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AMS Whitepaper: AMS CRDM Test Equipment Capabilities - Control and Shutdown Rod Temperature Maps for Coil Diagnostics

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A majority of Westinghouse pressurized water reactors (PWRs) have a commitment to verify the timing and sequencing of control rod drive mechanisms (CRDMs). More specifically, a test is typically performed following every refueling outage to verify that the Lift Coil and Moveable and Stationary Gripper mechanisms are actuating at the correct times and that their corresponding coils are operating at the appropriate levels of current. Historically, plants have only collected the CRDM coil current data during this maintenance activity, but Analysis and Measurement Services Corporation (AMS) has integrated simultaneous CRDM coil current and voltage data acquisition to unlock **new diagnostic capabilities such as in-situ calculation of CRDM coil resistances and coil temperature maps (Figure 1) to help identify CRDM degradation before it impacts operability**. This capability can be found in the latest generation of AMS equipment for measuring the timing and sequencing of CRDMs.

With current and voltage data acquired simultaneously, the resistance of each CRDM coil tested can be calculated using Ohm's law. Furthermore, it is well-known that electrical resistance is a function of temperature in CRDMs. As such, it is possible to model the behavior and determine the correlation between the two parameters to create a profile that allows for an estimate of CRDM coil temperature.

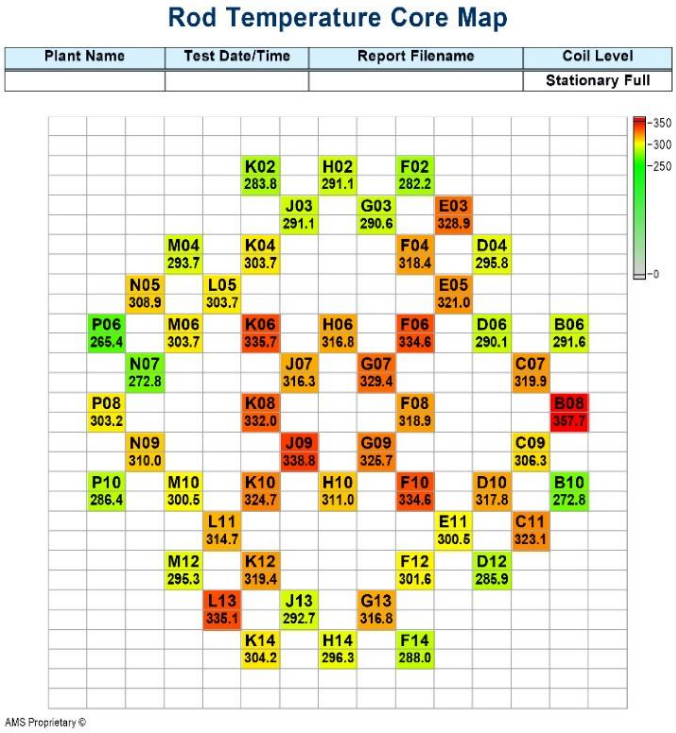

Figure 1. Example Rod Temperature Map

To produce generic temperature profiles for CRDM Lift, Moveable, and Stationary gripper coils, AMS collected resistance versus temperature measurements in the laboratory on actual CRDM coil assemblies at temperatures ranging from 72°F to 300°F. During testing, each coil was individually placed inside a forced-convection laboratory grade oven compliant with ASTM D5423-14 while DC resistance and inductance measurements were made to monitor the effects of temperature on the properties of the coil. The ambient temperature surrounding each coil was measured using a thin-film resistance temperature detector (RTD) attached to each coil, and at each data point, temperature was allowed to stabilize and reach steady-state for at least four (4) hours prior to data acquisition. The test setup including the laboratory oven used (left) and a CRDM coil assembly (right) is shown in Figure 2.

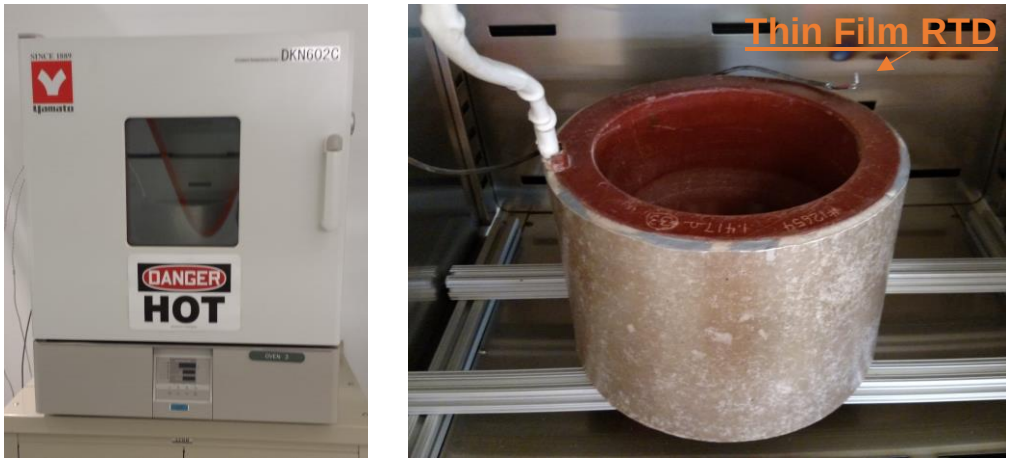

Figure 2. CRDM Lift Coil in Oven with Thin Film RTD

With CRDM coil resistance versus temperature profile models established for CRDM Lift, Moveable, and Stationary gripper coils, AMS developed a CRDM Data Map to give plant personnel an easy-to-view tool for CRDM coil diagnostics and health monitoring. Each box on the data map represents a control rod showing its location in the core, with the rod number shown at the top half of the box and the data value at the bottom half of the box. Each box is color-coded so the user can easily identify hot spots, patterns, or other important information at a glance. This information can be used to quickly identify patterns developing in the rod control system as a precursor to CRDM degradation. The software is able to display coil temperature, resistance, current, or voltage. It also has the capability to adjust the scaling, set a threshold at a certain level (Figure 3), or select only a subset of rods to be viewed (Figure 4). These capabilities allow a plant to effectively monitor CRDM coil temperatures, trend changes over time, and ultimately help identify degradation before it impacts plant operability.

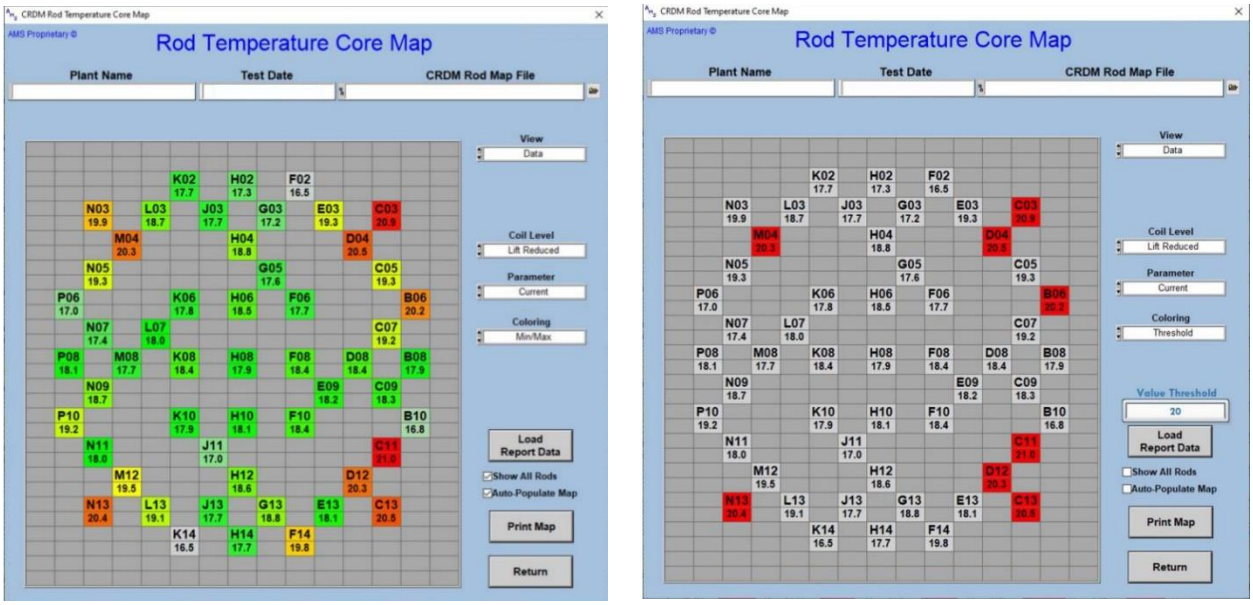

Figure 3. Min/Max and Threshold Examples Identifying Lift Coil Currents Above 20 Amps (Thresholds Can Also Be Established for Temperature, Resistance, or Voltage)

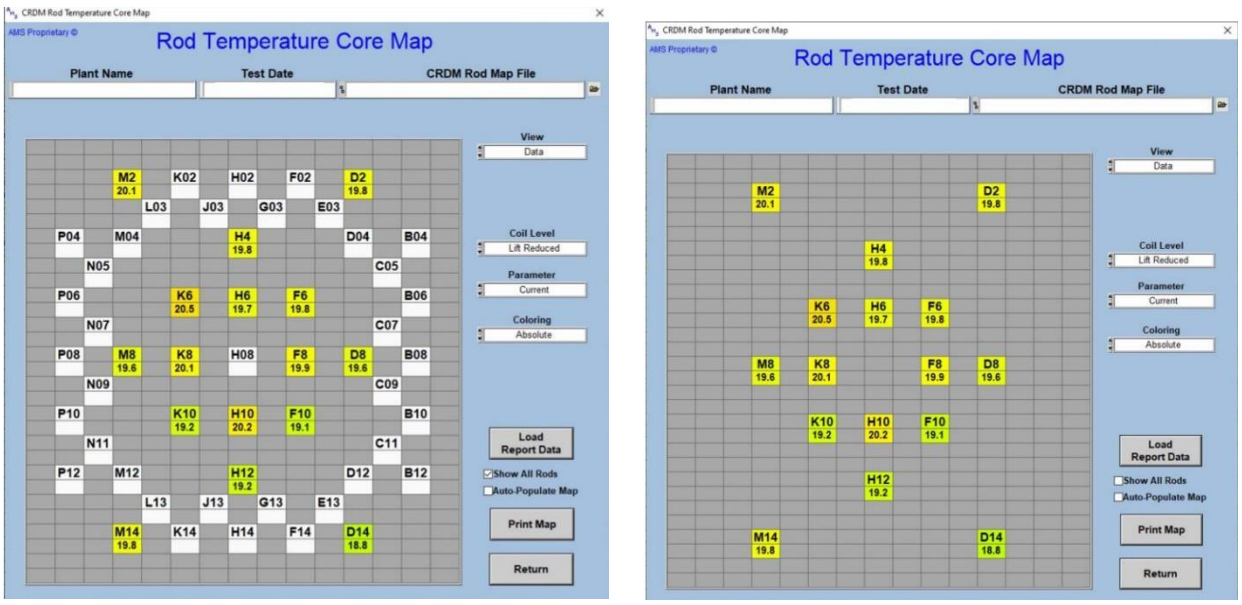

Figure 4. Rods with No Data Values can be Excluded from the Map for Clarity