

HVAC COIL COATINGS – PAY NOW OR PAY LATER...AND PERHAPS MUCH MORE

Coatings are only as good as their technology and application. The cathodic epoxy coating discussed in this whitepaper is the ElectroFin[®] E-Coat Process from Modine.

For more information, visit <https://modinecoatings.com/electrofin-e-coat-process/>

Modine's E-Coat process begins when specifying ElectroFin[®] E-Coat as the protective coating. Units that arrive at ElectroFin[®] undergo a complete inspection for damage. All units approved for production are labeled with an identification tag that remains with the coil throughout the coating process and the coil's lifespan. This ID number can trace every E-Coat process step and support Modine's 5-year warranty.

Prolonging condenser life has many benefits. Especially if it's installed in corrosive environments such as near the ocean or industrial settings where corrosive airborne contaminants such as sulfur dioxide, hydrogen sulfide, and chlorine are present. Extending service life, maintaining thermal efficiency, keeping pressure drop low, and keeping energy consumption at a minimum should be objectives for any installation. Anything that can make these objectives a reality should be considered when designing and specifying an HVAC system.

TESTING

The ASTM G85 Annex 3; Acidified Synthetic Sea Water Testing (also commonly referred to as the Sea Water Acetic Acid Test – SWAAT) was used to test the relative resistance to corrosion of coated or un-coated aluminum alloys and other metals when exposed to a changing climate of acidified synthetic seawater spray, followed by high humidity, both at an elevated temperature. SWAAT is an aggressive test that has become an industry standard when evaluating corrosion life of aluminum heat exchangers. The ASTM-B117 test is an accelerated form for atmospheric corrosion testing limited to just determining the corrosive effect of salt on metallic objects, and does not take into account acids commonly found where HVAC system are installed in corrosive environments.

The SWAAT testing was performed on a copper tube aluminum plate fin (RTPF) condenser manufactured by Modine. The condenser was constructed with galvanized steel side plates, rifled copper tubes and 16 fins-per-inch lanced aluminum fins. The finned face area of the condenser was 14.75" x 22" and the depth was 2.598".

A total of three identical condensers were tested:

- Bare, un-coated condenser for base-line comparisons
- Cathodic epoxy coated condenser having an additional UV coating*, and
- Immersed/sprayed modified-phenolic coated condenser

* The added UV coating further reduced coil thermal transfer over epoxy e-coat alone. See sidebar for details on cathodic epoxy coating.

The coatings were applied to the condensers in accordance with specified procedures.



Modine condenser used in coating tests.



Cathodic epoxy coated condenser shown.

Testing procedure included 2000 total SWAAT hours in 500-hour increments with one week between SWAAT exposure for performance testing. Please note the samples were rinsed and dried prior to each round of performance testing in an attempt to remove any loose corrosion by-products.

Other testing parameters were:

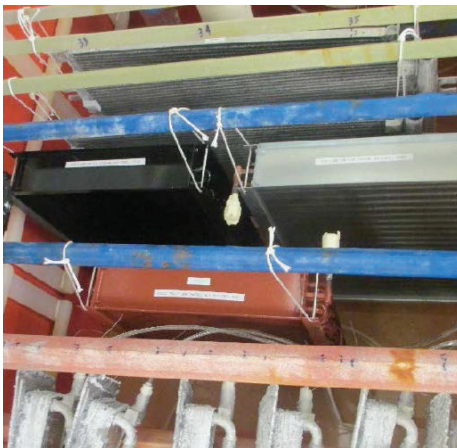
- Four steady-state points with R410a refrigerant
- Ambient air pressure and humidity at 95°F
- Four air flow rates 500, 700, 900 and 1200 SCFM
- Refrigerant inlet of 422 psia ($T_{sat} = 118F$), with 50°F superheat
- Refrigerant outlet at 10°F subcool
- Heat transfer of ~ 12,000-24,000 Btu/hr

Photographs of all three condensers were taken for baseline reference (bare and after coating application) and at the end of each 500 hour SWAAT cabinet exposure.

VIRTUAL SYSTEM MODEL APPROACH

To achieve predictable results, a virtual model used with the following approach:

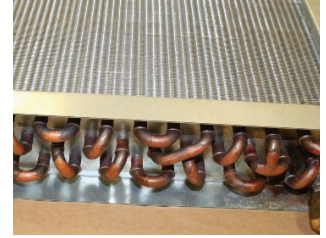
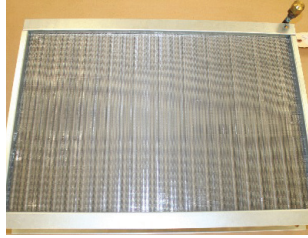
- A vapor compression system model that has the ability to model actual heat exchanger geometry and performance was developed. The model was calibrated with actual system level performance data from the light commercial air conditioning unit modeled.
- Standalone condenser models were developed to reflect the tested coil geometry and were calibrated to match test data for each coating option, air flow rate, and SWAAT time.
- The system model was then run with condenser degradation factors for each coating option and SWAAT time at the 2015 Air-Conditioning, Heating and Refrigeration Institute's 410 standard for Performance Rating of Commercial and Industrial Air-Conditioning and Heat Pump Equipment AHRI.



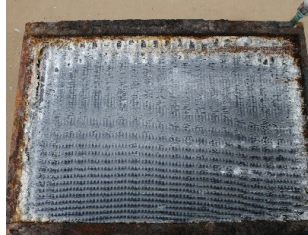
Three test condensers in SWAAT cabinet. Upper left cathodic epoxy coated condenser, upper right bare, un-coated condenser and bottom center immersed/sprayed modified-phenolic coated condenser.

TESTED CONDENSER PHOTOGRAPHS

Bare Condenser

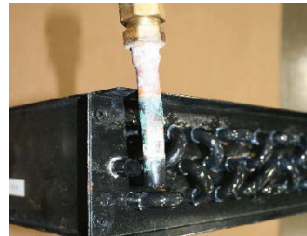
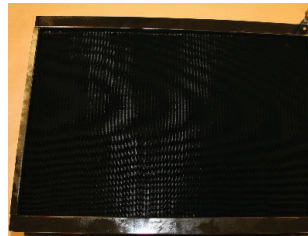


After Testing



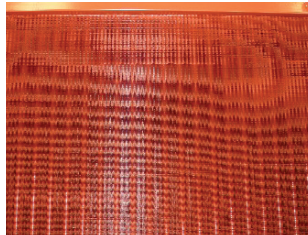
Note corrosion build up on fins, especially where aluminum fins came in contact with the galvanized header plates and side plates, subjecting the condenser to galvanic corrosion.

CATHODIC EPOXY COATED CONDENSER WITH ADDITIONAL UV COATING



Note less corrosion, especially at the fin/header plate/side plate interface areas.

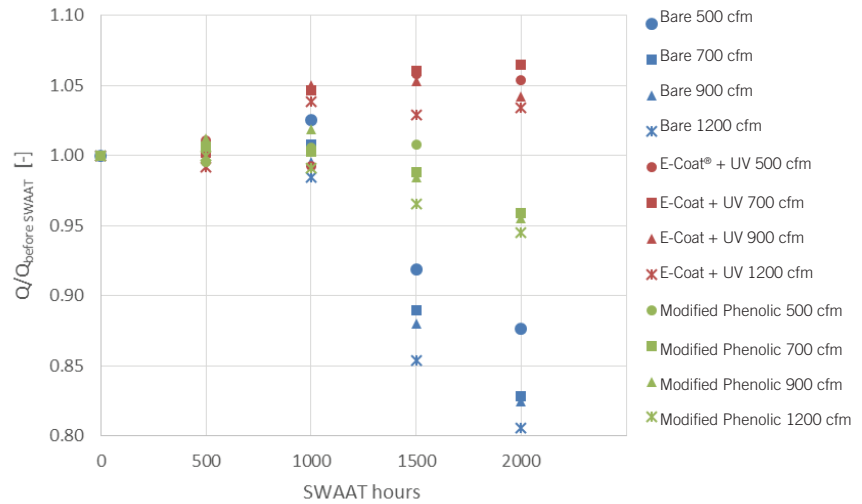
IMMERSED/SPRAYED MODIFIED-PHENOLIC COATED CONDENSER



Note extensive corrosion after 1000 hours and significant corrosion of the header plates and side plates at 1500 and 2000 hours.

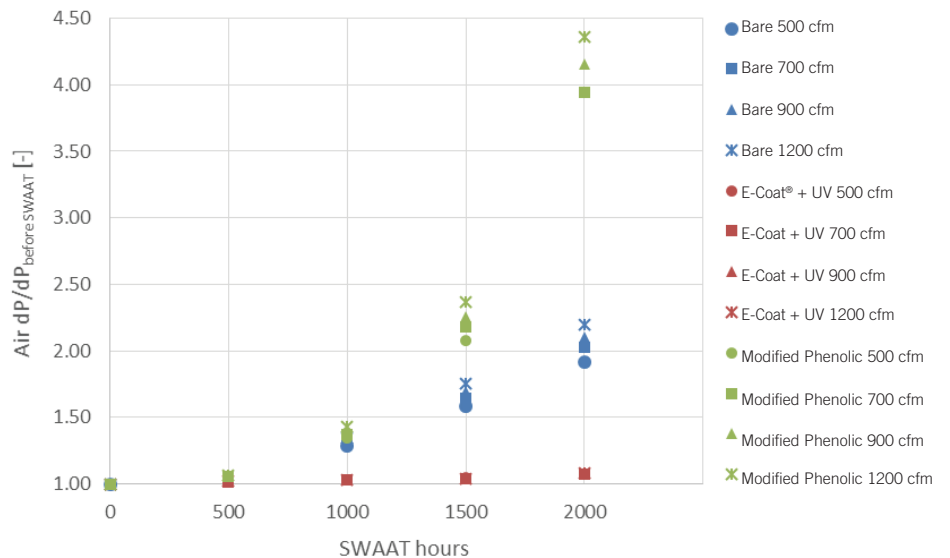
TEST RESULTS

Measured heat transfer variation with corrosion



Note Cathodic epoxy coated condenser, even with additional UV coating, retained significantly higher heat transfer rates over all SWAAT cabinet exposures and SCFM rates. The immersed/sprayed modified phenolic coated condensers performance dropped to 0.95 on average. The bare coil showed a 15-20 percent degradation after the 2,000 hour SWAAT exposure. Heat transfer rates declined for all condensers as the SCFM increased.

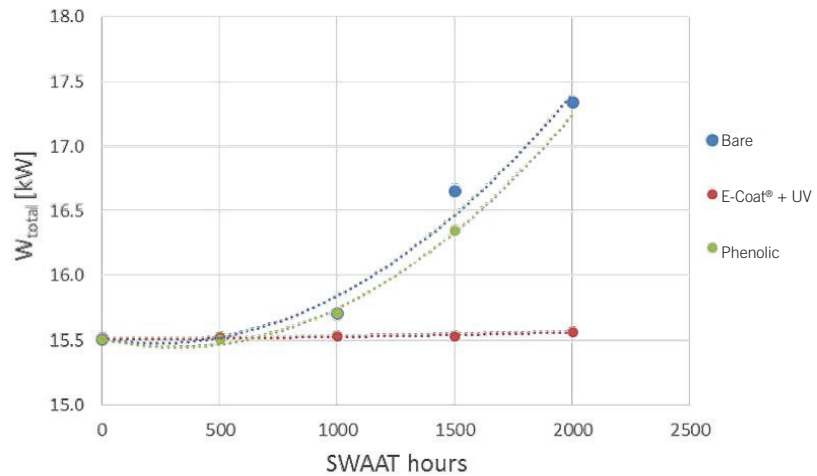
Measures air pressure drop with increased corrosion



As expected, corrosion inhibits air flow, which in turn impacts heat transfer rates. This graph shows that the immersed/sprayed modified-phenolic coated condenser lost the most air flow (pressure drop) as its coating de-laminated from the fins, resulting in reduced space between the fins. This significant pressure drop was not experienced to the same degree as the bare coil, particularly after the 2000 hour SWAAT cabinet exposure. Note the cathodic epoxy coated condenser experienced negligible pressure drop over its four SWAAT cabinet exposures.

TEST RESULTS

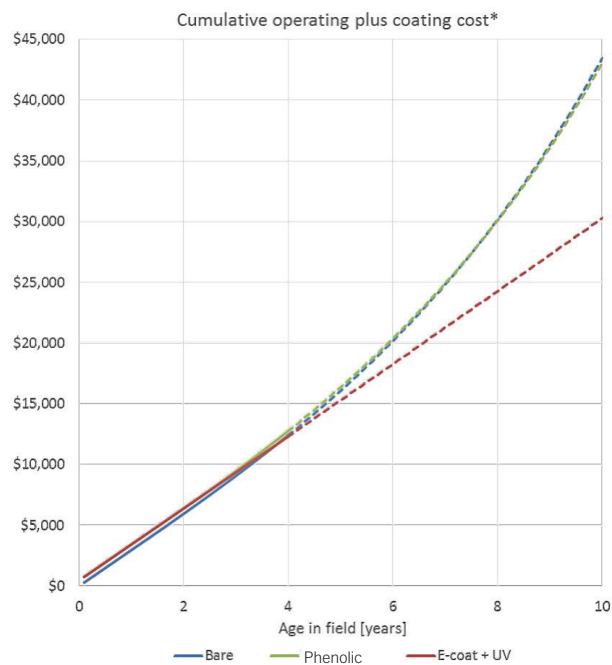
Simulated System Performance with Corroded Condensers



With increased corrosion comes decreased thermal transfer and higher pressure drops across the coil fins. All this adds up to increased power consumption for running the fan and compressor, higher operating pressures and the possibility of tripping pressure/limit switches. Note system power consumption for the cathodic epoxy coated condenser is essentially constant for all four SWAAT cabinet exposures, while the bare and immersed/sprayed modified-phenolic coated condensers experience very similar increases in power consumption.

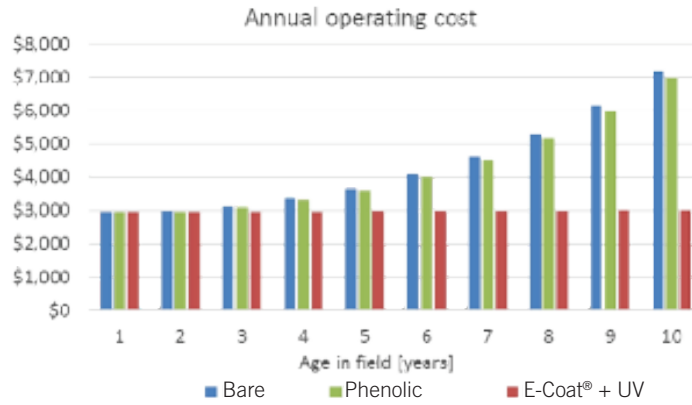
TEN YEAR OPERATING COST COMPARISONS

The test data at 2000 SWAAT hours represents accelerated corrosion for likely multiple years of field exposure. The exact correlation of SWAAT to field life does not exist, due to the varying severity of corrosion in the field. When this data is extrapolated out to ten years (a typical system life span in the simulated corrosive environment) and with an assumed kWh rate of \$0.1547, the savings become significantly greater for the cathodic epoxy coated system in the four to ten year period. The outcome of this investigation is a flexible model that can account for performance degradation from corrosion and its impact on operating cost.

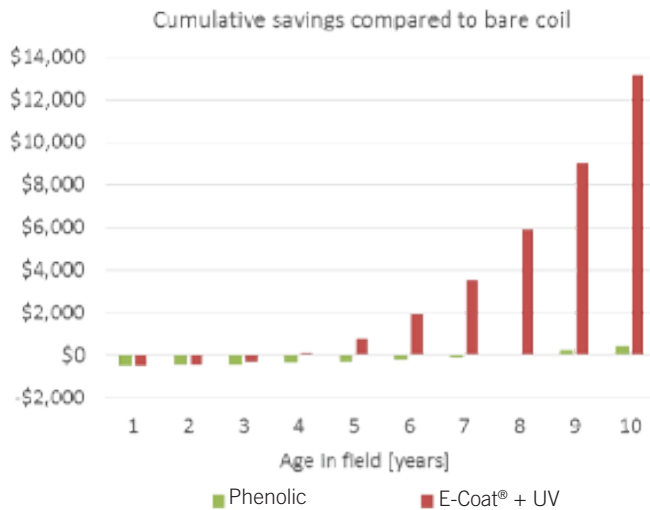


This graph shows a cumulative operating cost, plus the coating cost that's assumed to around \$500. Over ten years the cathodic epoxy coated condenser operating cost is \$46,878 and represents a \$19,889 savings over the bare or immersed/sprayed modified-phenolic coated condensers.

TEN YEAR OPERATING COST COMPARISONS



Annual operating costs, based upon a \$0.1547 kWh rate, show virtually a constant operating cost for the system with cathodic epoxy coated condenser, while annual operating costs for systems with bare or immersed/sprayed modified-phenolic coated condensers increase, and with greater annual increases four years after installation.



Directly comparing systems with cathodic epoxy coated condensers to systems with immersed/sprayed modified-phenolic coated condensers, the savings dramatically increase after four years of simulated service life.

SUMMARY

The ability to control and mitigate condenser and evaporator corrosion is the main factor determining a system's efficiency, life, and operating cost. When properly selected and applied, and prescribed maintenance protocols are followed, the correct coating can dramatically deliver a return on investment not always associated with up front installation costs.

As always, following the manufacturers' application and periodic maintenance requirements are key to realizing a coating's ability to deliver greater economy and system life.

From these test results, it's been shown that the cathodic epoxy coated condenser delivered the greatest benefits by:

- Corroding the least over projected system life
- Maintaining greater heat transfer rates
- Greatly reducing pressure drop rates
- Maintaining power efficiency
- Providing the greatest ROI and energy savings over system operating life

Owners wanting to prolong their building's system life and operating efficiency should consider making the upfront investment in the best condenser coating available that will not only save money in the long run, but also mitigate the possibility of refrigerant leaks caused by corrosion and the resulting outages and costly service calls.

OEMs and consulting engineers should make their customers aware that coating is an option they can add to their system with a modest upfront cost and slight adjustment to scheduling for delivery and installation.

HVAC contractors should make their customers aware system life can be extended and greater efficiency gained by installing replacement coils that have been coated with ElectroFin® E-coat. If a coil is to be replaced, also advise the building owner if other components need replacing. They might be at the end of their service life too, and not addressing their replacement will only result in another service call in the near future that could've been avoided. Not replacing components that need replacing is just as wrong as replacing components that don't need replacing.