Passivity of Alloy 22 in Concentrated Electrolytes. Effect of Temperature and Solution Composition

Kenneth J. Evans and Raúl B. Rebak

Lawrence Livermore National Laboratory
7000 East Ave, L-631, Livermore CA 94550

Alloy 22 is a candidate material to fabricate the high-level nuclear waste containers for the potential repository site in Yucca Mountain. Alloy 22 or N06022 is nickel-based (Ni) and contains 22% chromium (Cr), 13% molybdenum (Mo), 3% tungsten (W) and approximately 3% iron (Fe). Alloy 22 remains passive in most industrial applications and therefore has an exceptionally low general corrosion rate. Alloy 22 is also highly resistant to localized corrosion and environmentally induced cracking.

The paper will review literature data on the influence of metallurgical and environmental variables on the passive behavior and localized corrosion resistance of Alloy 22, both in aggressive conditions and in multi-ionic salt solutions. The paper will also discuss the latest results on ionic composition and temperature effects on the general corrosion characteristics and passive behavior of wrought and welded Alloy 22. Some of the concentrated multi-ionic environments may contain species typical of ground waters from the potential mountain site. Two of these evaporative waters were labeled simulated acidified water or SAW (Table 1) and simulated concentrated water (SCW). [1] Tests also were carried out in simpler -more aggressive- solutions such as concentrated calcium chloride ($CaCl_2$). Tests were carried out using freshly polished samples in deaerated SAW solutions of pH 2.8 and SCW of pH 10.3. The exposed area of the samples was 10.5 cm² and they had a PTFE creviced area of approximately 0.75 cm². Electrochemical tests included polarization resistance and cyclic polarization (ASTM G 3 and G 61). [2]

Figure 1 shows the corrosion rate of Alloy 22 in SAW solution as a function of the testing temperature. The numbers in Figure 1 are average values of approximately 15 measurements and were obtained after approximately 1 h immersion in SAW at each temperature. For the testing temperature range in Figure 1, the apparent activation energy for the active corrosion rate was 17 kJ/mol. Figure 2 shows the effect of the temperature on the anodic behavior of Alloy 22 in SAW. In the potential range of 300 mV above the corrosion potential, the passive current at 30°C was lower than the passive current at 90°C. Also, the passivity breakdown potential (E_b) at 90°C was 125 mV lower than the E_b at 30°C. The average passive current at 500 mV (SSC) increased from 7.4 µA/cm² at 30°C to 10.89 µA/cm² at 90°C. This increase translated into apparent activation energy for passive dissolution of 5.5 kJ/mol.

This paper will also discuss the passive corrosion behavior of Alloy 22 in concentrated alkaline multi-ionic solutions and in 5 M $CaCl_2$.

References

1. N. D. Rosenberg, G. E. Gdowski and K. G Knauss, Applied Geochemistry, 16, 1231 (2001).
2. Annual Book of ASTM Standards, Vol. 03.02 (West Conshohocken, PA: ASTM, 2001).

Table 1: Composition of SAW solution in mg/L.

K^+	Na^+	Mg^{2+}	Ca^{2+}
3,400	40,900	1000	1000

Cl^-	NO_3^-	SO_4^{2-}	Si
24,250	23,000	38,600	~40

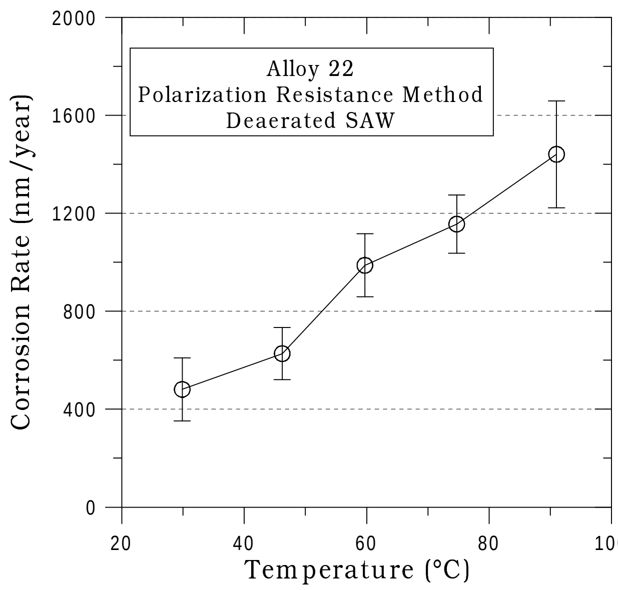

Figure 1: Corrosion Rate of Alloy 22 in SAW.

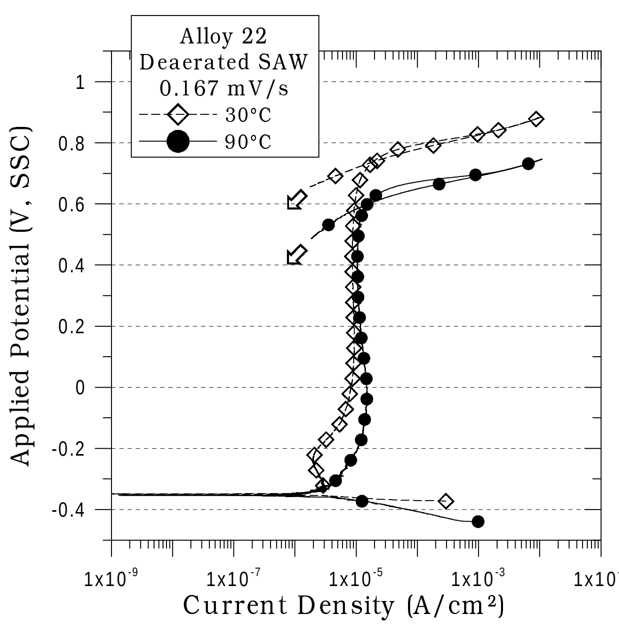

Figure 2: Cyclic Polarization of Alloy 22 in SAW.