Objectives and Main Engineering Features of the Next European Torus

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Abstract
The Next European Torus (NET) is the major plasma device envisaged, in the European strategy towards fusion, between JET and DEMO. NET aims to produce a plasma with reactor like parameters and will adopt, as far as possible, reactor relevant technologies. A reference parameter set is being defined which offers considerable safety margins against physics uncertainties and it is optimized for minimum cost. The degree of extrapolation between NET and DEMO appears offers to be acceptable.

1. Introduction

NET is the main fusion device, now in the definition phase, which should follow JET (Joint European Torus) as part of the European strategy towards the Demonstration Reactor (DEMO). A NET aiming at the full demonstration of plasma performance really relevant to a DEMO would already have, quite independently of whether or not reactor relevant technologies are applied, a rather high cost x risk factor; therefore a decision on construction of a NET is unlikely before a full exploitation of JET in the construction of NET i.e. 1992 ca. On this time scale adopting technological objectives as well as reactor-relevant technologies appears possible.

2. Physics objectives of the NET device.

NET should achieve ignition and produce a burning plasma lasting 200-1000 sec.. This operating regime must be achieved in a reproducible and reliable mode, with plasma and machine parameters which can be safely extrapolated to a DEMO, furthermore the plasma performance should allow to perform the envisaged technological programme which implies a plasma power density of 1 - 1.5 MW/m³.

3. Technological objectives of NET

The experimental programme of NET should include the following objectives :

I) To achieve reproducible burning pulses and, to evaluate the effects of operating conditions (sputtering, melting, stresses etc.) on the performance of components facing the plasma (first wall, limiter, divertor plates, heating launching structures).

II) To extend the burning pulse into the several hundred second range.

III) To assess the engineering performances and the reliability of the basic machine.

IV) To test blanket engineering performances related to the most important processes (e.g. neutronics, temperature and stress distribution, energy recovery, breeding factor and tritium recovery, tritium permeation and inventory corrosion).

V) To prove the operability of the apparatus at relatively high average availability (say 20 - 25 %) for about one year. During this period the operating conditions should gradually approach DEMO relevant conditions.

Reaching these objectives could fullfill the main task of NET namely to select and qualify satisfactory design concepts which would also meet the basic performance requirements of DEMO. A desirable, although not essential, objective of NET would be to extend the assessment of the nuclear component performance to higher fluence i.e. in the range of several MWa/m^2. On the other end it is expected that first wall and blanket of DEMO will be replaced after a first stage of operation of approximately 5 MWa/m^2 - DEMO, therfore, can be charged with the task of completing the long term testing of first wall and blanket in case this is not completed in NET due to the experimental nature of the apparatus. To study in depth and in a reasonable time the behaviour of a variety of materials under irradiation at required fluences between 3 - 6 MWa/m^2, an intense 14 MeV neutron source may prove to be a necessary additional tool (to NET and DEMO).

4. Operation scenario of NET

Several scenarios of operation are possible : in the one summarized in Table I. Objectives I to V are achieved by the end of Phase III. The operation shall be concentrated on short periods of high availability (with the exception of the first year of operation) up to continuous operation. Relatively long periods of down time for replacements, repair and improvements are envisaged (for instance in Phase III a down time of about 1.5. years for major refurbishing). This scenario envisages that NET will reach its best performance (25 % availability over one year) after 10 years from the beginning of the operation in D - T. The scenario here proposed would require a supply of Tritium growing from 300 gr/y to 1500 gr/y, but in the latter part of Phase III a breeding blanket with breeding ratio of 0.8 is needed since it is assumed that the external Tritium supply could not be larger than 1500 gr/y.

5 . Requirements of component testing in view of DEMO Design

At the end of Phase III the apparatus shall have undergone of the order of 10^5 cycles, i.e. comparable with the number of cycles envisaged in the life of DEMO. Neutron fluence will remain considerable by lower than expected in the first stage of DEMO operation, however synergistic effects due to neutron irradiation may also arise. By the end of Phase III the magnetic structure can be considered sufficiently tested and probably two series of components facing the plasma can be significantly tested from both the point of view of thermal - mechanical behaviour and erosion. Most of the engineering test indicated in objective IV can be performed within a continuous operation a period of several days; with an integral burn time of about 300 days, by the end of Phase III, several of these tests ban be performed at different operating conditions for more than one blanket concept. At the end of Phase III some blanket sectors would also provide the essential information on long time constant processes such as corrosion.

TABLE I - OPERATIONS PHASE OF NET

PHASE	I	II	III	IV
Av. Availability (%)	1	3	10	25
Duration (calendar years)	2	4	7	8
Fluence (MWa/m^2)	-	0.1	0.7	2
Integral burn time (days)	-	45	250	730
Av. Pulse duration (sec)	50	100	500	1000
No. of pulses ($\times 10^4$)	1	4	4	6.3
Tritium breeding ration	-	-	0.8	0.8

6 . Reference parameter set for NET

The first task is to define those parameters of the machine which impact more directly on the plasma performance so as to ensure the physics objectives under the most credible physics scaling. This definition is guided by the aim of making the machine the least expensive possible. It is therefore necessary to introduce the engineering constraints i.e. access for maintenance and heating, stress and strain limits, shielding, coil stability limits, blanket for tritium breeding, divertor collector plates, etc. as well as cost scaling of the various components. A code has been developed which takes all these factors into consideration; it identifies, for given performance objectives and design specifications, a Tokamak system that meets the relevant constraints and, at the same time, is optimised with respect to the cost. A first analysis is made to assess the influence of the various physics scaling in the presence of engineering constraints. Several scaling combinations have been considered, but all result in an optimised machine. The parameter set is almost uniquely determined by fixing one parameter (for instance the plasma current) irrespective of the underlying physical model; this is due to the dominant role of the engineering constraints.

In Table II the main parameters of NET study point now under detailed examination, are listed; fig. 1 gives a schematic overall view of NET.

TABLE II - MAIN PARAMETERS OF A NET STUDY POINT

Plasma current (MA)	10
Plasma minor radius (m)	1.65
Plasma major radius (m)	6.5
Field on axis (T)	5.7
Neutron wall load (MW/m^2)	1
Fusion power (MW)	750
T.F. coil bore (m)	10.7 x 6.9
T.F. coil maximum field (T)	12

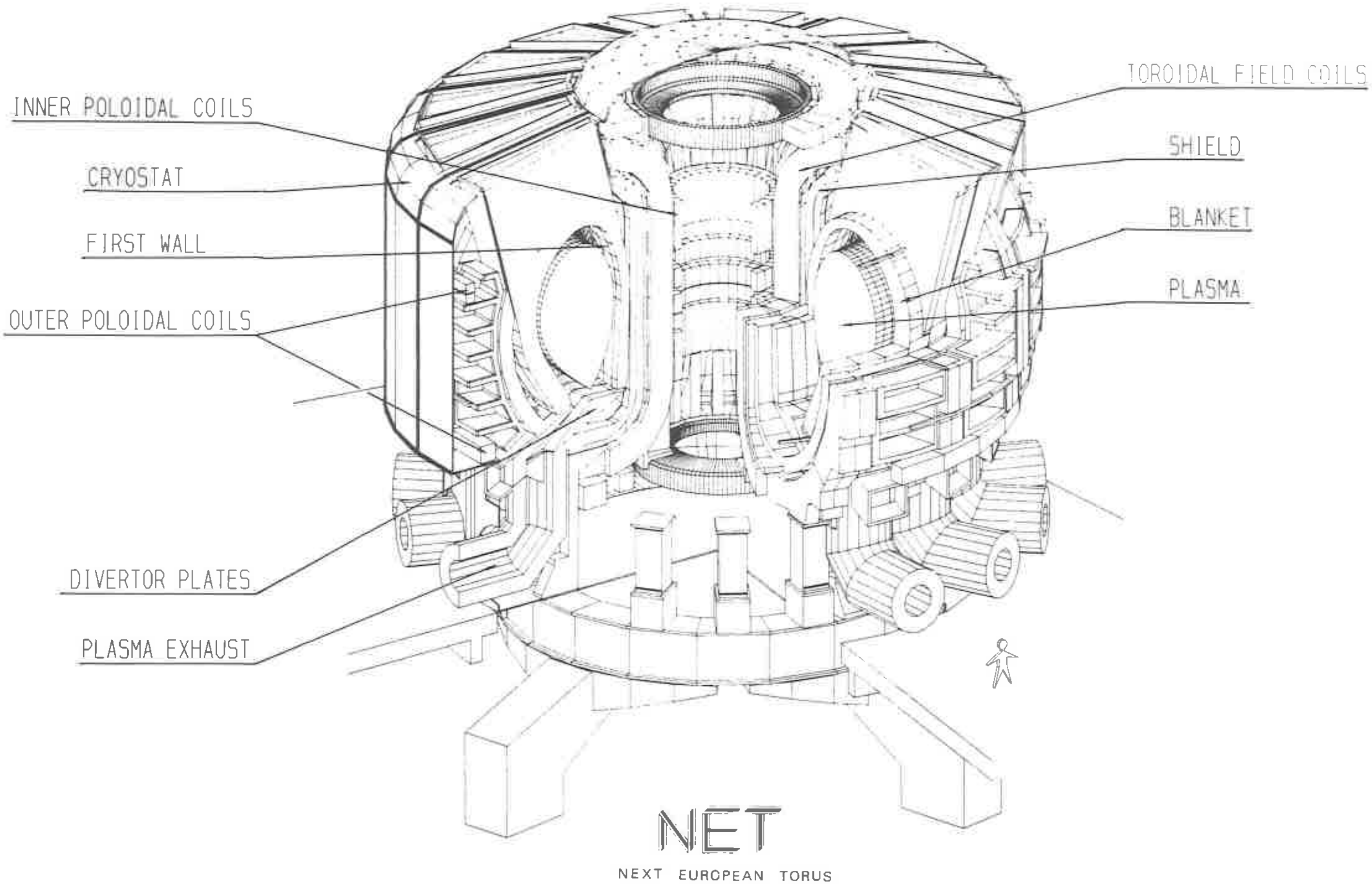
7. Extrapolation from-NET to DEMO and Reactor

The extrapolation factors as far as scale, performance, operating conditions and lifetimes are summarized in the Table III :

TABLE III - ESTIMATED EXTRAPOLATION FACTORS BETWEEN NET, DEMO AND REACTOR

	DEMO / NET	REACTOR / DEMO
Plasma minor radius	1.25	1.15
Plasma major radius	1.35	1.35
Pulse length	5	1
Plasma current	1.25	1.5
Fusion power	2.5	2
Wall loading	1.5	1.2
Neutron fluence	2 - 5	2
Breeding ratio	1.4	1
Availability	1.5	1.5

The extrapolation between NET and DEMO uncertainties will rest mainly with the long term performance and endurance of first wall and blanket. These uncertainties could in part be reduced by parallel testing with intense neutron sources; these tests will contribute mainly to the understanding of the material behaviour at high fluence. Global long term performance and endurance testing of engineering significance can only be carried out at full scale and in a true Tokamak fusion environment; for this reason DEMO should be designed and operated as a Component Test Reactor.



Schematic overall view of NET