## REFERENCES


Bagg, J. (1990) Computer calculation of liquid-junction potentials - I. Concentration profiles at junctions with concentrated KCl. Electrochimica Acta, 35(2), 361-365.

Bagg, J. (1990) Computer calculation of liquid-junction potentials – II. Junction potentials for junctions with concentrated KCl. Electrochimica Acta, 35(2), 367-370.

Bagg, J. (1992) Computer calculation of liquid-junction potentials – III. Temperature-dependence of junction potentials. Electrochimica Acta, 37(4), 719-723.

Bagg, J. (1993) Temperature and salinity dependence of seawater-KCl junction potentials. Marine Chemistry, 41, 337-342.

Barin, I. and Knacke, O. (1973) Thermochemical Properties of Inorganic Substances. Germany: Spinger-Verlag.

Barner, H.E. and Scheuerman, R.V. (1987) Handbook of thermochemical data for compounds and aqueous species. New York: John Wiley & Sons.

Bard, A.J. and Faulkner, L.R. (1980) Electrochemical Methods: Fundamentals and Applications. New York: John Wiley&Sons.

Barry, P.H. (1994) JPCalc, a software package for calculating liquid junction potential corrections in patch-clamp intracellular, epithelial and bilayer measurements and for correction junction potential measurements. Journal of Neuroscience Methodology, 51, 107-116.

Barry, P.H. and Lynch, J.W. (1991) Topical Review. Liquid junction potentials and small cell effects in patch clamp analysis. Journal of Membrane Biology, 121, 101-117.

Bogaerts, W.F. and Van Haute, A.A. (1984) Determination of activity coefficients for KCl at elevated temperatures. Journal of Electrochemical. Society, 131(1), 68-72.

Bosch, R.W., Bogaerts, W.F., and Zheng, J.H. (2003) Simple and robust external reference electrodes for high-temperature electrochemical measurements. Corrosion, 59(2), 162-171.

Broumas, A.P., Degnan, N.M., and Meier, M.L. (2003) Oxygen diffusion into titanium. ASEE Annual Conference Proceeding, 10783-10792.

Covington, A.K. (1966) The design of cells with liquid junctions and the elimination of the liquid junction potential. Electrochimica Acta, 11, 959-962.

Dobson, J.V., Firman, R.E., and Thirsk, H.R. (1971) The behavior of cells using silver/silver-chloride and skin-calomel Electrodes at temperatures from 25 °C to 200 °C and 1 bar to 2 Kbar pressure. Electrochimica Acta, 16, (793-809).

Ericson, K.L. and Rogers, J.W. (1988) Low temperature diffusion of oxygen in titanium oxide films. Applied Surface Science, 35(1), 137-152.

Handerson, M.A. (1999). A surface perspective on self-diffusion in rutile $TiO_2$. Surface Science, 419, 174-187.

Indig, M.E. (1990) Technology transfer: aqueous electrochemical measurements room temperature to 290 °C. Corrosion Engineering, 45(8), 680-686.

Ito, S., Hachiya, H., Baba, K., Asano, Y., and Wada, H. (1995) Improvement of the silver/silver chloride reference electrode and its application to pH measurement. Talanta, 42, 1685-1690.

Kelly, R.G., Scully, J.R., Shoesmith, D.W., and Buchheit, R.G. (2003) Electrochemical Techniques in Corrosion Science and Engineering. New York: Marcel Dekker.

Kim, Y.J. and Andresen, P.L. (2003) Data quality, issues, and guidelines for electrochemical corrosion potential measurement in high-temperature water. Corrosion, 59(7), 584-596.

Lvov, S.N. and Macdonal, D.D. (1996) Estimation of the thermal liquid junction potential of an external pressure balanced reference electrode. Journal of Electroanalytical Chemistry, 403, 25-30.

Lvov, S.N., Gao, H., and Macdonald, D.D. (1998) Advanced flow-through external pressure-balanced reference electrode for potentiometric and pH studies in high temperature aqueous solutions. Journal of Electroanalytical Chemistry, 443, 186-194.

Lvov, S.N., Gao, H., Kouznetsov, D., Balachov, I., and Macdonald, D.D. (1998) Potentiometric pH measurements in high subcritical and supercritical aqueous solutions. Fluid Phase Equilibria, 150-151, 515-523.

Lvov, S.N., Zhou, X.Y., and Macdonald, D.D. (1999) Flow-through electrochemical cell for accurate pH measurements at temperatures up to 400 °C. Journal of Electroanalytical Chemistry, 463, 146-156.

Macdonald, D.D., Hettiarachchi, S., Song, H., Makela, K., Emerson, R., and Ben-Haim, M. (1992) Measurement of pH in subcritical and supercritical aqueous systems. Journal of Solution Chemistry, 21(8) 849-881.

Macdonald, D.D., Scott, A.C., and Wentrcek, P. (1979) Silver-silver chloride thermocells and thermal liquid junction potentials for potassium chloride solutions at elevated temperatures. Journal of Electrochemical Society, 126(9) 1618-1624.

Marichev, V.A. (1996) A nonequilibrium approach to Development of reference electrodes and oxygen sensors for high-temperature aqueous systems. Corrosion Science, 52(1), 53-65.

Murray JR.,.R.C. and Aikens, D.A. (1976) A study of the contribution of solvent transport to liquid junction potentials between electrolytes in different solvents. Electrochimica Acta, 21, 1045-1053.

Oh, S.H., Bahn, C.B., and Hwang, S. (2003) Evaluation of thermal liquid junction potential of water-filled external Ag/AgCl reference electrodes. Journal of The Electrochemical Society, 150(6) 321-328.e

Perry, R.H. and Green, D.W. (1997) Perry's Chemical Engineers' Handbook. New York: McGraw Hill.

Prentice, G. (1991) Electrochemical Engineering Principles. New Jersey: Prentice Hall.

Navas, M. and Gemez Briceno, M.D. (1997) Behavior of reference electrodes in the monitoring of corrosion potential at high temperature. Nuclear Engineering and Design, 168, 183-189.

Sampedro, J.A., Rosas, N., and Valdez, B. (1999) A reference electrode system for electrochemical measurements at high temperature. Corrosion Review, 17(3-4), 253-262.

Sawyer, D.T. and Roberts, JR.,J.L. (1984) Experimental Electrochemistry for Chemists. New York: John Wiley & Sons.

Senanayake, G. and Muir, D.M. (1988) Studies on liquid junction potentials in concentratrated chloride solutions and determination of ionic activities and hydration numbers by the EMF method. Electrochimica Acta. 33(1), 3-9.

Suzuki, H., Hirakawa, T., Sasaki, S., and Karube, I. (1998) Micromachined liquid-juncetion Ag/AgCl reference electrode. Sensors and Actuators B. 46, 146-154.

The ASME Boiler & Pressure Vessel Committees and the American Society of Mechanical engineers (1998) 1998 ASME Boiler & Pressure Vessel Code: An International Coat Part D: Properties. New York: The American Society of Mechanical engineers.

# APPENDIX

The Barlow and Lame equation was applied to calculate the minimum required wall thickness, $t_m$, for the straight pipe under internal pressure. The correlation is as follow (Perry, 1997);

$$t_m = \frac{PD_o}{2(SE + PY)} + C$$

| | | | |
|---|---|---|---|
| where | $t_m$ | = | Minimum required wall thickness |
| | $P$ | = | design pressure |
| | $D_o$ | = | Outside diameter of pipe |
| | $C$ | = | sum of allowances for corrosion, erosion, and any thread or groove depth. (plus $\frac{1}{64}$ in when no tolerance is specified) |
| | $SE$ | = | maximum allowance stress |
| | $Y$ | = | coefficient having value, 0.4 for ductile nonferrous materials, and zero for brittle materials such as cast iron |

The seamless grade 2 titanium tubing with the outside diameter of $\frac{3}{8}$ inches was fabricated as the electrode body. The electrode was pressurized at the pressure inside the autoclave to a maximum of 2,000 psi during high temperature test. The maximum allowable stress for titanium is summarized in Table A1. The minimum wall thickness of electrode design at maximum temperature 600 °F (315 °C) then is;

$$t_m = \frac{2000 \times 0.375}{2((6.5 \times 1000) + (2000 \times 0.4))} + \frac{1}{64}$$

$$= 0.067 \text{ inches}$$

**Table A1** Allowable stress for seamless grade 2 titanium tubing)(The American Society of Mechanical Engineers, 1998)

| Temperature (F) | SE (ksi) |
|---|---|
| -20 to 100 | 14.3 |
| 150 | 13.7 |
| 200 | 12.4 |
| 250 | 11.3 |
| 300 | 10.3 |
| 350 | 9.5 |
| 400 | 8.8 |
| 450 | 8.2 |
| 500 | 7.6 |
| 550 | 7.0 |
| 600 | 6.5 |

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