Impact of Tritium Removal and He-3 Recycling on Structure Damage Parameters in a D-D Fusion System

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**Background**
- In a catalyzed D-D system with all produced tritium allowed to burn, several numbers of DD and DT neutrons are generated and neutrons carry 38.5% of the fusion energy. Produced DT neutrons could lead to considerable structural radiation damage limiting lifetime of chamber components.

- Several conceptual designs were presented in the past for catalyzed D-D commercial fusion plants (e.g., WILDCAT, SATURN).

- We propose developing large D-D magnetic fusion power plants where amount of tritium allowed to burn is systematically varied.

- Significant reduction in neutron flux is achieved in DT systems with tritium recycling.

- Other key material parameters are similar for the different structural materials.

**Description of Analysis**
- Structural material candidates considered:
  - SiC/SiC composite
  - Ferritic steel alloy 9Cr-2WVTa
  - V4Cr4Ti
  - LiC cooled vanadium alloy
  - Water cooled ferritic steel (FS) with Li2O blanket

- Peak radiation damage parameter determined also for a water cooled FS shield in the D-D system.

- Damage parameter calculated at neutron displacement rates, fission production rates, and thermal neutron transmutation of boron rates.

- For purposes of comparing results to those in a DT system, we normalized to same damage parameter that corresponds to a peak neutron wall loading of 50 dpa in a DT system.

**Neutron Production in D-D System**
- Significant reduction in fraction of energy carried by neutrons and spectrum softening achieved with a large amount of tritium being removed.

**V4Cr4Ti**
- Recycling He-3 obtained from decay of removed tritium also results in additional moderate reduction of fraction of fusion energy carried by neutrons.

**SiC/SiC Composite**
- Some of tritium removed is recycled as He-3.

**Ferrite Steel**
- Neutron production rate and total transmutation or burnup rate and Fraction of Tritium Removed
- Damage parameters calculated are atomic dpa, He appm, and neutron backscattering.

**Observations and Conclusions**
- Removing tritium produced by D-D fusion and recycling part of it after it decays to He-3 significantly reduces fraction of fusion energy carried by neutrons and softens the neutron energy spectrum.

- Relative effects on damage parameters are similar for the different structural materials.

- For a catalyzed D-D system (no tritium removal), peak dpa rate in candidate structural materials is 25-35% lower than that in an equivalent D-T system and gas production and transmutation rates are ~66% lower.

- As tritium is removed, gas production and transmutations decrease by more than two orders of magnitude and the dpa rate decreases by a factor of 2.3-2.8.

- An additional reduction of a factor of 1.6-1.7 in damage parameters is achieved by recycling the removed tritium as He-3.

- He appm drops below one when more than 75% of tritium is removed.

- Removing the produced tritium from the D-D system results in dpa and He production rates that approach values in fusion reactors.

- Information from tests in fusion reactor spectros will be useful in determining lifetime of structural materials.

- In addition to enhancing structural material lifetime, safety and environmental characteristics will improve.