

## Less-Toxic Coatings for Inhibiting Corrosion of Aluminum

It is no longer necessary to use highly toxic and carcinogenic chromates.

*John F. Kennedy Space Center, Florida*

Two recently invented families of conversion-coating processes have been found to be effective in reducing or preventing corrosion of aluminum alloys. These processes offer less-toxic alternatives to prior conversion-coating processes that are highly effective but have fallen out of favor because they generate chromate wastes, which are toxic and carcinogenic. Specimens subjected to these processes were found to perform well in standard salt-fog corrosion tests.

One family of processes is based on the treatment of suitably prepared aluminum-alloy workpieces with calcium hydroxide (lime) solutions. Preparation of a workpiece usually includes the following steps: (1) degreasing (e.g., by use of a solvent), (2) cleaning by use of a commercially available alkaline solution, (3) rinsing in water, (4) treatment with a commercially available deoxidizing solution, and (5) optionally coating with boehmite [ $\text{AlO}_x(\text{OH})_y$ ] and with transition-metal oxyanions that can include molybdates and/or permanganates, among others. The prepared workpiece is then treated in an aqueous conversion solution that contains between 0.06 and 0.15 weight percent of  $\text{Ca}(\text{OH})_2$  plus between 0.4 and 5 weight percent of alkali-metal nitrates. Typically, this treatment lasts between 2 and 20 minutes, during which the temperature of the solution is maintained between 50 and 100 °C.

The success of the process depends on the use of a freshly prepared conversion solution: The solution should be made by use of deionized water and should be heated to the treatment tem-

perature before adding the  $\text{Ca}(\text{OH})_2$ . Immediately before immersing the workpiece in the solution, the required amount of  $\text{Ca}(\text{OH})_2$  should be added.

Optionally, the workpiece can be post-treated to seal the conversion coat and contribute some additional resistance to corrosion. Suitable post-treatment sealing solutions include silicates, borates, and phosphates of alkali metals. The concentrations of the solutes in the sealing solutions can range from 0.05 to 10 weight percent, treatment times can range from 2 to 10 minutes, and treatment temperatures can range from 50 to 80 °C. Finally, the workpiece is rinsed with deionized water, then dried in air for several days.

The other family of processes is based on the treatment of suitably prepared aluminum-alloy workpieces with conversion solutions that contain molybdate ( $\text{MoO}_4^{2-}$ ) ions. The preparation of a workpiece for a process in this family is similar to that for a  $\text{Ca}(\text{OH})_2$  conversion-coating process: The workpiece is degreased and otherwise cleaned, deoxidized, and coated with boehmite. The prepared workpiece is then treated in an aqueous conversion solution that contains between 1 and 3 weight percent of molybdate ions plus, optionally, small percentages of any or all of the following ingredients: fluorides, oxyanions associated with high-valence transition-metal cations, silicates, borates, phosphates, and/or nitrates. Typically, the treatment lasts between 1 and 60 minutes, during which the temperature of the conversion solution is maintained between 25 and 100 °C and the pH of

the solution is maintained between about 10 and 12, the exact value depending on the composition of the solution.

As in the family of  $\text{Ca}(\text{OH})_2$  conversion-coating processes described above, the workpiece can be post-treated to seal the conversion coat and increase resistance to corrosion. One suitable post-treatment process involves the use of a  $\text{Ca}(\text{OH})_2$  conversion-coating solution as described above. Other suitable post-treatment solutions include silicates, borates, and phosphates of alkali metals — solutions like those mentioned above for post-treatment following  $\text{Ca}(\text{OH})_2$  conversion coating. The concentrations of the solutes in these sealing solutions can range from 4 to 10 weight percent, treatment times can range from 5 to 20 minutes, and treatment temperatures can range from 25 to 98 °C. Then, as described above, the post-treated workpiece is rinsed in deionized water and dried in air.

*This work was done by Zoran Minevski, Eric Clarke, Cahit Eylem, Jason Maxey, and Carl Nelson of Lynntech, Inc., for Kennedy Space Center.*

*In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:*

*Zoran Minevski*

*Lynntech, Inc.*

*7610 Eastmark Drive*

*Suite 202*

*College Station, TX 77840*

*Tel. No.: (979) 693-0017*

*E-mail: zoran.minevski@lynntech.com*

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## Liquid Coatings for Reducing Corrosion of Steel in Concrete

Structures could be protected more easily and less expensively.

*John F. Kennedy Space Center, Florida*

Inorganic coating materials are being developed to slow or stop corrosion of reinforcing steel members inside concrete structures. It is much simpler and easier to use these coating materials than it is to use conventional corrosion-inhibiting systems based on impressed electric currents. Unlike impressed

electrical corrosion-inhibiting systems, these coatings do not require continuous consumption of electrical power and maintenance of power-supply equipment. Whereas some conventional systems involve the use of expensive arc-spray equipment to apply the metallic zinc used as the sacrificial

anode material, the developmental coatings can be applied by use of ordinary paint sprayers.

A coating material of the type under development is formulated as a liquid containing blended metallic particles and/or moisture-attracting compounds. The liquid mixture is sprayed onto a con-