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DISCLAIMER

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ABSTRACT

Solid-state track recorder (SSTR) neutron dosimetry has been conducted in the Three-Mile Island Unit 2 (TMI-2) reactor cavity (i.e., the annular gap between the pressure vessel and the biological shield) for nondestructive assessment of the fuel distribution. Two axial stringers were deployed in the annular gap with 17 SSTR dosimeters located on each stringer. SSTR experimental results reveal that neutron streaming, upward from the bottom of the reactor cavity region, dominates the observed neutron intensity. These absolute thermal neutron flux observations are consistent with the presence of a significant amount of fuel debris lying at the bottom of the reactor vessel. A conservative lower bound estimated from these SSTR data implies that at least 2 tonnes of fuel, which is roughly 4 fuel assemblies, is lying at the bottom of the vessel. The existence of significant neutron streaming also explains the high count rate observed with the source range monitors (SRMs) that are located in the TMI-2 reactor cavity.

KEYWORDS

Solid-State Track Recorders, Neutron Dosimetry, Three-Mile Island Unit 2 (TMI-2)

INTRODUCTION

Recent data at TMI-2 indicate that the void in the upper core region is substantial and that much of the displaced fuel appears to have been reduced to rubble. It is possible that significant amounts of this fuel debris have been relocated out of the core boundaries into off-normal locations. Location of fuel material is important in planning recovery operations for the TMI-2 facility.

TMI-2 fuel distribution assessments can be carried out nondestructively by gamma-ray and neutron dosimetry. In gamma-ray dosimetry, gamma-rays associated with specific fission products are measured. In neutron dosimetry, neutrons generated from a combination of spontaneous fission, (α,n) reactions, and subcritical multiplication are measured.

Existing constraints preclude the application of many routine dosimetry methods for TMI-2 fuel distribution characterization. These constraints arise from many origins, ranging from sensitivity and background considerations to practical day-to-day restrictions of TMI-2 recovery operations. Two highly specialized methods have been applied to overcome these constraints, namely SSTR neutron dosimetry and continuous gamma-ray spectrometry with a Si(Li) Compton spectrometer. A general exposition on the applicability of SSTR neutron dosimetry for TMI-2 applications has already been published (Gold et al., 1983a). Efforts to characterize the fuel distribution in the TMI-2 makeup and the purification demineralizers with SSTR neutron dosimetry and Si(Li) gamma-ray spectrometry have been successfully completed (McNeece et al., 1983; Ruddy et al., 1983a; Ruddy et al., 1983b; Gold et al., 1983b; Gold et al., 1984a). Preliminary results from the SSTR neutron dosimetry experiment in the TMI-2 annular gap have already been reported (Gold et al., 1984b).

SSTR EXPERIMENT IN THE TMI-2 REACTOR CAVITY

The SSTR dosimeters used in the TMI-2 annular gap consisted of 1.91-cm diameter mica track recorders and asymptotically thick (~0.0127 cm) ^{235}U foil, 1.27 cm x 1.27 cm. Two axial stringers were deployed in the annular gap, with 17 SSTR dosimeters located on each stringer. Of the seventeen SSTR dosimeters, 14 were bare (i.e., aluminum covered) and 3 were cadmium covered. Axial locations (elevations) of these SSTR, which are shown in Figure 1, extend from the nozzles well above the core to the flow distributor plate well below the core. The region around the nozzles was of interest, since it has been speculated that some fuel debris might be lodged in the inlet or outlet nozzles.

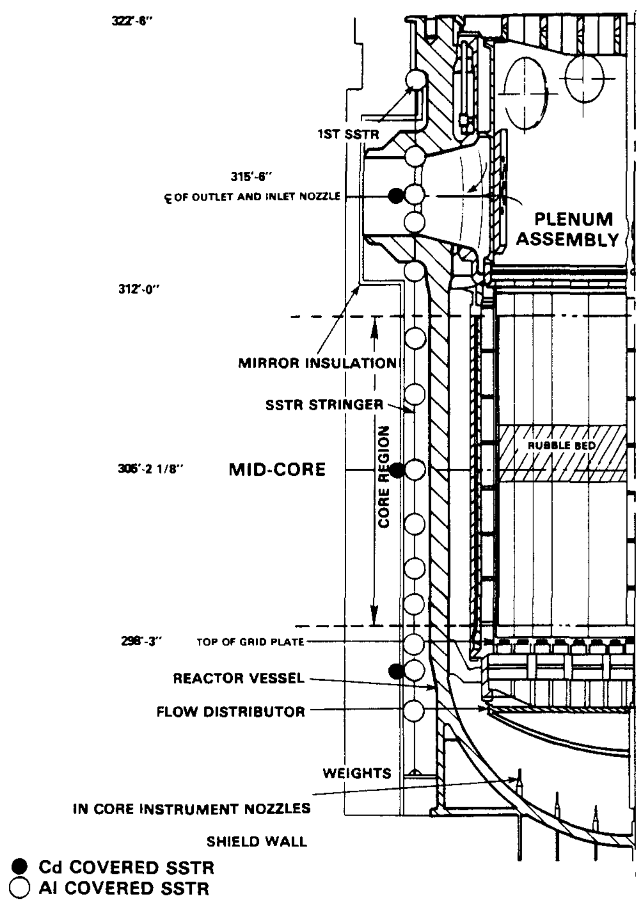

FIGURE 1. Deployment of SSTR Neutron Dosimeters on an Axial Stringer in the TMI-2 Annular Gap. Neg 8501182-1

Azimuthal locations of these two stringers, the east (E-SSTR) stringer and the west (W-SSTR) stringer, were chosen near the source range monitors (SRMs). The count rate of the SRMs are roughly an order of magnitude higher than normal. The location of the SSTR stringers was chosen so that some insight into the origin of this high count rage might be provided by the SSTR dosimetry data.

These SSTR stringers were exposed in the TMI-2 annular gap for approximately three weeks, from August 19, 1983 until September 9, 1983. After retrieval, they were shipped to Hanford and processed. Preliminary appraisal of these SSTR was completed within a week and revealed track densities that were high enough to provide quantitative results. Manual scanning of these SSTRs has now been completed.

ANALYSIS OF SSTR EXPERIMENTAL RESULTS

Absolute thermal neutron fluxes obtained from these SSTR data are plotted in Figure 2 in comparison with the thermal flux anticipated for the TMI-2 reactor cavity. The curves labeled M=2 and M=4 correspond to a core multiplication of 2 and 4, respectively. These curves were obtained by scaling of radiometric dosimetry conducted in the ANO-1 reactor cavity (Cogburn et al., 1984; Newton et al., 1984), a Babcock and Wilcox (B&W) plant of similar design to TMI-2. Normal shutdown neutron multiplication for such a B&W plant is M=12. However, the high concentration of borated water and the redistribution of the core lower the multiplication at TMI-2 down to the approximate range: $2 \lesssim M \lesssim 4$.

These TMI-2 annular gap results differ significantly in shape and magnitude from the thermal flux anticipated from an undisturbed core with similar borated water concentration and burnup. The TMI-2 thermal flux intensity exceeds the anticipated intensity by roughly an order of magnitude at high elevations and this difference grows with decreasing elevation to more than two orders of magnitude at the flow distributor elevation. In contrast with the axial symmetry one would expect about midplane, as is observed in the ANO-1 radiometric dosimetry data, the SSTR data for TMI-2 is clearly asymmetric.

The SSTR vertical profile of the neutron intensity is consistent with the presence of a significant amount of fuel debris lying at the bottom of the reactor vessel. Neutrons from this quantity of fuel can pass essentially unmoderated out of the reactor vessel into the concrete cavity beneath the vessel. There, they are moderated within the concrete and stream upward through the annular space between the vessel and the biological shield. A

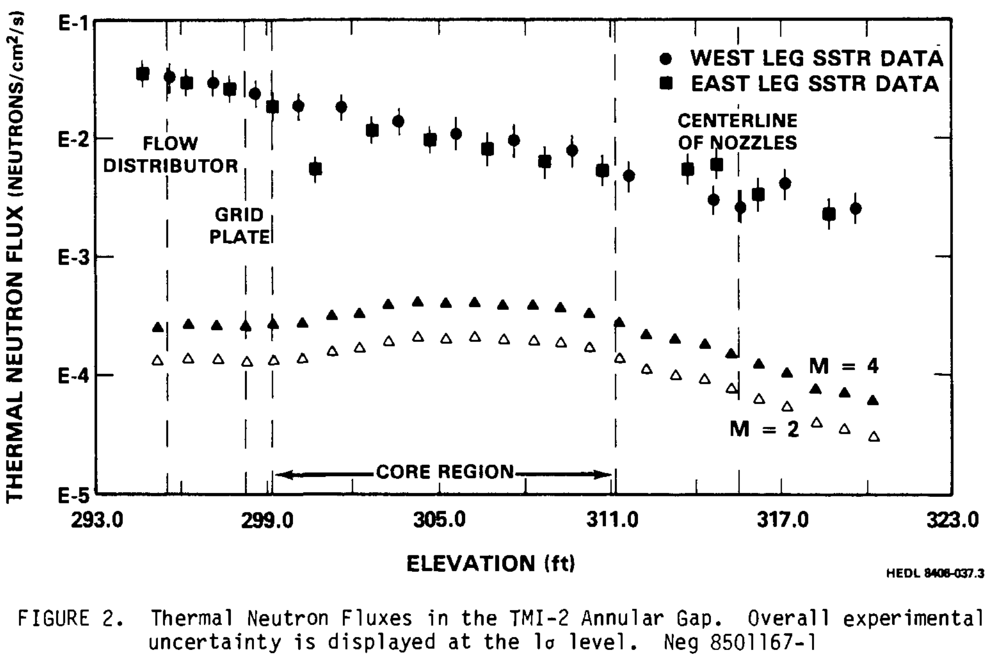

FIGURE 2. Thermal Neutron Fluxes in the TMI-2 Annular Gap. Overall experimental uncertainty is displayed at the 1σ level. Neg 8501167-1

lower bound for the quantity of fuel lying at the bottom of the reactor vessel has been estimated from these annular gap results and calibration efforts performed for the TMI-2 demineralizer A experiment (Ruddy et al., 1983a; Ruddy et al., 1983b). This lower bound estimate is approximately 2 tonnes of fuel, which corresponds to a fuel equivalent of at least four fuel assemblies lying at the bottom of the reactor vessel.

These SSTR data show that the count rate of the SRMs, which are located near midplane in the reactor cavity, should be considerably higher than normal. It is recognized that the existence of significant neutron streaming must be taken into account for proper interpretation of SRM data in TMI-2 recovery operations.

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