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Preface

This special issue of Fusion Engineering and Design describes the outcome of the European DEMOnstration power plant (DEMO) pre-concept design and R&D activities conducted from 2014 until 2020 to advance the technical design basis. DEMO is currently foreseen to come in operation around the middle of this century with the main aims of producing a few hundred megawatts of net electricity whilst demonstrating the operational feasibility of a closed-tritium fuel cycle and maintenance systems capable of achieving adequate plant availability.

As this special issue consists of a multitude of contributions from different authors, an introduction is included to briefly clarify the context of the results of the effort presented and to explain the limitations of this work.

The DEMO staged design approach developed by Europe is described in section 4 with emphasis on the Design Phases and Gates, the flow of relevant technical information from ITER and the dependencies with its schedule. The gate review conducted at the end of 2020 to evaluate the technical work conducted to date and to review the implementation plan for DEMO beyond 2020 is described here. The recommendations that were made were invaluable and were adopted to strengthen the plan for next project phase.

The process to define an appropriate set of machine parameters and the selection of the main technical features of the device is described in section 5. It starts with the definition of the high-level plant requirements (e.g. net electricity output, tritium self-sufficiency, plant availability, operation mode, etc.) and involves trade-offs between the attractiveness and technical risk associated with the various design options considered. It should be noted that some of the plasma physics assumptions (e.g. energy confinement, plasma pressure, H-mode access threshold, bootstrap current fraction, etc.), and technology assumptions (e.g. allowable divertor heat loads, n-load limits on the structural materials, maximum field in the superconducting magnets, plant thermodynamic efficiency, wall-plug efficiency of Heating & Current Drive systems, etc.) play a major role in the tokamak dimensioning process. The impact of the uncertainties of certain physics assumptions and issues associated with the problem of power exhaust in the divertor are discussed in section 6, noting the unconfutable fact that the divertor is a size-driver for DEMO.

The readers that hope to find fully-defined technical details and design parameters of the plant in this special issue will be disappointed, as many aspects of the design and technology solutions are yet to be frozen.

The focus during the Pre-Concept Design Phase has been on a design integration approach, based on systems engineering, which is recognised to be essential from an early project stage to identify and address the engineering and operational challenges, and prioritize the required technology and physics R&D.

As such, eight Key Design Integration Issues (KDIIs) have been selected and preliminary studied. They were identified as those that could potentially have a significant impact on tokamak and plant design architecture, physics performance, safety, maintainability and licensing. These KDIIs could be viewed as the precursors of a more systematic system engineering approach to be adopted for evaluating and selecting among multiple design options of systems and/or technologies with high technical risk or novelty. The outcome of this work is described in section 7.

Safety plays an important role in the ultimate selection of plant design choices and operating conditions (e.g. materials, coolants and operating conditions). Safety analyses were conducted to match the early evolution of DEMO design and to take into account the lesson learned from the ITER licensing process. This is described in section 8.

The adoption of a more systems-oriented design approach has also brought clarity to R&D priorities and, as a result, a targeted technology R&D has been defined and implemented that responds to critical design feasibility, performance and integration risks. The achievements of this work on the major DEMO systems are described in section 9.

As it is recognized that ongoing R&D of advanced and novel technologies and materials is vital to confirm the pathway to a commercial power plant, a longer term Prospective R&D program has been established. This is briefly described in section 10.

The recommended plan forward is described in section 11, together with the concluding remarks presented in section 12.

Throughout this special issue, the abbreviation DEMO refers to the European DEMO unless otherwise stated.

This special issue does not describe the design and R&D activities carried out in the EUROfusion Consortium in support of the DEMO Oriented fusion Neutron Source (DONeS), foreseen to become operative by the end of this decade [1]. This accelerator-based 14MeV neutron source will be important to validate data collected in material test reactors (MTRs) and extend irradiation data at higher fluences, relevant for DEMO.

References

[1] A. Ibarra, et al., The European approach to the fusion-like neutron source: the IFMIF-DONES project, Nucl. Fusion 59 (065002) (2019).

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