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Technical rehearsal of tritium operation at JET

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HIGHLIGHTS

- In preparation for the future tritium and deuterium-tritium campaigns at JET, a rehearsal of the procedures and technical systems was performed.
- The rehearsal included commissioning and characterisation of the NBI performance with a tritium-like gas feed configuration.
- A prototype tritium introduction module was tested and the torus hall depression and oxygen depletion system commissioning was started.
- The rehearsal also included emergency exercises, training of personnel, testing and optimising operational procedures.
- The rehearsal demonstrated that JET is still capable of operating with tritium in a safe and reliable manner.

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ABSTRACT

The final phase of the JET Programme in Support of ITER plans to operate with 100% tritium (TT) followed by deuterium-tritium (DT) operation, to help minimise risks and delays in the execution of the ITER Research Plan and the achievement of a fusion gain Q~10. In preparation for tritium operation, an 8-week technical rehearsal of the procedures and systems is being executed in 2015-16. The aim is to commission (in deuterium or hydrogen) and characterise the NBI performance with a tritium-like gas feed configuration, test the prototype tritium introduction module, commission the torus hall depression and oxygen depletion system, carry out emergency exercises, train personnel and to test and optimise operational procedures. The rehearsal demonstrated that JET is still capable of operating with tritium in a safe and reliable manner, and most importantly, provided operational experience and lead to recommendations for the preparation of these future tritium campaigns on JET.

1. Introduction

Deuterium-tritium is the foreseen fuel mixture for ITER and future fusion power plants as it provides the best fusion performance at the achievable operating temperatures. JET is presently the only tokamak capable of tritium operation and is currently preparing for the next two tritium campaigns, the 100% Tritium (TT in 2018) and the second Deuterium-Tritium experiment (DTE2 in 2019) as shown in the timeline presented in Fig. 1.

1.1. Tritium operation at JET

The preparations are based on the experience of the previous campaigns, the Preliminary Tritium Experiment (PTE) in 1991 [1], the first Deuterium-Tritium Experiment (DTE1) in 1997 [2,3] and the Trace Tritium Experiment (TTE) in 2003 [4,5]. The new campaigns will exploit some of JET's unique features such as the

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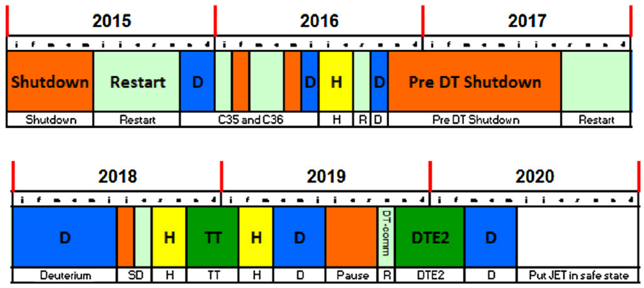

Fig. 1. JET timeline until 2020.

Table 1
Structure of the DT rehearsal in 2015–2016.

Campaign	Date	Aim
Restart	2015, 2016	Commissioning of technical systems
C37	July-August 2016	5 week rehearsal in hydrogen
C36B	October 2016	3 week rehearsal in deuterium

ITER-like first wall (beryllium, tungsten) [6], substantial upgrade of the heating systems (neutral beam upgrade, ITER-like ICRH antenna), extensive remote handling capabilities and the improvements in diagnostics since 2003.

There are a number of additional technical and safety requirements (compared to deuterium and hydrogen) to operate with tritium gas, a high DT neutron flux and neutron activation.

a) Tritium is stored in uranium beds and will be supplied by the tritium plant to one or two neutral beam boxes and five new tritium introduction modules. Other gases (e.g. deuterium, hydrogen, neon, argon) are provided from local gas cylinders or the gas store in the JET building to the standard gas introduction modules, disruption mitigation valves and pellet systems.
b) The torus hall atmosphere is under depression to limit the spread of tritium in case of accidential tritium release. In addition, the oxygen content of the torus hall is reduced to 15% as a fire suppression measure.
c) Access is restricted to key operational areas of the JET building for prolonged duration due to increased neutron activation and gamma radiation, the risk of tritium release and low oxygen level of the torus hall.
d) Tightened access restrictions are applied to computer networks.
e) The divertor and neutral beam cryo-pumps are regenerated after every operational day using cryo-forevacuum pumps to limit and monitor the tritium inventory outside the tritium plant.
f) Additional tritium operational procedures are used in the JET and the tritium plant control rooms.
g) More detailed experiment preparation and monitoring of the tritium inventory and neutron activation is required pulse by pulse.

The key safety requirements and safety measures are described in the DT safety case [7]. The JET operating instructions and the local rules provide the relevant procedures.

1.2. DT rehearsal

As part of the preparation for the TT and DT campaigns at JET, an 8-week technical rehearsal of the procedures and systems to be used in tritium operation is being perfomed (without use of tritium) in 2015-16 as shown in Table 1.

The aim of the DT rehearsal is to check if appropriate arrangements are in place for operation, monitoring and maintenance of selected technical systems under the restrictions imposed by tritium operation. The operating procedures follow those proposed for the TT and DT campaigns as closely as reasonable. An integral part of the rehearsal is the training of operational personnel.

Specifically the aims are to: a) characterise the neutral beam performance with a tritium-like gas feed configuration, b) test and characterise a prototype tritium gas introduction module with deuterium, c) rehearse the operation of technical systems (torus hall depletion and depression system, tritium fuel cycle with deuterium), d) clarify, test and optimise operational procedures, e) test and optimise monitoring of gas and neutron budgets, f) train control room and plant staff, and g) gain experience and make recommendations for the preparation of future tritium campaigns on JET.

This paper describes the requirements, preparation and execution of the technical rehearsal of tritium operation at JET in 2015-16.

2. Technical systems

2.1. Tritium fuel cycle

The tritium is stored in uranium beds in the tritium plant (AGHS – Active Gas Handling System) and reprocessed to a purity of 99.4% by gas chromatography. Tritium will be injected into the torus through the Tritium-Deuterium Gas Introduction System (TDGIS) [8] to one or two neutral beam boxes and 5 new tritium introduction modules. The foreseen quantity of injected tritium will be thus significantly higher compared to previous campaigns using one beam box and one gas introduction module only. In addition, there are 12 standard gas introduction modules, two pellet systems and two disruption mitigation valves injecting other gases. All gases are pumped by neutral beam and divertor cryopumps during the day and after their regeneration by the cryogenic forevacuum pumps in AGHS through an on-site closed circuit as shown in Fig. 2.

As part of the rehearsal the full fuel cycle was commissioned delivering deuterium gas from the uranium bed through the TDGIS to one neutral beam box and regenerating the cryopanels with the cryogenic forevacuum pumps. This allowed the testing of the gas introduction system to the neutral beam injectors using secondary containment required for tritium [8].

The neutral beams are expected to provide up to 17.6 MW heating power per neutral beam box in tritium (equivalent to 17.3 MW in deuterium). It was shown on the neutral beam testbed, that if the grid gas flow rate is sufficiently high, the arc efficiency and other characteristics such as species composition achieved in normal gas operation could be reached [9]. During the rehearsal, two weeks of reliable operation was achieved in grid gas with a single gas flow setting. In this time, 94% of the arc efficiency of standard operation was obtained. Further tests with higher gas flows are planned in the restart period in 2017.

As part of the final design of the new Tritium Introduction Modules (TIMs), a prototype gas introduction module has been assembled and installed at the midplane using a local deu-