60992

ERRATA

October 10, 2007

Report Number: **NUREG/CR-4667, Volume 36**

Report Title: Environmentally Assisted Cracking in Light Water Reactors
Annual Report
January--December 2005

Prepared by:
B. Alexandreanu, Y. Chen, O. K. Chopra, H. M. Chung,
E. E. Gruber, W. J. Shack, and W. K. Soppet
Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439

Date Published: August 2007

Instructions: Please replace pages 45 and 48 with the two attached pages marked "page 45" and "page 48."

Rulemaking, Directives and Editing Branch
Office of Administration

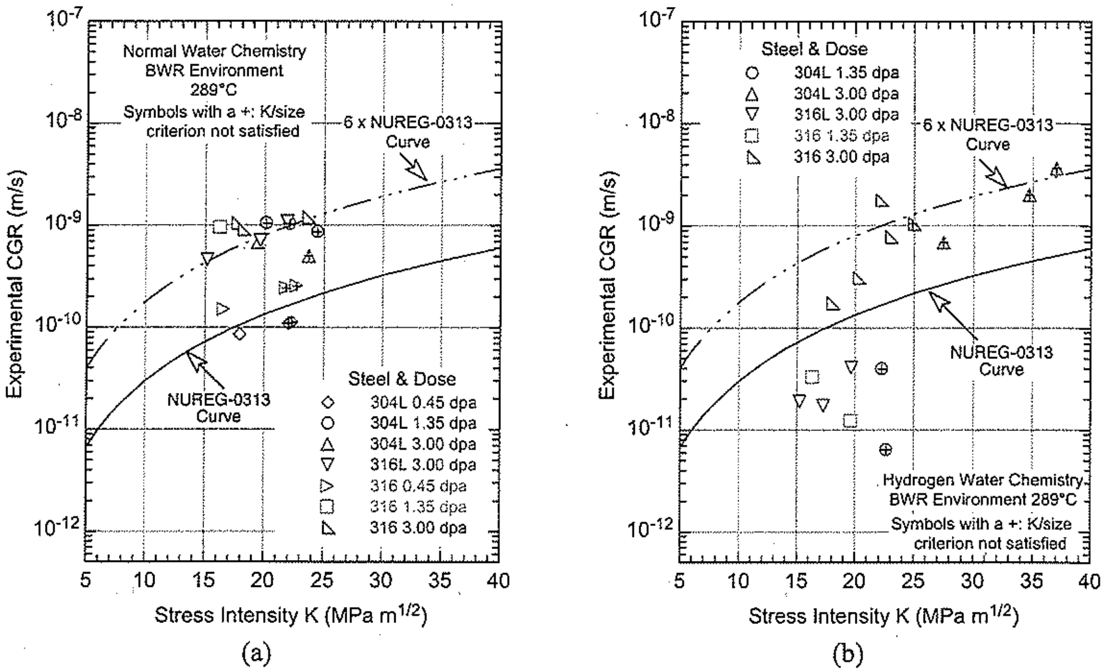
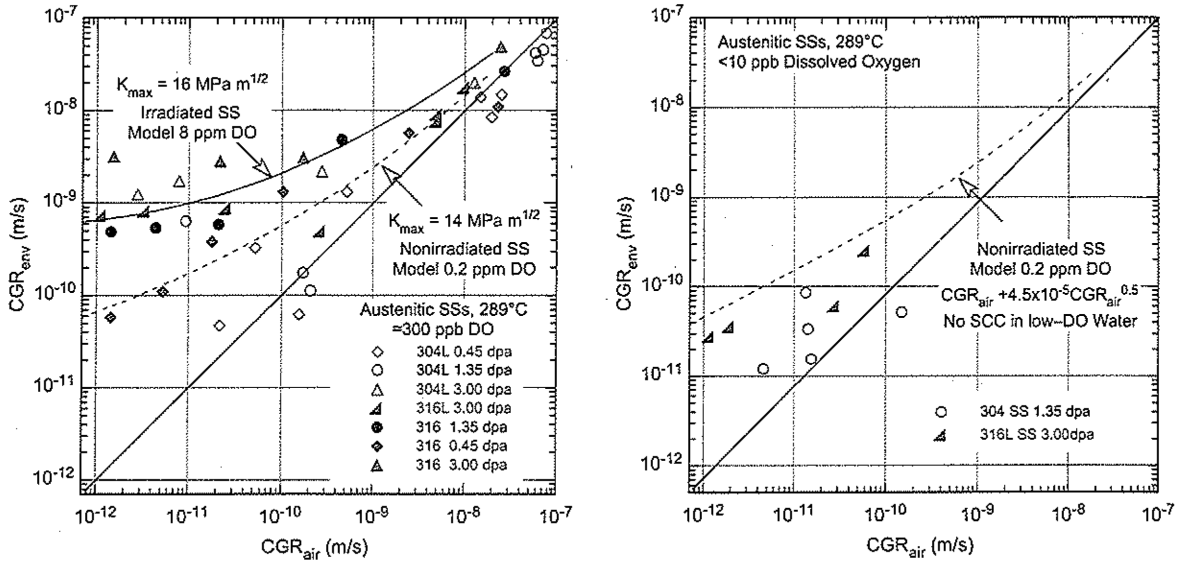


Figure 27. CGR data under constant load with periodic partial unloads for irradiated austenitic SSs in (a) normal water chemistry and (b) hydrogen water chemistry BWR water at 289°C.

3.0 dpa), the CGRs in the NWC BWR environment are comparable and a factor of ≈6 higher than the disposition curve for sensitized SSs in water with 8 ppm DO given in NUREG-0313.[82]

The results also indicate a benefit from a low-DO environment. In general, for the materials and irradiation conditions investigated in the present study, the constant load (or K) CGRs decreased more than an order of magnitude when the DO level was decreased from ≈300 to <30 ppb, i.e., from NWC to HWC BWR environment (Fig. 27b). A few specimens showed different behavior. For example, no benefit of the low-DO environment was observed for Heat C3 of Type 304L SS irradiated to 3.0 dpa (compare triangles in Fig. 27). For this specimen, the experimental CGR at ≈23.7 MPa $m^{1/2}$ (≈21.5 ksi $in.^{1/2}$) K_{max} remained at ≈5 x 10^{-10} m/s when the DO level was decreased from ≈300 to <20 ppb. The benefit of the low-DO environment was also not observed for Heat C21 during the second decrease in DO level at K_{max} ≈23.6 MPa $m^{1/2}$ (Table 13 and the right-angle triangles in Fig. 27). Although the CGR decreased by an order of magnitude when the DO level was decreased at K_{max} ≈17.6 MPa $m^{1/2}$ (16.0 ksi $in.^{1/2}$), it did not change when the DO level was decreased at 23.6 MPa $m^{1/2}$. At present, the reason for this behavior is not clear. For Heat C3, it may be caused by loss of specimen constraint because the applied K_{max} was 44% greater than the value allowed by the K/size criterion (Eq. 33) based on the effective yield stress (defined as the average of the irradiated and nonirradiated yield stresses). Experimental CGRs obtained under loading conditions that exceeded the K/size criterion are shown in Fig. 28; the numbers next to the data points represent the percentage by which the applied K_{max} exceeded the allowed value.

Loading conditions that exceed the K/size criterion should also influence the fracture mode. For example, if the thickness criterion is exceeded, the crack plane will be out-of-normal near the edges of the specimen, and if the specimen ligament criterion is exceeded, the crack would grow away from the normal plane. A detailed metallographic examination of the specimen of Heat C3 suggests that, although the proposed specimen size criterion was not met at the time when the DO level was decreased from ≈400



(a) (b)

Figure 30. CGR for irradiated specimens of austenitic SSs under continuous cycling at 289°C in high-purity water with (a) ≈300 ppb and (b) <30 ppb dissolved oxygen.

In these figures, the data points that lie along the diagonal represent predominantly mechanical fatigue, and those that lie close to the model curve indicate environmentally enhanced crack growth. The austenitic SS irradiated to 0.3×10^{21} n/cm^2 (0.45 dpa) shows very little environmental enhancement of the cyclic CGRs in high-DO water (open diamonds in Fig. 30a). Using Eqs. 22-28, the CGRs in water with ≈ 300 ppb DO may be represented by the NUREG-0313 curve and the Shack/Kassner model for nonirradiated austenitic SSs in high-purity water with 0.2 ppm DO.

The results for SSs irradiated to 0.9 or 2.0×10^{21} n/cm^2 (1.35 or 3.0 dpa) indicate significant enhancement of the CGRs in high-DO water under cyclic loading with long rise times. For these irradiation conditions, the CGRs in water with ≈ 300 ppb DO may be represented by the $\dot{a}_{SCC}$ curve for irradiated SSs (i.e., 6 x NUREG-0313 curve) and the Shack/Kassner model for nonirradiated austenitic SSs in high-purity water with 8 ppm DO.

For continuous cyclic loading, decreasing the DO level has a beneficial effect on CGRs. Decreasing the DO from ≈300 ppb DO to <30 ppb DO results in a factor of 25 decrease in the CGR. The growth rates are lower for the irradiated steels in water with <30 ppb DO than for nonirradiated austenitic SSs in high-purity water with 0.2 ppm DO (Fig. 30b).

3.2.5.2 Stainless Steel Weld HAZ Materials

The experimental CGRs for irradiated Type 304 SMA weld HAZ specimens in high-DO water and those predicted in air for the same loading conditions are plotted in Fig. 31. Results from tests performed on nonirradiated material are also included in the figures.[81] As before, the curves in the figure are based on the superposition model. In Fig. 31, the loading conditions for the data points shown with a "+" did not satisfy the K/size criterion of ASTM E-647.