PREFACE

FUSION DEVICE RADIATION STREAMING AND SHIELDING

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It has been a pleasure to work with the staff of *Nuclear Technology/Fusion* (*NT/F*) in the effort to present the following collection of papers from the 1981 American Nuclear Society (ANS) Miami Beach meeting special session entitled "Penetration Shielding Problems of Fusion Devices."

The subject for this special session was first suggested at a Radiation Protection and Shielding (RP&S) Division program committee meeting in late 1979, in recognition of the increasing impact of radiation streaming on shield design and plant operation and maintenance in such projects as the Engineering Test Facility (ETF), STARFIRE, and the International Tokamak Reactor (INTOR). The basic problem addressed is that fusion reactors require numerous penetrations into the plasma vacuum vessel to transmit vital services such as neutral beam injection, radio frequency heating, impurity control, vacuum pumping, fuel injection, and diagnostics. Unfortunately, in contrast with most fission reactor penetrations, the fusion penetrations are generally void. Furthermore, there is no self-shielding of the source region whatsoever. Thus, streaming of 14-MeV neutrons as well as all the down-scattered neutrons and secondary gamma rays along these penetrations is intense. Effectiveness of the bulk shield, if present, is greatly reduced by the transport of radiation through the penetrations. Usually, the outlying components and their duct connections with the vacuum vessel must also be shielded. Thus, all the considerations of radiation heating, damage, and activation must also be applied to all these components as well as those in the bulk shield or vessel region. The design problems extend beyond just neutronics, impacting greatly on the total capital cost of the plant.

Although neutronics calculations had already been done for Tokamak Fusion Test Reactor (TFTR) streaming by Ku at Princeton Plasma Physics Laboratory (PPPL) and Alsmiller's group at Oak Ridge National Laboratory (ORNL), and both neutronics and economic studies on TNS by Abdou's group at Argonne National Laboratory, a community forum on this subject appeared desirable. After extensive discussions, the RP&S Division program committee decided to organize a special session for the ANS annual meeting in June 1981 with the Fusion Energy Division as a cosponsor.

A tentative list of invited speakers was drawn up, representing the ETF, Fusion Materials Irradiation Test (FMIT) facility, INTOR, Joint European Torus, Mirror Fusion Test Facility, SOLASE, STARFIRE, TFTR, and ZEPHYR concepts and/or projects. Formal invitations were sent out in October 1980.

The response to the special session invitations was gratifying. A total of nine papers were presented along with a tenth streaming paper that was submitted to the adjacent session. Of these, six have been prepared in full form for *NT/F*. For convenience to the reader, the key aspects of these papers are briefly summarized below.

1. "ETF Vacuum-Pumping-Duct Shield Analysis," W. T. Urban [Los Alamos National Laboratory (LANL)], T. J. Seed (INESCO), D. J. Dudziak (LANL)

   A novel coupling of the MCNP Monte Carlo code and the TRIDENT-CTR discrete ordinates code to calculate the transport of neutrons and gamma rays from the ETF torus, along the neutral beam injector (NBI) duct, and out the vacuum pumping duct. Flux calculations were carried out through the duct shielding.

2. "Radiation Streaming Calculations for INTOR-J," Y. Seki, H. Iida (Japan Atomic Energy Research Institute), R. T. Santoro (ORNL), H. Kawasaki (Century Research Center Corporation Ltd.-Japan), M. Yamauchi (NAIG Nuclear Research Laboratory-Japan)
   The effects of radiation streaming through the throat and NBI port of the INTOR-J design were investigated using the MORSE-GG Monte Carlo code. Some new features of MORSE were utilized that permitted point detectors in the presence of reflective planes.

3. "Neutron Streaming Analysis for Shield Design of the FMIT Facility," L. L. Carter (Hanford Engigineering Development Laboratory)
   Some clever MCNP Monte Carlo techniques are described in this paper. Streaming problems at FMIT are particularly challenging in that they involve very high energy neutrons, long ducts with large length-to-diameter ratios, and many orders of magnitude attenuation. A new angular biasing approach is proposed.

4. "Prompt and Delayed Radiation Shielding Calculations for the ZEPHYR DT Ignition Experiment," A. Fischer, E. Fischer (University of Stuttgart), H. Krause (Max-Planck Institute)
   Before its cancellation by the German government, ZEPHYR had been the subject of a number of recent reports that attempt to document various aspects of the design effort. Extensive radiation transport analyses are described in this paper, including the effects of streaming through penetrations in the 70-cm "torus" shield.

5. "Neutronic Calculations for the TFTR Diagnostic Penetrations," L. P. Ku, J. Kolibal (PPPL)
   Very little radiation analysis has been done on small penetrations in fusion shields, such as diagnostics and fueling. These authors utilized a Monte Carlo method to evaluate streaming through 3-cm-radius diagnostic tubes in the concrete floor below the TFTR.

6. "Neutron and Gamma-Ray Streaming Calculations for the ETF Neutral Beam Injectors," R. A. Lillie, R. T. Santoro, R. G. Alsmiller, Jr., J. M. Barnes (ORNL)
   Done in support of the 1980 ETF project, this work used the two-dimensional DOT discrete ordinates code to calculate neutron and gamma-ray streaming through the NBI drift duct and the resulting cryopanel heating rates. Instantaneous dose rates to the insulators were also calculated.

It is hoped that publication of this collection of papers will stimulate further interest and inquiry among the fusion community in the challenging problem of fusion device radiation streaming and shielding. Also, it appears that these papers provide design information that can, in some cases, be used to help solve shielding problems for a variety of fusion devices.

The splendid cooperation of the authors in preparing these papers in the face of a tight time schedule is gratefully acknowledged. Likewise, the willingness of reviewers to respond quickly is appreciated. Also, the support and help of the RP&S Division program committee was essential to the success of this effort. Last, but not least, is the cooperation of the *NT/F* editorial staff.