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DYNAMIC HEAT TRANSFER EXPERIMENTS IN AN
ELECTRICALLY HEATED LMFBR FUEL ELEMENT MOCKUP¹D. N. Fry T. W. Kerlin² W. H. SidesOak Ridge National Laboratory
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Experiments were performed at the Fuel Failure Mockup Facility to obtain data for use in determining heat transfer and flow paths in simulated LMFBR fuel bundles that were operated with and without flow blockages. The heat input to one rod of a 19-rod bundle was modulated, and the temperature responses were monitored with thermocouples at various positions in the bundle. The experimental data were processed to yield frequency responses for the measured thermocouple-heater pairs.

The frequency responses showed that the measurement is sensitive to local heat transfer and flow conditions, especially for blocked bundles. However, the current state of the capability to analyze the detailed behavior of complex bundles with blockages is inadequate to provide theoretical models that will assist in interpretation of experimental results. Therefore, this report is limited to a discussion of the experimental results and the influence of bundle features on these results.

The results are grouped into two categories: steady-state, and higher-frequency. The steady-state results are obtained from the low-frequency gain, which is identical to the asymptotic response to a step input. The reason for using frequency response tests to obtain steady-state results is that, in essence, the step change is made many times and averaged to give a more precise estimate. The higher-frequency results are exploited when differences in time constants, transport delays, etc., cause the frequency dependence of the output to vary from one system configuration to another.

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The steady-state results indicate the following:

1. The steady-state gain varies with flow to the -0.75 power for thermocouples "near" the heated rod, and to the -1.7 power for thermocouples "far" from the heated rod.

2. Steady-state gains can be used to construct energy flow maps with vectors whose lengths are proportional to energy flow, relating selected heater effects to selected thermocouple responses. These maps show the edge swirl effect caused by the wire wrap spacers in the bundles.

3. The ratio of temperature increases detected by two thermocouples at two different axial positions was compared with the ratio of respective heated lengths. In an isolated, uniformly heated channel, the ratios should be equal, and deviations from equality would indicate either overcooling or undercooling. Both of these effects were observed, including a radial dependence of the ratio for thermocouples near an edge blockage.

The higher-frequency results show the following:

1. Results obtained at a point 12 in. into the heated section of a bundle with a blockage 3 in. upstream from the start of the heated length are identical with those obtained from an unblocked bundle.

2. Four different types of behavior are observed near the breakfrequency.

- a. Gains at all flow rates were different at low frequencies, but converged at higher frequencies. This behavior is observed for at least some of the heater-thermocouple pairs in all blocked and unblocked bundle tests.

- b. Gains at all flow rates were different at low frequencies, and gain vs frequency curves cross at higher frequencies. Curves that start at the lower frequencies with the lowest gain values reach values at the high frequencies that are as much as 20% higher than gains for other flows. This occurs mainly with unblocked and entrance blockage bundles.

- c. Gain curves cross as described in the preceding paragraph b., but the crossing is much more pronounced. Curves that start at the lower frequencies with the lowest gain values reach values at the higher frequencies that are three times as large as gains at other flows. This occurs only for bundles with centrally located blockages in the heated section.

d. Gains start at different values and never converge. This occurs only for bundles with edge blockages in the heated section.

Although these results were obtained for several heater-thermocouple combinations, many potential comparisons could not be made because sensors were not available in desired locations. These results indicate that this type of measurement is sensitive to changing heat transfer effects in different bundle configurations.

The data presented here provide an initial data base for any correlations of theory and experiment that will be needed should an analytical capability be developed for predicting the detailed performance of wire-wrapped bundles with internal blockages.