# Technical Note: An Electrochemical Evaluation of Sensitization in Homopolar Welds

BY S. C. TJONG, J. KEPNER, AND Z. ELIEZER

Sensitization due to welding is one of the most common causes of intergranular corrosion in Type 304 stainless steel in service. At some distance from the weld interface, the material might be in the sensitization temperature range long enough for chromium carbides precipitation to occur at the grain boundaries. The extent of sensitization is detected, in most cases, by the oxalic acid test (ASTM A262, Procedure A). Recently however, a new method for the detection of sensitization (electrochemical potentiokinetic reactivation, EPR) has been proposed (Ref. 1). It has been claimed that this method can detect lower degrees of sensitization than the ASTM method mentioned above.

*S. C. TJONG, J. KEPNER, and Z. ELIEZER are associated with the Department of Mechanical Engineering, Materials Science and Engineering Program, The University of Texas, Austin, Texas.*

The purpose of this note is to compare the relative merits of these two methods (ASTM A262 and EPR) in the detection of sensitization in Type 304 stainless steels welded by the homopolar resistance welding (HPRW) process (Ref. 2).

## Materials and Welding Procedure

Two HPRW specimens (identified in the text as W1 and W2) were provided. The specimens were from two different 4 in. (101.6 mm) diameter Schedule 80 welded stainless steel pipes. Specimen W1 had a flat-on-flat design, while W2 was of the double bevel configuration. The total input energy was about 510 kJ in W1 compared to 600 kJ in W2.

## EPR Testing Procedure

The EPR tests were performed in a manner similar to that described by Clark, et al., (Ref. 3). After being mounted in epoxy and polished down to 0.05 $\mu$m alumina slurry, the specimens were passivated at +200 mV vs. SCE and held for 2 minutes (min) in a 0.5 M $H_2SO_4$ + 0.01 M KCNS solution. At the end of the 2 min period, the potential was scanned from +200 mV into the active region at a scan rate of 1 mV/second (s).

The degree of sensitization was related to the value of the activation charge Q (in coulombs, C) which is equal to the integrated area beneath the reactivation peak in the potentiodynamic curve. The normalized charge, Na, was then calculated by dividing the activation charge by the specimen area and grain boundary area.

## Results and Discussion

Figures 1 and 2 represent the reactivation polarization curves for the two samples. The highest normalized charge, i.e., $N_a$ = 3.08 C/cm$^2$ of weld W2 (double bevel design, high energy input), was obtained at a distance of 5 mm (0.20 in.) away from the fusion line. This high $N_a$

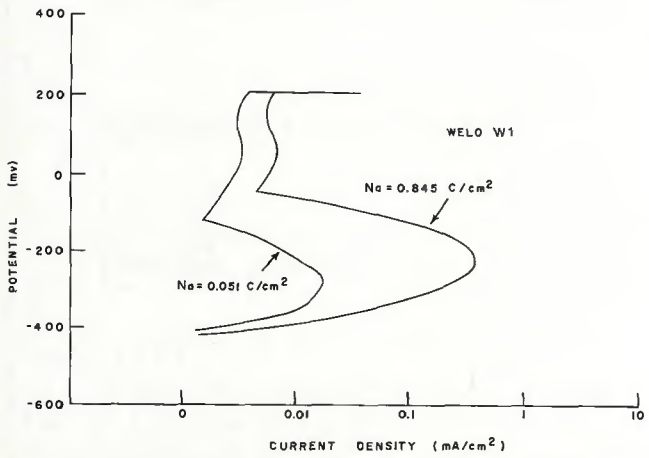


*Fig. 1—Electro-potentiokinetic reactivation curves of weld W1 at two distances from the weld interface*

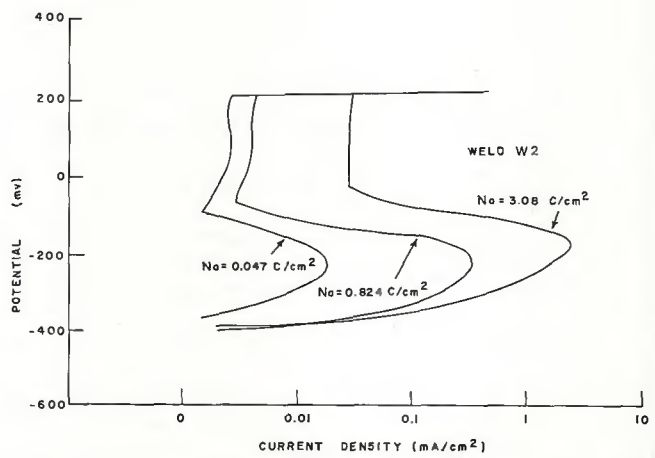


*Fig. 2—Electro-potentiokinetic reactivation curves of weld W2 at three distances from the weld interface*

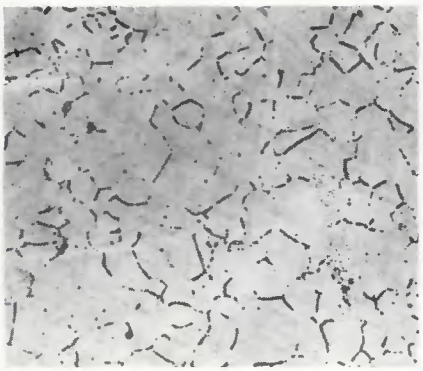

*Fig. 3—Microstructure of weld W2 at 5 mm (0.20 in.) away from the weld line after EPR test. Oxalic acid etch, X100. (reduced 32% on reproduction)*

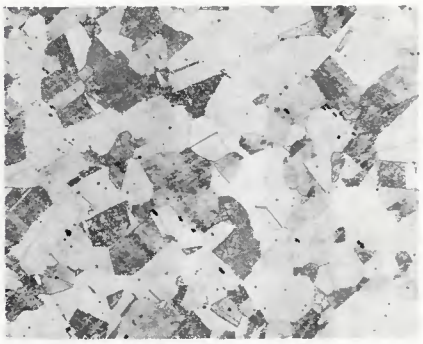

*Fig. 4—Microstructure of weld W1 at 3.8 mm (0.15 in.) away from the weld line. Oxalic acid etch, X100. (reduced 32% on reproduction)*

*Fig. 5—Same specimen as in Fig. 4 but at X500 magnification. (reduced 32% on reproduction)*

value indicates a large degree of sensitization. This conclusion is also substantiated by the oxalic acid test—Fig. 3. At 11 mm (0.43 in.) from the weld line the specimen was still slightly sensitized ($N_a$ = 0.824 C/cm$^2$).

As the specimen was machined 15 mm (0.59 in.) from the weld interface, $N_a$ dropped to 0.047 C/cm$^2$ which is similar to the $N_a$ value of the base metal. Weld W1, on the other hand, exhibited a maximum $N_a$ value of only 0.845 C/cm$^2$, which is indicative of some degree of sensitization. This sensitization could not be detected by the standard oxalic acid test—Fig. 4. However, at a magnification of X500 (Fig. 5), a small amount of precipitates at the grain boundaries could readily be seen.

It is concluded that the small degrees of sensitization (characteristic of properly performed HPRW welds) cannot be revealed by the standard ASTM oxalic acid test but can be detected by the EPR technique.

*Acknowledgments*

Partial financial support for this work was provided by Houston Lighting and Power Company, Gulf States Power Company and Central Power and Light Company. The authors would also like to thank Dr. R. E. Keith of the Center for Electromechanics at the University of Texas at Austin for kindly supplying the weld specimens and for his critical review of this article.

*References*

1. Clarke, W. L., Rowers, W. M. and Danco, J. C. *Detection of sensitization in stainless steel using electrochemical techniques.* General Electric report GEAP-21382, U. S. Nuclear Regulatory Commission NUREG-0251-1.

2. Grant, A. B., Featherston, W. M., Keith, R. E., Weldon, W. F., Rylander, H. G., and Woodson, H. H. 1979. Homopolar pulse resistance welding—a new welding process. *Welding Journal* 58(5):24-36.

3. Clarke, W. L., Cowan, R. L. and Walker, W. L. 1978. Comparative methods for measuring degree of sensitization in stainless steel. In *Intergranular corrosion of stainless steels,* ed. R. F. Steingerwald, ASTM STP 656, pp. 99-132. Philadelphia: American Society for Testing and Materials.

WRC Bulletin 279
July, 1982

**Weldability and Fracture Toughness of Quenched and Tempered 9% Nickel Steel: Part I—Weld Simulation Testing**
**by A. Dhooge, W. Provost and A. Vinckier**

An investigation on the weldability of a quenched and tempered 9% Ni steel using weld simulation and artificial aging to estimate the heat-affected zone ductility at cryogenic temperatures is reported in Part I. Charpy-V bars were subjected to various weld simulation cycles and subsequent heat treatments and, after notching, broken at a range of cryogenic temperatures.

**Weldability and Fracture Toughness of Quenched and Tempered 9% Nickel Steel: Part II—Wide Plate Testing**
**by A. Dhooge, W. Provost and A. Vinckier**

In addition to standard impact and tensile tests, a large number of wide plate specimens welded with various consumables and welding processes were tested to evaluate the toughness and defect acceptability of 9% Ni steel in plate thicknesses greater than 25 mm.

Publication of these reports was sponsored by the Weldability Committee of the Welding Research Council.

The price of WRC Bulletin 279 is $10.00 per copy, plus $3.00 for postage and handling. Orders should be sent with payment to the Welding Research Council, 345 East 47th St., New York, NY 10017.