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AN APPROACH TO TESTING FUSION COMPONENTS IN EXISTING NUCLEAR FACILITIES*

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A new approach for testing fusion reactor components in existing nuclear facilities is presented. The concept features a large test volume, and thermal and radiation fields similar to those expected from fusion.

There is a need to test components of developmental fusion devices in environments representative of those expected in fusion applications. This is particularly true of first wall/blanket/shield (FW/B/S) components where the interactions of radiation fields, dynamic loadings and thermal cycling are not well understood.[1] Obtaining those features from a fusion device will not be realizeable in the near future. However, the need to simulate a fusion environment as closely as possible remains a valid goal. An additional goal is to have a test volume large enough to enable testing of representative blanket modules and/or subsystems for synergistic effects.

The concept presented makes use of the fast spectrum in the Engineering Test Reactor (ETR) at the Idaho National Engineering Laboratory (INEL). Preliminary results show that an asymmetric, nuclear test environment with particle and radiant energy fluxes impinging on a first wall/blanket or divertor surface appears feasible in a neutron/gamma field not greatly different from that seen by a representative first wall/blanket module.

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The neutron energy distribution in a typical blanket module outer wall has been calculated (Figure 1) and, with the exception of the 14 MeV spike, the ETR fission spectrum is remarkably close to the fusion spectrum expected. The bulk heating from the ETR nuclear environment can be much higher than the anticipated heating of several typical blanket concepts. Although the shape of the ETR bulk heating curve is different from the others[2-5] shown in Figure 2, it can be modified using flux shields, reactor power, lithium-6 depletion, etc. to obtain a representative configuration and level.

Surface heat and particle loads are provided by a layer of ^{3}He undergoing (n,p) reactions with incident thermal neutrons. Estimates are that up to 150 kW/m^2 thermal load and up to 25 kW/m^2 fast particle load can be obtained at the surface of a blanket module exposed to the ^{3}He. Even greater fast particle heat fluxes can be obtained for materials evaluations at the outer boundry of the ^{3}He layer. This loading comes in the form of protons and tritons striking the surface at energies representative of fusion plasma particles.

Fusion radiation damage to materials is often described by the ratio of trapped He (appm, usually from n,α reactions) to atomic displacement per atom (dpa) brought about chiefly by neutron collisions. The He/dpa ratio anticipated in fusion applications is typically orders of magnitude greater than that produced in a fission spectrum for non-nickle materials.[6] To simulate this parameter as well, it is observed that tritium produced in the ^{3}He layer will readily permeate most materials considered for FW/B/S applications.[7,8] Some of this will decay into ^{3}He and become locked into the structure. Some of the locked ^{3}He will in turn be converted back to tritium by the neutron flux. Hence, by properly controlling the tritium concentration in the ^{3}He heating layer for the material and neutron flux employed, it appears possible to simulate the He/dpa ratio and thus get a reasonable estimate of material response in fusion environments. Experimental data from other facilities such as RTNS-II and FMIT will still be required to benchmark results.

The advantage of the present concept is that test volumes of tens of liters are available. Entire components can be tested under the combined environments of bulk heating, radiation, pressure oscillations and particle fluxes. By moving this test facility in and out of a fission core, the cyclic nature of the thermal loading can be simulated. Thus it appears possible to study the combined effects of neutron and gamma radiation, surface particle fluxes and true volumetric heating on the components of a fusion first wall/blanket using the environment of a modified fission reactor.

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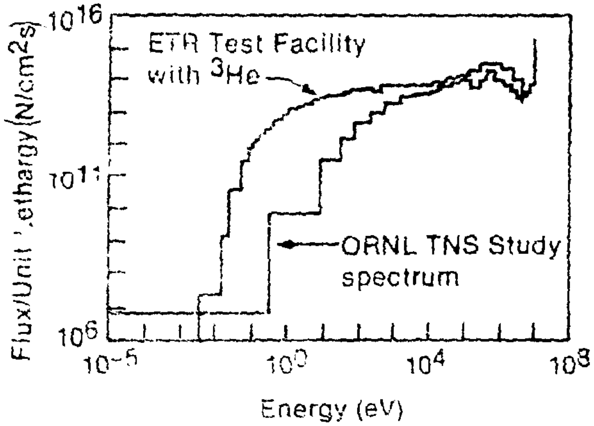
Figure Captions

Figure 1. Comparison of expected fusion first wall neutron spectrum with that anticipated in ETR FW/B/S test.

Figure 2. Comparison of bulk heating rates for several proposed blankets with the heating rate available in the ETR.



ETR Test Facility
with ^{3}He
ORNL TNS Study
spectrum
Flux/Unit Lethargy (N/cm^{2}s)
10^{16}
10^{11}
10^{6}
10^{-5}
10^{0}
10^{4}
10^{8}
Energy (eV)

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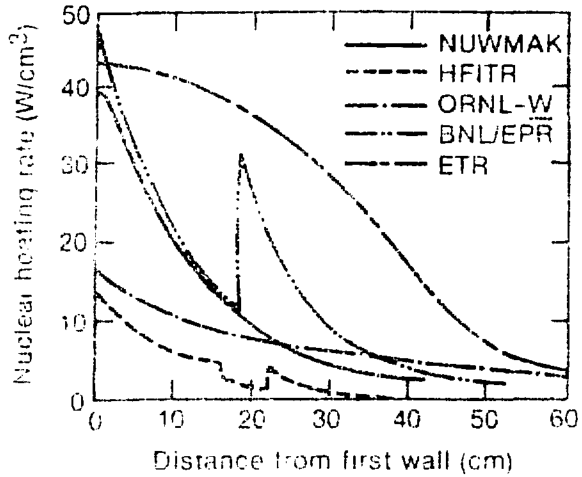

NUWMAK
HFITR
ORNL-W
BNL/EPR
ETR
Nuclear heating rate (W/cm³)
Distance from first wall (cm)
0
10
20
30
40
50
60

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