Validation of an Intermediate Heat Exchanger Model for Real Time Analysis*

by

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In Ref. 1, a new method was presented for LMFBR intermediate heat exchanger (IHX) analysis in real time for purposes of continuous on-line data validation, plant state verification and fault identification. For the validation of this methodology the EBR-II IHX transient during Test 8A was analyzed. This paper presents the results of this analysis.

The basic feature of the methodology of Ref. 1 is the utilization of spatial nodes whose size varies during a transient. The use of time-variant node sizes leads to adequately accurate solutions with a few nodes and consequently at short computation times. During a transient the node sizes in a one-dimensional average channel are determined from the equation

\[ Z_i = \frac{1}{y} \ln \left[ 1 + \frac{i}{n} \left( e^{yL} - 1 \right) \right] \]

where: \( Z_i \) = coordinate of the ith node upper boundary, \( n \) = total number of nodes, and \( L \) = IHX length. The parameter \( y \) is given by

\[ y = 2\pi r_o U \frac{1}{W_p C_p} - \frac{1}{W_I C_I} \]

where: \( r_o \) = outer tube radius; \( U \) = overall heat transfer coefficient; \( W_p, W_I \) = primary and intermediate sodium flow rates, respectively; and \( C \) = sodium specific heat. For the implementation of this methodology the computer code HEXA was written and was used to analyze Test 8A.

Test 8A was performed on March 28, 1979. It is characterized by a primary loss-of-flow followed by an intermediate sodium flow coastdown 17.5 s after the initiation of the transient. The initial plant conditions where:

- reactor power = 21.8 MW (thermal);
- primary IHX flow = 172.28 kg/s;
- intermediate IHX flow = 117.89 kg/s;
- primary inlet temperature = 717.37 K,

and
intermediate inlet temperature = 574.49 K. The EBR-II IHX design parameters are given in Ref. 3.

The primary and intermediate sodium flow coastdowns as well as the IHX primary sodium inlet temperature during the transient are shown in Fig. 1. The intermediate sodium inlet temperature was practically constant throughout the part of the transient that was analyzed.

In the analysis of this transient with HEXA eleven spatial nodes were used. The heat transfer coefficient of the secondary sodium, which flows through the tubes, was computed using the correlation of the SASSYS code

\[
Nu = 4.55 + 0.016 \, Pe^{0.86}
\]

where Nu is the Nusselt number, and Pe is the Peclet number. For the heat transfer coefficient of the primary sodium the Subbotin\textsuperscript{5} correlation

\[
Nu = 0.58 \left( \frac{2\sqrt{3}}{\pi} \left( \frac{P}{D} \right)^2 - 1 \right) 0.55 \, Pe^{0.45}
\]

was used, where P/D is the pitch to diameter ratio of the IHX tubes.

The predictions of the HEXA code for the intermediate sodium outlet temperature were compared with sodium temperature measurements near the intermediate outlet of the EBR-II IHX. The temperature sensor that provided these measurements was located -3 m from the IHX outlet and had a 60 s delay.\textsuperscript{2} The HEXA predictions were corrected for the transport effect from the IHX outlet to the sensor location and for the sensor delay as in the NATDEMO code.\textsuperscript{2,6} No comparisons between the HEXA predictions and measurements for the IHX primary outlet temperature were made. There were no measurements that could be quantitatively correlated with this temperature. Also, there were no temperature measurements along the length of the IHX.
The sodium temperatures measured near the intermediate IHX outlet as well as those predicted by the HEXA code for the same location are shown in Fig. 2. The agreement between the HEXA predictions and measurements is very good. The maximum difference between measurements and predictions is ~6 K.

In summary, the results of this analysis support the conclusion of Ref. 1 that the time-variant node-size approach leads to adequately accurate solutions with very few nodes.

References
Figure 2. Measured and Computed Sodium Temperatures at the Intermediate IHX Outlet.