. Cromer, P.E.

Appliance Laboratory (ALT)
Florida Solar Energy Center
1679 Clearlake Road
Cocoa, Florida   32922

EXECUTIVE SUMMARY

Adsil, a company in Palm Coast Florida, has developed a chemical and system to deposit this chemical on to a substrate such as the aluminum fins of AC evaporators and condensers. The chemical contains a high proportion of silica and the coating is thus referred to as a "glass" or "pre-ceramic." In addition to corrosion protection, the company claims that the coating provides an extremely thin layer (5 microns) that is strongly bonded and provides a 1% to 2% heat transfer improvement by wicking into sub-micron crevices and joints, where other coatings typically cause a 4 to 5% reduction in heat transfer. It is possible that this coating may significantly reduce HVAC related demand and consumption, especially on older units and units exposed to degradation of the condenser such as in salt spray environments. Further, the coating may prevent an increase in demand over time caused by corrosion and degradation of HVAC coil surfaces. It is therefore of interest to determine under controlled, reproducible tests if a demand or energy use savings is provided by the product.

This research project, funded by Florida Power & Light Company, to test the Adsil product includes five separate before-after tests of air conditioning equipment to be conducted within the controlled environmental chambers of the Appliance Laboratory at the Florida Solar Energy Center, University of Central Florida and a side-by-side long term test. The contract calls for a summary update report to be written after each of the tests. The long term test (test B), has been completed. This is the update report documenting that test.

Test B was a side by side test with two five ton Carrier units installed next to each other. The condensers for the two units were installed side by side outside of the Appliance Laboratory and the evaporator and air handler units were installed on a side by side basis within one of the environmental control chambers inside the Appliance Laboratory. Both indoor air handlers were ducted together to draw from the same return air duct and together supplied chilled air to the Appliance laboratory and were cycled on a thermostat setting. The two systems were monitored separately for Btu delivered to the space and kWh energy use. The condensers outdoors were also ducted together such that the same air condition flowed through both condensers. The air presented to the condensers was treated with a salt mist to enhance corrosion and provide accelerated aging of the condenser units. The test was run for 248 days and data on the performance of the units was taken for 5759 hours.

From these data, we can be 95% confident that the process of removing the factory applied coating by cleaning with a mild acid and then applying the Adsil coating to the new unit did not make a measurable difference in the units performance. As the condensers of the side by side units deteriorated under the accelerated aging of the salt mist, it became visibly clear that the factory coated unit deteriorated faster than the Adsil coated unit. At the end of the test period, we can be 95% confident that the less deteriorated Adsil coated unit operated with an energy savings between 10.5 and 11.4% with the expected savings to be 11.0%.

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TEST OF ADSIL COATING - TEST B UPDATE

PURPOSE OF THIS REPORT

This research project, funded by Florida Power & Light Company, to test the Adsil product includes a long term side by side test of air conditioning equipment to be conducted at the Appliance Laboratory at the Florida Solar Energy Center, University of Central Florida. The contract calls for a summary update report to be written at the completion of each test. This is the update report documenting the side by side long term test (Test B). General information concerning the Adsil product and a description of the air-enthalpy method of measuring Btu delivered by the air handlers are provided in the first report, Tests of Adsil Coating: Test A1 Update.

SET UP OF UNITS FOR LONG TERM TEST - TEST B.

Test B was a side by side test with two five ton Carrier units installed next to each other. The condensers for the two units were installed side by side outside of the Appliance Laboratory and the evaporator and air handler units were installed on a side by side basis within one of the environmental control chambers inside the Appliance Laboratory. Both indoor air handlers were ducted together to draw from the same return air duct and together supplied chilled air to the Appliance laboratory and were cycled together on a thermostat setting. The two systems were monitored separately for Btu delivered to the space and kWh energy use. The outdoor condensers were also ducted together such that the same air condition flowed through both condensers. The air presented to the condensers was treated with a salt mist to enhance corrosion and provide accelerated aging of the condenser units.

Figure 1 shows the two condensers installed side by side outside of the Appliance Laboratory. Figure 2 shows one of the units being treated with Adsil. Notice that the second unit was covered to prevent any Adsil over-spray from coating the second unit. Figure 3 shows the enclosures constructed around the condensers and the ducting constructed to provide uniform air to each condenser. Notice the tops of the condensers are open so the air from the condenser fans is drawn into the inlet duct and blown out the top of the condensers. Figure 4 shows the interior of the ducting to the condensers, part of the top of the duct has been folded back to illuminate the interior for the photo. The tanks used to hold the salt mixture and pump assembly for the two misting nozzles are visible to the left of the photo.

Figure 1. Installation of Two Carrier Condensers Side by Side for Test. Unit B1, the Adsil Unit Has Been Cleaned and Some of the Black Factory Coating Removed.

Figure 2. Adsil is Applied to Unit B1 Condenser.

Figure 3. Ducting Constructed around Side by Side Condenser Units.

Figure 4. View Down Condenser Ducting and Salt Solution Holding Tank.

Figure 5. Side by Side Installation of Air Handlers within Appliance Laboratory.

Figure 5 shows the ducting constructed for this test that is located within the indoor environmental control chambers. This ducting provides for the air-enthalpy measurement of Btus delivered by both the air conditioner units. The instrumentation set up is the same as utilized during tests A1 through A5. Measurements are made on the temperature and RH of the inlet air, temperature and RH of the outlet air, and the air flow cfm so that Btus delivered by each AC coil are measured directly. During the same time intervals, the energy use of the AC units are measured by a pick up of pulses from standard Kwh meters. The electrical use is measured for both the air handler fan and condenser fan as well as the compressor. The EERs for the units are calculated for each test hour by dividing the total measured cooling Btu's (both latent and sensible) by the measured watts used during that hour.

The test procedure consisted of setting up the two new Carrier systems in a side by side configuration as shown above. One unit, unit B1, was washed with the Adsil cleaning solution and coated with the Adsil treatment. This coating was completed by Adsil personnel. The other unit, unit B2, the control unit, was not treated and was used as it arrived in its box from the factory. The units were set up to cycle on and off simultaneously on a single thermostat value set at 70 degrees F. Approximately 10 Kwatts of heat was added to the Appliance Lab to provide a minimum typical duty cycle of approximately 50% during the winter months. The duty cycle was over 90% during the early and latter part of the test with hot ambient conditions. The units were switched by the same thermostat, so they were always both off or both running. When ever the units turned on, this would also cycle the mister pumps that added salt water mist to the air entering the condenser units. This provided for accelerated aging and deterioration of the condenser units under test.

TEST RESULTS FROM UNITS B1 AND B2 - TEST B

The two condenser units were installed new and operated under test from September, 11, 2000 through May 16, 2001 or 248 days. Both the condenser units experienced deterioration during the test. Figure 6 shows the two condenser units at the end of the test period as viewed from inside the duct providing air to the condensers. Though the assessment of visible deterioration is interpretive, it appears that approximately fifteen percent of the Adsil unit condenser area is corroded to the point of a significant reduction in heat exchange, while on the control condenser, approximately seventy-five percent of the fin area is similarly deteriorated. The Adsil unit corroded primarily at the area of heaviest input of the salt mist, where the control unit not only corroded more significantly in that area, but also experienced heavy corrosion in the bottom foot or so of the condenser around its entire parameter. Figure 7 shows a close-up view of the corroded area on the Adsil condenser at the end of the test, and Figure 8 shows a similar view of the untreated control compressor.

Operational performance data was scanned on sixty second intervals and averages stored for each hour. A total of 5759 hours of continuous data were recorded on both of the two units. EERs for each unit were calculated using data acquired only while the units were in operation. A table of the raw hourly EER values is provided in the Appendix. A plot of the recorded EER vs. test hours is provided as Figure 8.

Figure 6. View from Air Inlet Duct of Two Condensers: Adsil on Right, Control on Left.

Figure 7. Deteriorated Area of Adsil Coated Condenser.

Figure 8. Portion of Deteriorated Area of Control Condenser.

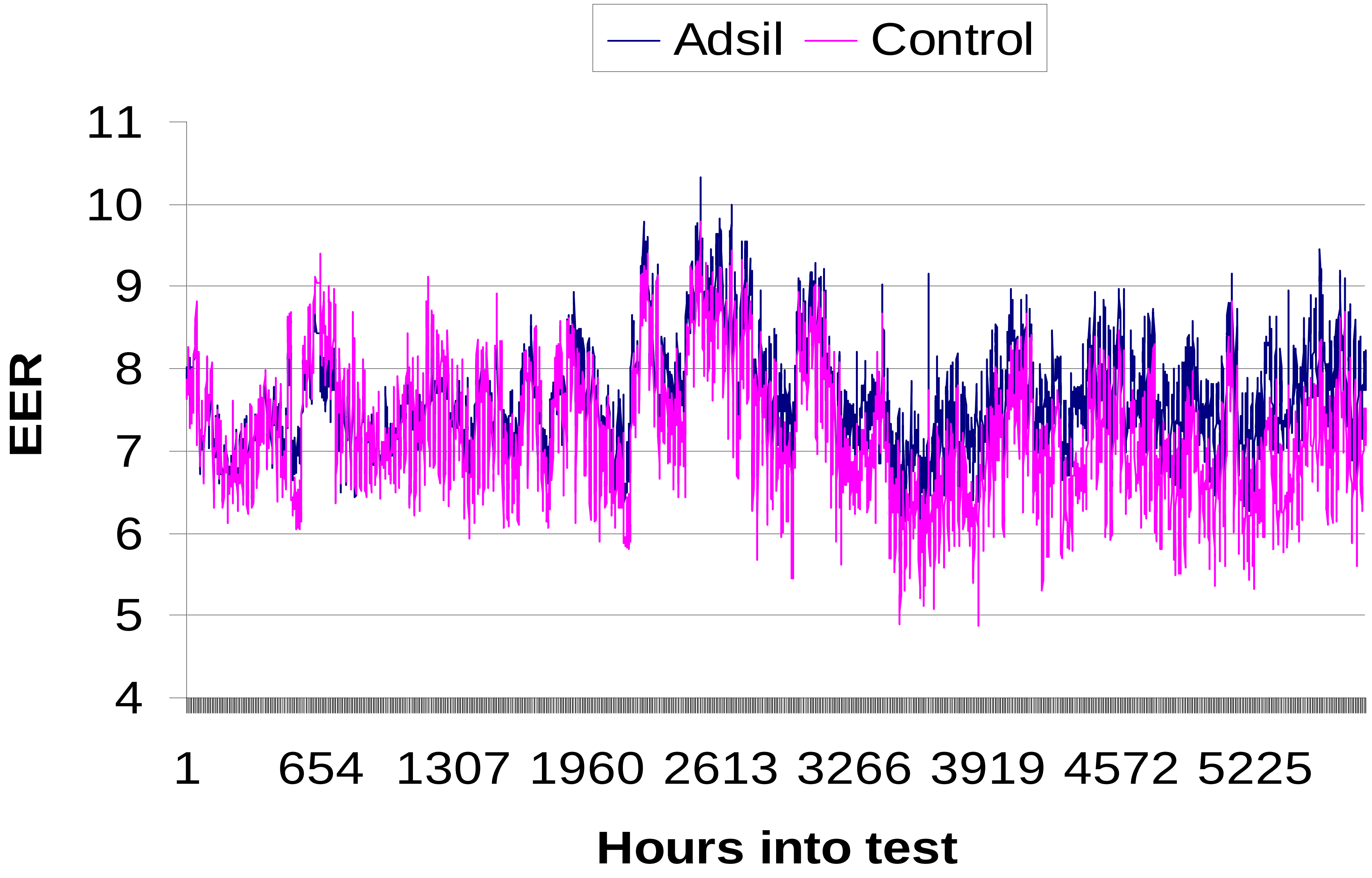

Figure 9. Plot of EER Over Time of Test. (Control is light color, Adsil is dark color)

ANALYSIS OF TEST B DATA

Unlike the previous before/after tests of this study (test group A), this B test sequence uses equipment side by side, one with the treatment of interest and one without (control). This type of testing, though more costly, has the benefit that it can be appropriately assumed that the indoor air condition for the unit with the treatment and the outdoor air condition for the unit with the treatment is identical to the indoor and outdoor air condition for the unit without the treatment. Thus, the equipment is inherently set up to test "apples to apples" input conditions.

SIGNIFICANCE TESTING FOR IMPROVEMENT IN EER

As with previous test group A data, a paired t-test on the difference of the treatment vs. control EER values was conducted to determine possible improvement in EER caused by the treatment. The test procedure is considered to be able to discern at the 95% confidence level, differences in performance that are at least 5% in magnitude. All statistical tests are completed with the Minitab statistical analysis software package.

TEST B RESULTS

Test 1 - Compare Unit B1 vs. Unit B2, Correct to Validate Similar Performance.

The first comparison test was completed on data taken during the first week (5 days) of side by side operation, prior to the addition of the Adsil product. These tests showed that under average operation and at the 95% confidence interval, Unit B2 operated with a measured EER that was 0.07 times higher than Unit B1. It is well known that two units with the same performance label that arrive from the factory may operate with slightly different performance when they are installed in the field. This may be due to any number of factors - slight differences in charge, slight differences in line lengths, or slight measurement differences to name a few. The measured EER from unit B1 was adjusted by this factor so the units would be assumed to start the testing with equivalent EERs on both units. The adjusted data from the pre-test was tested with the hypothesis that they were now equal vs. the hypothesis that they were different. This t-test validated that there was no difference in EER operation between the two units at the 95% confidence level to begin the test.

Test 2 - Compare EER on the Adsil Unit Before and After the Adsil was Applied.

A coin flip was used to determine which unit would receive the Adsil treatment. As a result of the coin flip, the Adsil was applied to Unit B1. The second comparison t-test that was completed was on the EER of the new Unit B1 comparing EER prior to Adsil application and after Adsil application. The unit was run continuously and data was taken for two hours prior to the Adsil application, then after the Adsil was applied, the unit was run for an hour to dry the Adsil, then two hours of "after" Adsil application data was taken on operational EER. The t-test on the data showed at the 95% confidence interval, there was no discernable difference in EER between the unit operation before the Adsil was applied and after it was applied.

Test 3 - Compare Control Unit vs. Adsil Unit for First Week of Operation.

During the first seven days of operation after the Adsil was applied, both units were in operation for 116 hours for approximately a 65% duty cycle. These data are provided in the Appendix. A t-test of means for this 116 hours showed that at the 95% confidence level, there was no discernable difference in EER between the two units operating side by side. For this week of operation, the average outdoor run temperature was 89.7 degrees F, and the control unit operated with an average EER of 7.66 and the Adsil unit operated with an average EER of 7.66.

Test 4 - Compare control Unit vs. Adsil Unit for Last Week of Operation.

During the last seven days of operation after the Adsil was applied, both units were in operation for 154 hours for approximately a 90% duty cycle. These data are provided in the Appendix. A t-test of means for this 154 hours showed that at the 95% confidence level, there was a discernable difference in EER between the two units operating side by side. The t-test hypothesis that the Adsil unit operated with a higher average EER, also is accepted at the 95% confidence level. During the last week of test under an average outdoor run temperature of 83.4 degrees, the control unit operated with an average EER of 7.21 and the Adsil unit operated with an average EER of 7.99, an eleven percent (11%) improvement in performance over the non-treated unit.

Test 5 - Comparison of EER Performance Over Time.

It can be seen from the plot of Figure 9, that the measured EER of both units shows high variability. EER is temperature dependent. It depends both on the outside temperature and on the inside temperature that varies within several degrees, the swing of the thermostat. Once a week, the condensers of both units were rinsed with a hose. After the rinsing, both units typically showed an increase in EER. Other factors affecting EER may be wind speed and direction and relative humidity indoors and outdoors. Finally, the variability within the sensors themselves has an effect on the measured variability. Never the less, through the variability shown on Figure 9, one can visually identify a trend over time of the Adsil coated unit maintaining a higher EER while the control uncoated unit showing a trend of reduced EER over time. The photos also allude to this trend, as the control condenser visibly showed more corrosion damage over time than the condenser with the Adsil coating.

A linear regression of the difference in hourly measured EER over time showed with a confidence greater than 95%, that 62% of the differences measured between the two units, control and Adsil, were directly due to the effect of the time associated degradation of the two units. In other words, the Adsil coated unit performed with an EER significantly better over time, and this improvement increased as time went on. As mentioned above, factors other than the effect of time degradation also affected the measured difference in EERs. At 95% confidence, these unknown effects are about 38% of the measured variability (both high and low). This unexplained difference is demonstrated by the residuals between the predicted difference due to the effect of time and the measured difference. A normalized plot of the residual differences is provided as Figure 10. Notice that this plot is near linear and balanced about 0. This means that the residuals are almost perfectly normal in their distribution. Residuals that are affected by some other consistent effect will show a bias due to this effect and will not produce a normal distribution. Random influences produce normal variances. Thus these residuals indicate that, though 38% of the variability is not explained by the effect of the Adsil, this unexplained or residual effect is normal in its distribution, that is, for any one hour, after the effect of the Adsil treatment is removed (leaving the residuals), the measured EER values of either of the units are just as likely to be higher as they are lower. Thus, the unexplained variability is most likely due to random effects.

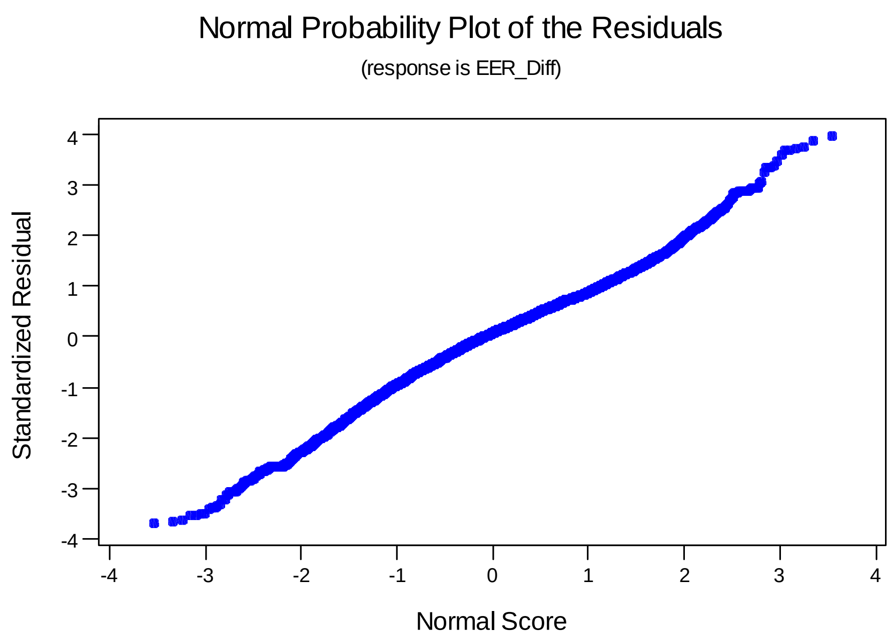

Figure 10. Normal Probability Plot of Regression (EER Improvement vs. Time) Residuals.

Percentage in EER performance relates directly to energy savings. There was no savings measured on the new unit when the Adsil was applied, however, an energy savings appeared as the control condenser deteriorated faster than the Adsil coated one. This measured savings increased as the condensers continued to degrade under the accelerated aging test. Assuming that the control unit condenser was nearing its useful life at the end of the test, then the percent energy savings that could be expected during any percentage life of a unit is represented by the regressed difference in EER (savings) vs. time. This equation was found to be: Percentage Energy Savings = -1.49 + (0.163 * Unit Age in %), where the Unit Age in % is a value over 10%. In other words, if the unit is new, or under 10% of its useful life, no improvement in performance is expected from the addition of the Adsil. However, at 25% of its life, about 3 % energy savings is expected, and at 80% of its useful life, a 11.5% energy savings could be expected as a result of the Adsil having been applied when it was new. It should be cautioned that these results apply only to those systems who's operational life and performance is dominated by condenser degradation rather than compressor wear.

TEST B CONCLUSIONS

From these data, we can be 95% confident that the process of removing the factory applied coating by cleaning with a mild acid solution and then applying the Adsil coating did not make a measurable difference in the units performance. As the condensers of the side by side units deteriorated under the accelerated aging of the salt mist, it became visibly clear that the factory coated unit deteriorated faster than the Adsil coated unit. At the end of the test period, with the units operating for 5759 hours over 248 days, we can be 95% confident that the less deteriorated Adsil coated unit operated with an energy savings between 10.5 and 11.4% with the expected savings to be 11.0%.