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The DTT device: Guidelines of the operating program

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HIGHLIGHTS

- DTT is a facility designed, within the European Fusion Road Map, aiming to study the completely integrated (Physics-technology and bulk-edge) power exhaust problems.
- We illustrate the guidelines covering a period of about thirty years, up to the phase when the DEMO final design should be realized.
- "Flexibility" is not only a concept in the machine design, but also a requirement affecting the general developments during all the exploitation period.

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ABSTRACT

The DTT facility is designed to study, within the European Fusion Road Map, the completely integrated (physics-technology and bulk-edge) power exhaust problems. The scientific program is characterized by the tight balance between clear guidelines and the "flexibility" to tackle all the present scientific questions as well as the ideas possibly arising along the years of its operative life; in particular, it will be ready to answer to the necessities arising from both ITER operation and/or DEMO design. The paper discusses the guideline of DTT operations program to be carried out during its operative life, planned in about thirty years.

1. Introduction

Motivated by several convergent reasons, the main guideline of the DTT design is the *flexibility*.

The need for flexibility is given by technical and scientific reasons. The DTT facility is designed to study several, quite different solutions for the power exhaust problem, such as advanced divertor magnetic configurations [1–3] and liquid divertor metals [4,5], but also to propose innovative, presently "unknown", solutions.

Flexibility is also required because of its long operative time scale. DTT is planned to operate for about 25–30 years, to accompany the ITER experiment as well as the DEMO design, until the start up of the its construction [6,7].

Finally, in few years, the JT60SA [8] operations will start. The main aim of the Japanese device (the study and the development of robust scenarios with improved energy confinement) is rather different from that of DTT facility, but in some sense complementary. Therefore a fruitful synergy between the two experiments can be promoted, provided that DTT will be as flexible as required to take advantage from the results provided by JT60SA.

For all these reasons, the entire DTT project is based on concepts of adaptability and flexibility.

For this purpose, DTT will be equipped with a set of poloidal coils able to guarantee a wide range of different divertor magnetic configurations. In particular, the presence of a set of small internal coils will allow to easily modifying the local magnetic configuration, so as to generate a large set of quite different topologies.

In addition, a large space has been allocated at the bottom of the machine to easily allow the installation of a several divertor modules based on different concepts, including liquid metal technology.

Moreover a mix of different additional heating systems has been designed to provide in a flexible way the required power, including $\approx 10 \div 25$ MW Electron Cyclotron Resonance Heating (ECRH) at 170 GHz; $\approx 15 \div 20$ MW Ion Cyclotron Resonance Heating (ICRH) at 60–90 MHz; $\approx 0 \div 10$ MW Neutral Beam Heating (NBI) at 300 keV. Here the power range of each heating system is indicated with two figures: the first is the heating power designed for the starting configuration (total power $P_{ADD} = 45$ MW), and the second indicates the possible upgrade, where the actual sharing will be decided at the end of the first operations taking advantage from the achieved experimental results and from the information about the difficulties arisen.

In this paper the guideline of the DTT operating program is discussed.

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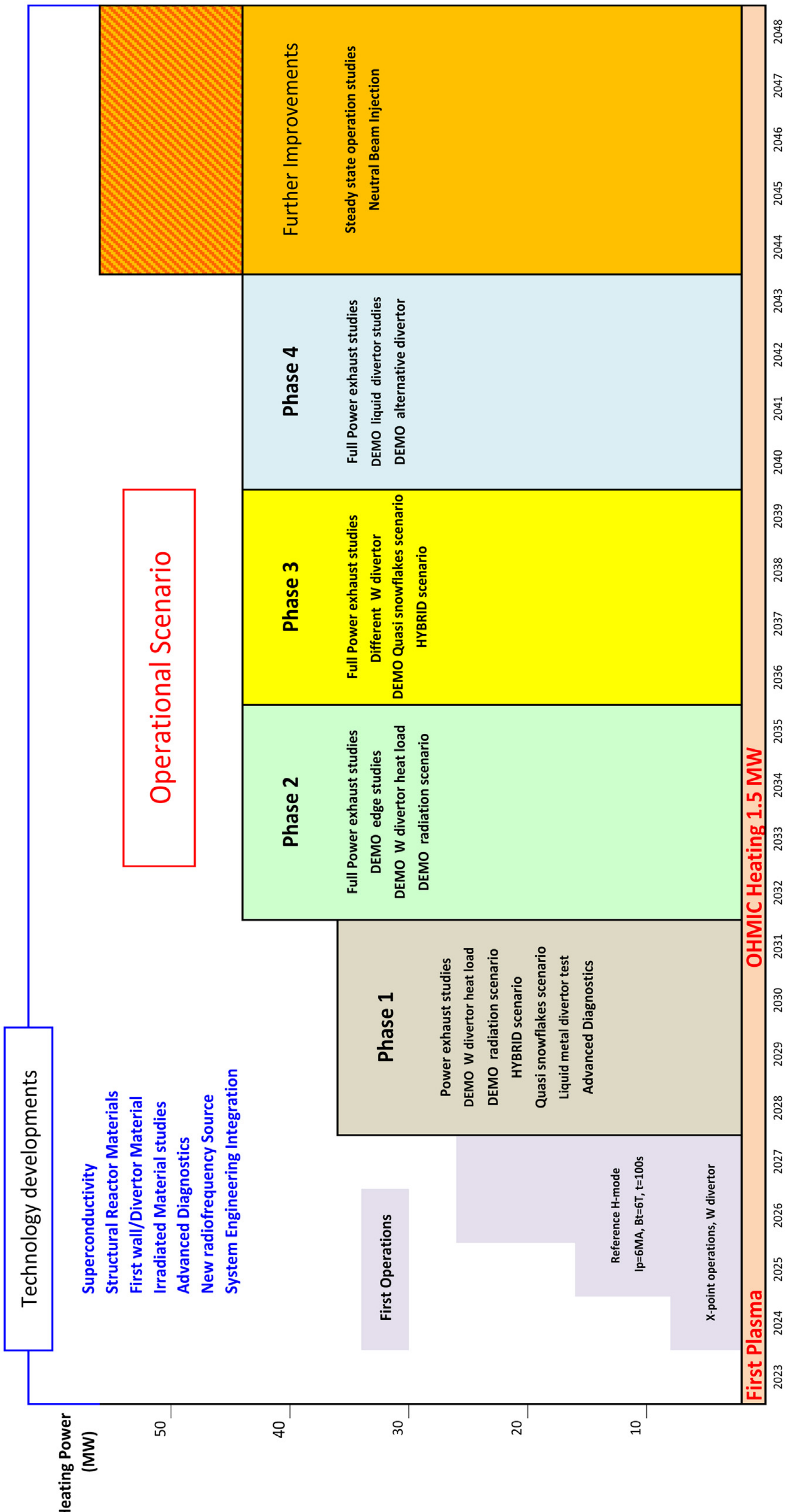

Fig. 1. Schematic planning of the DTT operation phases.

In Fig. 1a tentative exploitation program is reported on a period lasting about 25 years; however extensions are expected to meet new possible specific needs. The program has been arranged in 5 different phases, each characterized by a specific target, and accompanied by suitable intermediate milestones. The main activities to be performed and the targets to be achieved in each phases are

Fig. 2. Main targets of the operation phases.

detailed are summarized in Fig. 2 and discussed in details in the following sections.

This paper is part of a Special Issue of *Fusion Engineering and Design*, aimed at describing the entire project "Divertor Tokamak Test facility (DTT). The general framework of DTT project as well as the technical and technological solutions adopted in the design are described with details in the other papers of the collection.

2. Commissioning and *First Operations* activities

2.1 Commissioning

The Commissioning is a critical step of the whole operative program; it will last about 6 months.

Each component and subsystem will be tested in terms of effectiveness and in the capability to satisfactorily reach the design targets.

A large number of measurements of different parameters (thermal, mechanical, electromagnetic and so on) will be acquired and collected with the objective to assess the proper behaviour of each element before and during the installation and, in addition, to compare the actual performance with model predictions. For example the toroidal and poloidal coils will be tested at the He liquid temperature as well as the first wall panels will be tested at high temperature and etc.

Then, according to the assembly procedure, all the subsystems will combined within the general design layout and, in order to assess the effectiveness of the general integration, both local and remote suitable integration tests will be carried out.

Due to the importance of the data treatment, during the commissioning phase a fundamental role will be played by the control and data acquisition systems.

It should be noticed that in the Commissioning phase, the assessment of all the components and subsystem is planned, including

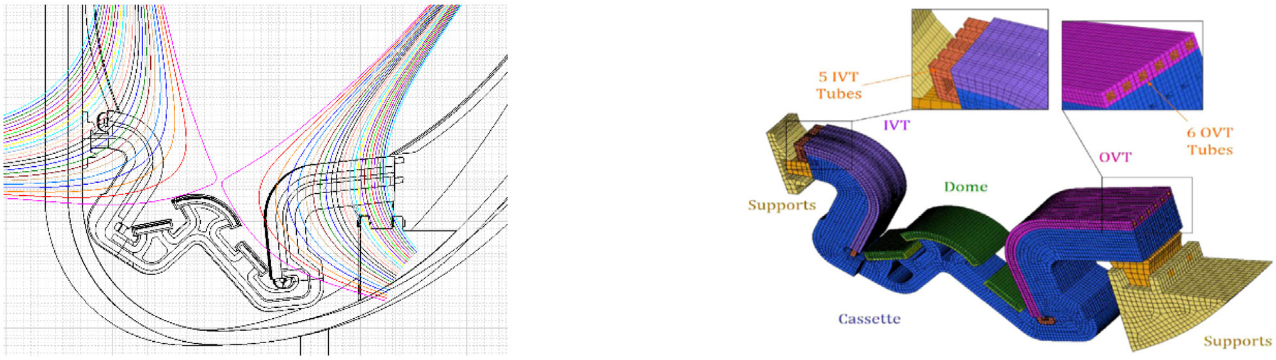

Fig. 3. Design of the reference initial divertor for the proposed DTT. The left one is a conceptual one. The right one is the first draft design.

those, like the remote handling, that will be operational only later in time.

2.2 First Operations activities

The main goal of the First Operations activities is the achievement of the nominal plasma performances in the standard H-mode scenario, i.e. a discharge with a plasma current of $I_p = 6MA$ and electron density $<n_e> \approx 1.5\ 10^{20}\ m^{-3}$, in a toroidal field of $B_T = 6T$, lasting $\tau_s = 100s$.

The divertor (Fig. 3) is made in tungsten monoblocks actively cooled; in the strike point regions, it is ITER-like shaped to allow effective experiments with the most relevant alternative magnetic configurations.

In this phase the additional power is limited to 25 MW.

The goal of the *First Operation* phase is very challenging because it requires that all the subsystems are set-up in time and, in order to achieve the machine target parameters, that all of them are able to perform at their nominal level of performance.

3. First phase

In this phase the DTT operation will take benefit from an increase of the available additional power: an amount of 10 MW of ECRH will increase the total available power up to the level of $P_{ADD} = 35$ MW.

The experimental campaigns will be articulated in three main subsequent steps.

3.1 High radiation scenario

Aim of the first step is to assess the possible radiation limits without energy confinement degradation, in a plasma regime close (in terms of dimensionless parameters) to those in ITER and DEMO. The standard divertor (actively cooled monoblock) and the first wall are both in tungsten, as also envisaged in DEMO design.

3.2 Alternative magnetic configurations

The design of the magnetic system includes a number of small coils located inside the vessel in the divertor region, able to generate, in a very flexible way, several alternative magnetic profiles. This second step is devoted to assess the impact on the plasma performance of such magnetic configurations and, in addition, to verify possible synergies between the magnetic topology and the local radiation.

3.3 Liquid metal divertor

The assessment of some concepts of a liquid metal divertor is the main aim of this activity. A liquid metal module based on the capillary porous system (CPS) will be installed; the testing program includes also the technical characterization of the materials and the assessment of the plasma compatibility.

4. Following phases

The following three phases are scheduled in quite longer time scale; of course their operations will be necessarily linked and strongly affected by the results of the previous activities. Therefore the proposed guideline is unavoidably a bit more faded, but always preserving the clarity of the methods and the respect of the strategic goals.

4.1 Second phase

In this phase the total power will be upgraded (additional 10 MW) up to its nominal final value of $P_{ADD} = 45$ MW.

Presently, among the three different heating concepts, the NBI solution (proposed also for ITER) seems to be the most appropriate and capable to provide some momentum input. However a suitable qualified confirmation is necessary; therefore, in this phase, a careful comparison (also based on the results achieved and the experience gained during the first phase) will be performed among the three different systems, with the aim to assess their main strengths and weaknesses.

In addition, all the studies performed on the first phase (and, in particular, the effectiveness of the alternative magnetic configurations) will be repeated, taking advantage from the higher additional power available.

4.2 Third phase

This phase is devoted to the experimentation, testing and characterization of at least a new divertor device. Which divertor concept has to be selected is a difficult choice to be taken; however, the experience gained in the previous phases will provide an effective support. At moment, the main idea is to design and install a divertor suitably "optimized" for the most promising alternative magnetic configurations. A different hypothesis is the design of a conventional divertor based on the CPS technology; a third hypothesis is the mix of the previous two: a divertor based on the CPS but with geometry optimized for the alternative configurations.

4.3 Fourth phase

The main aim of the fourth phase is to test "new ideas" that will arise over the years in the scientific community.

Which new concept has to be selected is a critical choice that has to take into account the results achieved in the previous phases. In any case, the DTT design flexibility will be able to allow a wide range of possibilities.

One of the possible concepts, provided that it is not already adopted in the third phase, should be the liquid metal divertor (in Fig. 4a possible design proposed in [9]). Presently the liquid metal divertor is an idea still in progress, but some preliminary design has been already performed to assess the possibility to use this concept on the DTT.

5. Further additional program

The main aim of last phase will be essentially the testing of some new concept of divertor that could/should be used in DEMO and, in addition, to facing some new need possibly arising during its design activity. A further upgrading of the total additional power

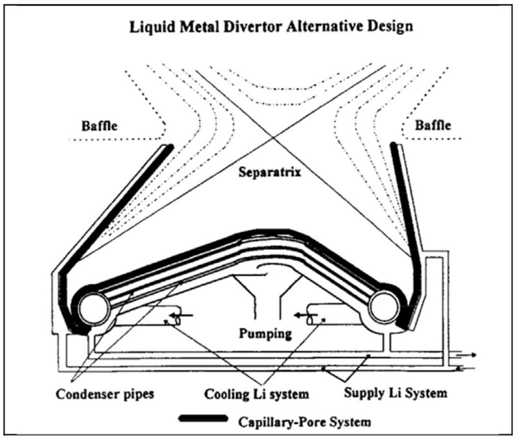

Fig. 4. Draft design of a liquid metal divertor module for DTT [9].

(up to P_{ADD} = 55 MW) will guarantee to best approach the actual DEMO exhaust conditions.

Moreover, a number of additional challenging tests are planned with the aim to provide an important assessment of new superconducting technologies to be applied in the future commercial reactors. In particular, the substitution has been programmed of both an upper poloidal coils and the central solenoid with a new components realized by using a high temperature superconductor.

The positive synergy of the new central solenoid and the increased additional power promises to provide new increased performance to the device, especially useful for new advanced steady state experiments.

6. Conclusions

Within the project of a facility like DTT, designed to operate at least for some decades and to face with problems and difficulties currently not fully known, the planning of operation is a challenging exercise.

In addition the DTT is designed to serve as a facility; therefore it is supposed to be open to the actual questions coming from the scientific and industrial community and ready to answer to their actual needs.

Therefore the operation program is designed to be very flexible.

However, from the other side, in order to guarantee the best pursuit of the project objectives, a number of clear and strong guideline have been fixed about what the facility has to achieve, when and how.

The operation program of DTT, taking into account all the conflicting constraints, proposes a suitable combination of determination and flexibility, but in any case, perfectly placed within the spirit of the European Fusion Road Map and the DEMO needs.

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