AEC-NASA TECH BRIEF

Electrochemical Study of Aluminum Corrosion in Boiling High Purity Water

An electrochemical study of aluminum corrosion in boiling high-purity water has been reported. An equation relating current and electrochemical potential was derived on the basis of a physical model of the corrosion process.

The study of the reaction of a metal with water was designed for use as a reference base for aqueous solution studies. The purpose was to ascertain the mechanism by which a protective oxide film is formed and maintained on the surface of a metal such as aluminum when immersed in water.

The work involved an examination of the cathodic polarization behavior of 1100 aluminum during aqueous oxidation. The measurements were restricted to cathodic polarization, because anodic polarization is more likely to alter the system under study. Aluminum was selected as the test material because it is considered typical of the "film-forming" metals, because of its many practical applications, and because much empirical information is available on this material. The choice of 1100 aluminum rather than high-purity material was prompted by the rapid intergranular corrosion characteristic of the high-purity aluminum in

pure water. High-purity water was used as the test medium because the small amounts of impurities present in distilled water were found to exert an appreciable effect on the corrosion process.

At temperatures close to the boiling point of water, the reaction of aluminum with water produces hydrogen and a surface film of α-aluminum monohydrate (Böhmite). The transport phenomena likely to be involved in this type of corrosion process are shown in the figure. The anodic process involves ionic transport through the film (aluminum ions outward); the cathode process involves the transport of electrons to the solution side of the oxide barrier where proton reduction is thought to occur. Some hydrogen production is also possible at the metal oxide interface as a result of proton migration through the film.

The equation relating current and electrochemical potential was based on this model. The total potential drop from metal to solution is the sum of potential contributions arising from the interfacial reactions at the metal-oxide and oxide-solution interfaces and that which derives from the transport of charged species through the film.

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On the basis of some simplifying assumptions, the derived equation reduces to $E = IR + K_S \ln(1 + ID)$, where R and D are complex constants and K_S is equal to $RT/\alpha zF$ for the liberation of hydrogen at the surface of the protective layer. This equation has been fitted successfully to experimental data. Assigning the value usually attributed to α for the hydrogen reaction (1/2), optimum values of the constants were found to vary reasonably with time. If a value of α is not assigned, the equation can be fitted to experimental data over a wide range of values for the three constants.

Polarization measurements alone are not sufficient to determine unequivocal values for the constants, hence a determination of the aqueous oxidation mechanism of aluminum will require additional independent measurements.

Notes:

1. Details are available in *CORROSION*, Nat'l Assoc. of Corrosion Eng., Vol. 23, No. 12, pp. 365-373, December 1967, "An Electrochemical Study of Aluminum Corrosion in Boiling High-Purity Water," by R. A. Legault and L. E. Draley of Argonne National Laboratory.

2. This information may be of interest to metallurgists and designers of fluid delivery and storage systems.

3. Inquiries concerning this innovation may be directed to:

> Office of Industrial Cooperation
> Argonne National Laboratory
> 9700 South Cass Avenue
> Argonne, Illinois 60439
> Reference: B69-10033

> > Source: R. A. Legault and J. E. Draley
> > Metallurgy Division
> > (ARG-10306)

Patent status:

Inquiries about obtaining rights for commercial use of this innovation may be made to:

> Mr. George H. Lee, Chief
> Chicago Patent Group
> U.S. Atomic Energy Commission
> Chicago Operations Office
> 9800 South Cass Avenue
> Argonne, Illinois 60439