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Cathodic Epoxy Electrocoat For Automotive Radiators

Improving the corrosion resistance of automotive radiators...

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Copper/brass heat exchangers, which are used mainly in automotive applications such as radiators, have been used regularly as cost-effective means of cooling engine fluids and providing internal corrosion resistance. The external surfaces of the exchangers, however, continue to corrode at an increasingly faster rate. Once restricted to severe marine environments, external corrosion of copper/brass heat exchangers is now seen in a wider geographical area. The body of evidence available suggests three primary reasons for the increased external corrosion rates.

1. Higher levels of atmospheric pollution, especially sulfur dioxide;
2. Increased use of salt for road deicing;
3. Generation of sulfur trioxide and hydrogen sulfide in catalytic converters.

The presence of sulfur oxides in the atmosphere leads to a dramatic drop in rainwater's pH, which has been observed as low as 2.0. This level of acidity is quite harmful to the copper/brass surfaces. Road salts, either sodium- or calcium-based, in combination with acid rain lead to pitting and crevice corrosion.

The oxidation of sulfur emissions to sulfur trioxide by catalytic converters in combustion engines frequently occurs at cold engine temperatures. This supplies yet another source of acidity. Catalytic converters also generate significant levels of hydrogen sulfide, especially during stop-and-go commuter driving. This pollutant is capable of attacking copper/brass metals. These chemicals can synergistically combine to accelerate corrosion of the base metals in the radiators, further enhancing the problem. The increasing corrosive environment that copper/brass automotive parts face presents a challenge to manufacturers.

Copper/brass under-the-hood components, such as radiators, historically have been coated with inexpensive, low-performance, spray-applied black cosmetic coatings. This practice poses several problems for copper/brass heat exchangers:

- Spray application poorly penetrates the tight, densely packed tube-and-fin structure of the heat exchanger, resulting in incomplete coverage of the interior surfaces;
- Areas not completely covered often have loosely adhered paint that can trap contaminants such as road salt and moisture, providing for a concentrated corrosive environment;
- Typical radiator coatings based on alkyd chemistry fail to provide an adequate moisture barrier, essential to corrosion protection;
- Uniform coating film thickness on heat exchangers is difficult to obtain with spray application, and high coating builds can lead to bridging between the closely packed fins, hampering air flow through the exchanger core;
- Carbon black pigments used in paint formulations can promote galvanic corrosion when coupled to brass, solder and even copper.

The last problem, combined with incomplete coverage and spray-applied coatings' propensity to trap contaminants, explains test results where coated radiators exhibited less corrosion resistance than uncoated radiators.

A better way to protect external surfaces of copper/brass heat exchangers from corrosion would have to include:

Special Effects Coating for Automobiles

Soft to the touch and pleasing to the eye. These are the qualities that special-effect, two-component polyurethane coatings can deliver for interior plastic automotive components.

Special-effect polyurethane coatings are increasingly specified by both North American and European auto makers for the multiple benefits they provide steering wheels, airbag cover doors, instrument panels, door handles and other interior trim plastic parts.

The coatings contain a Bayer resin that helps them provide a luxurious look and feel to interior plastics. The coatings also offer UV protection and chemical resistance; abrasion, scratch and mar resistance; and reduced squeaks and rattles, which are often associated with plastic parts. Also, the coatings can be supplied in virtually any color.

The 1992 Chevrolet Corvette was the first North American-produced vehicle to incorporate a special-effect polyurethane coating. Ford Motor Com-pany's Lincoln Mark VIII made its debut

- Minimum 10 years corrosion protection;
- Negligible effect on the air flow and heat-transfer properties of the exchanger;
- Best combination of performance and applied cost;
- Minimal environmental impact for the coating process;
- Cure temperatures that will not affect radiator solder, gaskets.

with the largest ever use of special effect coatings. The soft look and feel were provided for 26 hard interior plastic components ranging from the instrument panel and interior trim to the car's two airbag covers and center console. Within the next several years, special-effect coatings are expected to be protecting and enhancing interior components in nearly 45 pct of all North American made cars, trucks and vans.

Cathodic epoxy electrocoat offers a promising solution to the corrosion problems encountered with copper/brass heat exchangers. One of the advantages of electrocoat is its ability to provide complete surface coverage with excellent film uniformity. Its ability to coat the entire copper/brass core greatly enhances corrosion resistance. Special epoxy electrocoats cover even fine copper fins in heat exchangers with a substantial film thickness, further enhancing corrosion performance. Precise control of the electrocoat application results in little or no coating bridging between the fins, and negligible effect on thermal performance.

Electrocoating copper/brass heat exchangers requires some small variations in the process. Cleaning and pretreating usually do not require a phosphate application, since ferrous metals are usually not a large component of the heat exchanger. The recommended procedure for preparing these parts for electrocoating involves an alkaline degrease, city and DI water rinses and a warm-air blowoff. A dilute citric acid pickle can be used if the copper is heavily tarnished.

The electrocoat best suited for this application is a high-edge-coverage lead-free cathodic epoxy. The high-edge-coverage formulations maximize film build on the sharp edges of the fins in the heat exchanger core. The epoxy chemistry is best suited for long-term corrosion protection, even at a dry-film thickness less than 0.5 mil. After electrocoating, it is important to rinse the cores well. This recovers excess electrocoat for reuse and aids coating bridging on the fins.

Cure temperature of the electrocoat should not be higher than 300 to 325F. Above these temperatures, the solder, gaskets and plastic used in copper/brass automotive radiators can be negatively affected. As lead-free solders become standard in production processes for heat exchangers, the 325F bake restriction will rise in importance.

Corrosion testing of coated and uncoated copper/brass automotive radiators indicates that electrocoat can dramatically increase the anticipated service life. One study compares electrocoated radiators with uncoated and standard alkyd coated radiators under two ASTM corrosion tests: Neutral Salt Spray, ASTM B117-85; and Sea Water Acetic Acid Test, ASTM G-85-85 A3.

These results indicate that electrocoat can increase the expected corrosion resistance over conventionally painted radiators by a factor of 30 in salt spray testing and a factor of three to four in the acidified sea water test.

A different accelerated corrosion test has been developed to simulate more closely the road environment that automotive heat exchangers face. The two-week REP (Road Environment Pollution) test consists of high cabinet temperatures (80C) with alternating exposures to a 3.5 pH, +500 mV Redox potential solution (NaCl, $CaCl_2$, $NaNO_3$, Na_2SO_4, $NaNO_2$ and H_2O) and to a sulfide solution (Na_2S, H_2O). Electrocoated radiators performed extremely well in this severe test, which is believed to simulate 10 years of vehicle service.

In addition to providing outstanding corrosion resistance, the ideal coating for copper/brass heat exchangers must have minimal impact on thermal performance as measured by heat transfer and air pressure drop. Coating bridging between fins can reduce the core's ability to pass air unimpeded, which would degrade thermal performance. The coating itself must not insulate the fins in such a way as to alter their heat-transfer properties. Multiple tests of electrocoated radiator samples indicate negligible change in either heat transfer, measured in Btu/min/F and kW/m^2/C, or air pressure drop, measured in Pascal's and inches of water. Cross sections of coated radiators show no bridging of the coating across the fins, observed frequently with dip or spray-applied liquid and powder coatings.

In addition to the corrosion performance, other considerations such as environmental emissions and the performance/cost relationship must be taken into account. The electrocoat process offers significant advantages for both emissions and performance/cost. Electrocoat has

Recycling and the American Automobile

Members of the American Automobile Manufacturers Association, Chrysler, Ford and General Motors support recycling, both as purchasers of recycled-content materials and components and as producers of a recyclable product. The effective and prosperous infrastructure for automotive recycling that exists today began to develop, along with the automobile itself, in the early years of the twentieth century.

- Cars are the number one recycled product on the market in North America, according to the Steel Recycling long been recognized as an environmentally friendly process. Material use rates typically exceed 90 pct. Many systems operating with a closed-loop rinse approach 98 to 99 pct transfer efficiency. Cathodic epoxy electro-coats, such as those used in the aforementioned radiator studies, are waterborne coatings with VOC and HAP levels as low as 0.5 lb/gal. The impact on the end user generally involves major source permitting under the Clean Air Act Amendments of 1990. The 10 ton limit for individual HAP emissions affects many users of organic coatings and is often the most difficult requirement to meet in order to avoid major source permitting. It is possible that the use of low-VOC and low-HAP electrocoat could help avoid major source permitting for a radiator coating line.

The performance/cost relationship of electrocoated heat exchangers can be markedly enhanced over uncoated or conventionally coated radiators. Corrosion test results were a minimum of three to four times better when electrocoat was used as the heat exchanger finish. Material use is higher with electrocoat due to its total coverage capability. Conventional spray coatings may only penetrate and coat 15 to 25 pct of the total surface area present. The higher material use of the electrocoat process is offset by two cost savings.

1. Higher transfer efficiency with electrocoat, leading to less coating waste;
2. Ability to use thinner gauge copper strip in electrocoated radiators due to the total coverage and greatly enhanced corrosion protection of the fins in the core, leading to savings in copper stock material.

Institute. Aluminum cans are second.

- Today, 95 pct of all automobiles scrapped in the U.S. are collected for reuse and recycling.
- 9.5 million out of the approximately 10 million cars retired annually are collected for recycling purposes (this varies year to year). On average, cars built before the 1995 model year are 75 pct recyclable. The goal is to make all vehicles built at the turn of the century 85 pct recyclable.
- At least 75 pct of each vehicle, by weight, is recycled. For example, each year 12 million tons of metals are reclaimed and reused. Cars are made up of 70.2 pct ferrous metals; 8.7 pct non-ferrous metals; and 21.1 non-metal components and fluids.

The American automobile industry built the Vehicle Recycling Development Center in Highland Park, Michigan, to streamline recycling procedures for dismantlers and shredders so more metal, glass, plastic, rubber and foam would wind up back in new cars and trucks. **PF**

A final area of concern when evaluating heat exchanger finishes is the cure temperature of the coating. Today's automotive radiators often contain solder, gaskets and plastic tanks that are sensitive to high baking temperatures. High-edge-coverage epoxy electrocoats are capable of curing in the 300-325F range. Hundreds of copper/brass radiators have been coated successfully and cured in this baking range without damage to the more heat-sensitive components and without sacrificing performance properties.

Electrocoat offers many substantial advantages for the protection of copper/brass heat exchangers from external corrosion. As compared to conventional alkyd spray or dip coatings, cathodic epoxy electrocoats can dramatically extend the service life of automotive radiators. Electrocoat provides a highly corrosion-resistant finish at dry-film thicknesses well below one mil. The ability to completely coat even the most densely constructed cores with a precisely controlled film offers excellent protection of the copper/brass surfaces without impacting thermal performance or other components in the radiator. All of these enhanced properties can be realized without negative impact on the performance/cost relationship or environmental emissions. Electrocoat truly offers the manufacturers of automotive copper/brass heat exchangers and the individual consumer a value-added, long-term benefit. **PF**

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