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Nuclear Heating in Reference ZrH Reactor Shield

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ABSTRACT

Internal heat generation in the conceptual design shield was found to be 7.82 kw. This is about half the preliminary estimate made during the shield materials trade study. Spatial distribution of this heating is presented so that heat transfer calculations may be performed and shield operating temperatures determined.

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Introduction

As a result of a shield materials trade study,⁽¹⁾ a reference shield concept was selected.⁽²⁾ The reference concept⁽³⁾ has a 0.5-in. tungsten gamma shield followed by a 8.5-in. lithium hydride neutron shield at the side and top of the reactor. At the bottom of the reactor, toward the space station, there is a 6.5-in. lead gamma shield followed by a 22.0-in. lithium hydride neutron shield above the equipment gallery. Below the gallery there is a 3.2-in. uranium gamma shield followed by a 11.6-in. lithium hydride neutron shield.

As a part of the materials trade study, shield operating temperatures were computed.⁽⁴⁾ The most critical situation for the reference shield occurs in the LiH side section where the estimated operating temperature is about 1230°F, which is close to the LiH melting temperature of 1270°F. This result was based on a total energy deposition in the shield of 14.6 kw. Since this value was derived for a materials trade study, it had been estimated pessimistically, i.e., on the high side.

In May, ORNL ran a combined neutron and photon, two-dimensional (r,Z) transport calculation (DOT) for the reference ZrH reactor and shield. From the computer output AI calculated the total energy deposition as 3.96 kw. Since this value disagreed significantly from the preliminary AI estimate and because of its consequence on shield temperature, the DOT output was reviewed and it appears that different neutron absorption cross sections for lithium hydride had been used for the flux calculation and for the energy deposition "activity." ORNL is currently investigating the discrepancy.

The purpose of this study is to establish a current reference set of nuclear heating values in the shield in order that more detailed thermal analysis can be initiated.

Discussion

Gamma Heating

The original AI estimate of gamma heating in the shield was based upon point-kernel-integration methods (QAD) for the reactor gammas and secondary gammas due to neutron capture in the shield were taken to be completely self absorbed at their point of origin. Both of these factors tend to overestimate the magnitude of gamma heating in the shield. The ORNL/DOT calculation uses photon transport methods which more accurately represent the flux in the reactor and shield regions for both primary and secondary gammas. In their analytical model it is not possible to separate the total into various components. Also, since the DOT output contained only the spatial distribution of the gamma heating and did not include region summaries, a small computer code was written to perform the integration. The DOT results were used exclusively as a basis for this set of gamma heating values.

Neutron Heating

Because of the heating activity errors in the DOT (2-D) results, a series of ANISN (1-D) cases were set up. Separate models were used for 1) radial, 2) axial-up, and 3) axial-down. Since the DOT flux calculation appears to be correct, the ANISN models were "tuned" until the fluxes in the three directions agreed. The most convenient measure of agreement is neutron dose since the codes calculate the spatial distribution of the multigroup integration. Figures 1 thru 3 show that the AI/ANISN neutron models are an excellent average of the ORNL/DOT model. Consequently, they can be confidently used to calculate neutron energy deposition in the shield.

Results

Figures 4, 5, and 6 show the spatial distribution of the gamma and neutron heating components for the side, top, and bottom shields, respectively. Figure 7 shows the total heating distribution in the shield. Table 1 lists the total heating in each shield section by neutrons and gammas. The total energy deposition in the shield is 7.82 kw. This indicates that the preliminary AI value was high by about a factor of 2.

FIG. 1
NEUTRON DOSE
SIDE SHIELD

FIG. 2
NEUTRON DOSE
TOP SHIELD

FIG. 3
NEUTRON DOSE
BOTTOM SHIELD

FIGURE 4

NUCLEAR HEATING

SIDE SHIELD

600 KW REF ZRH REACTOR

FIGURE 5

NUCLEAR HEATING
TOP SHIELD
600KW REF 2RH REACTOR

FIGURE 6
NUCLEAR HEATING
BOTTOM SHIELD
600 KW REF 2RH REACTOR

FIGURE 7

SHIELD NUCLEAR HEATING
600 KW REF ZPH REACTOR

TABLE I

SHIELD NUCLEAR HEATING
600KW REF 2RH REACTOR

SHIELD SECTION	THICKNESS & MATL	TOTAL HEATING , KW		
		GAMMA*	NEUTRON†	TOTAL
SIDE	0.5" W	1.47	—	1.47
	8.5" LiH	0.27	3.70	3.97
TOP	0.5" W	0.40	—	0.40
	8.5" LiH	0.08	0.70	0.78
BOTTOM	6.5" Pb	0.43	0.11	0.54
	22" LiH	0.03	0.63	0.66
				7.82

* ORNL / DOT

† AI / ANISN

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