EUROfusion

Assessment of the Dose Rates due to Water Activation on an Isolation Valve of the DEMO WCLL Breeding Blanket Primary Heat Transfer System

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ABSTRACT

Within the framework of the activities foreseen by the EUROfusion action on the cooling water activation assessment for a DEMO reactor equipped with a Water Cooled Lithium Lead Breeding Blanket (WCLL BB), the University of Palermo is involved in the investigation of the absorbed dose induced by the decay of nitrogen radioisotopes produced by water activation, in the main components (e.g. isolation valves) of both First Wall (FW) and Breeder Zone (BZ) cooling circuits.

The aim of this work is to assess the spatial distribution of the absorbed dose in the DEMO Upper Pipe Chase (UPC), focusing the attention on the space neighbouring a typical isolation valve of the Primary Heat Transfer System (PHTS). To this end, a computational approach has been followed adopting MCNP5 Monte Carlo code. In particular, a totally heterogeneous neutronic model of a portion of the UPC has been set up, including the valve and the main FW and BZ PHTS piping, and the spatial distribution of nitrogen isotopes concentrations, previously assessed, have been used to model the photonic and neutronic sources.

The results obtained, herewith presented and critically discussed, provided some information on the nuclear issues of the WCLL BB PHTS, to be considered as hints for the blanket design optimization.

INTRODUCTION

Within the framework of EUROfusion action on the "Cooling water activation assessment", the University of Palermo is involved in the dose assessment around both First Wall (FW) and Breeder Zone (BZ) cooling circuits (e.g. isolation valves, hot and cold legs) of the DEMO reactor equipped with a Water Cooled Lithium Lead Breeding Blanket (WCLL BB). The research activity is to assess the spatial distribution of the absorbed dose, due to the decay of nitrogen isotopes produced by coolant activation, around some key components of WCLL BB cooling circuit, focusing the attention on the Primary Heat Transfer System (PHTS), in the Upper Pipe Chase (UPC) of the reactor.

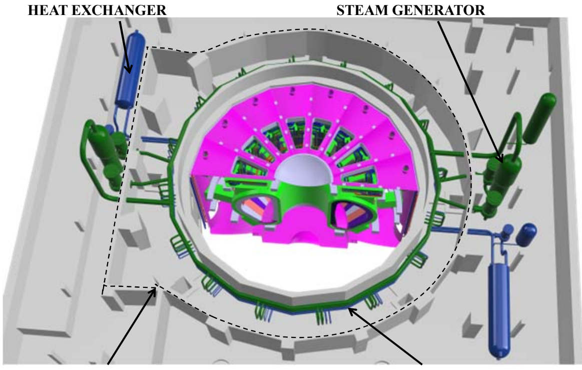


Fig. 1. View of DEMO PHTS in the UPC.

INPUT DATA AND MODEL

The WCLL BB PHTS foresees 2 parallel and distinct cooling circuits for FW and BZ. Attention has been focused on the PHTS piping arranged in the UPC where important devices as isolation valves could be located. The study has considered a slice of 22.5°, corresponding to one blanket sector, where it is possible to notice the borated heavy concrete walls, the AISI 316 LN pipes in which the radioactive water flows and a simplified model of a DN 150 gate valve.

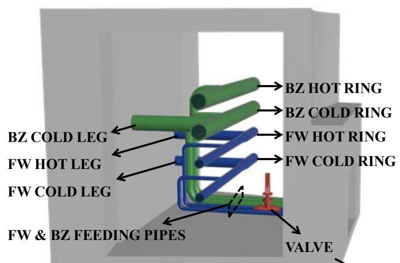
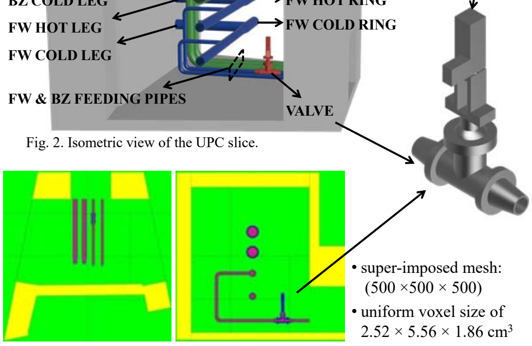


Fig. 2. Isometric view of the UPC slice.

ACTUATOR



- super-imposed mesh: (500 ×500 × 500)
- uniform voxel size of 2.52 × 5.56 × 1.86 cm³

Fig. 3. Sections of the MCNP model of the UPC: a)Toroidal-Radial section; b)Poloidal-Radial section.

- Energy distributions of both ^{16}N photons and ^{17}N neutrons biased taking into account their discrete spectra with the related branching from each energy level

Table 1. Nitrogen activity in the FW circuit [GBq].

NODE	^{16}N	^{17}N
Hot Feeding Pipe	2.718E+02	3.093E-02
Hot Ring	6.941E+02	6.781E-02
Hot Leg	1.484E+02	1.163E-02
Cold Leg	9.741E+01	5.664E-03
Cold Ring	3.261E+02	1.845E-02
Cold Feeding Pipe	8.526E+01	4.717E-03

Table 2. Nitrogen activity in the BW circuit [GBq].

NODE	^{16}N	^{17}N
Hot Feeding Pipe	4.893E+02	5.132E-02
Hot Ring	2.089E+03	1.903E-01
Hot Leg	9.368E+02	8.316E-02
Cold Leg	1.683E+02	4.425E-03
Cold Ring	3.488E+02	8.937E-03
Cold Feeding Pipe	5.826E+01	1.466E-03
Valve	6.973E+01	7.313E-03

RESULTS

Detailed 3D photonic and neutronic analyses have been carried out for the assessment of the dose nearby FW and BZ cooling circuit key-points, due to γ radiation from ^{16}N and neutron emission from ^{17}N.

A period of **7 FPY** has been considered as it is assumed to be the expected life of the breeding blanket of DEMO taking into account an availability factor of ~33%. A steady state scenario has been taken into account considering the plasma flat-top phase of the reactor.

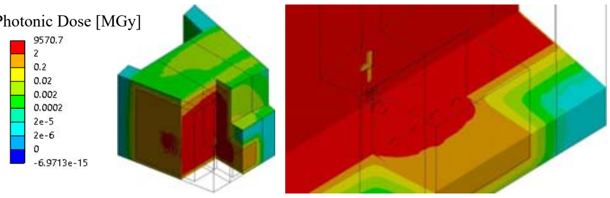


Fig. 4. Absorbed γ dose spatial distribution in the UPC slice (left) and an enlarged detail (right)

γ dose assessment:

- **10¹¹** histories for **photon** transport
- The full-scale of **2 MGy** represents the reference value for the qualified valves in NPP.
- Some design modifications of the BB and/or the PHTS must be foreseen.

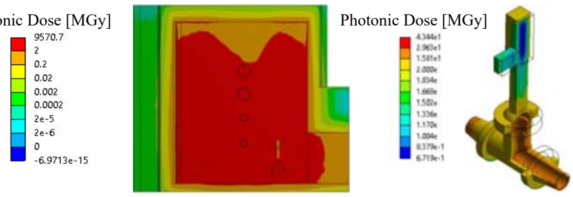


Fig. 5. Absorbed γ dose spatial distribution in a UPC slice detail (left) and in the valve (right).

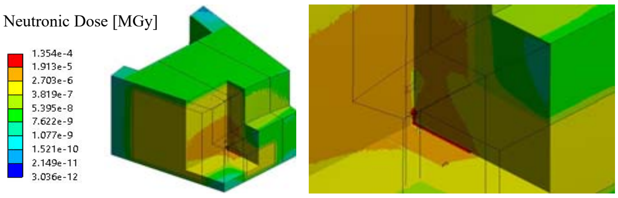


Fig. 6. Absorbed neutron dose spatial distribution in the UPC slice (left) and an enlarged detail (right).

***Neutron** dose assessment*:

- **6·10¹⁰** histories for **neutron** transport
- Dose due to neutron radiation is several order of magnitude lower
- ^{17}N activity deserves further neutron transport studies to evaluate the inventory of activation products

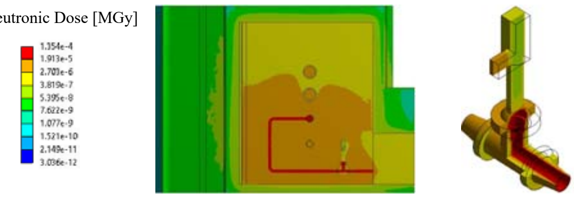


Fig. 7. Absorbed neutron dose spatial distribution in a UPC slice detail (left) and in the valve (right).

CONCLUSIONS

Within the framework of EUROfusion action, at the University of Palermo a research campaign has been performed in order to assess the dose absorbed in some key components of the WCLL BB PHTS in the DEMO reactor. The results obtained show, as expected, that the main contribution to the absorbed dose by matter in the UPC comes from the photons emitted by the ^{16}N decay and that, on the other hand, the estimated ^{17}N activity leads to consider specific analysis for the evaluation the extent of neutron activation in the pipes.

Furthermore, these outcome lead to a further development of the present research activity aimed at developing PHTS design changes in order to lower the dose absorbed by the valve. In particular, the peculiarities of the spatial distribution of dose found suggest some simple modifications such as the use of bulkheads to shield the valve and/or change the lay-out of the pipes and/or develop more rad-resistant material for specific cases.

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