INTRODUCTION

A series of four experiments is being conducted at Argonne National Laboratory's TREAT Reactor. The purpose of these experiments, which are sponsored by an international consortium organized by the Electric Power Research Institute, is to investigate the source term. They have been designed to provide some of the necessary data regarding magnitude and release rates of fission products from degraded fuel pins, physical and chemical characteristics of released fission products, and aerosol formation and transport phenomena. These are in-pile experiments, whereby the test fuel is heated by neutron induced fission and subsequent clad oxidation in steam environments that simulate as closely as practical predicted reactor accident conditions. The test sequences cover a range of pressure and fuel heatup rate, and include the effect of Ag/In/Cd control rod material. Table 1 shows the test parameters as well as the type of accident simulated.

EXPERIMENTAL SYSTEMS

Identical experimental systems consisting of a primary vessel, secondary containment, aerosol characterization system and associated plumbing and instrumentation are used in each test. See Figures 1 and 2. Four previously irradiated fuel pins (plus control rod material in STEP-4) are located in the lower section of the primary vessel, which is suspended into the core of the TREAT Reactor. Steam is introduced at the bottom of the primary vessel. As it flows between the pins it oxidizes the clad, yielding hydrogen. The steam/hydrogen mixture flows to the top of the primary vessel, carrying the volatile fission products. Aerosols form as the steam cools beyond the fuel region to a nominal 644 K.

Aerosol Sampling Canisters. Approximately thirteen percent of the fission product laden steam/hydrogen mixture is directed to two aerosol canisters. Flow through the canister chambers is laminar. Each canister contains three chambers of fourteen collection stages. The stages, which are partitioned to create a labyrinthine channel, are stacked to create a long flow path, thereby enhancing particle collection efficiency and size stratification. See figures 3 and 4. Flow to the different chambers is
controlled by solenoid valves, which are operated sequentially to allow for temporal separation of the particles.

The collection devices in the stages are removable settling plates and fine wires. See Figure 5. The stainless steel plates sit on the floor of the stages, and are intended to collect particles that settle by gravity and diffusion. The fine wires range from 0.1 to 10 mil (2.54 to 254 mm) in diameter. They are positioned perpendicular to the gas flow such that they collect particles by impaction, interception and diffusion. Coupons of various metals are also located on the floor of some of the stages. They interact chemically with the gaseous fission products.

Filters. Metal filters located in the lines downstream of each of the canister chambers collect aerosol particles that are not removed in the canisters. These filters are attached to the primary vessel at a height that allows them to be viewed by a gamma detection system, enabling real-time identification of the radioactive fission products.

Sample Tree. Particulate and gaseous fission products entrained in the bulk of the steam/hydrogen mixture are collected on metal coupons located on a sample tree that hangs in the center of the primary above the fuel pins. It also contains cone-shaped traps that collect liquid that condenses on the body of the tree. See Figure 6.

AEROSOL COLLECTION

Theoretical values of particle collection efficiencies for the canisters for the low and high pressure tests appear in Figures 7 and 8. These include gravitational settling, impaction around bends and diffusion. Laboratory confirmation of the collection mechanisms of the canisters is being conducted using monodisperse polystyrene latex (PSL) particles suspended in air. A TSI, Inc, Tri-jet aerosol generator (model 3640) is being used in conjunction with a Climet optical particle counter (Model 225). Initial experiments have been done to experimentally confirm the collection efficiencies of the fine wires [11]. Theory and experiment are in agreement for the larger wires, but solid particle bounce significantly affected the data for the smaller wires.

POST-TEST EXAMINATION AND ANALYSIS

The fission product samples collected during the tests are subsequently retrieved and prepared for examination at Argonne's Hot Fuel Examination Facility. The settling plates and wires are examined using a scanning electron microscope. Particle size distributions and elemental compositions are obtained for representative samples. The metal coupons from the sample tree and the canisters are chemically analyzed to determine elements and compounds resulting from fission product reactions with the various metals. Data obtained on particle size and composition will be combined with thermal-hydraulic data taken during the tests and extrapolated to determine the main stream aerosol composition.
REFERENCES


Table 1. STEP TEST CONDITIONS

<table>
<thead>
<tr>
<th>Test</th>
<th>Pressure (psia)</th>
<th>ΔT avg (°C/min)</th>
<th>Duration (min.)</th>
<th>Steam Flow (lbm/h)</th>
<th>Accident Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>STEP-1</td>
<td>~60</td>
<td>100</td>
<td>20</td>
<td>5.5-1.9</td>
<td>PWR-large coolant pipe break, failure of ECC</td>
</tr>
<tr>
<td>STEP-2</td>
<td>~45</td>
<td>17</td>
<td>20</td>
<td>2.7-1.8</td>
<td>BWR-loss of coolant flow, successful scram</td>
</tr>
<tr>
<td>STEP-3</td>
<td>1150</td>
<td>50</td>
<td>20</td>
<td>4.0-1.9</td>
<td>PWR-loss of heat removal capability, subsequent boiling</td>
</tr>
<tr>
<td>STEP-4</td>
<td>1150</td>
<td>50</td>
<td>20</td>
<td>4.0-1.9</td>
<td>Like 3 but with control rod material present</td>
</tr>
</tbody>
</table>

aPrior to oxidation

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Figure 1. STEP In-Pile Vehicle
Figure 3. Aerosol Sampling Canister

Figure 4. Aerosol Sampling Canister Stage
Figure 5. Sampling Devices

Figure 6. Sample Tree

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Figure 7. Attenuation Through Canister-Steam

Figure 8. Attenuation Through Canister-$H_2$