Postweld Heat Treatment to Improve Localized Corrosion Resistance of Alloy 22 High-Level Waste Container Weldments

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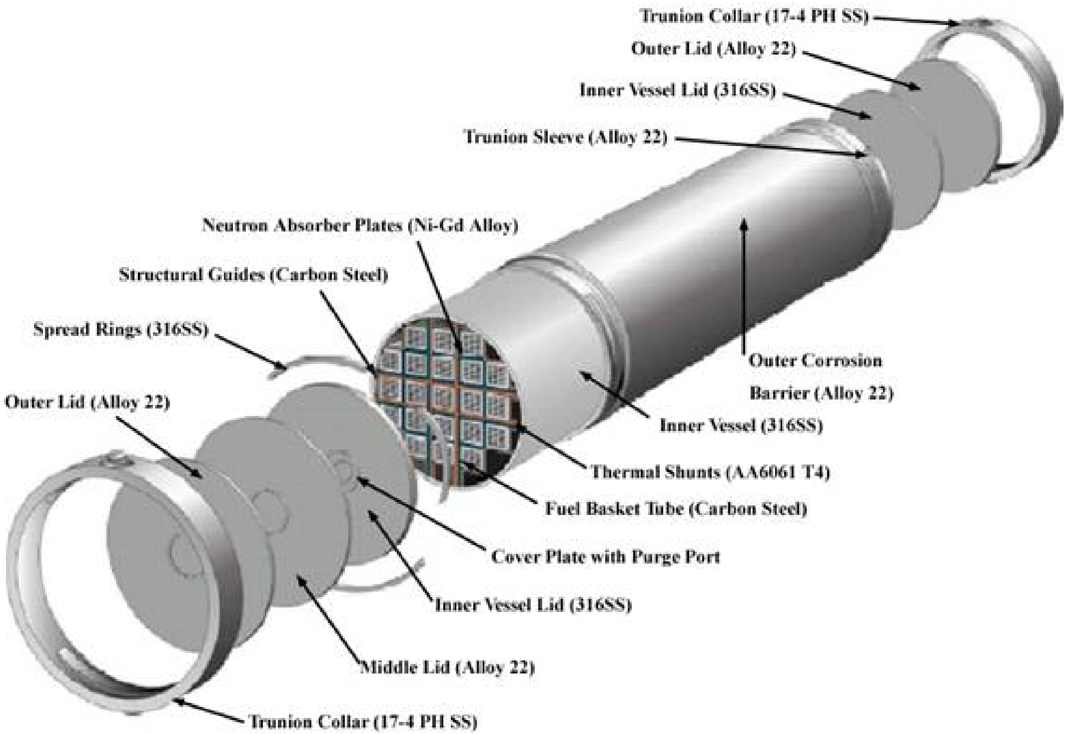
Waste Package Design for High-Level Nuclear Waste Disposal

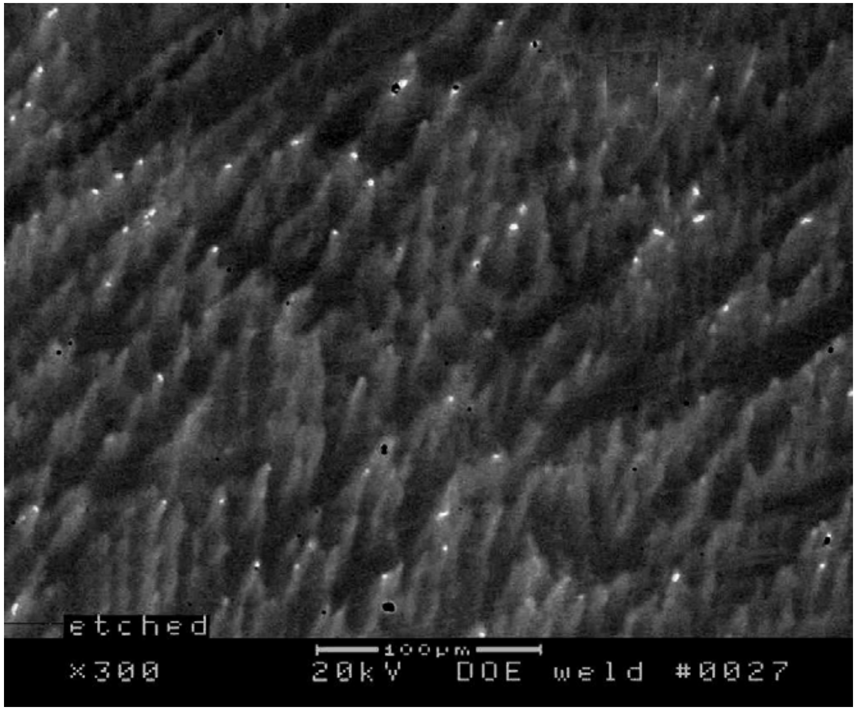


- 21-PWR uncanistered fuel waste package
- Alloy 22 (Ni-22Cr-13Mo-4Fe-3W in wt%) outer container for corrosion resistance
- Type 316 NG stainless steel inner container for structural support
- Long lifetime of waste package is considered to be a key performance attribute of the potential Yucca Mountain high-level waste repository

Fabrication Processes

- Waste package fabrication will require cold forming operations including rolling and machining
- Multiple welds (i.e., fabrication welds and closure welds) will be applied for construction of the Alloy 22 outer container
- Solution annealing is proposed for the Alloy 22 outer cylinder assembly to mitigate the detrimental effects of phase instability and remove residual stress created by forming and welding operations

Solution Annealing of Alloy 22 Weld



- The U.S. Department of Energy proposed solution annealing treatment of the Alloy 22 outer cylinder assembly at

  1,150 °C [2,102 °F]
- Element segregation in Alloy 22 welds substantially increases the stability of topologically close-packed (TCP) phases
- Thermodynamic calculations predicted a solution-annealing temperature window in the range of 1,265 and 1,325 °C [2,309 and 2,417 °F] for Alloy 22 gas tungsten-arc welds

Objective and Scope

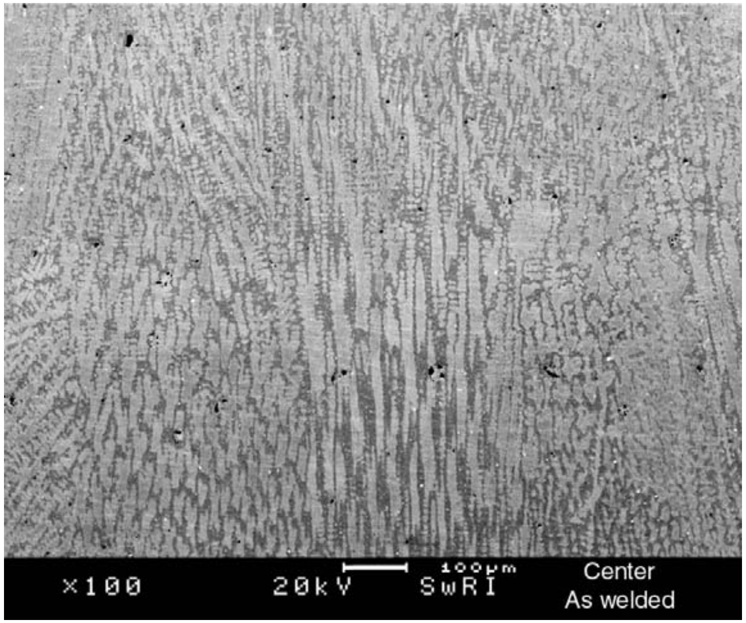
- Evaluate the effect of postweld heat treatment on the localized corrosion susceptibility of welded Alloy 22
  - Solution-anneal Alloy 22 welded materials at temperatures ranging from 1,125 to 1,300 °C [2,057 to 2,372 °F] for up to 4 hours
  - Measure the repassivation potential for assessing crevice corrosion using electrochemical tests
  - Correlate localized corrosion test results with weld microstructure

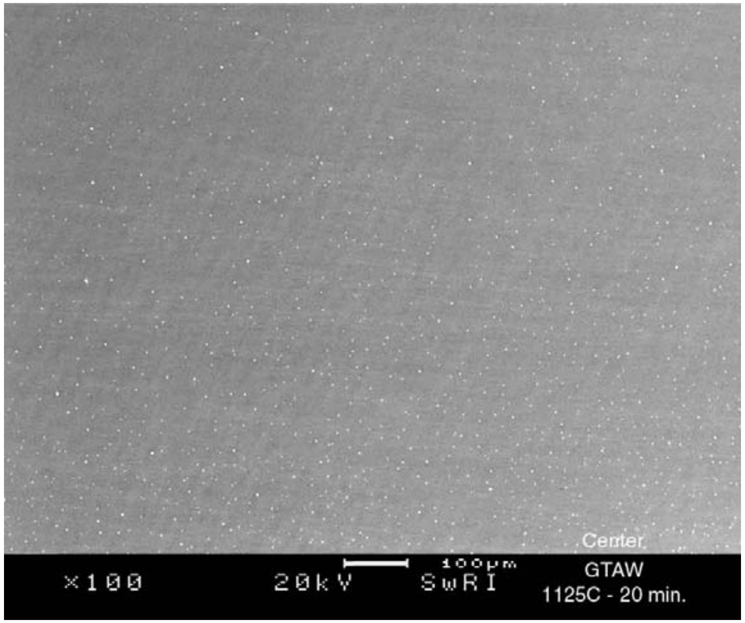
Welded Materials

Material	Chemical Content (wt%)						
	Ni	Cr	Mo	W	Fe	Co	C
Alloy 22 Heat 2277-3-3292	56.78	21.22	13.64	2.96	3.69	1.32	0.004
Alloy 622 Filler Heat WN813	57.50	22.24	13.70	3.13	2.37	0.41	0.003

- 25.4-mm [1.0-in] gas tungsten-arc welded plate
- Results for Alloy 22 in an as-welded condition and welded plus solution annealed at 1,125 °C [2,057 °F] for 20 minutes presented here

Alloy 22 Weld Microstructure

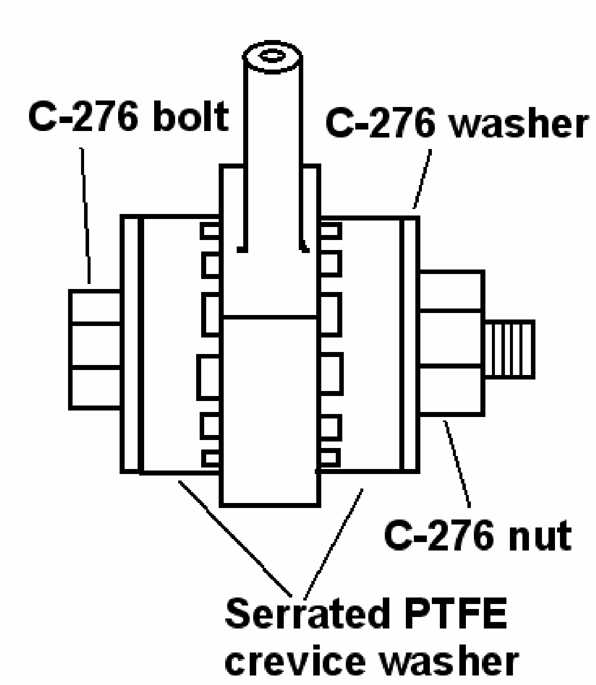




- As-welded
- 0.37 vol% precipitates

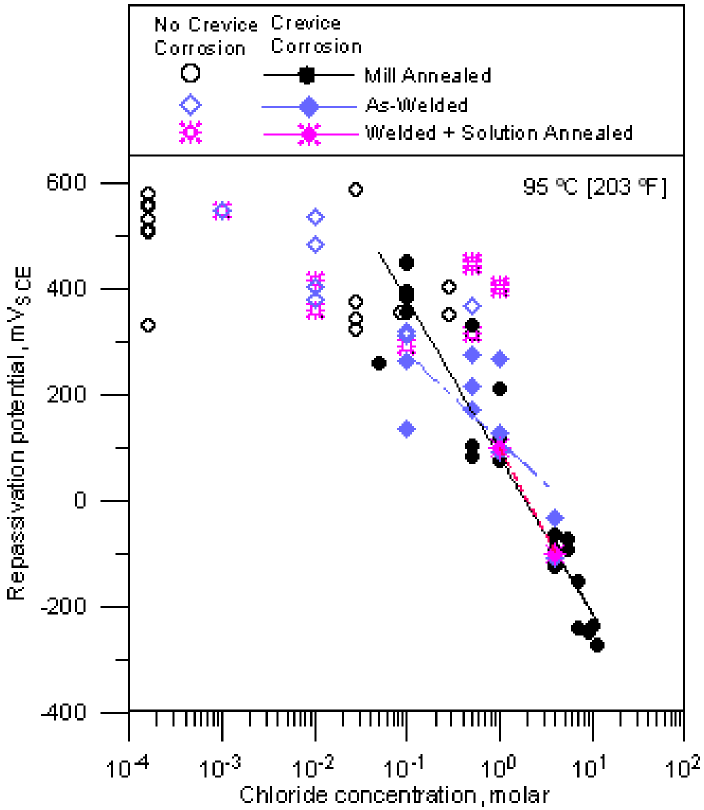
- Solution-annealed at 1,125 °C [2,057 °F] for 20 minutes
- 0.28 vol% precipitates

Localized Corrosion Tests



- Flat specimens with two polytetrafluoroethylene (PTFE) crevice forming washers
- N_2-deaerated solutions containing 0.001 to 4.0 M Cl^-
- Crevice corrosion repassivation potential measurements using potentiostatic hold followed by reverse potentiodynamic sweep

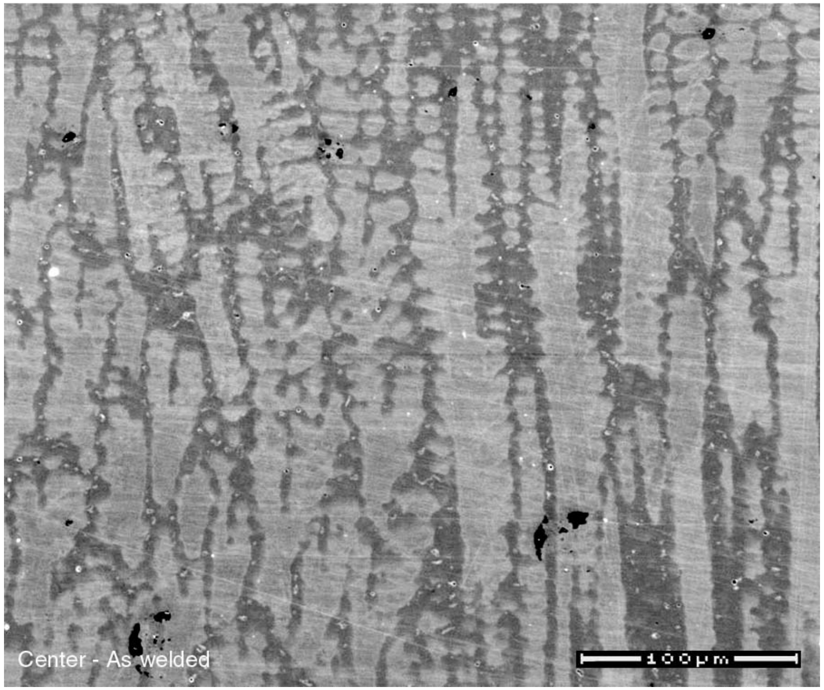
Localized Corrosion Susceptibility

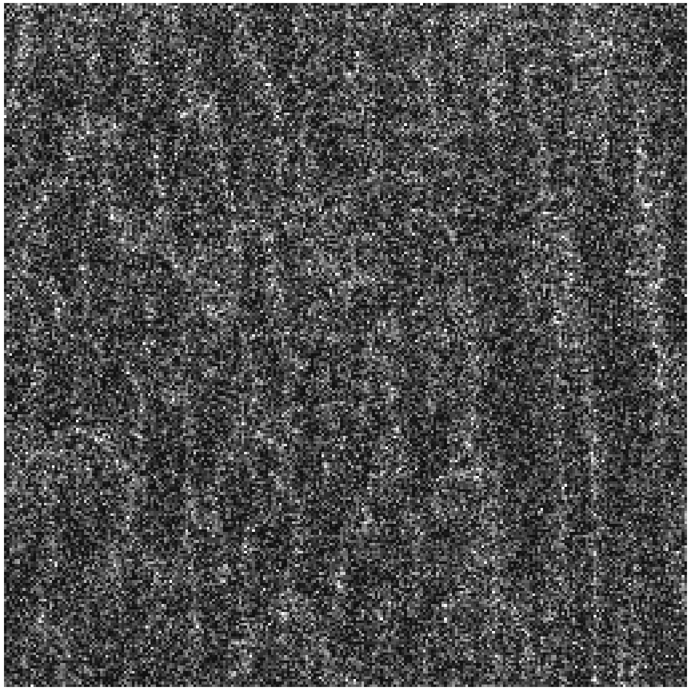


Note: Mill-annealed data from Dunn, et al., 2005, CNWRA Report 2005-02

- Crevice corrosion repassivation potential used as critical potential for the long-term initiation of localized corrosion
- Similar repassivation potential with a little metallurgical condition dependence
- Localized corrosion of solution-annealed Alloy 22 weld observed at higher chloride concentrations compared to the as-welded and base alloy

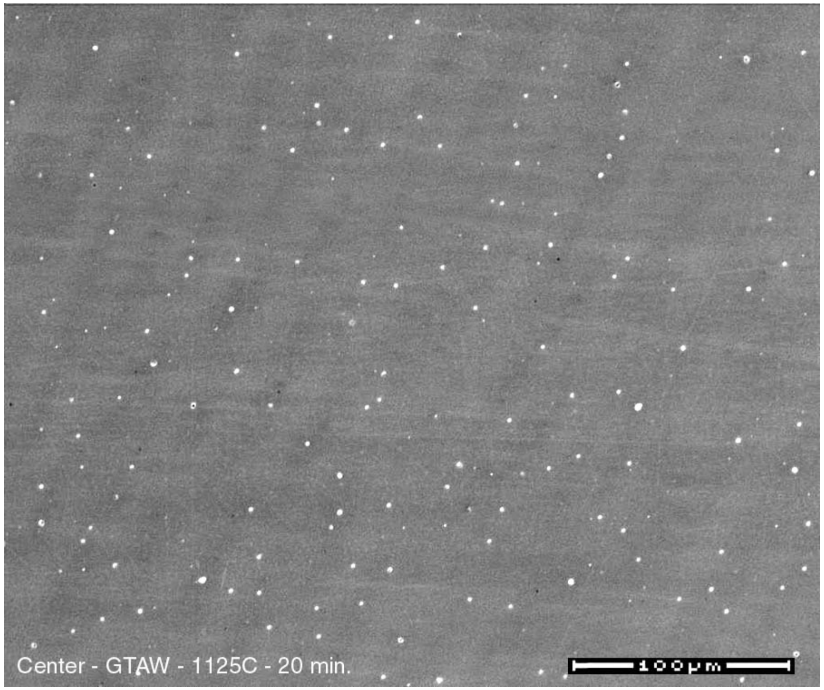
Solidified Weld Microstructure

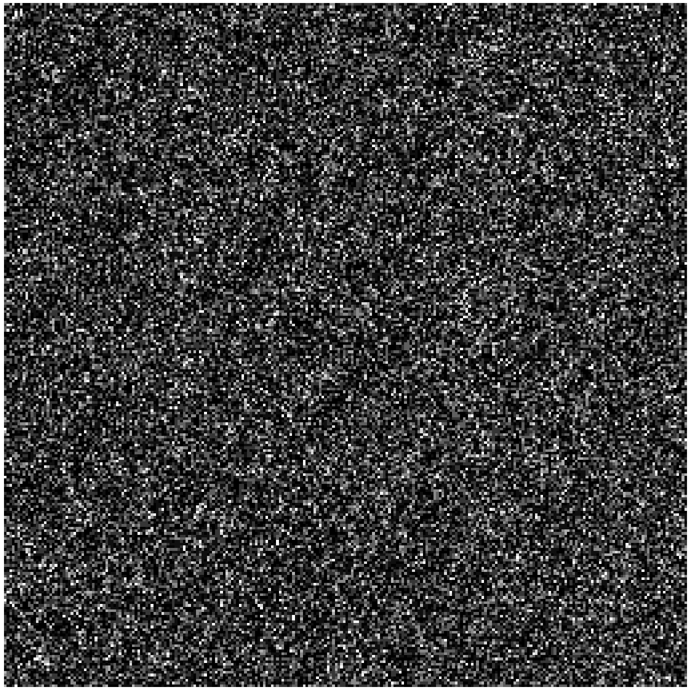




- Segregation of Mo to interdendritic regions due to alloying element partition in as-welded Alloy 22
- Mo-rich precipitates (white spots) and alloying element segregation reduce the localized corrosion resistance

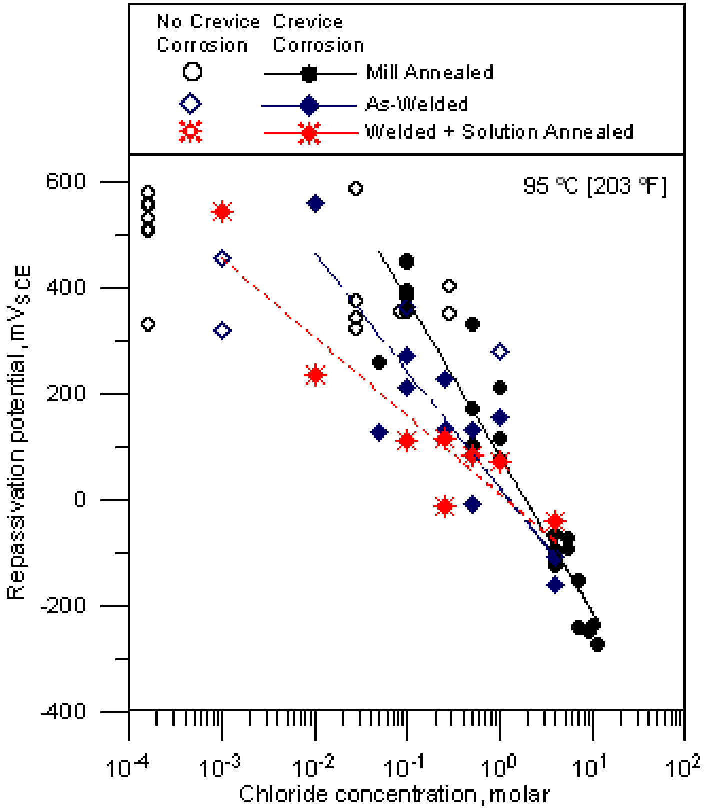
Effect of Solution Annealing on Weld





- Partial homogenization of solidification-induced segregation in welded Alloy 22 after solution annealing
- Detrimental effects of precipitates (white spots) and element segregation mitigated by solution annealing

Effect of Weld Variability on Localized Corrosion Susceptibility



Note: Data from Dunn, et al., 2005, CNWRA Report 2005-02

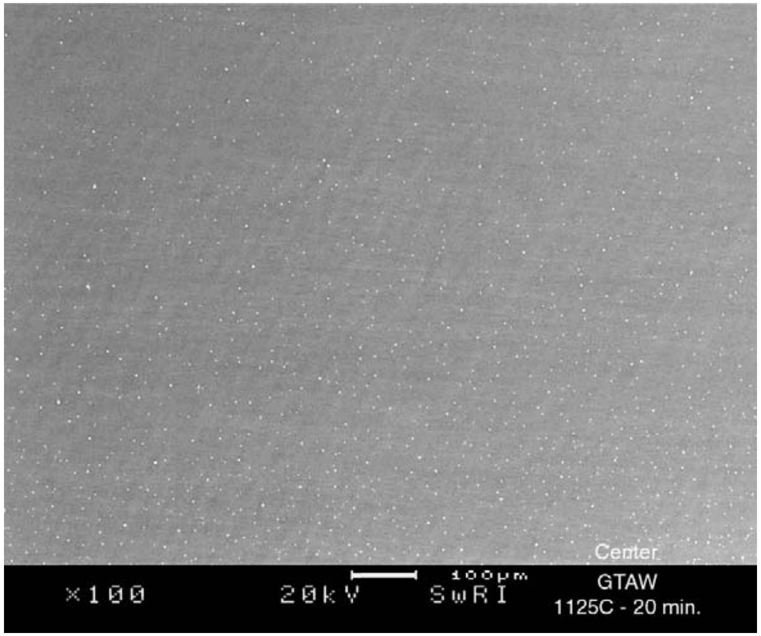
- 38.1-mm [1.5-in] gas tungsten-arc welded plate
- Localized corrosion resistance reduced by welding and solution annealing at 1,125 °C [2,057 °F] for 15 minutes
- Welding process operations and parameters may affect the quality of the weld and the resultant weld microstructure

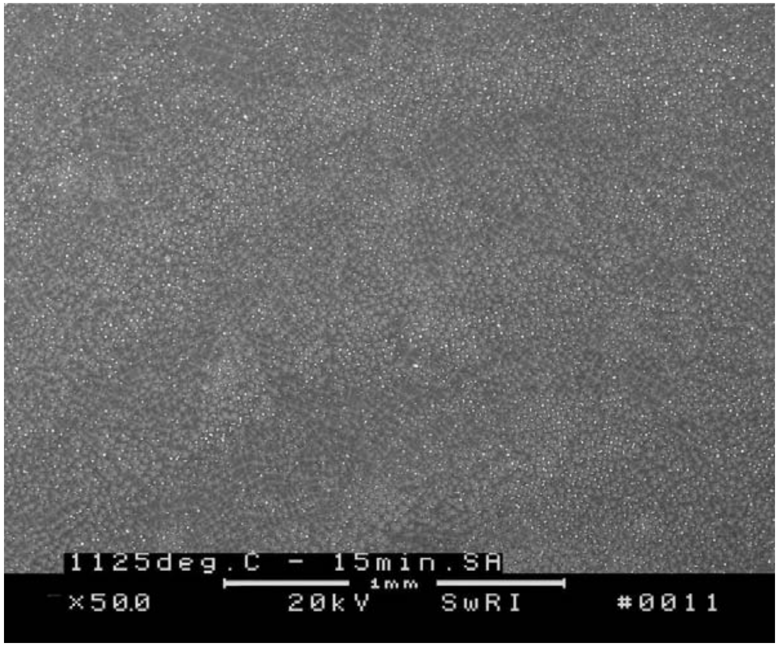
Welded Material Used in Previous Work

Material	Chemical Content (wt%)						
	Ni	Cr	Mo	W	Fe	Co	C
Alloy 22 Heat 059902LL2	59.58	20.35	13.85	2.63	2.85	0.01	0.005
Alloy 622 Filler Heat XX2048BG	59.40	20.48	14.21	3.02	2.53	0.02	0.001

- 38.1-mm [1.5-in] gas tungsten-arc welded plate
- Weld filler has a slightly higher Mo content (14.21 wt%) compared to that (13.70 wt%) used in this study
- Metallurgical conditions
  - As-welded
  - Welded plus solution annealed at 1,125 °C [2,057 °F] for 15 minutes

Microstructural Variation





- Alloy 22 welded plate used in this study
- Solution annealed at 1,125 ºC [2,057 °F] for 20 minutes
- 0.28 vol% precipitates

- Alloy 22 welded plate used in Dunn, et al. (2005)
- Solution annealed at 1,125 ºC [2,057 °F] for 15 minutes
- 1.77 vol% precipitates

Summary

- Similar repassivation potential was observed for Alloy 22 in mill-annealed, as-welded, and welded plus solution annealed conditions
- Solution annealing at 1,125 °C [2,057 °F] for 20 minutes improves the localized corrosion resistance of the welded material as a result of homogenizing the weld fusion zone
- The observed difference in the localized corrosion susceptibility of Alloy 22 welds may be attributed to microstructural and compositional variations as a result of welding process and parameters
- Additional testing is in progress to evaluate the effect of solution annealing at higher temperatures and longer times

Disclaimer

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