WP 09-10

MATERIALS SCIENCE RESEARCH IN FDF

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Submitted to the
DOE ReNeW Process for
Posting on the ReNeW Website

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February 20, 2009

GENERAL ATOMICS

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The FESAC Planning Panel Report states under **Materials Science in the Fusion Environment:**

"Understand the basic materials science for fusion breeding blankets, structural components, plasma diagnostics and heating components in high neutron fluence areas."

With neutron fluence at the outer midplane of 1–2 MW/m^2 and a goal of a duty factor on a year of 0.3, FDF can ***produce fluences of 3–6 MW-yr/m^2*** in 10 years of operation onto complete blanket structures and/or material sample volumes of about 1 m^3. FDF can enable **irradiation qualification of materials** in port material sample exposure stations. This level of fluence should enable qualification of at least the first few years of DEMO operation.

Materials Science: With fluences of 3–6 MW-yr/m^2 (dpa of about 30–60, perhaps more), FDF can make a significant contribution on relatively large, fully integrated and engineered components. FDF could take two ports and fill each with about a cubic meter of samples including welds and small assemblies and leave them there in controlled conditions for 10 years to accumulate a fluence of 3–6 MW-yr/m^2. Samples can be removed periodically to accumulate data versus dose.

PFC and Divertor Materials Lifetime: The issue here is erosion of plasma facing surfaces. With ten times greater plasma fluence onto surfaces, FDF will make a major contribution.

FW/Blanket Materials and Components Lifetime: This issue could be phrased much more broadly. Fusion has yet to capture its first fusion neutron in a blanket. Everything in combined first wall/blanket development remains to be done experimentally. FDF will test whole, real size first wall/blanket structures with significant neutron fluxes and fluences, relevant first wall heat and plasma fluxes, and in a real system with disruptions and other challenges. FDF will be designed with the flexibility and maintainability to allow ten test blanket variations to be tested in 10 years and 1–2 changeouts of the main full tritium producing blanket. Further, first wall materials and structures and near first wall components like rf launchers and diagnostics will be developed in a fusion relevant environment. FDF will be a test bed for learning how to engineer reliable first wall/blanket structures and make first efforts on reliability growth.

Materials Testing Research Plan in Port Blanket Sites

If the issue of material testing is put as obtaining potential lifetime irradiations of materials (>150 dpa), then only IFMIF can produce the required fluence, albeit only into a 0.5 liter volume of test articles. However, with fluences of 3–6 MW-yr/m^2 (dpa of about 30–60) as shown in Fig. 3-1, FDF can make a significant material science research contribution in two different types of available testing conditions. The first one is on the relatively large fully integrated and engineered components such as the main tritium module and the test port module. Key issues of material properties, thermal stress, cyclic stress, compatibility, safety, induced radioactivity, nuclear waste and disposal, radiation damage, and lifetime limits as a function of neutron fluence for the first wall and blanket components can be addressed. Unique RAMI data can be collected.

The second type of testing is for multiple sample material science research. FDF could have two ports — each filled with about a cubic meter of samples including welds and small assemblies and expose them under controlled conditions for 10 years to accumulate a fluence of 3–6 MW-yr/m^2. Samples can be removed periodically to accumulate data as a function of fluence and specific control temperatures and fluid flow conditions. Basic material damage phenomenon for metallic structural materials as indicated in Table 1-1 can be provided. Advanced fusion relevant high performance alloys like ODFS, V-alloy, W-alloy, SiC/SiC composite, and SiC-foam as flow channel insert, tritium barriers and electrical insulators can also be tested to high fluence and under controlled exposure conditions. Depending on the specific material testing requirements, additional tests on key issues of thermal stress, compatibility, safety, induced radioactivity, nuclear waste and disposal, radiation damage, and lifetime limits as a function of neutron fluence for the first wall and blanket components can also be addressed in the relative large available testing port volume from FDF.

Table 1-1
Damage Phenomenon for Metallic Structural Materials in the Fusion Environment
(Courtesy of R. Kurtz, PNL)

Damage Phenomenon	Temperature Range, Fraction of Melting Point	Dose Level, dpa
Hardening & Embrittlement	<0.3	0.1
Phase Instabilities	0.3 - 0.6	>1
Irradiation Creep	<0.45	>10
Volumetric Swelling	0.3 - 0.6	>10
He Embrittlement	>0.5	>10
Volumetric Swelling, Irradiation Creep, & Thermal Conductivity Change in SiC	<0.4	0.01