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INTERIM REPORT ON HTLTR MOCKUP RUN NUMBER 1

Summary

Large mockup Run Number 1 has been completed and the results partially analyzed. In general, the run proved satisfactory with the graphite core being heated to a maximum average temperature of 1070 °C. At this time the minimum and maximum temperatures were about 1050 °C and 1130 °C, respectively, depending upon the thermocouple location within the graphite core.

Gas System

One of the foremost problems of mockup operation is achieving and maintaining the recirculating nitrogen gas purity. The mockup was alternately evacuated to about 12 mm of mercury absolute and filled with nitrogen some 17 times prior to high temperature operation. The last sample taken just before the start of heating the mockup indicated 99.9 volume % nitrogen, 0.01 % oxygen and less than 0.01% carbon dioxide, 0.1% carbon monoxide, 0.01% water and 0.01% hydrogen. However, as the temperature was increased above approximately 600 °C, substantially larger quantities of the contaminants were detected. During the course of the run maximum CO₂ and H₂ concentrations observed were 0.3% and 1.4%, respectively, with H₂O concentrations in excess of 1%.

General corrosion of graphite structural materials, in addition to weight losses of graphite samples which remained in the mockup during the run evidenced attack from high gaseous impurity concentrations observed.

Heater System

Two of the four heater elements which were installed in the mockup exhibited no corrosion damage in those areas protected by the graphite core. However, the unprotected portion of all the elements extending between the graphite core and inlet bus bar exhibited considerable corrosion damage. In addition to the exposed surfaces, small corroded areas were observed in the vicinity of the four thermocouple openings opposite the third element. Complete failure of the fourth element resulted from extensive corrosion damage at a single location. This rod also exhibited damage opposite thermocouple openings. The failure of the element is attributed to formation of a hot spot in the element due to an undetected flaw in the graphite
which accelerated the corrosion at this location. In general, one can say the heater elements performed satisfactorily, but were selectively attacked by gaseous impurities depending on location.

Heater element connections (sliding collets and grounding wedges) appeared to be in excellent condition. No large temperature gradients, detectable by color difference, which would indicate high electrical contact resistance were noted while viewing one of the grounding wedges through a sight-port directed at the wedge.

Temperature Measurement

Graphite core temperatures were monitored using three types of 0.060 inch OD thermocouples: (1) Tungsten/5% Rhenium-Tungsten/26% Rhenium sheathed in molybdenum, (2) Platinum-Platinum/13% Rhodium sheathed in molybdenum and (3) Chromel-Alumel sheathed in Hastelloy B. There were four of each type of thermocouple inserted in the core for a total of twelve thermocouples. Temperatures at thermal insulation interfaces were monitored by Chromel-Alumel thermocouples sheathed in Inconel 600. All thermocouple wires were 36 gauge and insulated from the sheath by magnesium oxide beads. When high enough temperatures had been attained, an optical pyrometer was used to monitor surface temperatures of the graphite core for comparison with the temperatures obtained from the thermocouples.

Following is a synopsis on the operating history of thermocouples installed in the core:

<table>
<thead>
<tr>
<th>Type</th>
<th>TC No.</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>W/5Re-W/26Re - U(1)</td>
<td>2</td>
<td>Not satisfactory - as much as 700 F low</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>W/5Re-W/26Re - G(2)</td>
<td>3</td>
<td>Not satisfactory - as much as 700 F low</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>Not satisfactory to 1200 F (150 F low) above 1200 F satisfactory</td>
</tr>
<tr>
<td>Pt-Pt/13 Rh - U</td>
<td>10</td>
<td>Not satisfactory - 550 F high; failed after 1 day</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>Not satisfactory - 600 F high; failed after 21 days</td>
</tr>
<tr>
<td>Pt-Pt/13 Rh - G</td>
<td>7</td>
<td>Not satisfactory - 600 F high; failed after 2 days</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>Type</td>
<td>TC No.</td>
<td>Comments</td>
</tr>
<tr>
<td>--------------------</td>
<td>--------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>Chromel-Alumel - U</td>
<td>6</td>
<td>Satisfactory - failed after 33 days</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>Satisfactory - failed after 18 days</td>
</tr>
<tr>
<td>Chromel-Alumel - G</td>
<td>4</td>
<td>Satisfactory</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>Satisfactory</td>
</tr>
</tbody>
</table>

(1) Junction not grounded to sheath.
(2) Junction grounded to sheath.

Removal of the thermocouples at the end of Run 1 disclosed the Hastelloy B sheaths were extremely brittle and sheath failure could possibly be the direct cause of failure of the two chromel-alumel thermocouples rather than failure of the thermocouple itself.

Of the three types of thermocouples tested it appears Chromel-Alumel provided the most reliable indication of core temperatures for operation at 1000 C or less. The fact that the tungsten alloy thermocouples indicated low temperatures and platinum thermocouples indicated high temperatures is unexplained. Individual calibration data supplied by the vendor checked within the ISA calibration tolerances.

Samples of each of the sheathing materials were sent for metallographic examination. In summary, the results of these examinations show that the molybdenum sheaths were unaffected by the mockup atmosphere, Inconel 600 was slightly corroded and the Hastelloy B sheaths were extremely embrittled. All of the Chromel-Alumel thermocouples sheathed in Hastelloy B were broken during removal from the mockup.

An oscillographic check was made for AC pickup by three of the thermocouples with an RC filter connected between the thermocouple leads and case ground. AC voltages of 1.5 and 3 were observed on the grounded thermocouples with the filter in the circuit. Unfiltered voltages greater than 15 were detected. Without the filter an AC voltage less than 50 millivolts was observed on a couple which was not grounded to the sheath.

X-ray examination revealed that thermocouple Number 7 failed due to wire breakage at a location 3 inches from the junction while thermocouple Number 10 failed at the junction.

Thermocouple Number 12 was returned to the vendor for repair when a pre-installation check showed no generated emf when the thermocouple was heated. This is difficult to understand in that the vendor was required by specification to test the thermocouples to 1500 F and provide the data obtained as calibration information.

Based on the information obtained to date, Chromel-Alumel thermocouples sheathed in molybdenum are recommended for operation at or below 1000 C.
Assembly and Maintenance

Following are miscellaneous comments which may be of value to the reactor operating staff and designers:

1) With proper precautions an elevation tolerance of \( \frac{1}{2} \) 1/32 inch was maintained for the brick supporting the graphite core. cribbing.

2) It was possible to enlarge one of the core holes by boring. The hole was 10 feet in length and was enlarged from 2-3/4 inches to 3 inches ID. The machining rate was approximately 2 feet per hour.

3) A diamond tipped core drill was used to bore a sight tube hole for observing the surface of one of the heater elements after installation of the brick.

4) General Electric RTV Silicone was effective in sealing leaks around the mockup doors.

5) An ultrasonic leak detector was utilized to pinpoint leaks with satisfactory results in lieu of a helium leak detector when the atmosphere near the leak became contaminated with helium.

6) A torque of 50 inch-pounds was applied to the heater element collet and wedge bolts.

7) Removal and installation of a thermocouple was accomplished during heated operation.

8) After sealing the system, inleakage of air at a system pressure of 140 mm Hg absolute was 0.7 psi/hr.

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