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Numerical simulation of draining and drying procedure for the ITER Generic Equatorial Port Plug cooling system

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HIGHLIGHTS

- The cooling system of the ITER Generic Equatorial Port Plug (GEPP) is of a complicated combination of horizontal and vertical channels.
- The calculation model for the entire GEPP cooling circuit comprising 12 sub-circuits and built up of 2421 finite-volume elements has been developed.
- Transient analysis of this model simulating the draining procedure by the KORSAR/B1 code has been performed.
- Water in amount of 263 g of initial 531 kg in the GEPP remains in the dead-ends of the DSM and DFW channels in 150 s of draining procedure.
- Almost 3 h are required to boil off 263 g of water trapped in the dead-ends.

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ABSTRACT

For effective vacuum leak testing all cooling circuits serving the ITER vessel and in-vessel components shall be drained and dried so that after this procedure taking less than 100 h the purge gas passing through a component has water content less than 100 ppm. This process is four-stage, with the first stage using a short blast of compressed nitrogen to blow most of water in the coolant channels out of the circuit. This process is hindered by volumes which trap water due to gravity. To remove the trapped water, it is necessary, first, to heat up the structure by hot and compressed nitrogen, and then water is evaporated by depressurized nitrogen. The cooling system of the ITER Diagnostic Equatorial Port Plugs is of a complicated hydraulic configuration. The system branching might make difficult removal of water from the piping in the scheduled draining mode. The authors have proposed the KORSAR computation code to simulate draining of the GEPP cooling circuit. The numerical simulation performed has made it possible to describe the process dynamics during draining of the entire GEPP cooling circuit and to define the process time, amount and location of residual water and evolution of two-phase flow regime.

1. Introduction

The water supply system to be used for ITER inner components is to purge these components of water and to remove them, if necessary, from the machine. As stated in Ref. [1], the ITER in-vessel components shall be dried so that after this procedure taking less than 100 h the purge gas passing through a component has a residual steam partial pressure of 2 kPa [2].

This process is four-stage [3], with the first stage using a short blast of compressed nitrogen to blow bulk of water in the coolant channels out of the circuit. The process is hindered by volumes, which trap water due to gravity. To remove the trapped water, it is necessary first to heat up the structure by hot and compressed nitrogen, and then water is evaporated by depressurized nitrogen.

Starting from 2001 the authors have been concerned with the problem of draining of various ITER in-vessel components: divertor, upper and equatorial port plugs. The results of the activities were reported in a number of reports and ITER official documents [4,5].

The paper presents and discusses the results of numerical simulation of draining and drying of the cooling system of the Generic Equatorial Port Plug (GEPP).

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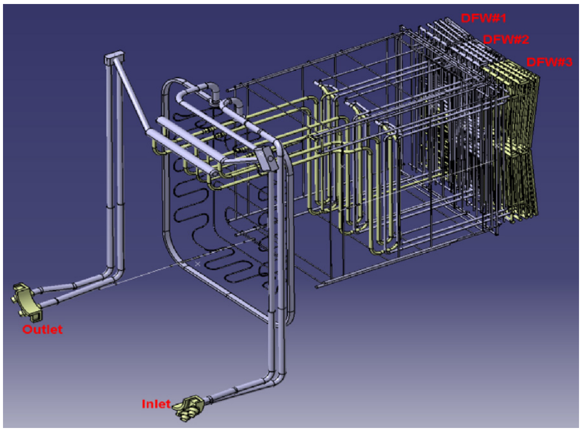
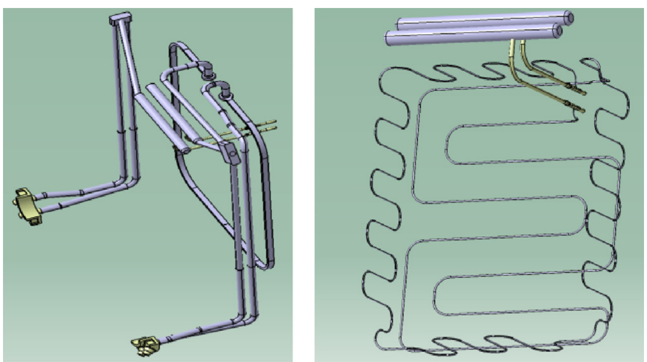


Fig. 1. General view of the GEPP cooling system.



(a) (b)

Fig. 2. PP flange (a) and flange serpentine (b) cooling sub-circuits.

2. Design of GEPP cooling system

The ITER GEPP cooling system is of a complicated combination of horizontal and vertical channels drilled in bodies of the shielding module and port plug structure (Fig. 1), which might make it difficult to remove water from the piping in the scheduled draining mode.

The entire GEPP circuit (Fig. 1) is a system of series-parallel cooling passages combined in twelve parallel branches cooling in sequence the Port Plug (PP) flange (Fig. 2a), Diagnostic First Walls (DFWs) (six independent branches, see Fig. 4a), then three Diagnostic Shielding Modules (DSMs) supplied with water also in parallel (Fig. 4b). The PP structure is cooled in parallel to the main cooling circuit servicing the DFWs and DSMs (Fig. 3), and the branch cooling the plug is connected in parallel to this PP structure (Flange outer serpentine, Fig. 2b).

3. Draining and drying scenario for ITER cooling system

The following common scenario for draining and drying of the cooling circuits of different ITER components, in particular, the GEPP cooling circuit, has been specified:

- blow-out mode, when cold (40 °C) nitrogen compressed to 4.0 MPa is delivered to the inlet of the cooling circuit filled with water;
- heat-up mode, when the whole inner structure of the reactor component to be dried is heated up by hot (210 °C) compressed (2.1 MPa) gas to a temperature of 160–180 °C;

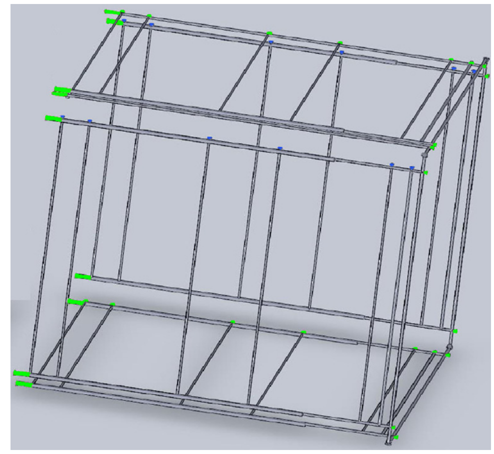
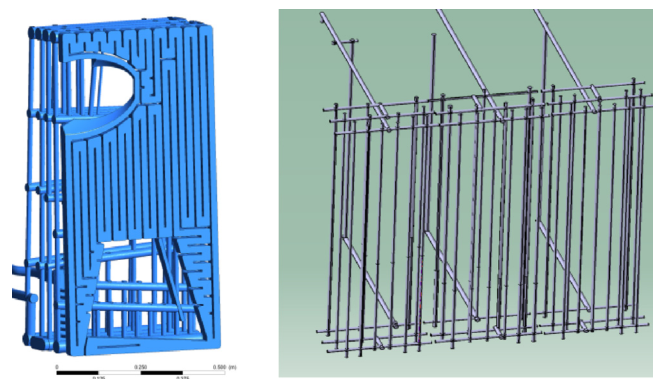


Fig. 3. PP structure cooling sub-circuit: dead-ends are marked with green (horizontal) and blue (vertical). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)



(a) (b)

Fig. 4. DFW (a) and DSMs (b) cooling sub-circuits.

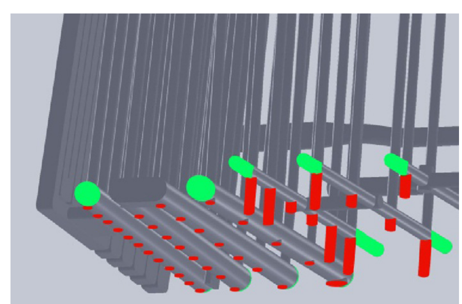


Fig. 5. Horizontal and vertical dead-ends with trapped water (lower part of DFW #01 BOT and DSM#01).

- dry-out mode, when the pressure in the heated-up cooling channels is reduced from 2.1 to 0.6 MPa, as a result the water heated above the saturation temperature and trapped in vertical dead-ends is boiled off.
- The process is considered completed, when the amount of water vapor at the cooling channel outlet becomes lower than 100 ppm.

4. Description of blow-out process and code selection

The first stage of the draining and drying procedure for the GEPP cooling circuit is realized by the Draining and Refilling System (DRS), which is part of the ITER Tokamak Cooling Water System (TCWS). The process starts with that cold (40 °C) nitrogen com-