

**TUESDAY, AUGUST 23, 2005, A.M.**

**SESSION 16: INTERNATIONAL SYMPOSIUM ON MATERIALS  
DEGRADATION: INNOVATION, INSPECTION, CONTROL AND  
REHABILITATION**

**CORROSION BEHAVIOUR, CHARACTERIZATION AND APPLICATIONS II**

Sponsor(s): Material Performance and Integrity Section, The Metallurgical Society of CIM

Room: Bannerman

Chair(s): G.P. GU, CANMET, Canada

PAPER 16.1 — 8:30

EFFECTS OF MULTI-HEAT-STABLE SALTS ON CORROSION IN AMINE TREATING PLANTS.

P. SRINIVASAN and A. VEA WAB, University of Regina, Canada

This work investigates synergistic corrosion effects that may exist in amine treating plants containing a mixture of heat-stable salts. The investigation was experimentally carried out in a 5 kmol/m<sup>3</sup> monoethanolamine (MEA) solution containing 0.20 mol/mol CO<sub>2</sub> loading at 80°C under atmospheric pressure using carbon steel 1018. Six heat-stable salts including formate, oxalate, bicine, acetate, thiosulfate, chloride were tested with a series of salt combinations. Potentiodynamic Polarization, Tafel Extrapolation, and Cyclic Polarization were used for revealing corrosion behavior, determination of corrosion rate, and examining the pitting tendency, respectively.

PAPER 16.2 — 8:55

PERFORMANCE OF COPPER CARBONATE AS CORROSION INHIBITOR IN AMINE TREATING PLANTS.

I. SOOSAI PRAKASAM and A. VEA WAB, University of Regina, Canada

This work investigated inhibition performance of copper carbonate (CuCO<sub>3</sub>) which is less-toxic than conventional heavy-metal corrosion inhibitors in amine treating plants. The investigation was experimentally carried out in a bench-scale electrochemical corrosion cell under an atmospheric pressure. The inhibition performance of CuCO<sub>3</sub> in an aqueous solution of monoethanolamine (MEA) was examined under a wide range of operating conditions and subsequently correlated to process parameters including amine concentration, inhibitor concentration, temperature and carbon dioxide (CO<sub>2</sub>) loading in solution.

PAPER 16.3 — 9:20

OXYGEN CONTROLLED CORROSION OF ALLOY 625 AT HIGH TEMPERATURE AND PRESSURE.

E. ASSELIN, A. ALFANTAZI and S. ROGAK, University of British Columbia, Canada

Low temperature electrochemical tests were performed on alloy 625, Ni, Cr and Mo in solutions analogous to those which led to a failure at the UBC Supercritical Water Oxidation reactor. Surface analysis and thermodynamic stability calculations were also performed in an attempt to correlate low temperature morphology and surface films to those which were observed under SCWO conditions. Potentiodynamic measurements showed that alloy 625 behaves much like Cr with the exception of a small anodic peak corresponding to the oxidation of Ni – likely through a reaction leading to the formation of hexammine nickel(II), Ni(NH<sub>3</sub>)<sub>6</sub><sup>2+</sup>. Alloy 625 has a large passive region and rapid corrosion is only visible at transpassive potentials. The corrosion morphology observed at transpassive potentials in the room temperature experiments is similar to that which was observed in the SCWO piping. Furthermore, there appears to be a trend towards increased de-alloying of the passive film with increasing temperature as seen by X-ray Photoelectron Spectroscopy of alloy 625 samples polarized in the passive region at 25, 50 and 75°C. Thus the passive region obtained at low temperature can be correlated with the passive film seen under SCWO conditions which is heavily Ni depleted.

These correlations demonstrate that the most likely mode of corrosion failure for alloy 625 in ammoniated salt solutions is transpassive attack and that low temperature electrochemical tests may suffice to predict the morphology and possible failure of SCWO tubing. However, the morphology observed under both passive and transpassive conditions is also similar to that which one might expect from below critical potential de-alloying and bulk de-alloying, respectively.

**STUDY OF STRESS CORROSION CRACKING AND FATIGUE DAMAGE**

Chair(s): M. ELBOUJDAÏNI, CANMET, Canada

PAPER 16.4 — 9:45

FAILURE ANALYSIS OF 316L STAINLESS STEEL TUBING OF THE HIGH PRESSURE STILL CONDENSER.

T.M. AHMED, A. ALFANTAZI, The University of British Columbia, Canada,

J. BUDAC and G. FREEMAN, Sherritt International Corporation, Canada

Sherritt international has experienced corrosion failures with 316L stainless steel tubing of the high pressure still condenser employed for ammonia recovery. A failure analysis was conducted on the tubing to determine the mode and the root cause of failure. The analysis included both optical and scanning electron microscopy (SEM) of the inner and outer surfaces of the tube and also, characterization of the corrosion products. Results revealed that corrosion attack was confined to the first few inches (~ 100 mm) of the tubing at the inlet end where the tube is rolled joint to the tube plate. The tube suffered both external stress corrosion cracking (SCC) and crevice corrosion from the shell side (water side), and wall thinning in the tube side (inner surface) due to general corrosion. The cracks were oriented in the circumferential direction suggesting that the primary source of stress was the longitudinal residual stresses due to tube rolling. It was evident that failure of one of the tubes (Tube C) occurred due to SCC that penetrated the whole wall thickness and resulted in a leak failure. Some prevention measures are proposed to prevent this type of corrosion attack in the future.

COFFEE BREAK—10:10-10:25

PAPER 16.5—10:25

NITRATE STRESS CORROSION CRACKING OF CARBON STEEL IN THE HEAT RECOVERY STEAM GENERATORS OF A CO-GENERATION PLANT.

F.N. SMITH, Consultant, Canada

The carbon steel casings of Heat Recovery Steam Generators (HRSGs) in a co-generation plant were found to have developed cracks that originated on the process-side. The HRSGs received hot exhaust gases from the primary gas turbines (GTs), which were fuelled with pipeline natural gas. At the time, the GTs were operating without any suppression of nitrogen oxides (NOx). The casings were fitted with insulation on the inside (process-side). After being in service for about 2 years, some of the cracks were found to have penetrated right through the ¼" thick casings. Analysis of samples cut from the casing walls revealed (i) fine cracks propagating through the steel and (ii) the presence of relatively large amounts of nitrate ion on the process-side of the steel. It was concluded that the nitrate ions originated from nitric acid that was condensing on the relatively cooler walls of the casings behind the insulation. Nitric acid formed in the GT exhaust gases by the combining of water vapour (from combustion of the hydrocarbon fuel and from moisture in the combustion air) and nitrogen dioxide (from nitrogen and oxygen in the combustion air).

PAPER 16.6—10:50

ON THE CALIBRATION OF THE POTENTIAL TECHNIQUE FOR MONITORING CORROSION FATIGUE CRACK GROWTH USING FINITE ELEMENT METHOD.

F. WANG, V. CARATHANASSIS and S.A. SHIPILOV, University of Calgary, Canada

When selecting a method for crack monitoring, the sensitivity or crack size resolution plays a dominant role in the selection. Even though there are several visual and non-visual methods, the direct current (DC) potential drop method is more applicable for monitoring crack growth due to the high resolution of this method. The method has been used for the last few decades and has gained increasingly wide acceptance in fracture research as one of the most accurate and efficient methods for monitoring propagation of cracks. Furthermore, most R&D experience has proven that the electrical potential method can be used in most of the "aggressive" environments. Due to the above reasons, the DC potential drop method was selected as the method to be used for designing a testing machine for fatigue crack growth monitoring. A sensitive testing machine with special equipment for studying the kinetics of crack growth and that simultaneously provides measurement of electrochemical parameters during stress corrosion and corrosion fatigue crack propagation in metals was designed. With temperature stability of no less than  $\pm 0.5^\circ\text{C}$ , it was possible to detect as little as 0.005-mm crack extension. The use of finite element modelling is shown to facilitate the application of the DC/PD method for monitoring fatigue crack growth in steels. The 2D model calibration provided a good description of the test data and proved more accurate than the analytic Johnson's formula, specifically at  $a/a_0 < 2$ .

PAPER 16.7—11:15

HYDROGEN EMBRITTLEMENT AND STRESS CORROSION CRACKING BEHAVIOR OF  $\alpha$ -TITANIUM ALLOY.

Z. SUN, Z. TANG, X. ZHANG and X. LI, Institute of Aeronautical Materials, China

The hydrogen embrittlement and stress corrosion cracking (SCC) behavior of a  $\alpha$ -titanium alloy and its two kinds of welding samples have been investigated. The results show that it has very low susceptibility to SCC, and the values of K<sub>ISCC</sub> for the alloy are 46.4MPa•m<sup>1/2</sup> and 65.86 MPa•m<sup>1/2</sup> in the direction of T-L and L-T respectively. The scanning electron fractographs show transgranular and quasi-cleavage fracture. The hydrogen embrittlement results show that the notch sample of the alloy is not sensitive to hydrogen, but the electro beam welding and diving arc welding samples are sensitive.

PAPER 16.8—11:40

SELECTING OF APPROPRIATE ELECTRODE IN FULLY SALT-WATER BY FUZZY LOGIC.

S.-E. Vahdat, University of Azad, Iran

The goal was selecting of appropriate electrode for dummy load of diesel engine in fully salt-water in DESA factory. Electrochemical corrosion rate of general structural steel, commercial pure aluminum and cathode copper is calculated as weighting, volumetric and commercially in fully salt-water by city power. After several testing and then using fuzzy logic method, the result is general structural steel is the best selection for our aim.