Effects of Water Chemistry on Corrosion of Stainless Steel and Deposition of Corrosion Products in High Temperature Pressurised Water

Jon Morrison, John Hewett, Chris Cooper, Clive Ponton, Brian Connolly
University of Birmingham, UK

Andrew Banks
Rolls Royce Plc

Abstract

In any water-cooled nuclear reactor, the corrosion of the structural materials in contact with the coolant and the deposition of the resulting oxidised species follows a defined pattern. Corrosion of the structural materials at all points in the reactor leads to low concentrations of oxidised metal species in the coolant water. The oxidised metal species can often be found deposited out as so-called crud deposits at various points around the reactor's primary and secondary loops. The deposition of initially soluble oxidised material at any location in the reactor cooling system is undesirable due to the deposition within core radiation fields where the deposit structure incorporates radiologically activated nuclei and impaired heat transfer efficiency when the deposits form on the fuel cladding and in the steam generator tubing. The work presented here is an attempt to determine and understand the fundamental corrosion and deposition behaviour of 316L stainless steel under simulated reactor coolant conditions.

The rates of corrosion of structural materials within pressurised water reactors are depend heavily on the condition of the exposed surface. Surface conditioning is known to reduce corrosion rates and studies of various surface finishes on different materials subject to the water chemistry and temperatures expected in a reactor have been studied. The effect of mechanical and electrolytic polishing have previously been studied in order to better understand the formation of the oxide film; further experiments are now being carried out to determine the parabolic corrosion rates exhibited depending on the initial surface condition.

The corrosion of stainless steel in water via electrochemical oxidation leads to the formation of surface iron, nickel and chromium based spinels. While these spinel species have a low solubility in reactor coolant, it is of great importance to determine the solubility constants. The solubility of magnetite, stainless steels' major corrosion product, in high purity water continues to be studied at pHs between 9 and 11, at temperatures between 473 and 573K.

Finally, it has been recognised that there is an electrokinetic component to the deposition occurring within flow restrictions, but very little has been done to study the electrokinetic behaviour at a restriction. Work that has been previously attempted has focused on electrokinetics of crud deposition in the secondary side water chemistry. This electrokinetic behaviour, manifested as a streaming current, is believed to be highly influential in the electrochemical conditions occurring at flow restrictions resulting in the formation of the observed crud deposits.

A high velocity (up to 30 ms^{-1}) flow rate loop operating at high temperature (up to 315°C) and pressure (up to 150 bar) has been constructed and installed to study the deposition of material at a flow restriction of known geometry under simulated primary side water chemistry, temperature and

pressure conditions. The loop operates at temperatures up to 573K, pressures up to 115bar and flow rates up to 26ms^{-1} (it should be noted that initial testing will be performed over a range of 12-20 ms^{-1}). Furthermore, to assist in the understanding of measured streaming currents present as a function of desired geometries, preliminary experiments utilising a second 'cold' loop will be performed, where water of up to 373K will be flowed at high velocity through an instrumented sample section.

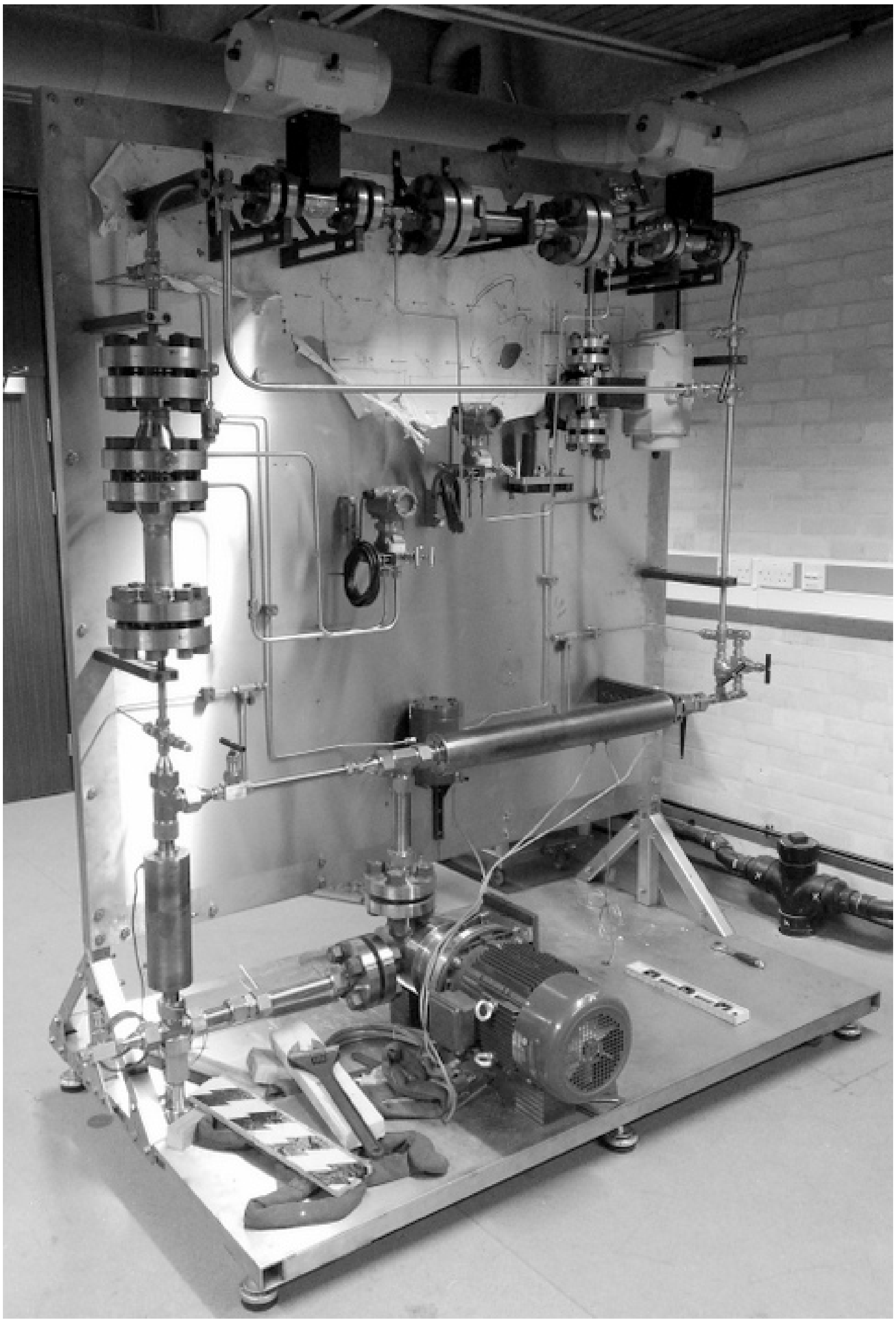

Figure 1, The University of Birmingham Hot Loop