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Fusion Safety and Environmental Opportunities Afforded by ITER

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ITER FORUM

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Areas of Interest

- Regulatory Support and Design Integration
- Safety Analysis and Safety Computer Code Verification and Validation
- Tokamak Dust Source Term and Chemical Reactivity
- In-vessel Tritium Source Term
- Verification Activities During Operation

Regulatory Support and Design Integration

- Precedent is very important in regulatory matters
- Specific regulatory requirements imposed by the host on ITER can have ramifications for ANY future fusion facility built anywhere in the world
- US safety team needs to be actively engaged in discussions with the ITER safety team and the regulatory authorities to “push back” on requirements that do not make sense for fusion
- US goal is to obtain maximum operational flexibility for ITER, given its experimental nature, yet still meet a set of regulatory requirements that make sense for fusion
  - When ITER enters the operations phase, limits may be placed on operation based on the traditional fission approaches. This could potentially hinder future operations. US needs to be involved here.
- Safety/design integration is also an area where the US has been strong. Integration of safety requirements into the design in a rational coherent manner is very important to retain maximum flexibility and still have an adequate safety envelope for operations

Safety Analysis and Safety Computer Code Verification and Validation

- ITER FEAT safety report is based on the safety report report developed in the EDA
- Many of the calculations were performed using US state of the art fission computer codes (e.g. MELCOR) and codes written specifically for fusion(TMAP4,MAGARC)
- Updates of the INEEL developed fusion specific modifications need to be integrated into the latest version of the MELCOR code for future safety analysis
- Application of MELCOR to a limited set of key accident sequences would be a useful verification exercise and enhance the quality of the ITER safety documentation

Safety Analysis and Safety Computer Code Verification and Validation

- Greater participation in validation studies of the codes used in the ITER safety analysis is necessary
- All regulators expect codes used in the safety analysis to be verified and the results validated
- US needs to be more involved in the current international thermal-hydraulic benchmark and experiment validation program developed under IEA auspices
- US involvement has been limited because of budget constraints
- Benchmarking of such codes is in the long term interest of the US because it will support future fusion designs
- Additional support is needed by the ITER team in the area of magnet arcing. US codes are unique in their ability to model such events from a safety perspective

Tokamak Dust Source Term and Chemical Reactivity

- Dust is one of the two principal radioactive source terms for ITER
- Characterization of size and steam reactivity of dust is very important in the safety analysis
- US/INEEL was heavily involved in establishing the particle size distribution and specific surface area of dust collected from tokamaks worldwide
- Additional uncertainties still remain on the distribution of very small particles (< 0.5 microns). New characterization techniques and dust formation modeling may help ease the limits currently envisioned to be imposed on ITER.
- Additional work is needed to measure the chemical reactivity of dust

Dust Limits in ITER-EDA

Limit Based on Chemical Reactivity

6 kg H_2 limit in vacuum vessel

1 kg allocated for dust/steam reactions

6 kg dust limit on 'hot' surfaces (> 300˚C)

Dust size:
CMD=0.5 μm, GSD=2, SSA = 4m^2/g

Safety factors

- Dust sizes measured in tokamaks and plasma guns
- Chemical reaction rate measurements of Be metal and powder
- Specific surface area (SSA) measurements of dust & powders

Accident analysis to show results are within limits

Limit Based on Radiological Hazard

Radiological risk limit:
'no evacuation'

50 mSv early dose at site boundary

350 kg of activated W dust

ITER Dust Strategy

- Establish administrative limits based on the amount of dust generated in the vacuum vessel
- No demonstrated method for monitoring and removing dust
- R&D program to measure dust mobilization in ITER relevant conditions and to test various dust measurement and removal techniques
- Results should help better validate proposed confinement strategies and estimates of routine dust releases during maintenance activities

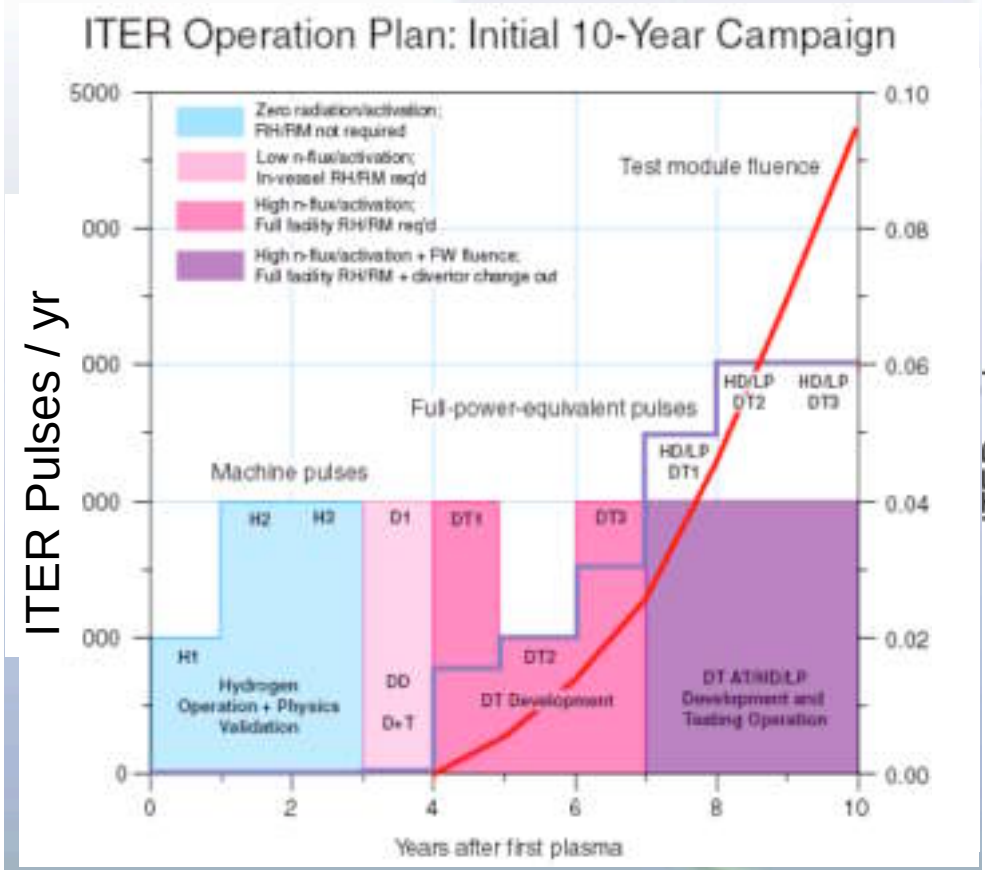
Grooved structure on the chamber floor

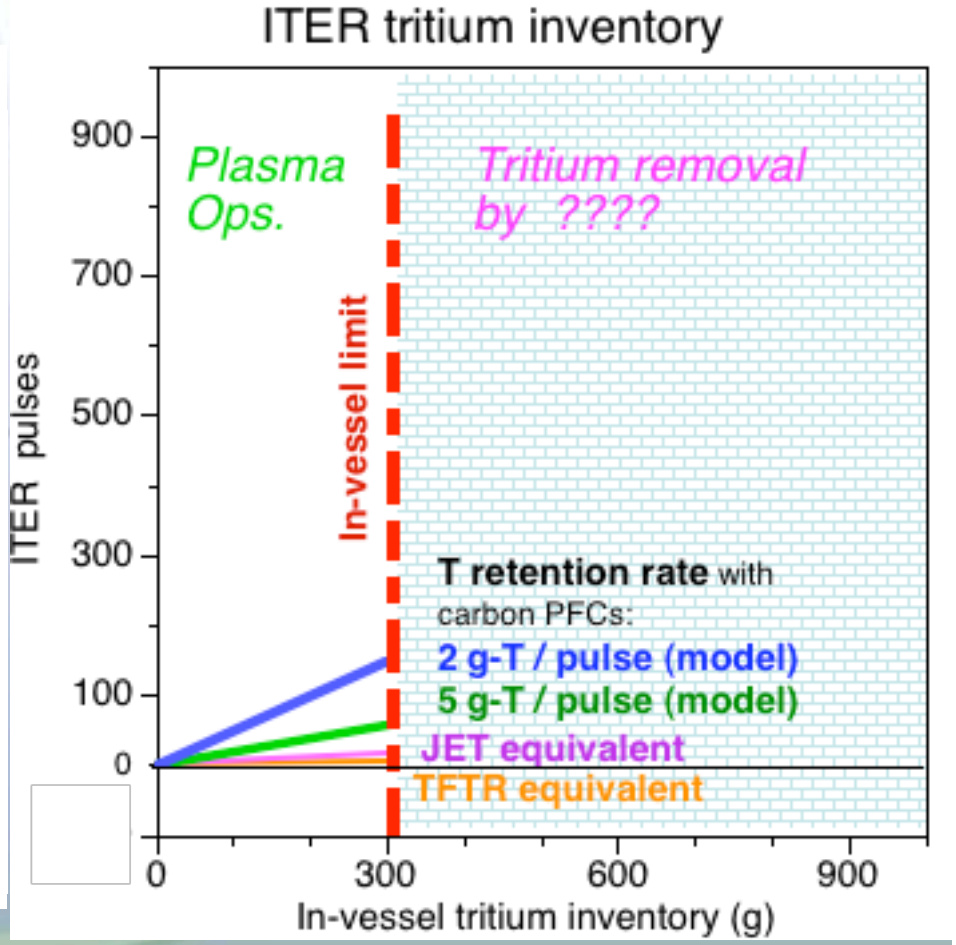
Wall deposits after mobilization

In-vessel Tritium Source Term

- In-vessel tritium inventory is the second major component of the ITER radiological source term
- Influence of mixed materials (Be, C, W) on the tritium inventory has been studied but many questions remain unanswered
- Use of carbon will result in buildup of large tritium inventories without de-tritiation
- Because of the safety importance of the inventory, validation of the assumptions used in the estimate will be required (including any computer code calculations such as the US code TMAP)

Potential US contributions to serious plasma material interaction issues in ITER.





Anything wrong in these pictures ?

Courtesy C. H. Skinner, PPPL

SNOWMASS report E3:

"ITER, on the other hand, will encounter a T-retention problem within less than 1 month of sustained full-FPE operation (< 200 FPE pulses) at the 1%- of-fueling retention level.

- Final design and procurement of ITER PFCs scheduled for 2006 - 2008
  - now is the time for R&D !
- Europe has initiated a task force to address PWI issues.
  (http://www.efda-taskforce-pwi.org/)
- US needs equivalent formal framework.
- Some potential areas where US expertise could contribute to ITER:
  - Tritium removal *(required for ITER operation)*
  - Dust detection & removal *(required for ITER operation)*
  - Diagnostic mirror cleaning demonstration in tokamaks *(required for diagnostics)*
  - SOL transport and turbulence *(to better predict T retention)*
  - Expanded wall/edge diagnostics on C-mod, DIII-D, NSTX, + related modeling.
  - Mixed materials studies (Be/C already underway in PISCES)
  - .....

New US framework and dedicated resources needed now to focus on PWI issues

In-vessel Tritium Source Term

- Need to evaluate current strategy being proposed by ITER to stay below the administratively fixed tritium inventory limit
- Goal should be to allow maximum operational flexibility given current limits and methods for removing tritium
- Use of Tritium Plasma Experiment to study expected behavior and potential de-tritiation techniques
- Propose to work with the tritium/plasma material interactions community on this task
- Better estimates of the tritium inventory will allow greater flexibility with respect to establishing the margin to the in-vessel inventory limit and will permit more accurate assessments of radiological risks to workers during maintenance and the public under off-normal conditions

Verification Activities during Operation

- Many of the assumptions used in the ITER safety analysis can only be verified during early machine operation and commissioning activities
- In some cases operation at full power will be required (e.g. tritium inventory in key components,activation product inventories, decay heat, operational behavior of pressure suppression system, tritium cleanup and dust removal systems)
- Obtaining these data are critical to obtaining regulatory approval for ITER in a staged approach that is typical of experimental facilities
- Being involved in this activity would be useful for the design of future fusion machines as conservatisms in the safety approach could be relaxed as real world data on an actual large-scale tokamak are gathered, assessed and understood

Summary

- The decision to reenter ITER affords the US fusion program some important opportunities in the area of fusion safety and environment including
  - Regulatory Support and Design Integration
  - Safety Analysis and Safety Computer Code Verification and Validation
  - Tokamak Dust Source Term and Chemical Reactivity
  - In-vessel Tritium Source Term
  - Verification Activities During Operation
- Many of these activities will also benefit any future fusion designs