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CORROSION AND ARC EROSION IN MHD CHANNELS

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I. OBJECTIVE AND SCOPE OF WORK

The objective of this task is to study the corrosion and arc erosion of MHD materials in a cooperative effort with, and to support, the MHD topping cycle program. Materials tested in the Avco Research Laboratory/Textron facility, or materials which have significant MHD importance, will be analyzed to document their physical deterioration. Conclusions shall be drawn about their wear mechanisms and lifetime in the MHD environment with respect to the following issues; sulfur corrosion, electrochemical corrosion, and arc erosion. The impact of any materials or slag conditions on the level of power output and on the level of leakage current in the MHD channel will also be noted, where appropriate.

II. SUMMARY

The effort to determine actual, as opposed to apparent, values of axial leakage current has continued. Existing CDIF operating data are being examined in greater detail with the objective of improving estimates of electrode surface voltage loss and transverse leakage current. We are also trying to determine if new measurements and diagnostic equipment are feasible for reaching this objective, consistent with the constraints imposed by the CDIF hardware and test schedule.

Bench scale tests of water-side corrosion of 75% tungsten-25% copper (75W-25Cu) have been carried out over a range of pH and dissolved oxygen concentration. The rate of corrosion is found to vary in a way significant for the planning and interpretation of the upcoming Proof-of-Concept (POC) tests.

III. DISCUSSION

Current Distribution

As noted in the previous quarterly, uncertainty in the actual axial leakage current can be linked to uncertainty in the actual values for transverse current and transverse electric field strength, ie to the accuracy of the measured CDIF data.

The two most likely phenomena affecting accuracy are 1) transverse leakage current along the slag layer coating the insulator walls of an MHD duct, and 2) electrode surface voltage drops. Both phenomena are well known and their existence is not in question. But numerical values have seldom been measured, and never measured in the CDIF. Another unmeasured number, needed in order to correct the transverse electric field strength determined from peg wall voltage measurements, is the resistivity of the side-wall boundary layer at low current density (milliamp per cm^2).

All three of the above numbers can be estimated, but the uncertainty is large. The uncertainty could be reduced by obtaining the following measurements.

1) Better static pressure distributions. This would improve estimates of Mach number, of true Faraday current and of plasma conductivity.
2) Conductance of the slag layer on the side walls in the transverse

direction, preferably for both bar and peg configurations. This would allow an accurate determination of true Farady current, and contribute to a more accurate determination of the Faraday electric field.

3) Probe measurements of voltage profiles close to an electrode. This might improve estimated surface voltage drop.

4) Plasma uniformity at the channel entrance. This would improve all aspects of performance analysis by showing how much of what is observed in the MHD duct is due to burner conditions.

5) Slag surface temperature distribution axially. This would provide a better basis for calculating the resistive component of the slag leakage current.

6) Side wall voltage plots from the last as well as first half of the channel. In the last half of the duct effects due to the burner, such as incomplete mixing and seed deposits on the walls, should be much less thus simplifying interpretation of the remaining effects.

These measurements are listed in rough order of estimated ease of implementation on the CDIF and/ or cost of new hardware.

Meanwhile, an effort is being made to use existing data to determine the numerical values. Unavoidably, this involves making assumptions that are arguable, but the net result should be an improvement in understanding how current distributes itself over duct wall elements, how the distribution varies with operating parameters such as wall temperature, mean current density, and generator size, and how it relates to duct lifetime.

Corrosion

Bench scale water corrosion tests of 75W-25Cu at AVCO demonstrated excellent performance at pH 7. These tests were performed at ambient dissolved oxygen (3-4 p.p.m.) to simulate CDIF conditions even though power plant conditions call for almost 1000 times less dissolved oxygen (DO). Water corrosion of Mo is similar to W and is dependent upon the level of DO, with no corrosion at 0 DO. Therefore the lack of DO control at the CDIF places 75W-25 Cu at a distinct disadvantage for the POC test.

Furthermore, bench scale tests showed a deterioriation of the performance of 75W-25 Cu at pH 5 in contrast to the excellent results at pH 7. It is not clear to what extent pH control will be implemented for the POC test. The absence of any pH control will further penalize the performance of 75W-25 Cu since past experiences shows that the CDIF water fluctuates between 5 and 6.5.

For these reasons it has been difficult to reproduce the excellent bench-scale waterside performance of 75W-25 Cu in real-time tests at the CDIF.

While we do not believe that uncontrolled water for the POC test will be life-limiting for 75W - 25 Cu, a deterioriation of the performance could cast a misleading doubt on its usefulness as a waterside material for the next generation channel scale-up. Additional corrosion on the waterside could produce additional thermal resistance for heat transfer to the water. In that case the resulting increase in gas-side operating temperature will produce additional and unnecessary wear of the gas-side surface.

The high visibility green-colored corrosion layer which can develop in the 75W - 25 Cu water passages does so when the passages air dry under dirty conditions. Repeated (25x) air drying of 75W - 25 Cu with tap water showed little evidence of the greenish corrosion layer. 6 months continuous underwater exposure to an aqueous environment with ambient DO produced little surface corrosion (some slight blackening). The test was done in the absence of other materials whose presence might produce corrosion couples between the dissimilar materials. However the pH decreased from 7 to 3.5 during the test so stagnant water conditions were authentic, except for the absence of dissimilar materials.

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