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Progress in nuclear analyses of the ITER TBM Port Plug with Dummy TBMs

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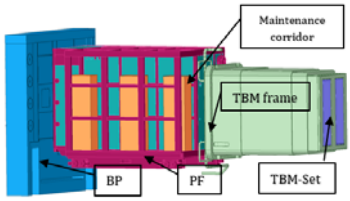
1. Introduction

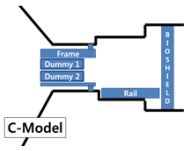
- Test Program for Tritium Breeding Modules (TBM) in ITER equatorial ports.
- TBM-sets (TBM + shield) to be replaced by Dummy-TBMs in case a TBM-set is not available.
- Maintenance within Port Interspace areas require hands-on operations.
- Nuclear analysis to compute Shutdown Dose Rates (SDDR) at 10^6 s (ca. 12 days) after shutdown, with respect to 100 µSv/h limit.



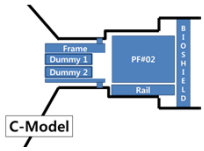
Main equipment of Test Blanket System, with Bioshield Plug (BP), Pipe Forest (PF), maintenance corridor and TBM Port Plug (Frame and TBM-Set or Dummy-TBM)

2. Neutronics Models

- Reference model of ITER tokamak sector, C-Model V1 R2.1.
- New MCNP model of TBM Port Plug, Dummy-TBM, Pipe Forest #02 (HCCB(CN) + LLCB(IN) piping), and Bioshield Plug from CAD models.
- Simplification and conversion to MCNP geometry according to established ITER guidelines with high-level of details.
- Configurations (for Equatorial Port #02):
  - C1: Empty Port-Interspace (+ BP with pipe-sections & air gaps)
  - C2: With Pipe Forest (connected to BP with pipe-sections & air gaps)



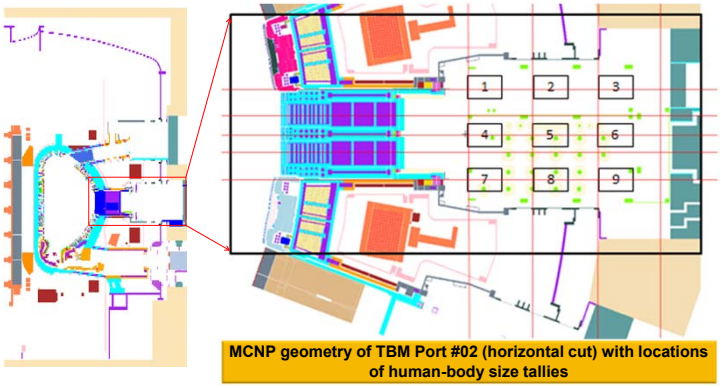
Configuration C1 schematic



Configuration C2 schematic

3. Computational Methodology

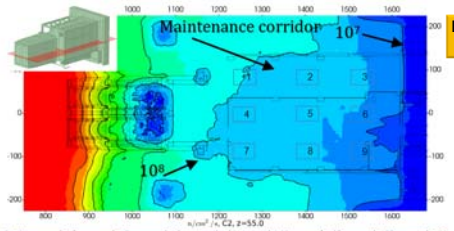
- R2S calculations of SDDR using MCNP6 and FISPACT-II, global model
- Superimposed Cartesian mesh of 3cm/15cm spacing (in equatorial port) and 30 cm (in tokamak)
- Weight Window mesh for variance reduction by ADVANTG3 simulations.
- Operational scenarios:
  - Short TBM relevant operation (first 4 years of nuclear operation)
  - Full ITER SA2 operation (14 years of nuclear operation, 0.3 MWyr/m²)



MCNP geometry of TBM Port #02 (horizontal cut) with locations of human-body size tallies

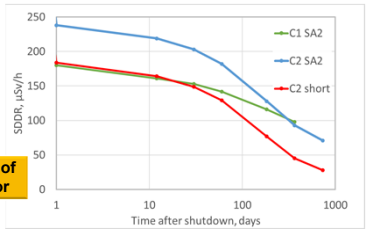
4. SDDR calculations

- Responses in human-body size tallies in maintenance corridor and as 3D radiation maps.
- Significant contribution, up to ~85%, by external structures, e.g. port duct walls.
- Minor contributions by Dummy-TBM (~2 µSv/h) and TBM-frame (~20 µSv/h).
- SDDR in PF corridor is above limit, also for short scenario, except in PF entry area.



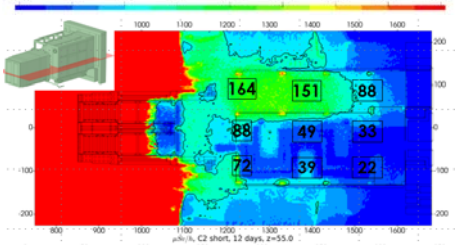
Neutron flux distribution across TBM port (C2)

Peak SDDR in position 1 of the maintenance corridor

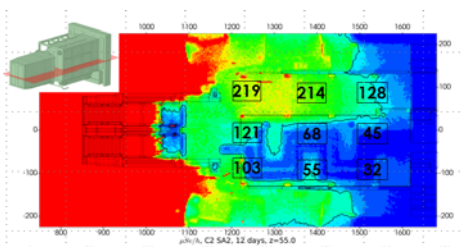


Part of model	Position 1	Position 2	Position 3
Equatorial port	161	133	83
Components			
2 Dummy TBMs	2	1	0.5
TBM frame	20	8	4
Rest	139	124	79
External structures	30	41	16
Total	**191**	**174**	**99**

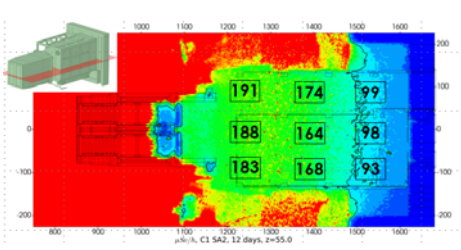
Contributions to SDDR [µSv/h] in empty Port Interspace (C1)



SDDR map (C2) with PF #02 in PI, short irradiation



SDDR map (C2) with PF #02 in PI, full ITER SA2 irradiation



SDDR map (C1) for empty PI, full ITER SA2 irradiation

5. Conclusions

- Models and analyses at pre-PDR maturity are provided for SDDR relevant for hands-on maintenance operations within Port Interspace of TBM Port
- SDDR in PF entry area are compliant with ITER limit; in other areas higher by about a factor of 2.
- Contribution of the TBM Port Plug is only up to 15% of total SDDR.
- Further reduction of SDDR by appropriate design choices and additional shielding structures is still required.

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