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FFTF PIPE CHASE STREAMING EXPERIMENT*

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The present FFTF reactor design includes sodium inlet and outlet pipes which penetrate the 4-ft-thick reactor cavity wall at a height of approximately 19 ft above the top of the core. Most neutrons enter these pipe chases at a slant angle and streaming subsequent to scattering in the chase contributes an important source of neutrons to the heat exchanger vaults. Streaming of neutrons can take place along the sodium in the pipes as well as along the clearance gaps and along the low-density insulation surrounding the pipes. Two experiments have been designed to validate analytical methods which will be used to predict the flux levels in the heat exchanger vault and piping. The experimental calculation reported on here was a steel-lined concrete pipe chase and sodium-filled pipe mockup placed in a collimated neutron beam at an angle of 60 deg. The second configuration which will be reported later consists of a steel-lined concrete vault containing in one wall a mockup of the pipe penetration through the IHX shadow shield.

Experimental Measurements

Measurements at the Tower Shielding Facility have been made with nine Bonner balls¹ and the Benjamin spectrometer (hydrogen counter)² behind a 46-1/2-in.-long pipe chase mockup located 15 ft from the TSF reactor collimator exit and oriented at an angle of 60 deg from the beam axis as shown in Fig. 1.

The pipe chase consists of a 4-ft-cube concrete block with a 31-1/4-in.-diam cylindrical hole having a 3/8-in.-thick steel liner and concrete on the outside. This assembly was surrounded with additional concrete which simulated a wall through which the sodium inlet and outlet pipes might pass. The three configurations used for measurements were:

- A. Empty Pipe Chase,
- B. Sodium-Filled Pipe in Pipe Chase,
- C. Sodium-Filled Pipe and Surrounding Insulation in the Pipe Chase.

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The sodium was contained in a type 304L stainless steel pipe, 16 in. outside diameter, 46-1/2-in. long with a 3/8-in. wall thickness. The sodium

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had a density of 0.935 g/cm^3 . The insulating material (KAYLO-10STS) in configuration C extended radially from 1 in. outside of the sodium pipe to the steel chase liner.

For all three configurations horizontal Al traverses were made with nine Bonner balls at the axis elevation 24 in. behind the pipe chase. Horizontal traverses 24 in. behind the pipe chase and below the pipe axis were also made with the 5-in. Bonner ball. Axial traverses using three Bonner balls were made in the empty pipe chase.

For background measurements a water tank was placed in front, and a 12-in. LiH shield behind the assembly. In addition, some lithium loaded paraffin was placed next to the water tank on the side closest to the reactor. This setup, shown in Fig. 2, was designed to ensure that the measured background did not include neutrons transmitted through the concrete wall or the pipe chase but only those neutrons which had scattered around the wall.

Benjamin spectrometer measurements were made for the full pipe chase configuration C at three locations, 12 in. north, 12 in. south, and on the centerline at the axis elevation 24 in. behind configuration C. The off-centerline positions are approximately at the location where maxima were obtained in the Bonner ball traverses.

Calculations

The DOT-III³ code with an RZ geometry representation was used for all calculations as this is the proposed method for the FFTF shielding analysis. Because of the cylindrical symmetry required for two-dimensional calculations, comparisons should be made between the DOT results at a particular radius and the azimuthally averaged experimental results at that radius. However, the 5-in. Bonner ball results showed that the experimental average at a particular radius was equal within the experimental errors to the average of the values on the horizontal traverse at an equal distance from the pipe axis. Comparisons are presented of DOT calculations at a particular radius (distance from the pipe axis) to these average experimental values with the background subtracted.

It was found that a relatively coarse mesh (17 pts) could be used in the radial direction (across the pipe) while a relatively fine mesh (33 pts) was required down the pipe, especially in the first foot from the entrance as a consequence of the 60-deg entrance angle. A special biased quadrature set was derived for these calculations. The symmetric quadrature sets have a few azimuthal angles in polar levels near the vertical direction with a larger number of azimuthal angles in polar levels near the horizontal direction. For the empty pipe chase a dominant part of the response is due to neutrons which after one or two scatterings traverse the duct. To calculate this component it is efficient to have a quadrature biased so as to have many azimuthal angles in polar levels near the vertical and relatively fewer azimuthal angles in polar levels near the horizontal. The S-380 set is a compromise in that in each of 24 polar levels directed toward the pipe exit it has the same nine azimuthal angles.

The 50-group P_3 cross sections used in these calculations were from the library currently in use at ORNL for FFTF shield design support calculations. The multigroup processing was performed by SUPERTOG. For sodium and stainless steel 304 the updated library utilized ENDF-III data. For the constituents of the concrete and Kalo the point data was from ENDF-II.

Corrections of the order of 3 to 17% were made to the incident TSF spectrum to include the effects of 15 ft of air attenuation. Corrections were also made for the source variation across the entrance face (3%) and for the fact that the nominal calculations estimate the response at a point detector located at the center of the Bonner ball rather than on the incident hemispherical surface where the response functions are defined. The resulting size corrections to the calculated Bonner ball responses range from 2% for the 2-in. ball to 15% for the 12-in. ball.

Figures 3-5 show comparisons of the calculated and measured results for the 3, 5, and 12 in. Bonner ball horizontal traverses 24 in. behind and parallel to the exit face of all three configurations. The effect of the addition of the sodium-filled pipe to the empty chase way was to approximately halve the transmitted flux and the further addition of the insulation again approximately halved the transmitted flux.

The calculated Bonner ball traverses are in good agreement with the measured values for the seven balls ranging from the 12-in. to the 3-in. diameter ball. There is a slight disagreement in shape most marked at a radius of about 3 ft from the pipe axis but in general the agreement in shape is good. For some of the Bonner balls the calculation is higher than the experiment with the insulation in the pipe. The largest difference occurs with the 5-in. ball. Uncertainties in the chemical composition of the KAYLO 10STS insulation and in particular the water content and density lead to an uncertainty of 10% in the calculated responses.

For the other two Bonner balls which are used to determine the thermal flux the calculations are lower than experiment. For the Cd ball (2 in.) the calculation is lower than experiment by 25% for the open pipe, 15% for the pipe plus sodium and is in good agreement with the insulation present. The bare BF₃ results show a large discrepancy ranging from the calculations being 35% low for the open pipe to about 10% low for the configuration with insulation. The exact reasons for these disagreements are not presently known. The effects of thermal neutron air scattering have been investigated and determined to be on the order of 5%. The exit thermal flux appears to be dominated by contributions from incident thermal neutrons in the source and the disagreement may be due to disagreement in calibrations of the Blosser spectrometer used to measure the thermal source and the bare BF₃ used to measure the thermal flux at the pipe chase exit. Happily, the comparison disagreement is reasonably small (10%) for the full pipe chase assembly.

Figure 6 shows the calculated and measured pipe axis traverses for the 5-in. Bonner ball. The calculations are in good agreement with the measured values, and similar agreement was obtained for the 3- and 12-in. balls.

The calculated spectrum from 0.05 to 1.5 MeV for configuration C with insulation is in good agreement with the unfolded Benjamin spectrometer experimental results as seen in Fig. 7. All comparisons are on an absolute basis with the calculations being normalized to TSR II power through the previous measurements and continuous power monitoring.

Conclusions

The agreement between calculation and experiment has shown that the transport through the pipe chase of obliquely incident neutrons can be accurately calculated with the two-dimensional discrete ordinates method. A more complete description of this work will be available in a forthcoming ORNL report.

References

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Figure Captions

Fig. 1. Geometry for the First Phase of the TSF Pipe Chase Streaming Experiment.

Fig. 2. Experimental Configuration for Determination of Background Counting Rates in the Pipe Chase Streaming Experiment.

Fig. 3. Comparison of DOT Calculations with 3-in. Bonner Ball Traverses for Configurations A, B, and C.

Fig. 4. Comparison of DOT Calculations with 5-in. Bonner Ball Traverses for Configurations A, B, and C.

Fig. 5. Comparison of DOT Calculations with 12-in. Bonner Ball Traverses for Configurations A, B, and C.

Fig. 6. Comparison of Calculation and Experiment for 5-in. Bonner Ball Traverse Along Center of Empty Pipe Chase.

Fig. 7. Comparison of DOT Calculations with the Unfolded Hydrogen Counter Spectrum on Centerline 24 in. Behind Configuration C.

NOTE: DIMENSIONS
IN INCHES