RESEARCH OBJECTIVE

The general goal of this program is to develop innovative flow visualization methods and reliable predictive techniques for the energy, mass, and momentum transfer in the presence of surface reactions for the passivation treatment operations of SNF elements.

RESEARCH PROGRESS AND IMPLICATIONS

This report summarizes the work accomplished after about two and a half years of a three-year collaborative project. The University of Idaho developed a flow visualization technique to simulate a passivation reaction between oxygen gas and uranium hydride found on corroded, wet-stored SNF elements. An apparatus was constructed whereby a mixture of hexanoic acid and mineral oil flowed down a long channel. The hexanoic acid and mineral oil represented the oxygen and helium, respectively in the passivating gas. In the channel we placed a thin, flat aluminum plate with a small cavity filled with sodium metal. The sodium represented an exposed, corroded area on an SNF element. As the solution flowed over the plate, the acid in the solution reacted with the sodium, releasing hydrogen bubbles into the flow.

Based on observations of the generic SNF canister, our experiments were performed along a flat plate, at a Reynolds number of around 350. Figure 1 shows a typical flow pattern as viewed from the side. The fluid moves from left to right, and one observes the bubbles floating up and being convected downstream. The rising bubbles stretch and thin the dye filaments, and compress the streamlines toward the air-fluid interface. As the flow progresses downstream, nonlinear interactions between the bubbles and the dye cause further mixing. It is clear from the photograph and subsequent observations that the chemical reaction along the solid surface and subsequent release of the hydrogen bubbles convect the fluid away from the reaction, and introduce velocity fluctuations into an otherwise laminar flow. The bubble entrainment enhances mixing, and may serve to break flow symmetries and uneven flow distribution that have been observed in previous experiments. These flow symmetries, which may be circumferentially periodic, prevent a complete and thorough mixing throughout the canister, and decrease the likelihood that all of the possible corroded areas will be properly treated.

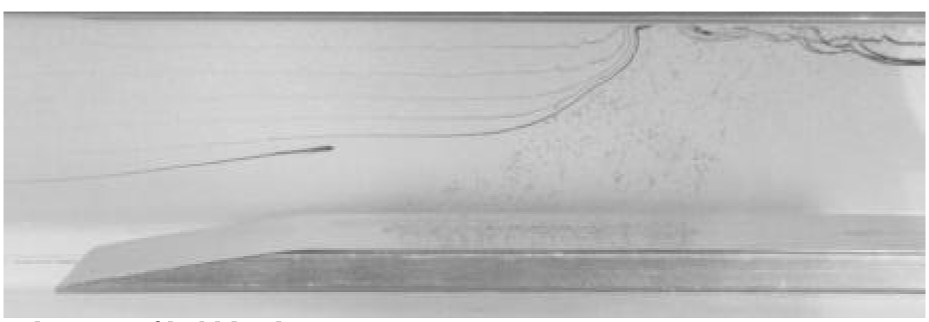

Figure 1. Side view of bubble-dye interaction

The objective of the INEEL and OSU effort is to develop an innovative measuring system and obtain fundamental measurements of the basic velocity and turbulence fields in generic idealizations of flow processes in SNF canisters. A water-flow experiment with a 3/4-scale model of the generic SNF canister was used for overall flow visualization and velocity measurements, with and without an array of simulated fuel elements. The flow is approximately circumferentially periodic and symmetrical about cross-sections through the four outer tubes for experiments using each of the three perforated plates. Figure 2 shows complicated, non-uniform flow patterns with a wide range of velocities in the simulated region of the fuel element array.

Local velocities differed by more than an order-of-magnitude from the bulk mean velocity used in simple analyses. These data demonstrate clearly that the flow in a typical basket would not be co-axial with its elements. Flows were both across, inducing turbulence, and along the elements at a low Reynolds number, encouraging laminarization. The expected effects on local mass transfer to support chemical reactions at the surface would be highly non-uniform.

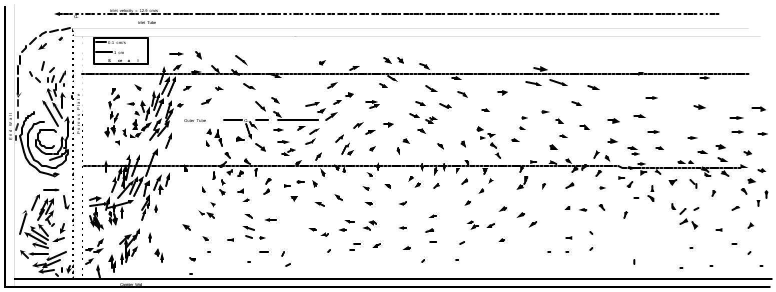

Figure 2. Velocity measurements in a plane midway between two simulated fuel elements.

The INEEL used its Matched-Index-of-Refraction flow system to measure flow in and around complex geometries, employing optical techniques without disturbing the flow. A 0.6-scale model has been installed in this unique facility to obtain detailed pointwise data for the three-dimensional flow field by laser Doppler velocimetry. New velocity and turbulence measurements to date have concentrated on low Reynolds number turbulent flow in the entry tube and the semi-confined, submerged impinging jet. Other experiments were performed to determine the turbulence and velocity fields of the flow approaching the perforated plate, and the inflow turbulence of the impinging jet. The examination of these questions requires fundamental measurements of the decay of turbulence and velocity in the low Reynolds number impinging jet and its surroundings and of the low Reynolds number turbulent flow in the inlet tube. Initial measurements of U, V, u', v' and $\overline{uv}$ have been obtained in the tube, about a diameter upstream from the exit, and at 0.07 diameters along the jet axis for Re ≈ 2510. These data provide the initial conditions for the impinging jet and permit assessment of the turbulence models employed in the numerical predictions.

The objective of the computer modeling effort is to qualitatively assess the flow patterns in support of the experimental effort and to work towards validation of the modeling approach. Various turbulence models were utilized to model the pipe flow, and the computational results compare favorably with previously published experimental data. Several standard turbulence models were used to analyze the flow out of the pipe onto the lower plate. It was also necessary to examine the sensitivity of the jet spreading to the type of numerical model used (turbulence model and upwinding scheme). Results show a large variation in the different models and numerical schemes. It is readily apparent that the type of model and numerical scheme selected will impact the predicted flow field.

PLANNED ACTIVITIES

The research group is continuing the experiments and analysis stated above in order to complete our tasks before the end of the project. A renewal proposal is being prepared to finalize the work accomplished so far, and to assist the SNF clean-up mission.

INFORMATION ACCESS

Updated information is available at: http://teton.if.uidaho.edu/emsp/index.html