Fusion Engineering and Design xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Fusion Engineering and Design

journal homepage: www.elsevier.com/locate/fusengdes

Radwaste management aspects of the test blanket systems in ITER

J.G. van der Laan[a,*], D. Canas[b], V. Chaudhari[c], M. Iseli[a], Y. Kawamura[d], D.W. Lee[e], P. Petit[f], C.S. Pitcher[a], D. Torcy[a], D. Ugolini[g], H. Zhang[h]

[a] ITER Organization, Route de Vinon sur Verdon, F-13067 Saint Paul Lez Durance, France
[b] CEA, DEN/DADN, centre de Saclay, F-91191 Gif-sur-Yvette cedex, France
[c] Institute for Plasma Research, Bhat, Gandhinagar 382428, India
[d] Japan Atomic Energy Agency, Naka-shi, Ibaraki-ken 311-0193, Japan
[e] Korea Atomic Energy Research Institute, Daejeon, Republic of Korea
[f] European Commission, DG ENER, Brussels, Belgium
[g] Fusion for Energy, Barcelona, Spain
[h] China Nuclear Energy Industry Corporation, Beijing 100032, China

HIGHLIGHTS

- Test Blanket Systems are operated in ITER to test tritium breeding technologies.
- The in-vessel parts of TBS become radio-active during the ITER nuclear phase.
- For each TBM campaign the TBM, its shield and the Pipe Forests are removed.
- High tritium contents and novel materials are specific TBS radwaste features.
- A preliminary assessment confirmed RW routing, provided its proper conditioning.

ARTICLE INFO

Article history:
Received 31 August 2015
Received in revised form 28 February 2016
Accepted 2 March 2016
Available online xxx

Keywords:
ITER
Nuclear
Waste
Characterization
Decommissioning
Test Blanket Systems

ABSTRACT

Test Blanket Systems (TBS) will be operated in ITER in order to prepare the next steps towards fusion power generation. After the initial operation in H/He plasmas, the introduction of D and T in ITER will mark the transition to nuclear operation. The significant fusion neutron production will give rise to nuclear heating and tritium breeding in the in-vessel part of the TBS. The management of the activated and tritiated structures of the TBS from operation in ITER is described. The TBS specific features like tritium breeding and power conversion at elevated temperatures, and the use of novel materials require a dedicated approach, which could be different to that needed for the other ITER equipment.

1. Introduction

Test Blanket Systems (TBS) will be operated in ITER in order to prepare the next steps towards fusion power generation, in particular the breeding of ^{3}H (or T) fuel from lithium compounds, see the overview by Giancarli et al. [1]. After the initial operation in H/He plasmas, the introduction of D and T in ITER will mark the transition to nuclear operation. ITER is an international research project located in France and registered as 'Installation nucléaire de base' (INB-174) under French legislation.

The fusion neutron production in ITER will allow tritium breeding in the Test Blanket Module (TBM) by neutron-capture in lithium compounds, but it will also lead to strongly activated structures. Depending on the materials composition short-lived and/or long lived radionuclides are formed, and the resulting radiation field limits human access for short term inspections and maintenance, but also causes the TBS components to be contaminated, and in the long term they need to be treated as radioactive waste (radwaste) requiring disposal in a suitable repository.

* Corresponding author.
E-mail address: JaapG.vanderLaan@iter.org (J.G. van der Laan).

http://dx.doi.org/10.1016/j.fusengdes.2016.03.022
0920-3796/

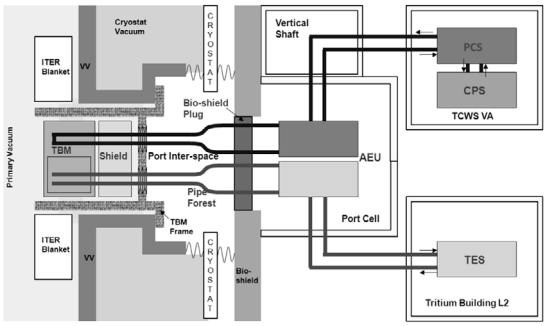

Fig. 1. Simplified schematic diagram of a Test Blanket System integrated in the ITER facility.
The TBSs are located in various rooms in the Tokamak and adjacent buildings, as visualized in Fig. 2.

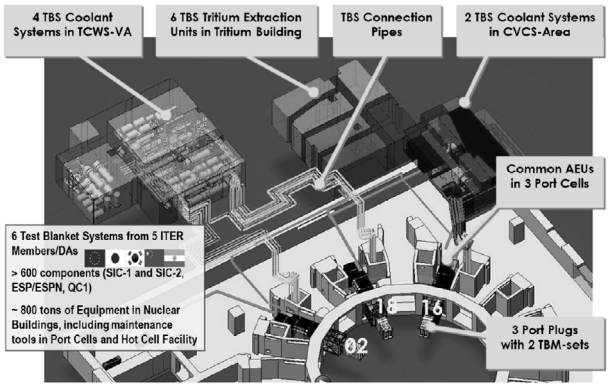

Fig. 2. Overall lay-out of the 6 Test Blanket Systems to be installed and operated in ITER.

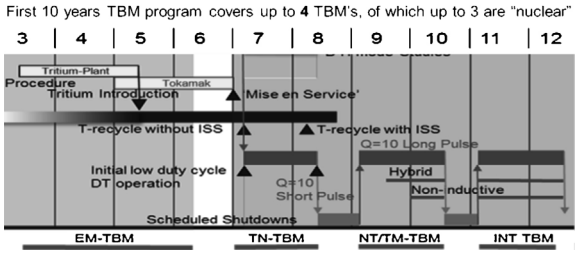

Fig. 3. Simplified schedule of TBM Program in ITER (status 2014).

Each TBS is comprised of a TBM-Set and various ancillary equipment and systems, see the general overview [1], which is summarized as follows, see also Figs. 1 and 2:

1. A TBM-Set consists of the TBM and the TBM shield. Two TBM-sets are placed in the TBM Frame, and form the TBM Port Plug (PP).
2. The Ancillary equipment and systems, depending on the specific TBS design [1], may consist of:
   3. Ancillary Equipment Unit (AEU)
4. Primary Cooling System (PCS) (e.g. Helium or Water)
5. Lithium–Lead Cooling System (LLCS)
6. Helium Purge System (HPS)
7. Coolant Purification System (CPS) (linked to PCS)
8. Tritium Extraction/Removal System (TES)

The TBM program preliminary foresees TBMs being operated in 4 campaigns over a 10 years period, starting from "2nd assembly phase", conforming to the ITER Research Plan, see Fig. 3. At each Long Term Maintenance period, the Port Plugs with TBMs are removed, and replaced by new sets. In the same period the AEU is refurbished. In case a specific TBM will not be operated for a certain campaign, its place can be filled by a "dummy-TBM", which is a water-cooled stainless steel structure, as described by Kim et al. [2].

The TBS specific features like tritium breeding and power conversion at elevated temperatures, and the use of novel materials require a dedicated radwaste management approach, which could be different to that needed for the other ITER equipment, as reported by Rosanvallon et al. [3].

Most of the TBS (e.g. port plug, tritium extraction/removal system, liquid metal loop) are Protection Important Components (PIC). TBSs have components classified as Safety Important Class PIC/SIC-1 and -2, as well as some Safety-Relevant and other non-PIC. Therefore the subject of most of this paper is a Protection Important Activity (PIA).

2. Management of the TBS radwaste

The TBM Program is established in the framework of the ITER Project and is therefore part of the ITER project objectives, but the radwaste generated from the TBS operations has to be separately assessed and managed as the TBM Program was established as an additional program to the ITER Project. Indeed it was established by the ITER Council as an additional activity necessary to achieve the purpose of the ITER Organization pursuant to Article 3.1.d of the ITER Agreement established after the ITER Agreement. According to Article 14 of the ITER Agreement the ITER Organization shall observe applicable laws and regulations of the Host State in the fields of public and occupational health and safety, nuclear safety, radiation protection, licensing nuclear substances, environmental protection and protection from acts of malevolence. Consequently, the Host State has participated in the definition of the conditions of temporary storage and disposal of the TBS radwaste in France. The entity responsible for the disposals in France is Andra (French National Agency for the Radioactive Waste Management).

Therefore the TBM-Program Committee has charged a Working Group (WG) to address technical, strategic and legal issues for the TBS radwaste management. The charges of this WG, involving the ITER Organization, the ITER Members (IMs) and the Agence ITER France (AIF), are:

- Generation and homogenization of the data for the six TBSs needed to define the radwaste classification, and temporary storage conditions, and/or additional treatments;
- Definition of models adopted to perform the estimation of the components tritium inventory and outgassing behavior;
- Definition of the actions required from the disassembly of TBM and TBS up to the disposal;
- Identification of the interfaces with other ITER systems such as the Hot Cell Facility, and ensure full compliance with the ITER license;
- Identification of cost drivers for TBMs temporary storage and shipment to external facilities for Post-Irradiation Examinations, TBS rad-waste temporary storage, transportations and disposal;
- Development of a detailed approach addressing detritiation and chemical treatments, and assessment of the impact on cost drivers, in support of TBM development.

Four categories of radwaste are considered in the ITER Project, see the more detailed descriptions of their routings up to disposal by Andra as given by Rosanvallon et al. [3], and Canas et al. [4]:

Please cite this article in press as: J.G. van der Laan, et al., Radwaste management aspects of the test blanket systems in ITER, Fusion Eng. Des. (2016), http://dx.doi.org/10.1016/j.fusengdes.2016.03.022