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WHITE PAPER

CORROSION OF ALL-ALUMINUM HEAT EXCHANGERS USED IN OUTDOOR HVAC APPLICATIONS

Environ™ Coil System

CONTENTS

SUMMARY

Lennox' Environ™ Coil, an all-aluminum condensing coil, significantly reduces refrigerant charge requirements in Energence® rooftop units, with innovative technology that helps to maximize sustainability and reliability. By using up to 52% less refrigerant than traditional tube-and-fin condenser coils, the Environ Coil offers users sustainable savings. The all-aluminum construction also results in a lighter unit weight, shaving approximately 90 pounds from a 10-ton rooftop unit. Fewer brazed joints—up to 20% fewer compared to traditional coils—decrease the potential of leakage for increased system reliability. Finally, a mounting configuration that uses rubber inserts provides vibration dampening to prevent damage during shipping, as well as isolation to protect against corrosion.

This white paper will detail the effects of corrosion on the Environ Coil as compared to standard industry all-aluminum coils, with specific regard to contributing factors, mechanisms and the outdoor environment.

Environ™ Coil System

OVERVIEW OF ALUMINUM CORROSION

When we process ores from the earth, we add energy to produce metals. Corrosion is simply nature's process of returning a metal to its original, more stable, lower-energy state. We intervene in nature's process by understanding and controlling corrosion drivers.

Corrosion rates are a function of:

Time of wetness

Wetness includes everything from invisible thin films to wet spray. On some surfaces, the presence of high humidity is sufficient for the formation of thin films. At marine sites, winds can carry ocean spray far inland and keep surfaces continually wet. Condensation, another source of wetness, occurs whenever a surface is below the dew point of the surrounding air, and is known to occur even in desert climates. Home lawn sprinkler systems also supply occasional wetness.

Presence of ionic contaminants

Wetness must be accompanied by the presence of some ionic species. Ocean spray is an example of a naturally occurring source of chlorides. Combustion processes are a continuing source of sulfur compounds.

pH

The oxide surface layer that typically naturally protects aluminum is dissolved when the wet surface is sufficiently acidic or basic (i.e., low or high pH). There can be localized shifts in pH as the ionic solution becomes more concentrated while drying out.

Temperature

The rate of chemical reaction (i.e., corrosion) increases with an increase in temperature levels. Temperature cycling often repeatedly evaporates moisture and concentrates contaminants, especially where there is a continual source of wetness.

CORROSION MECHANISMS OF CONCERN

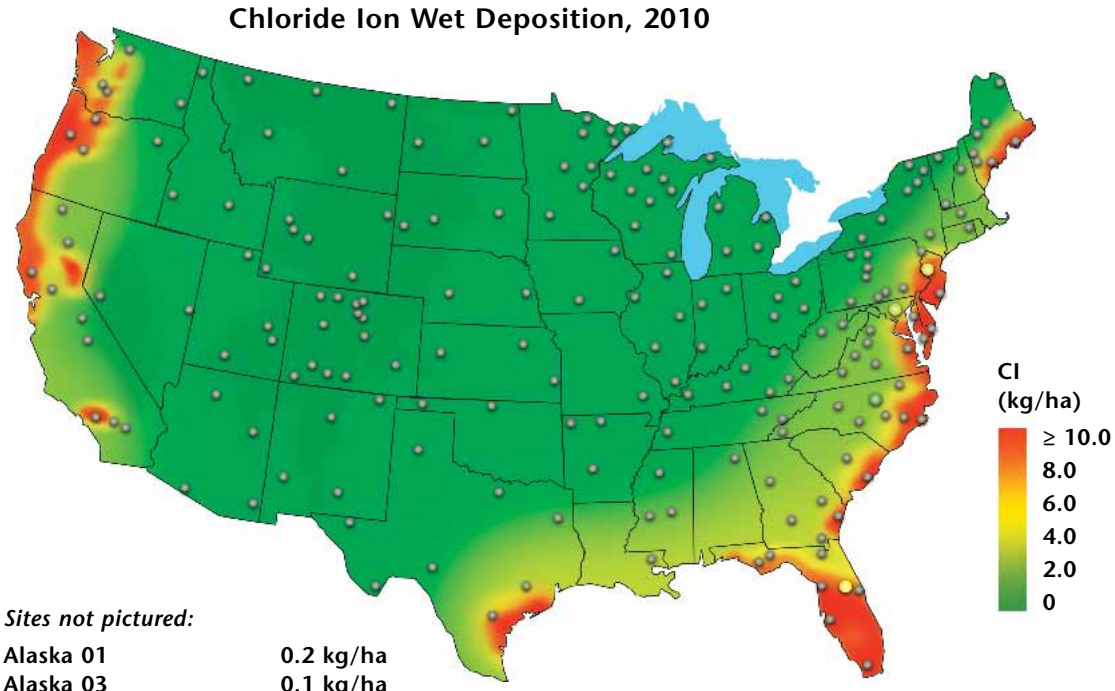
General, or uniform, corrosion results in a long-term material loss of the component. General corrosion is considered a "wear-out" mechanism, which is not likely to significantly affect the unit function during its normal life.

Pitting, or extremely localized corrosion, results in a hole through the wall of the heat exchanger tube, allowing the refrigerant to leak. This failure mode results in a total loss of cooling function.

THE OUTDOOR ENVIRONMENT

One of the most aggressive outdoor environments for aluminum is the seacoast as illustrated by Figure 1, which compares wet chloride ion concentrations throughout the United States. Note that time of wetness, temperature and frequency of temperature cycles (from cooling unit cycling) are likely to be relatively higher in many coastal applications.

Figure 1: Chloride Ion Concentrations Across the United States



Sites not pictured:

Alaska 01	**0.2 kg/ha**
Alaska 03	**0.1 kg/ha**
Alaska 06	**0.1 kg/ha**
Puerto Rico 20	**87.2 kg/ha**
Virgin Islands 01	**38.7 kg/ha**

National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

Notes:

- kg/ha (kilogram per hectare) is a surface density measurement unit
- 1 kilogram per hectare = 0.1 gram per meter^2
- 1 hectare = 10 000 m^2 = 2.47 acre
- 1 kg = 2.2 lb

ACCELERATED TESTING

Lennox uses a proprietary test protocol that includes:

- Three ASTM corrosive solutions
- Testing at high temperature similar to condensing temperatures
- Wet/dry conditions and temperature cycling to concentrate the corrosive solutions
- Stresses that are slightly biased for the pitting failure mode, but also include general corrosion
- Multiple samples tested to leak failure
- Comparison to known customer-accepted all-aluminum product
- Checking for leaks every weekday during testing

Figure 2: Samples in Test Chamber

The test protocol is used at the Lennox research and development facility for aluminum product development. In addition, Lennox has been field-testing an all-aluminum product that met the minimum acceptance criteria. Now running nearly fourteen years, the field test has yielded no reports of corrosion leaks from the Lennox all-aluminum coils.

The same protocol was used at an independent test lab to evaluate Lennox' Environ™ Coil used on the Energence® rooftop unit. The test included multiple samples of both uncoated and E-coated versions of Lennox' Environ Coils, along with samples of a standard industry all-aluminum coil technology. Figure 2 illustrates the samples in one of two test chambers prior to testing.

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ACCELERATED TESTING

Figures 3, 4, and 5 show the three types of samples before the testing.

Figure 3: Standard Industry Sample Before Testing

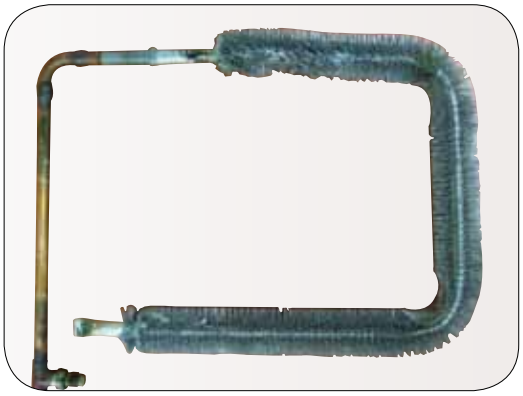


Figure 4: Uncoated Sample Before Testing

Figure 5: E-Coated Sample Before Testing

Figures 6, 7, and 8 indicate the condition of the three types of samples after testing.

Figure 6: Standard Industry Sample After Testing

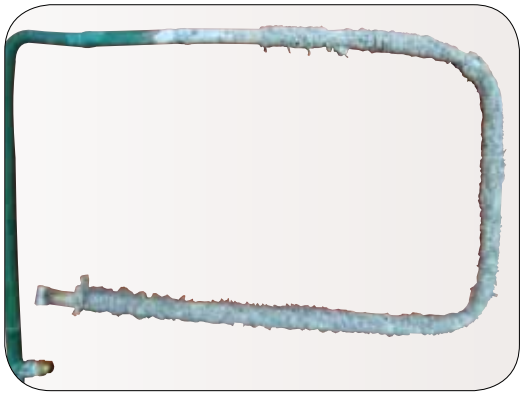


Figure 7: Uncoated Sample After Testing

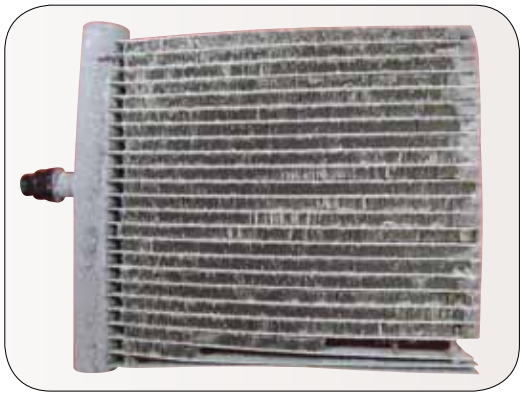
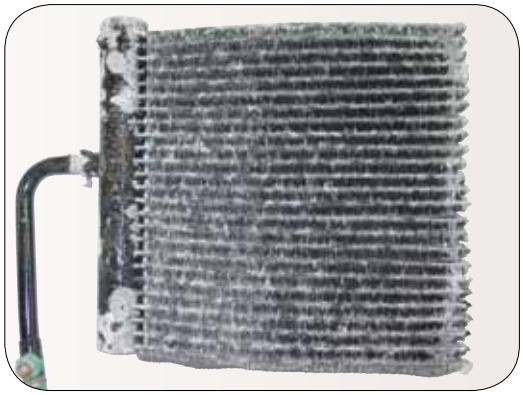


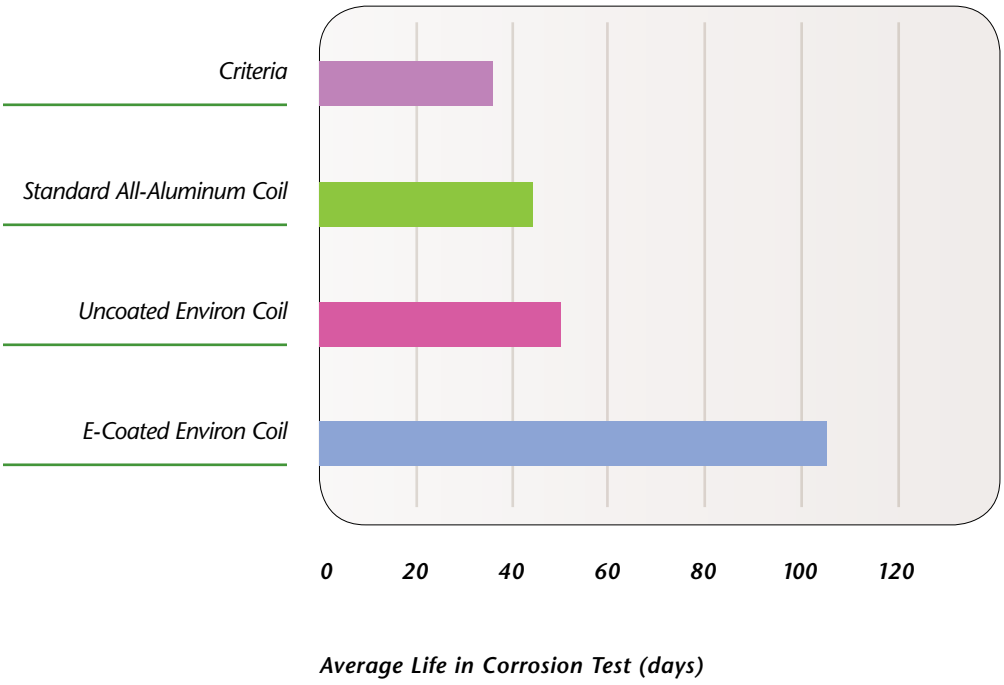
Figure 8: E-Coated Sample After Testing



RESULTS

Corrosion test results on leak robustness for the three types of coils are illustrated in Figure 9.

Figure 9: Corrosion Test Results on Leak Robustness



As shown in Figure 9, all samples exceeded the test requirements. The standard all-aluminum coil exceeded the test criteria by 28%. The uncoated Environ™ Coil performed 37% above the test requirement and 7% better than the industry standard coil. In contrast, the E-Coated Environ Coil outperformed the industry standard coil by 131% and the test requirement by 197%.

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CONCLUSION

Based on test data from an independent corrosion test lab, Lennox' Environ™ Coil exceeds the test requirements. The data also indicates that the standard Environ Coil is at least equivalent to, and potentially better than, an all-aluminum product that has been generally accepted in coastal applications. In addition, the data shows that the E-Coated Environ Coil shows superior performance to all other options tested.

Previous field testing of Lennox' all-aluminum coil, started nearly 14 years ago, have no reports of corrosive leak problems over time. This accelerated test demonstrates that the uncoated Environ Coil has at least 91.8% of the same life as these field test units.

ABOUT LENNOX COMMERCIAL

Lennox Commercial is a leading provider of high-efficiency packaged rooftop units, split systems, HVAC controls, furnaces and indoor air quality products for the light commercial industry. Committed to helping our customers through advanced products and unsurpassed customer service, Lennox Commercial delivers effective HVAC solutions that improve comfort and protect profits.

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