ITER EDA DOCUMENTATION SERIES No. 24

International Thermonuclear Experimental Reactor
(ITER)

Engineering Design Activities
(EDA)

ITER TECHNICAL BASIS

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Plasma Performance

The device should:

- *achieve extended burn in inductively driven plasmas with the ratio of fusion power to auxiliary heating power of at least 10 for a range of operating scenarios and with a duration sufficient to achieve stationary conditions on the timescales characteristic of plasma processes.*
- *aim at demonstrating steady-state operation using non-inductive current drive with the ratio of fusion power to input power for current drive of at least 5.*

In addition, the possibility of controlled ignition should not be precluded.

Engineering Performance and Testing

The device should:

- *demonstrate the availability and integration of technologies essential for a fusion reactor (such as superconducting magnets and remote maintenance);*
- *test components for a future reactor (such as systems to exhaust power and particles from the plasma);*
- *Test tritium breeding module concepts that would lead in a future reactor to tritium self-sufficiency, the extraction of high grade heat, and electricity production.*

Design Requirements

- *Engineering choices and design solutions should be adopted which implement the above performance requirements and make maximum appropriate use of existing R&D database (technology and physics) developed for ITER.*
- *The choice of machine parameters should be consistent with margins that give confidence in achieving the required plasma and engineering performance in accordance with physics design rules documented and agreed upon by the ITER Physics Expert Groups.*
- *The design should be capable of supporting advanced modes of plasma operation under investigation in existing experiments, and should permit a wide operating parameter space to allow for optimising plasma performance.*
- *The design should be confirmed by the scientific and technological database available at the end of the EDA.*
- *In order to satisfy the above plasma performance requirements an inductive flat-top capability during burn of 300 to 500 s, under nominal operating conditions, should be provided.*
- *In order to limit the fatigue of components, operation should be limited to a few 10s of thousands of pulses*
- *In view of the goal of demonstrating steady-state operation using non-inductive current drive in reactor-relevant regimes, the machine design should be able to support equilibria with high bootstrap current fraction and plasma heating dominated by alpha particles.*
- *To carry out nuclear and high heat flux component testing relevant to a future fusion reactor, the engineering requirements are*
  Average neutron flux ≥ 0.5 MW/m^2
  Average neutron fluence ≥ 0.3 MWa/m^2
- *The option for later installation of a tritium breeding blanket on the outboard of the device should not be precluded.*
- *The engineering design choices should be made with the objective of achieving the minimum cost device that meets all the stated requirements.*

Operation Requirements

The operation should address the issues of burning plasma, steady-state operation and improved modes of confinement, and testing of blanket modules.

- *Burning plasma experiments will address confinement, stability, exhaust of helium ash, and impurity control in plasmas dominated by alpha particle heating.*
- *Steady-state experiments will address issues of non-inductive current drive and other means for profile and burn control and for achieving improved modes of confinement and stability.*
- *Operating modes should be determined having sufficient reliability for nuclear testing. Provision should be made for low-fluence functional tests of blanket modules to be conducted early in the experimental programme. Higher fluence nuclear tests will be mainly dedicated to DEMO-relevant blanket modules in the above flux and fluence conditions.*
- *In order to execute this program, the device is anticipated to operate over an approximately 20 year period. Planning for operation must provide for an adequate tritium supply. It is assumed that there will be an adequate supply from external sources throughout the operational life.*

the details of procurements and to optimise costs, all technical data necessary for future decisions on the construction of ITER is now available. Following the completion of Explorations, the next step is for the Parties negotiators to agree on a preferred site to allow specific site adaptation, and a text for the construction agreement ready to sign.

1.2 Design Overview

500 MW thermal output

1.2.1 Design

ITER is a long pulse tokamak with elongated plasma and single null poloidal divertor (Figure 1.2.1-1 to Figure 1.2.1-5 and Table 1.2.1-1 to Table 1.2.1-3). The nominal inductive operation produces a DT fusion power of 500 MW for a burn length of 400 s, with the injection of 50 MW of auxiliary power.

The major components of the tokamak are the superconducting toroidal and poloidal field coils which magnetically confine, shape and control the plasma inside a toroidal vacuum vessel. The magnet system comprises toroidal field (TF) coils, a central solenoid (CS), external poloidal field (PF) coils, and correction coils (CC). The centring force acting on the D-shaped toroidal magnets is reacted by these coils by wedging in the vault formed by their straight sections. The TF coil windings are enclosed in strong cases used also to support the external PF coils. The vacuum vessel is a double-walled structure also supported on the toroidal field coils. The magnet system together with the vacuum vessel and internals are supported by gravity supports, one beneath each TF coil.

Inside the vacuum vessel, the internal, replaceable components, including blanket modules, divertor cassettes, and port plugs such as the limiter, heating antennae, test blanket modules, and diagnostics modules, absorb the radiated heat as well as most of the neutrons from the plasma and protect the vessel and magnet coils from excessive nuclear radiation. The shielding blanket design does not preclude its later replacement on the outboard side by a tritium-breeding blanket constrained to the same temperature cooling water as the shielding blanket.

The heat deposited in the internal components and in the vessel is rejected to the environment by means of the tokamak cooling water system (comprising individual heat transfer systems) designed to exclude releases of tritium and activated corrosion products to the environment. Some elements of these heat transfer systems are also employed to bake and consequently clean the plasma-facing surfaces inside the vessel by releasing trapped impurities. The entire tokamak is enclosed in a cryostat, with thermal shields between the hot components and the cryogenically cooled magnets.

induced draft (mechanical) cooling towers have been assumed. These cooling towers require significant quantities of fresh water ("raw") for their operation. For 450 MW average dissipation, approximately 16 m^3/minute of the water is lost by evaporation and drift of water droplets entrained in the air plume, and by blowdown. This water also supplies make up to the storage tanks for the fire protection system after the initial water inventory is depleted. Cooling towers may not be suitable for an ITER site on a seacoast or near a large, cool body of fresh water. Therefore open cycle cooling will be considered as a design option.

C. Energy and Electrical Power

1. Electrical Power Reliability during Operation

Assumption The grid supply to the Steady State and to the Pulsed switchyards is assumed to have the following characteristics with respect to reliability:

Single Phase Faults	-	a few tens/year	80%: t < 1 s
	-	a few / year	20%: 1 s < t < 5 min
		where t = duration of fault	
Three Phase Faults	-	a few/year	

Bases ITER power supplies have a direct bearing on equipment availability which is required for tokamak operation. If operation of support systems such as the cryoplant, TF coil supplies and other key equipment are interrupted by frequent or extended power outages, the time required to recover to normal operating conditions is so lengthy that availability goals for the tokamak may not be achieved. Emergency power supplies are based on these power reliability and operational assumptions.

2. ITER Plant Pulsed Electrical Supply

Assumption A high voltage line supplies the ITER "pulsed loads". The following table shows the "pulsed load" parameters for the ITER Site:

S.Krivit Note: 500 MW peak electrical input

Characteristic	Values
Peak Active Power*,#	500 MW
Peak Reactive Power	400 Mvar
Power Derivative*	200 MW/s
Power Steps*	60 MW
Fault Level	10-25 GVA
Pulse Repetition time	1800 s
Pulsed Power Duration**	1000 s

S. Krivit Note: up to 400 MW continuous electrical input load during 400-second plasma burn phase

from which up to 400 MW is a quasi-steady-state load during the sustained burn phase, while the remaining 80 – 120 MW has essentially pulse character for plasma shape control with a maximum pulse duration of 5 – 10 s and an energy content in the range of 250 – 500 MJ.