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NEUTRON AND GAMMA-RAY STREAMING CALCULATIONS FOR THE ETF NEUTRAL-BEAM INJECTORS*

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The tritium plasma of the Engineering Test Facility (ETF) fusion reactor will be heated and ignited by the injection of neutral deuterium. Since the deuterons must be injected through straight ducts into the plasma, the neutron and secondary gamma radiation produced as a result of the D-T reactions will stream directly into the neutral beam injectors and lead to adverse effects in vital components. The radiation leaking through the injection ports will be comprised of ~14 MeV neutrons (from the D-T reactions) plus a low-energy neutron and secondary gamma ray distribution that results from the interactions of the energetic neutrons with the plasma liner and the primary shielding about the torus. In this paper two-dimensional radiation transport calculations carried out to estimate the effects on the injector components of radiation streaming through the injection duct will be described and the results of these calculations will be presented and discussed.

The analysis was performed using the current ETF plasma dimensions, shielding configuration and composition, and operating scenario.[1] The neutral beam injectors were assumed to be the same as those proposed for use with the Tokamak Fusion Test Reactor (TFTR)[2] but appropriately modified to couple with the injection duct configuration of the ETF. The components

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of the injector, i.e., bending magnet, calorimeter, baffles, and cryocondensation pumping panels remained the same as those described in Ref. 2.

The radiation environment within the injector and duct shielding depends upon the spatial, angular, and spectral distributions of the radiation entering the injector duct. This radiation is comprised of particles that enter the injector duct at the first wall and either stream directly into the injector or undergo collisions in the duct shield and then scatter into the injector. To approximate the radiation source, the plasma was divided into two regions. The first region was taken to be the volume of the plasma which is viewed from a point on the duct centerline at the injector entrance. Particles that originate in this volume can stream directly into the injector without undergoing collisions in the injector duct shield. The remaining plasma volume was taken to be the second source region. Particles originating in this volume undergo collisions in the primary torus shield or the injector duct shield before entering the injector.

The radiation originating in the viewed volume of the plasma was approximated using a point source located at the intersection of the plasma and injector duct centerlines. The radiation originating from the remainder of the plasma volume was approximated using a ring source located at a radial distance of 1.05 m from the intersection of the plasma and injector duct centerlines. For large duct length to duct diameter ratios (L/D), the point source gives rise to radiation levels at the injector entrance that closely approximate the levels due to the viewed plasma volume provided the magnitude and spectral shape of the point source are properly chosen. The validity of using a ring source depends on the proper choice of its location as well as its magnitude and spectral shape. Locating the ring source at 1.03 m from the duct centerline represents a conservative location. Since most of the unviewed volume of the plasma is at radial distances greater than 1.03 m, the selection of this location enhances the probability that particles originating in the unviewed plasma region will enter the injector.

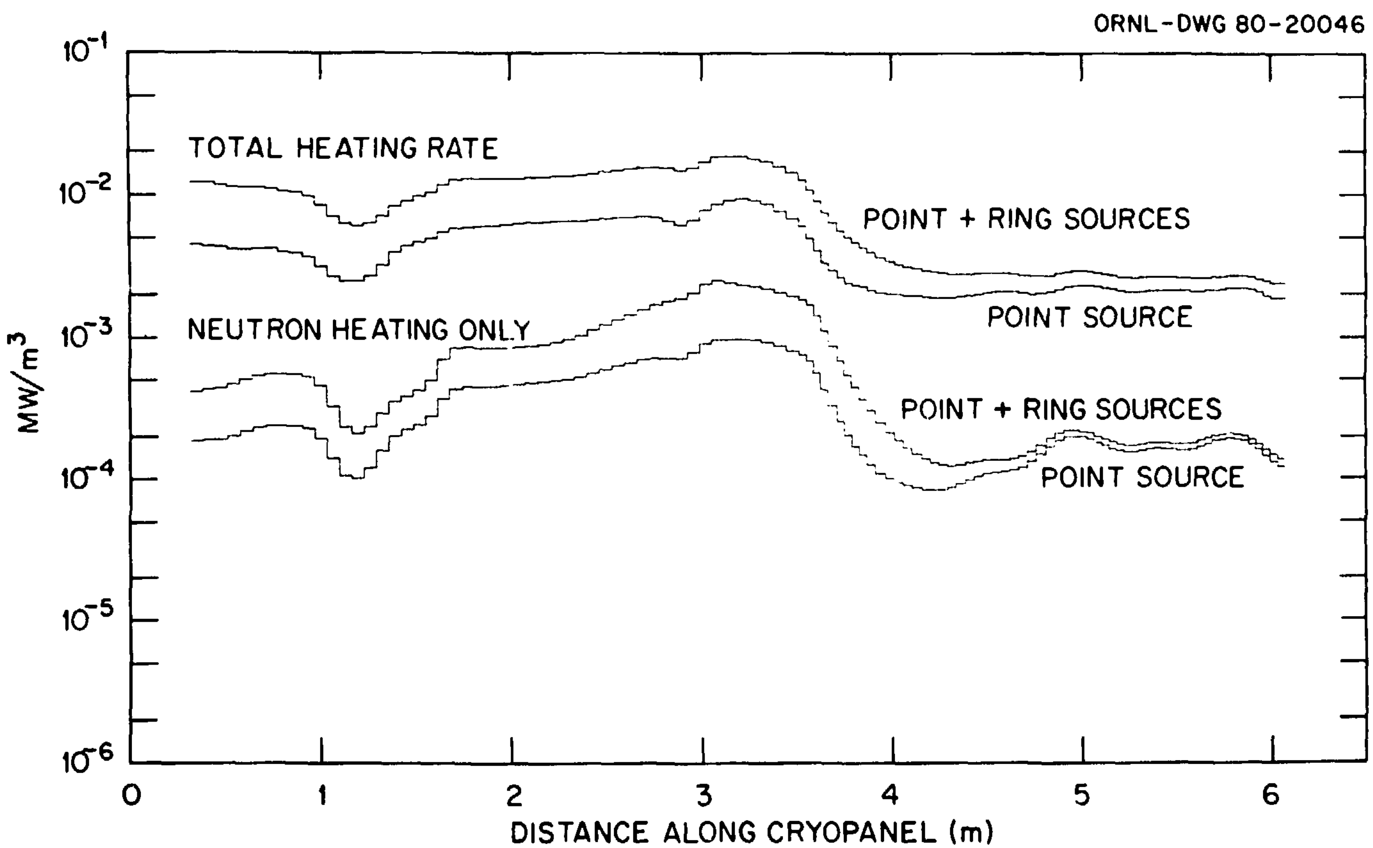
The magnitude of the uncollided 14 MeV neutron component of the point source was obtained by considering the ratio of the viewed plasma volume to the total plasma volume. The magnitude of the uncollided 14 MeV neutron component of the ring source was obtained by conserving the total neutron wall loading of 2.4 MW/m^2 at the center of the entrance to the injector duct. To obtain the spectral shape of both the point and ring sources, a one-dimensional discrete ordinates calculation was performed using ANISN[3] with the 14 MeV D-T neutron source (i.e., the plasma region) and the primary shield surrounding the plasma modeled as infinite cylinders about the toroidal axis of the ETF. The details of obtaining these distributions will be discussed in the presentation.

The radiation transport calculations were performed using the two-dimensional discrete ordinates code DOT IV.[4] These calculations were carried out using a relatively low order S_8 angular quadrature set. Since this quadrature set is not capable of treating radiation streaming, particularly through ducts with large L/D's, the DOT code was used in conjunction with the first flight estimation code GRTUNCL.[5]

In both the one- and two-dimensional procedures, the radiation transport was performed using a 35-neutron and 21-gamma-ray energy group transport library. These data were obtained by collapsing the 100-neutron, 21-gamma-ray energy group VITAMIN-C (ENDF/B-IV) data set.[6] The angular dependence of the group-to-group transfer coefficients was treated using P_3 Legendre expansions. The neutron and gamma ray kerma factors were generated using the MACK[7] and SMUG[8] codes, respectively.

The calculated instantaneous nuclear heating rates as a function of distance along the cryocondensation pumping panel in the ETF neutral beam injector are shown in Fig. 1. Two pairs of curves are plotted. The upper pair of curves show the total heating rate (due to neutrons plus gamma rays) and the lower pair of curves show the heating rate due to neutrons only. For each pair of curves, the upper curve shows the response due to the combined contributions of radiation from the point and ring sources and the lower curve is the heating rate due to the point source only. The heating rates are normalized to a neutron loading on the first wall of 2.4 MW/m^2 and are obtained assuming the cryopanels are composed of stainless steel type 316.

Calculated results of the instantaneous dose rate in the ion gun insulators has also been obtained and will be presented.



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TOTAL HEATING RATE
POINT + RING SOURCES
POINT SOURCE
NEUTRON HEATING ONLY
POINT + RING SOURCES
POINT SOURCE
MW/m³
10⁻¹
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
0
1
2
3
4
5
6
DISTANCE ALONG CRYOPANEL (m)

Figure Caption

Fig. 1. Energy deposition rate (MW/m^3) as a function of position along the neutral beam injector cryopanel.

References

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